An Exploration of Pediatric Sleep Health in a Special Population

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Insufficient sleep is a pervasive problem for children and can impact growth and development. Emerging research suggests that a child's sensory processing abilities, specifically sensory sensitivities, may influence their sleep health (Foitzik & Brown, 2018; Mazurek & Petroski, 2015). Within populations who seek out occupational therapy services, many children have sensory processing patterns that impact participation in daily life, however sleep is often overlooked. In this dissertation, we characterize sleep health for children with sensory sensitivities and examine pediatric occupational therapists' perspectives regarding assessing and intervening in sleep concerns within their daily practice.

We use parent and child-reported subjective measures, daily sleep diaries, and movement-based actigraphy measures to thoroughly characterize multidimensional sleep health for children with and without sensory sensitivities. Our findings suggest a significant difference in subjective sleep health, by both parent and child report, and significant sleep onset delay for children with sensory sensitivities compared to peers. Measures of rest-activity rhythms and sleep variables using actigraphy were similar between groups, indicating that once a child with sensory sensitivities falls asleep, their sleep may not be different than children without sensory sensitivities.

In our qualitative descriptive study, we examined perspectives of 20 pediatric occupational therapists regarding addressing sleep concerns within routine care. Therapists said that sleep health was within their scope of practice, but often personal, family, setting specific, or external barriers impacted their abilities to address sleep in their practice. Therapists said they were not confident

in their knowledge surrounding sleep concerns and highlighted several areas of supports and barriers they regularly experience.

This body of work lays a foundation for two lines of future research. First, we present novel characterization of multidimensional sleep health for children with sensory sensitivities compared to peers without sensory sensitivities. These findings can drive future studies examining neurological differences between these groups that may contribute to sleep and sensory processing within the brain. Second, we identified supports and barriers that impact a pediatric occupational therapists' ability to intervene on sleep concerns. Future research can move forward to address barriers and expand upon supports to better equip occupational therapists to become sleep professionals.

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Preface

The road to a PhD is not a road that one takes alone. From the very moment the thought about pursuing a PhD entered my mind, I have been accompanied by unwavering support from my husband and my two daughters. We have had tremendous support from our family and friends, without which I would not have been able to reach the finish line of this journey.

A heart-felt thanks goes to Roxanna Bendixen, my mentor and advisor, who has guided me with grace and poise through this PhD journey. My committee, Drs. Adriane Soehner, Murat Akcakaya, Dilhari DeAlmeida, and Stefanie Bodison have been supportive collaborators and critical mentors, without whom this work would not have been possible. I would like to thank the School of Health and Rehabilitation Sciences, the Department of Occupational Therapy, the Pediatric Research Laboratory, and the Center for Sleep and Circadian Science, especially Drs. Daniel Buysse and Martica Hall, for their willingness to take in this rogue OT into the throes of sleep research. A special thanks goes to the participants and families who lent their time and wrists to this research. Finally, my sincere thanks go to the Fishbowl, my PhD cohort, for guidance on all the things.

To position this work, I share with you that I am a white, cisgendered female who is a pediatric occupational therapist. As an occupational therapist, I have worked in 4 different states and been able to learn from a variety of clients, their families, and fellow therapists. I am also a mother of two small children. While my children have not presented with sensory sensitivities that impact their daily life, we as a family have experienced a variety of sleep difficulties related to our children's sleep. In writing this dissertation, I attempted to be thoughtful in language choices to highlight the gifts rather than the deficits, while not oversimplifying the struggles that were

identified by the families that shared their stories and their time for these studies. I aim to continue to participate in research that is driven by the clients I serve and am humbled to have the privilege to engage in research to elucidate areas we can direct intervention.

This work was supported by two grants from the School of Health and Rehabilitation Sciences: the PhD Student Award and the Research Fund Award. We also received support from the Sensory Integration Education Network through the PhD Student award. Publications, presentation, and awards associated with this work are listed in Appendix A.

Sweet dreams, reader.

1.0 Introduction

1.1 Sensory processing

Throughout the day and night, our body is registering, processing, and reacting to internally and externally gathered sensory information. Our eyes register the sunlight peeking through the window telling us it is time to get up. Our stomach stretches to indicate it is getting full. Our brain filters out extraneous auditory input, like the clock ticking or people talking in the next room, to focus our attention on the teacher in the front of the room. This complex process can be referred to as *sensory processing* and is a critical aspect for child development (L. Miller, Nielsen, Schoen, & Brett-Green, 2009). About 13-16% of school-aged children exhibit sensory processing patterns that negatively impact the way they participate in daily activities and occupations (Ahn, Miller, Milberger, & McIntosh, 2004; Ben-Sasson, Carter, & Briggs-Gowan, 2009; Dunn, Little, Dean, Robertson, & Evans, 2016). Within neurodiverse populations, sensory processing patterns have been noted to negatively influence daily life for 60-92% of children (Abou El Wafa, Ghobashy, & Zakaria, 2022; Dellapiazza et al., 2021; Tomchek & Dunn, 2007). Some children can experience sensory processing patterns that result in registering more sensory stimuli than most people. These children are detail oriented, show increased emotional reactivity and empathy, and can become easily overstimulated (Aron, Aron, & Jagiellowicz, 2012; Greven et al., 2019). Other children have sensory processing patterns that result in low registration of sensory information, which has been associated with increased activity levels, inattention, and persistence (DeSantis, Harkins, Tronick, Kaplan, & Beeghly, 2011; L. J. Miller, Anzalone, Lane, Cermak, & Osten, 2007). Rehabilitation professionals, like occupational therapists, often work with children with unique sensory processing patterns when they find daily occupation negatively impacted. In this dissertation, we focus on one foundational occupation that impacts child development and health: sleep.

1.2 Pediatric sleep health

Insufficient sleep is a pervasive health concern in children, impacting up to 33% of children in the general population (Gadoth & Oksenberg, 2014; J. A. Owens, Rosen, Mindell, & Kirchner, 2010). After a poor night of sleep, children can demonstrate difficulties paying attention, problem solving, and have higher rates of behavioral concerns (Spruyt, 2019). Additionally, chronic insufficient sleep leads to significant delays in cognitive development, emotional regulation, and even physical growth by impacting multiple physiological processes (i.e. stress, body metabolism, physical healing, hormonal balance, and immune system activity; (Beebe, 2011, 2016; Bonanno et al., 2019; James & Hale, 2017; Raikkonen et al., 2010)).

While there are many potential reasons children are not getting sufficient sleep, it has been noted that typically developing children who are poor sleepers may have specific sensory processing patterns (e.g., sensory sensitivities, specifically with tactile, gustatory, and olfactory senses) that are different than their good sleeping peers (Foitzik & Brown, 2018; Shochat, Tzischinsky, & Engel-Yeger, 2009; Vasak, Williamson, Garden, & Zwicker, 2015). Interestingly, poor sleep is also highly prevalent in special populations that have high rates of co-occurring atypical sensory processing patterns. For example, up to 65% of children with attention deficit-hyperactivity disorder (ADHD) and 80% of children with autism spectrum disorder (ASD) have been reported to have significant sleep dysfunction (Cortesi, Giannotti, Ivanenko, & Johnson, 2010; Singh & Zimmerman, 2015; K. B. van der Heijden, Stoffelsen, Popma, & Swaab, 2018).

While current research suggests a common sensory processing characteristic in poor sleepers across these different diagnoses (S. Reynolds, S. Lane, & L. Thacker, 2011), sleep in children with sensory sensitivities alone has not been investigated.

Two of the studies presented in this dissertation focus on examining the sleep health of children with sensory sensitivities compared to their peers without sensory sensitivities. As sleep health is multidimensional (Buysse, 2014; Meltzer, Williamson, & Mindell, 2021), multiple tools exist to characterize pediatric sleep health. Each measurement tool provides a unique perspective on sleep and has strengths and limitations to consider. Polysomnography (PSG) is the gold-standard of sleep measurement and provides an objective measurement of brain activity during different stages of sleep and wakefulness. Parent- and child-reported questionnaires provide a subjective, retrospective measure of sleep health dimensions like sleep behaviors, satisfaction of sleep, daytime alertness, sleep timing, and sleep duration. Activity monitoring across multiple days and nights provides, in real-time, a movement-based estimation of sleep and rest-activity rhythms that can also characterize timing of activity/sleep, sleep duration, and sleep efficiency. We utilize both subjective (parent- and child-reported questionnaires) and movement-based (actigraphy) measures to describe sleep health for children with and without sensory sensitivities.

Understanding the relationship between sleep health and sensory processing is a crucial next step in building effective and efficient treatment plans for children receiving rehabilitation services. There is extensive evidence that poor sleep impacts the goal areas being addressed in rehabilitation therapies (Dunn et al., 2016; L. Miller et al., 2009; Piwinski, Hoss, Velasco, & Jess, 2021). Further, there is a known high prevalence of atypical sensory processing in many diagnostic populations who seek out rehabilitation therapies (Ausderau et al., 2016; Dunn & Bennett, 2002; Dunn, Myles, & Orr, 2002; Panagiotidi, Overton, & Stafford, 2018). Despite this, sleep health is rarely part of routine care within rehabilitation services (Coren, 2009; Fung, Wiseman-Hakes, Stergiou-Kita, Nguyen, & Colantonio, 2013; Siengsukon, Al-dughmi, & Stevens, 2017; Tester & Foss, 2018). Understanding the specific interaction between sensory processing and sleep health will inform future incorporations of sleep intervention into routine care.

While a client's sleep health should be a concern for all health care professionals, pediatric occupational therapists are uniquely positioned to address sleep health in a holistic, family centered way. Occupational therapists have a sound foundation in the neurological processes involved in development (including sleep and arousal circuits) and address habits, routines, personal factors, and environmental barriers- all aspects of pediatric sleep intervention (American Occupational Therapy Association, 2020; Tester & Foss, 2018). However, like rehabilitation therapy as a whole, sleep health has a history of being overlooked in occupational therapy practice and research (Beisbier & Laverdure, 2020; Fung et al., 2013; Green, 2008; Tester & Foss, 2018). Despite the call for occupational therapists to address sleep as an occupational need, research has yet to explore the pediatric occupational therapists' perspective surrounding sleep health and the barriers/supports to optimal treatment and care (Beisbier & Laverdure, 2020; Gronski & Doherty, 2020).

1.3 Specific aims

Considering these important gaps, the overarching objective of this dissertation is to identify ways to support good sleep health in children with atypical sensory processing patterns, specifically children with sensory sensitivities. This is accomplished through four aims:

(1) Examine differences in sleep for children with and without reported sensory sensitivities using parent- and child-reported questionnaires **(Chapter 3)**

(2) Examine the relationship between sensory processing patterns and reported sleep problems for children with and without sensory sensitivities **(Chapter 3)**

(3) Characterize rest-activity patterns and sleep period variables (e.g., sleep efficiency, wake after sleep onset) using 24-hour activity monitoring (actigraphy) and parent-reported sleep for children with and without sensory sensitivities **(Chapter 4)**.

(4) Identify occupational therapists' perspective of addressing sleep health with their pediatric clients, including opportunities for future education and support **(Chapter 5)**.

Together these aims provide the groundwork for future research focused on the development and assessment of sleep interventions for children with atypical sensory processing patterns.

1.4 Conclusion

Currently, research has yet to fully understand the relationship between sensory processing and sleep, resulting in gaps in pediatric care related to sleep health. This project is significant because it lays a solid foundation on which health care practice can grow. Here we incorporate stakeholders (clinicians, children, and caregivers) and uses thorough measurement (subjective and objective) to create a comprehensive view of sleep health for children with sensory processing deficits. This is the critical next step towards creating specialized and effective care for children with sensory sensitivities and uncovering a path towards improved intervention involving sleep in children with sensory processing difficulties across diagnostic populations.

2.0 Sensory processing and sleep: A critical examination of the relationship

2.1 Introduction

The relationship between sensory processing patterns and participation in sleep is an area of emerging interest in research (Foitzik & Brown, 2018; Hartman, 2021). Within the brain, the sensory processing circuits and the sleep/arousal circuits share common pathways that point to possible interactions between sleep, arousal, and sensory processing (Batista-Brito, Zagha, Ratliff, & Vinck, 2018; Jones, 2020; Koziol, Budding, & Chidekel, 2011). Population-based studies have found evidence that atypical sensory processing, specifically reports of sensory sensitivities, are associated with reported sleep problems (Foitzik & Brown, 2018; Shochat et al., 2009; Vasak et al., 2015). However, research has yet to parse out the contributions of different sensory processing patterns to sleep behaviors found across multiple diagnostic groups.

In this chapter, we present extensive background information on the state of the science to describe what is known about the relationship between sensory processing and sleep. We highlight the gaps in knowledge surrounding characterizing sleep and posit that examining sleep in a specific population, children with sensory sensitivities, is the critical next step in understanding the relationship of interest. This work is significant because it further develops the existing research by examining the foundational contribution of sensory processing on sleep. These findings will inform future research and clinical intervention across diagnostic populations.

2.2 Sensory processing in the brain

Sensory processing, or multisensory integration, refers to the neurological capabilities of processing sensory input from the internal and external environment (A. J. Ayres, 1971; Dunn et al., 2016; Mailloux et al., 2011; Watling, Bodison, Henry, & Miller-Kuhaneck, 2006). This processing informs behavioral responses that impact arousal levels and regulation throughout the day. It is estimated that 13%-16% of children have atypical sensory processing patterns that impact their daily lives (Ahn et al., 2004; Ben-Sasson et al., 2009; Dunn et al., 2016). For neurodiverse children, estimates of atypical sensory processing range from 66% in children with attention deficit-hyperactivity disorder (ADHD; (Mimouni-Bloch et al., 2018; Panagiotidi et al., 2018) to above 80% for children on the autism spectrum (ASD; (C. McCormick, Hepburn, Young, & Rogers, 2016; Tomchek & Dunn, 2007)). While the sensory processing pathways have been a focus of neuroscience for many years, the specific neurological differences in children with atypical sensory processing are still being explored (Koziol et al., 2011).

2.2.1 Neurological underpinnings of sensory processing

There are 5 primary sensory systems - somatosensory (tactile), visual, auditory, olfactory and gustatory - that register sensory stimuli from the external environment through specific sensory structures (e.g., skin, eyes, ears, etc.) to the brain for processing. There are also other intricate sensory systems that provide information about body position (proprioception), head position in relation to gravity (vestibular), and internal sensory signals like stretching of the bladder and gut (interoception). Detection of sensory stimuli starts at the sensory structures throughout the body (for an example, the outer ear and cochlea for auditory input) and progresses into the brain through a series of neural pathways for processing.

2.2.1.1 The sensory processing pathways

Within every system except the olfactory system, sensory structures take information from the environment to the thalamus before projecting to the specific primary sensory area within the cortex. The thalamus acts as a relay station to the cerebral cortex, passing both sensory and motor information from the body systems to the primary sensory and motor areas in the brain. There are also specific thalamic nuclei that communicate with the association areas of the cortex and are involved in higher level processing (Eagleman & Downar, 2016).

The primary sensory areas are organized in a map-like way where neighboring neurons represent neighboring parts of that particular sensory field. For example, neurons in the primary visual cortex create a visual field map in which adjacent points in the cortex aligns with adjacent points in the visual field. From these primary sensory areas, information passes to nearby secondary and tertiary sensory areas in the cortex, increasing the complexity of processing (Eagleman & Downar, 2016).

The highest level of integration happens within the association areas of the cortex. Here, sensory and motor information are integrated and linked with cognitive processing, resulting in a behavioral interaction with the environment (Eagleman & Downar, 2016). Association areas are separated into three multimodal association areas: the posterior association area, the anterior association area, and the limbic association area (Eagleman & Downar, 2016). Each of these systems oversee the highest integration of information in the brain.

2.2.1.2 Multisensory integration

Multisensory neurons respond to stimuli from the different sensory systems to integrate the information in an efficient way (Stein & Stanford, 2008). These neurons have been examined in a number of different species and have been found at all levels of the brain and in all mammals (Stein & Stanford, 2008). Dr. A. Jean Ayers, an occupational therapist and neuropsychologist, examined multisensory integration which she termed sensory integration (SI) and defined SI as the neurological process of combining sensory stimuli from the environment and the body to effectively move through and interact with the environment (A. J. Ayres, 1971). She proposed two important principles upon which she built her theory: "the brain is a self-organizing system" and "intersensory integration is foundational to function" ((A Jean Ayres, 1968); pg. 41). Ayres' used her clinical research to understand how sensory integration may be impacted for children with learning disabilities (A Jean Ayres, 1968).

2.2.1.3 Neurological differences in children with atypical sensory processing

Scientists and researchers have built upon Ayres' work over the past 50 years and have applied SI theory to examine the role of sensory integration for many children within neurodiverse populations (Lane et al., 2019; Roseann C. Schaaf, Dumont, Arbesman, & May-Benson, 2017). A few studies have looked at specific brain structures and neurologic processes to understand what differences lead to atypical sensory processing in children (Cardon, Hepburn, & Rojas, 2017; Giudice, Rogers, Johnson, Glass, & Shapiro, 2019; Leigh, 2016; Szymusiak & McGinty, 2008). Research shows that differences along any part of the sensory processing pathway can result in sensory processing difficulties. Differences in the somatosensory association cortex and thalamic radiation tracks have been noted in children with neonatal arterial ischemic stroke where impacted sensory processing is a common co-morbidity (Giudice et al., 2019). Sensory gating within the thalamus has been noted to be an indicator for atypical sensory processing in adults with mental illness (Bailliard & Whigham, 2017), children and adolescents with ASD (Chang et al., 2014), and adults with ADHD (Holstein et al., 2013). Additionally, differences in white matter in the cortext have been found in children with atypical sensory processing compared to peers without atypical sensory processing (Chang et al., 2015). Specifically, children with atypical sensory processing had lower densities of white matter in the posterior portion of the parietal lobe and occipital lobes, which are areas of the posterior association area and visual sensory systems. These differences are hypothesized to impact the coordination of sensory information transmission and the capabilities of processing across multiple sensory systems (Leigh, 2016).

Studies have also highlighted differences in sympathetic and parasympathetic nervous system activation in children with atypical sensory processing compared to peers (Davies & Gavin, 2007; R. C. Schaaf et al., 2010). More specifically, measures of low sensory gating and baseline vagal tone (or high frequency heart rate variability) have been proposed as potential, objective validation tools for sensory processing disorders (P. L. Davies, W.-P. Chang, & W. J. Gavin, 2009; R. C. Schaaf et al., 2010). Researchers have examined event-related potentials as measures of multisensory integration and salivary cortisol as a measure of hypothalamic-pituitary-adrenal axis activity for children with atypical sensory processing (Brett-Green, Miller, Schoen, & Nielsen, 2010; Lane, Reynolds, & Thacker, 2010; Stacey Reynolds & Lane, 2009). Despite this work, there has yet to be a biomarker identified to use in diagnosing sensory processing disorders (Galiana-Simal et al., 2020).

2.2.2 Characterizing sensory processing in pediatric populations

Clinically and within research, standardized tests, caregiver questionnaires, and clinical observations are primarily used to identify different sensory processing patterns. A recent systematic review found 15 unique tests in the literature that have published psychometrics for the US population (Jorquera-Cabrera, Romero-Ayuso, Rodriguez-Gil, & Triviño-Juárez, 2017). Through these tests, clinicians, researchers, and parents attempt to characterize a child's sensory processing patterns to understand how best to support the child within their daily life. Two categorizations of sensory processing patterns are dominate in the literature: defining sensory processing disorder along with subtypes within this diagnosis and defining sensory processing patterns.

2.2.2.1 Sensory processing disorder

Sensory processing disorder (SPD) is a clinical diagnosis that describes people with sensory processing abilities that impact engagement in daily life occupations (L. Miller et al., 2009). SPD is a heterogeneous condition that can be characterized by multiple sub-types. Miller and colleagues (2007) proposed three main categories of SPD: sensory modulation disorder, sensory-based motor disorder, and sensory discrimination disorder (Figure 1).

Children with sensory modulation disorder (SMD) have difficulties with grading their behavioral responses to sensory input. This may result in variable emotional and attentional responses to daily stimuli. SMD has three sub-types: sensory over-responsivity (characterized by a quick, intense, or sustained response to one or more types of sensory stimuli), sensory under-responsivity (characterized by a delay or lack of response to sensory stimuli), and sensory seeking (characterized by an active engagement in experiencing intense sensory input).

The second category of SPD is sensory-based motor disorder (SBMD). Children with SBMD experience difficulties with postural or volitional movement as a result of sensory processing difficulties. The sub-categories of SBMD are dyspraxia, or an inability to conceive, plan, sequence, or execute novel motor actions, and postural disorders, which are described by difficulties with postural stabilization in order to complete a task.

The final category of SPD is sensory discrimination disorder (SDD). Children with SDD perceive sensory stimuli but may have difficulties with the subtleties of the qualities of the stimuli. SDD commonly co-occurs with other types of SMD and SBMD. In a sample of 78 children with identified sensory processing difficulties, Mulligan at colleagues (2021) found support for Miller's proposed categories. The most commonly endorsed category was sensory modulation, over-responsivity subtype. They also found that 53% of their sample identified with more than one these SPD subtypes.

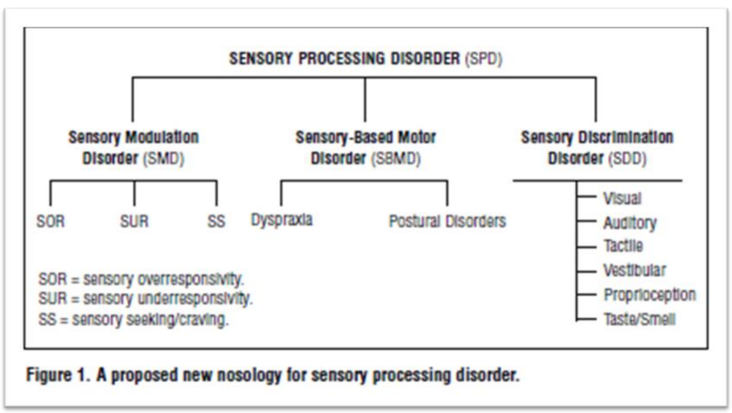

Figure 1 Miller's Classification of Sensory Processing Disorder
Miller, et al., 2009, used with permission © AOTA

2.2.2.2 Sensory processing patterns

Some research characterizes the differences seen in sensory integration by describing sensory processing patterns. In Dunn's Model of Sensory Processing (1997), sensory processing patterns are influenced by a person's neurological threshold and the behavioral response to sensory stimuli (e.g., passive or active self-regulation; Figure 2). Both concepts are presented as individual continua that, when intersected, present 4 basic patterns of sensory processing: Low Registration (high neurological threshold, passive behavioral response), sensation seeking (high neurological threshold, active behavioral response), sensory sensitivity (low neurological threshold, passive behavioral response), and sensation avoiding (low neurological threshold, active behavioral response). Dunn highlights that a person has multiple patterns of sensory processing, and when one's specific sensory processing needs are met, they have more opportunities to participate in activities successfully (Dunn, 2007). In a large latent profile analysis using the Sensory Profile-2, a parent-reported questionnaire developed to characterize sensory processing patterns (Dunn, 1997), Little and colleagues (2017) identified 5 profiles of sensory subtypes in a community sample of children with and without developmental disabilities: *balanced, interested, intense, mellow until…, and vigilant*.

Children with a *balanced* profile report low frequencies of sensory behaviors across all four sensory processing patterns. This profile represented the majority of children in Little's study, with 88.6% of typically developing children, 35% of children with ASD, and 53% of children with ADHD falling in this profile. Children with an *interested* profile were significantly younger than other profiles and presented with more frequent endorsements of seeking behaviors. The *intense* profile was made up of children who exhibited increased levels of all sensory patterns concurrently. Almost 20% of children with ASD and 10% of children with ADHD within the same fit within this profile. The *mellow until…* profile is characterized by high frequencies of avoidance and low registration behaviors. These children have been known to tolerate some sensory stimuli without difficulties, sometimes seeming to miss critical pieces of information. However, when the threshold for sensory input is met, a child with this profile may struggle to employ self-regulation techniques in order to appropriately handle the feeling of overstimulation. Finally, the *vigilant* profile is composed of increased sensitivity and avoidance sensory patterns. This profile had the lowest number of typically developing children (1%) and the highest number of children with a developmental diagnosis (about 15% of children with ASD, 13% of children with ADHD).

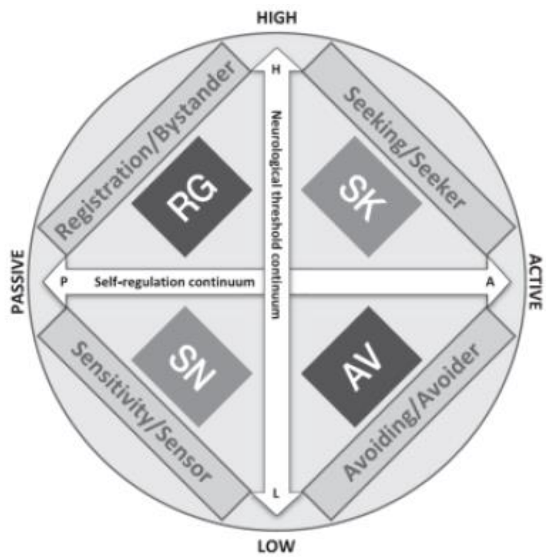

Figure 2 Dunn's Model of Sensory Processing
Dunn, 2014, used with permission © Pearson

2.2.3 The influence of sensory processing on occupations

Regardless of how sensory processing differences are described, a core principle of understanding this line of research is one that was proposed by Ayres (1968) and still holds true through current research findings: A person's unique sensory processing influences all aspects of their life (A Jean Ayres, 1968). Research has begun to identify specific sensory processing characteristics that influence participation in daily life (Dellapiazza et al., 2021; Koziol et al., 2011; L. Little, E. Dean, S. Tomchek, & W. Dunn, 2017). A scoping review found evidence that sensory processing is specifically linked to social participation, cognition, and temperament (Dunn et al., 2016; Sleeman & Brown, 2021). Research suggests that children with lower neurological thresholds (sensory sensitive or avoiding) are at higher risk for challenging behaviors, depression, and decreased quality of life while higher neurological thresholds, specifically seeking behaviors, predict resiliency and protect against depression (Costa-López, Ferrer-Cascales, Ruiz-Robledillo, Albaladejo-Blázquez, & Baryła-Matejczuk, 2021; Dean, Little, Tomchek, & Dunn, 2018). Occupational therapists and healthcare providers work to align a child's sensory strengths and needs with the demands of the environment and activities to best support participation and success in daily activities (Mori, 2015).

2.3 Sleep and sleep health

The occupation of sleep is a critical aspect of health and impacts growth and development (American Occupational Therapy Association, 2020). Sleep is also a specific area of interest in pediatric research (Meltzer et al., 2021). Research suggests that 20% - 30% of children experience poor sleep (Calhoun, Fernandez-Mendoza, Vgontzas, Liao, & Bixler, 2014; J. A. Owens & Moore, 2017), a number that increases substantially in diagnostic populations that have co-morbid atypical sensory processing. Between 30%-64% of children with ADHD and up to 60%-86% of children on the autism spectrum report having sleep problems (Souders et al., 2017; K. B. van der Heijden et al., 2018). The relationship between sleep and health has been studied at length for children and a recent meta-review highlights sleep's essential role in health outcomes (Matricciani, Paquet, Galland, Short, & Olds, 2019).

2.3.1 Sleep and arousal processes

Within the brain, the sensory processing and sleep-arousal circuits are intricate and expansive. Both circuits involve the whole body and nearly all areas of the brain. Sleep is driven by the delicate balance of arousal level and our activity patterns. Sleep and arousal networks are initiated deep within the brainstem and diencephalon and impact cortical activity and arousal levels throughout the body (Jones, 2020). Using neurochemical specific structures, the arousal circuits delicately balance sleep and arousal levels as well as sensory encoding within the brain and body (Batista-Brito et al., 2018; Szymusiak & McGinty, 2008).

The arousal and sleep circuits within the brain are highly connected in a mutually inhibitory way. These two processes create a bistable system that allows only one system to dominate- one can either be awake or asleep but not both. While arousal and sleep can be considered part of a continuum, the transition from awake to asleep can be impacted depending on the arousal state one finds oneself cycling through prior to bedtime (Chong, Abel, Pao, McCormick, & Schwichtenberg, 2021; Hoyniak et al., 2021). Arousal level is often measured by level of activity within the cortex (Olcese, Oude Lohuis, & Pennartz, 2018). High arousal is associated with desynchronized cortical activity and low arousal with more synchronized activity. When arousal turns into non-REM sleep, regular, slow synchronized waves are seen throughout the cortex.

2.3.2 Characterizing sleep health in pediatric populations

Sleep health is defined as a multidimensional construct that includes satisfaction with sleep, daytime alertness, sleep timing, sleep efficiency, and sleep duration (Buysse, 2014). For pediatric populations, an additional domain of sleep-related behaviors is added to describe actions that either support or undermine optimal sleep (Meltzer et al., 2021). Each of these domains are situated in a socio-ecological framework that considers individual child factors, family and school factors, and neighborhood and broader socio-cultural factors that influence the child's sleep (Figure 3). Within this dissertation, we used the pediatric sleep health framework to drive our characterization of sleep in a novel population in order to add to the body of research in pediatric sleep health.

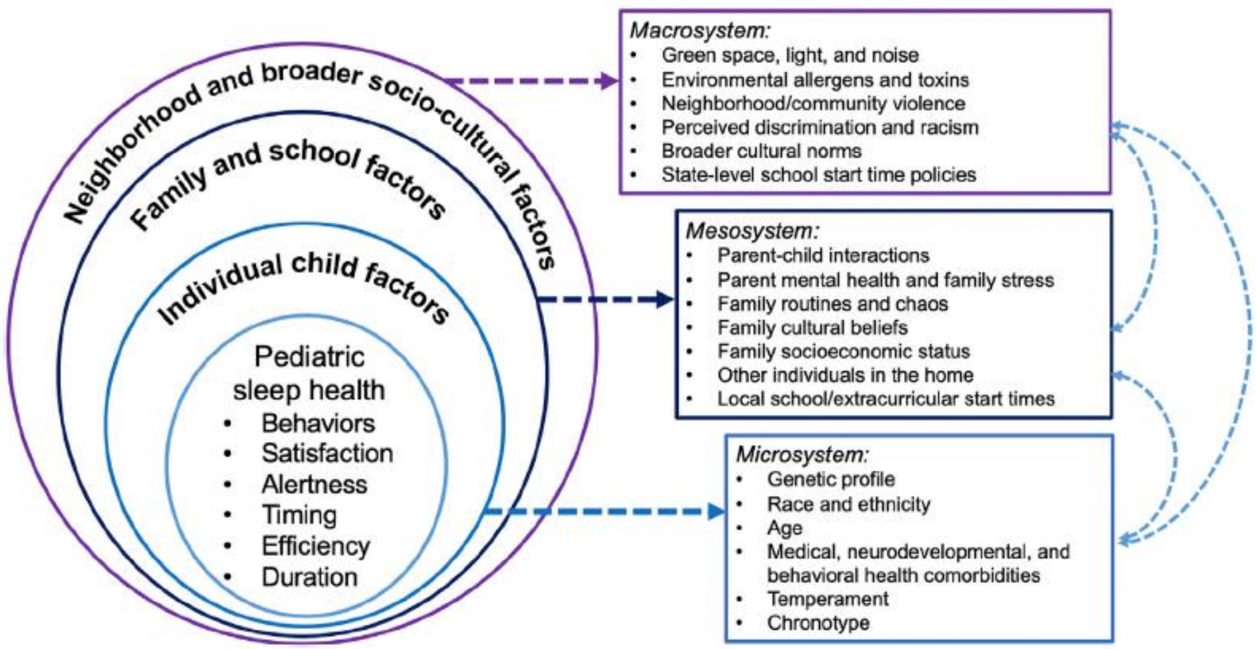

Figure 3 Pediatric sleep health framework
Meltzer, Williamson & Mindell (2020), used with permission © Elsevier

2.3.3 Common sleep difficulties in pediatric populations and their influence on pediatric occupations

Children can experience a variety of sleep problems that impact participation in daily occupations. Insomnia, nocturnal awakenings, and hypersomnia are the most common sleep disorder found in pediatric populations (Maski & Owens, 2016; Mindell & Owen, 2015; Robinson-Shelton & Malow, 2016). Rates of insomnia are higher in children with autism and other neurodevelopmental disorders compared to neurotypical children (Beth A. Malow et al., 2012; Beth A Malow et al., 2006 2017). Research specifically identifies bedtime resistance, increased nocturnal awakenings, and decreased sleep efficiency to be common sleep characteristics for neurodiverse children (Beth A Malow et al., 2006; Mindell & Owen, 2015; Robinson-Shelton & Malow, 2016).

Insufficient sleep can lead to a myriad of poor health outcomes that can profusely impact a child's engagement in daily occupations. For example, children with sleep problems have higher rates of poor attention and emotional regulation (Gregory & Sadeh, 2012). These difficulties could contribute to the decreased academic performance, difficulties with participating in play with peers, even gross motor performance in sport activities (Chaput et al., 2016). Poor sleep has also been associated with lower cognitive functioning and decreased executive functioning abilities (Sun et al., 2018; Turnbull, Reid, & Morton, 2013), which can impact activities of daily living like sequencing a morning routine and influence general feelings of success at home and school. Many reviews stress the critical public and personal health impact of insufficient sleep for children and urge parents and healthcare providers to address sleep concerns early and often (Chaput et al., 2016; Meltzer et al., 2021; Sun et al., 2018).

2.4 Understanding the relationship between sleep and sensory processing

There are many potential reasons children experience insufficient sleep like irregular bedtime routines, environmental aspects like excessive screen time or light. Researchers have started to examine the role sensory processing plays in sleep health (Appleyard et al., 2020; Foitzik & Brown, 2018; Manelis-Baram et al., 2021; Mimouni-Bloch et al., 2021). However, current studies exist predominately in typically developing children (without atypical sensory processing), children with autism, or children with ADHD. Therefore, to understand the role sensory processing may play in sleep, we first look to the shared neurological areas and pathways to understand the potential relationship between sleep and sensory processing. Then, we will examine how this relationship has been examined in different populations

2.4.1 Shared neurological areas and pathways

While research directly exploring the interaction between sleep and sensory processing systems is scarce, the hypothalamus and thalamus are integral regions in the brain for both processes and can shed light on a potential relationship. The hypothalamus plays a vital role in monitoring the state of the body and brain. It is intricately linked with the body through the spinal cord, the brainstem, cerebral cortex, and other parts of the diencephalon (Eagleman & Downar, 2016). One of the primary roles of the hypothalamus is managing sleep and arousal throughout the body (Szymusiak & McGinty, 2008). Within the hypothalamus there are neurochemically specific structures, like the suprachiasmatic nucleus and ventrolateral preoptic nucleus, that delicately balance sleep and arousal levels as well as sensory encoding within the brain and body (Batista-Brito et al., 2018; Szymusiak & McGinty, 2008). Arousal level can be estimated using measures of pupil dilation, heart rate variability, and stress indicators like cortisol levels or sweat glad activity (Frazier & Parker, 2018; Reimer et al., 2014). Pupil dilation and heart rate variability have not been characterized in children with atypical sensory processing patterns. Instead, salivary cortisol has been used as a measure of hypothalamic-pituitary-adrenal (HPA) axis activity (Kos-Kudla, Buntner, Marek, Ostrowska, & Swietochowska, 1996) and electrodermal responses (EDR), or skin conductance, has been used to measure sympathetic adrenal medullary (SAM) activity

(Fowles et al., 1981; McIntosh, Miller, Shyu, & Hagerman, 1999; L. J. Miller et al., 1999). The HPA axis manages longer-term stress and the SAM drives the acute “fight or flight” reaction (Frazier & Parker, 2018; McEwen, 2005). These two circuits have been explored in both children with atypical sensory processing and children who are poor sleepers (see Table 1 for an overview of findings).

Children with sensory sensitivities have perceptions to sensory stimuli that activate the HPA axis more frequently than peers without sensory sensitivities (Christensen et al., 2020; L. J. Miller et al., 2007). This results in an abundance of stress in the nervous system, resulting in negative behavioral responses, and high levels of arousal throughout the day (L. J. Miller et al., 2007; S Reynolds, Lane, & Gennings, 2010). Several studies have measured HPA axis activity in children with atypical sensory processing patterns, most commonly sensory sensitivities, through salivary cortisol collection, finding indications of high stress and low rates of habituation to stimuli compared to peers without sensory sensitivities (McIntosh et al., 1999; S Reynolds et al., 2011). Poor sleeping neurotypical children also experience similar high levels of cortisol throughout the day compared to good sleeping peers (Chrousos, Vgontzas, & Kritikou, 2000; Han, Kim, & Shim, 2012; Hatzinger et al., 2008; Raikkonen et al., 2010; S Reynolds et al., 2011; van Dalfsen & Markus, 2018). Experimental studies depriving adults of sleep show increases in cortisol reactivity to psychosocial stress, demonstrating an interesting cause-effect relationship (Schwarz et al., 2018; van Dalfsen & Markus, 2018). While it is unknown if the higher levels of cortisol in poor sleepers are related to sensory processing dysfunction, or if the high stress experienced by children with sensory sensitivities impacts their ability to sleep, there is evidence to suggest that the HPA axis plays an integral role in understanding the link between sleep and sensory processing.

Similar findings of high arousal levels in children with atypical sensory processing and children who are poor sleepers have been found using electrodermal reactivity (EDR) measurements during sensory challenge tasks (Christensen et al., 2020; McIntosh et al., 1999; S Reynolds et al., 2011; Schoen, Miller, Brett-Green, & Nielsen, 2009; Su, Wu, Yang, Chen-Sea, & Hwang, 2010). EDR is often used as a measure of general arousal and attention and "fight or flight" responses. Additionally, emerging research identifies little to no habituation to repeated stimuli during sensory challenge trials for children with atypical sensory processing (McIntosh et al., 1999; Su et al., 2010), however further studies are needed to confirm this (Schoen et al., 2009). Through measures of cortisol and EDR, it is evident that patterns of stress measurement are similar in children with atypical sensory processing and children with sleep dysfunction. Stress directly disrupts the sleep and arousal system; therefore, it is plausible, though currently unsubstantiated, that children with atypical sensory processing patterns may have a higher risk for sleep dysfunction.

Finally, children with atypical sensory processing and children who are poor sleepers show similar difficulties with sensory gating in the thalamus. The thalamus plays a significant role in filtering, or "gating", sensory information and relaying information to the primary sensory areas in the cortex (D. A. McCormick & Bal, 1994). Children with atypical sensory processing often have difficulties with sensory gating which results in an inability to disregard irrelevant or redundant stimuli and leads to overstimulation (Brett-Green et al., 2010). Individuals with ASD and ADHD are also known to have difficulties with sensorimotor gating (Cheng, Chan, Hsu, & Liu, 2018; P. L. Davies, W. P. Chang, & W. J. Gavin, 2009; Micoulaud-Franchi et al., 2015). Sleep onset and maintenance difficulties have been linked to poor sensory gating in neurotypical children, children with ASD, and ADHD (Paula Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008; Milner, Cuthbert, Kertesz, & Cote, 2009; Ruiz-Herrera, Guillén-Riquelme, Díaz-Román, Cellini, & Buela-Casal, 2020). Improving sleep has been noted to enhance sensory gating in neurotypical adults (Gumenyuk, Korzyukov, Roth, Bowyer, & Drake, 2013) and has been postulated to improve sensory gating symptoms in children with ASD (Deliens & Peigneux, 2019). In addition to gating, the thalamus has been found to be intricately involved with controlling arousal, attention, and consciousness as well as non-REM sleep (Eagleman & Downar, 2016; Gent, Bassetti, & Adamantidis, 2018). Considering this "dual-role" of the thalamus, it is plausible to believe that dysfunction in sensory gating at the thalamus, which contributes to atypical sensory processing patterns, could in fact impact arousal and sleep.

Table 1 Overview of neurological measures in children with atypical sensory processing and poor sleeping children

	Children with atypical sensory processing	Children with poor sleep
Hypothalamic-pituitary-adrenal axis (measured by salivary cortisol)	Elevated levels in response to stimuli, little to no habituation, potential compounding effect after multiple stimuli. Hypothesized overall higher levels throughout the day (Christensen et al., 2020; Lane et al., 2010)	Elevated levels throughout day, large spike after sensory stimuli (Hatzinger et al., 2008; Raikkonen et al., 2010; S Reynolds et al., 2011; van Dalfsen & Markus, 2018)
Sympathetic adrenal medullary activity (measured by EDR)	High magnitude, potentially low habituation (Christensen et al., 2020; Lane et al., 2010; McIntosh et al., 1999; Schoen et al., 2009; Su et al., 2010)	High magnitude, similar habituation (Raikkonen et al., 2010; S Reynolds et al., 2011)
Thalamic sensory gating (measured by ERP)	Decreased gating and more variability, maturation different than typical peers (P. L. Davies et al., 2009; Koziol et al., 2011; McIntosh et al., 1999)	Poor gating during pre-sleep wake in poor sleepers, sleep on-set and sleep maintenance difficulties correlated to poor gating (P. Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008; Milner et al., 2009)

2.4.2 Sleep and sensory processing relationship in the literature

There is limited research examining the role sensory processing differences play in diagnostic populations with high rates of poor sleep. The current research that exists examines the relationship between sleep and sensory processing exists in a few specific populations. In a population-based sample, a positive relationship between parent-reported sleep problems and endorsed sensory behaviors was found in children (K. Foitzik et al., 2018; Vasak et al., 2015) and adults (Engel-Yeger & Shochat, 2012). This finding has been replicated in studies with neurodivergent children with ASD (Deliens & Peigneux, 2019; S. Reynolds, S. J. Lane, & L. Thacker, 2011), ADHD (Merikanto et al., 2019; Saito et al., 2019), and other neurodevelopmental conditions like developmental coordination disorder (Koziol et al., 2011). Interestingly, research on sleep in those with sensory processing disorder alone is sparse.

Key findings in the current literature have made some important links between poor sleep and atypical sensory processing. Poor sleep has been associated with: (i) an increase in diagnostic symptoms (i.e., attention difficulties, high energy, stereotypic behavior, sensory filtering issues) in children with ADHD and ASD (Lambert, Tessier, Rochette, Scherzer, & Godbout, 2016; Merikanto et al., 2019; Singh & Zimmerman, 2015), (ii) vestibular-related oculo-motor and postural control decline in neurotypical adults (Besnard et al., 2018), and (iii) higher cortisol levels in response to sensory stimuli in children with ASD and their neurotypical poor sleeping peers (K. W. Adkins, S. K. Weiss, S. E. Goldman, T. Clemons, & Malow, 2012; Raikkonen et al., 2010).

Atypical sensory processing has also been noted to be a predictor of poor sleep. In a study of children with ASD and neurotypical peers, cortical activity, salivary cortisol levels, and reported sensory modulation behaviors predicted good versus poor sleepers within 85.7% accuracy (S Reynolds et al., 2011). Increased sensitivity to sensory stimuli has also been found to be a significant predictor of sleep difficulties in a number of studies of neurotypical children (Shochat et al., 2009; Vasak et al., 2015) and adults (Engel-Yeger & Shochat, 2012). Perhaps seemingly intuitive, research also suggests that those with higher daytime arousal, or higher arousal prior to bed, have a harder time falling and staying asleep (Chong et al., 2021; Hoyniak et al., 2021). This high arousal has been linked to sensory modulation disorder (sensory overresponsive type; (Mazurek & Petroski, 2015; S Reynolds et al., 2011; Thomas, Bundy, Black, & Lane, 2015)..

2.5 Applying research to fill the gaps in knowledge

There is still much to explore regarding the relationship between sleep and sensory processing dysfunction. Current research has examined this relationship within special populations, however there are complexities that are unique to each diagnostic population outside of atypical sensory processing that could also impact sleep. In order to parse out the unique contribution sensory processing patterns have on sleep; our research focuses on first measuring sleep in children specifically with sensory sensitivities only compared to children without sensory sensitivities (and no other diagnosis). As detailed above, children with sensory sensitivities show high rates of arousal and stress that we postulate to critically impact sleep health. We delve into how sleep is impacted by sensory sensitivities by choosing this specific population without additional confounders that are found in other diagnoses. With knowledge from future studies in this population, sleep measurement and intervention can target specific underlying factors that are found to impact sleep in both children with a broader sensory processing disorder diagnosis as well as those with other diagnoses with atypical sensory processing patterns.

The first step in this line of scientific inquiry is to ask: “How is sleep characterized in children with sensory sensitivities?”. Since sleep has not been measured in this population, sleep outcome measures should cover all domains of sleep health (Buysse, 2014; Meltzer et al., 2021). Using subjective (e.g., caregiver-reported questionnaires, sleep diary) and objective (e.g., actigraphy) sleep outcome measures will give researchers a more complete view of sleep health. We also look to understand the relationship between sensory processing patterns and reported sleep within our samples of children with and without sensory sensitivities. This initial analysis can inform future research and treatment by identifying potential sensory patterns that may more strongly impact sleep health in pediatric populations.

3.0 Characterizing sleep differences in children with and without sensory sensitivities

This chapter describes a cross-sectional, observational study examining parent- and child-reported sleep health for children with and without sensory sensitivities. This chapter has been developed into a manuscript and is currently in press in the journal *Frontiers in Psychology* (doi: 10.3389/fpsyg.2022.875766).

3.1 Introduction

Sensory processing, or multisensory integration, occurs in specific areas of the brain as sensory input from the external environment is transformed into usable data, supporting our ability to act in the world (Bundy & Lane, 2019). Epidemiological studies estimate that 5 to 16% of children in the general population experience sensory processing patterns that negatively impact their daily life (Ahn et al., 2004; A. J. Ayres, 1971; Dunn et al., 2016; Galiana-Simal et al., 2020; Mulligan et al., 2021).

Using Dunn's Sensory Processing Framework (2014), sensory processing patterns can be characterized in four quadrants: (i) low registration, (ii) sensory seeking, (iii) sensory sensitivity, and (iv) sensory avoiding. The low registration and sensory seeking patterns are characterized by their high neurological thresholds for sensory input. Children with higher thresholds often tolerate busy environments more easily than those with low thresholds. They can miss sensory information like verbal cues during school or details in a more complex activity. Children with sensory sensitivity and sensory avoiding patterns have lower neurological thresholds and tend to register and attend to more sensory input than others. They can be very detail-oriented and can flourish with consistent routines that allow them to predict the sensory input they will experience. Each of these sensory processing patterns influence participation in many areas of occupation, such as activities of daily living, play and leisure, and education (Cohn, Kramer, Schub, & May-Benson, 2014; Dunn et al., 2016; Koenig & Rudney, 2010; R. C. Schaaf et al., 2015).

Sleep is an area of occupation that is of interest in healthcare. Emerging research suggests that certain sensory processing patterns, specifically sensory sensitivities, may have a negative impact on sleep health for typically developing children (Rajaei et al. 2020), children with attention-deficit hyperactivity disorder (ADHD; (Mimouni-Bloch et al., 2021)), and children with autism (Tzischinsky et al., 2018). However, the literature has yet to assess sleep in children with predominate sensory sensitivities, which is necessary to begin to disentangle sensory processing difficulties from other neurological differences in special populations and uncover its impact on sleep.

We hypothesize that children with a low neurological threshold, that is, children who are sensory sensitive or sensory avoiders, will exhibit more difficulties with sleep processes. Sleep requires a shift from awake and alert to a relaxed state that allows one to transition to sleep. This process involves complex processes involving biological (Jones, 2020), psychological (Carskadon, 2002), social (Belísio, Louzada, & Azevedo, 2010), environmental (Caddick, Gregory, Arsintescu, & Flynn-Evans, 2018), and family factors (Gregory et al., 2005; L. J. Meltzer & Montgomery-Downs, 2011). Children with lower neurological thresholds can experience high sensitivity to sensory information and are more prone to hyperarousal (Koziol et al., 2011; Lane et al., 2010; McIntosh et al., 1999). It is our hypothesis that children who experience these sensory processing patterns find it difficult to calm down to fall asleep at night (delayed sleep-onset).

We chose to focus on children with predominate tactile (touch) and oral-tactile sensory sensitivities for our study because emerging evidence has identified tactile sensitivity as a potential key contributor to the reported sleep problems in children with autism (Tzischinsky et al., 2018), fetal alcohol spectrum disorder (Wengel, Hanlon-Dearman, & Fjeldsted, 2011), and typically developing children (Shochat et al., 2009).

The goal of this study was two-fold. First, we aimed to characterize parent- and child-reported sleep health in children (ages 6-10 years old) with reported sensory sensitivities (SS) compared to children without sensory sensitivities (NSS). Using data from validated parent- and child-reported questionnaires, we examined differences between groups in common bedtime experiences. We specifically investigated reported sleep-onset difficulties for both groups using parent- and child-reported questionnaires and expected to see higher rates of sleep problems reported for children with SS.

Second, we examined the relationship between a child's sensory processing patterns and their reported sleep problems (parent and children reported). We posed the question: "Is there a significant association between a child's sensory processing pattern and reported sleep problems?" We hypothesized that children who have a lower neurological threshold for sensory input, those identified as *sensors* or *avoiders* using Dunn's Sensory Processing Framework (Dunn et al., 2016), will have higher rates of reported sleep problems.

3.2 Methods

3.2.1 Study Design

This cross-sectional, observational study utilized validated parent- and child-reported questionnaires to characterize sleep in children with and without sensory sensitivities. All procedures and consent forms were approved by the University of Pittsburgh's Institutional Review Board (STUDY20050082).

3.2.2 Participants

Children between the ages of 6 and 10 years old in the United States and their families were recruited to take part in this remote research study. An *a priori* sample size calculation using the Children's Sleep Habits Questionnaire total score indicates a total sample of 17-20 participants in each group would achieve at 95% power to capture important differences between groups. Interested families were screened and consented by the PI (first author) over the phone. Caregivers (all identifying as parents) reported participating in at least 4 nights of their child's bedtime routine each week. All participating children did not have known sleep disorders and had not engaged in behavioral sleep intervention in the past, or while participating in this research study.

Two groups of children were recruited for this study: children with sensory sensitivities (SS) and children without sensory sensitivities (NSS). Children recruited for the NSS group reported no diagnoses or sensory processing difficulties that impact their daily life. Children recruited for the SS group reported tactile and oral-tactile sensitivities, established by answering "yes" to 6 of the 8 tactile and oral-tactile sensitivity questions posed in the screening process (taken from the Sensory Profile-2 Questionnaire, see Appendix B). Children with a diagnosis of autism, ADHD, or Down's syndrome were excluded from this study as these diagnoses have different components (e.g., neurological, medical) that may impact sleep.

3.2.3 Protocol

Upon enrollment in the study, all parents and children completed sleep and sensory processing related questionnaires reflecting on the past month: Children's Sleep Habits Questionnaire (parent-report, CSHQ; (J. Owens, Spirito, & McGuinn, 2000), Child's Sleep Self-Report (child-report, SSR; (J. Owens, Spirito, McGuinn, & Nobile, 2000), and the Sensory Profile-2 (parent-report, SP2; (Dunn, 2014)). Study data were collected and managed using REDCap, an electronic data capture tool hosted at the University of Pittsburgh (Harris et al., 2019; Harris et al., 2009) (Clinical and Translational Sciences Institute at the University of Pittsburgh Grant Number UL1-TR-001857). REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies. Questionnaires and a demographics survey were sent electronically using REDCap software. Prior to completing the questionnaires, parents were instructed to allow their child to complete the Sleep Self Report on their own, helping only if their child needs help reading or understanding the questions.

3.2.4 Outcome Measures

All questionnaire data were reviewed by the study team for completeness. Participants who missed questions were contacted to complete these items.

3.2.4.1 Demographic Questionnaire

A parent-reported demographics survey was developed by the study team to capture important characterizations for each participant. Age, sex, race, ethnicity, and geographic location (e.g., rural, suburban, urban) information was collected for both the parent and child. Parents were asked if their child was currently taking medication and the timing of medication and if any medications or supplements were being taken to aid sleep.

School information was collected, specifically the child's grade and if school was virtual, hybrid, in-person, homeschool, or another form of schooling. Parents also reported if this year's school situation was different than what is typical for their child (e.g., before the pandemic) in order to understand if a significant change in schooling could impact sleep.

3.2.4.2 Children's Sleep Habits Questionnaire (CSHQ)

The CSHQ is a parent reported questionnaire that includes 33 unique items reflecting on a child's sleep over the past month. Questions are scored on a 3-point Likert scale (Rarely, Sometimes, Usually) with higher scores indicating worse sleep. Six items are reverse scored (items 1, 2, 7, 9, 10, 28). The data produce 8 subscale scores: bedtime resistance (6 items), sleep duration (3 items), night waking (3 items), sleep onset delay (1 item), sleep anxiety (4 items), parasomnias (7 items), sleep disordered breathing (3 items), and daytime sleepiness (8 items). Two questions are found in both the bedtime resistance and sleep anxiety subsections, creating a total of 35 questions in the questionnaire. A total score on the CSHQ consists of the sum of 33 unique items. Internal consistency coefficients of the CSHQ are near (0.68) or above (0.78) acceptable standards for the community and clinical samples, respectively (J. Owens, A. Spirito, & M. McGuinn, 2000). A cut-point of 41 correctly identifies 80% of children with clinically significant sleep problems (Owens, Spirito, and McGuinn 2000).

3.2.4.3 Sleep Self-Report (SSR)

The Sleep Self-Report is a 26-item, 1-week retrospective survey designed to be administered to school aged children between 6 and 12 years (J. Owens, A. Spirito, M. McGuinn, et al., 2000). This questionnaire is designed to capture domains similar to the CSHQ (parent-report). This tool produces three subscales: bedtime behavior (12 items), sleep behavior (7 items), and daytime sleepiness (4 items). Each item is rated on a 3-point scale (Usually, Sometimes, Never) with a higher score indicating more disturbed sleep. All items are summed for a total score. Internal consistency coefficient is acceptable (0.88) (J. Owens, A. Spirito, M. McGuinn, et al., 2000).

3.2.4.4 Child Sensory Profile-2 (SP-2)

The Child Sensory Profile 2 (SP-2) is a newly updated caregiver-reported questionnaire that evaluates the child's neurological threshold and self-regulation continuums (Dunn, 2014). The original Sensory Profile has an over 90% discrimination rate between neurodivergent (e.g. children with ASD, ADHD) and neurotypical children (Ermer & Dunn, 1998). The updated SP-2 is found to significantly discriminate between vulnerable populations at a similar rate as the original version (Dunn, 2014). National normative data for clinical and population-based samples are available (Dunn, 2014). The SP-2 uses 86 items scored on a 5-point scale of "Almost Always" (5 points), "Frequently", "Half the Time", "Occasionally", and "Almost never" (1 point). A "Does not apply" option (0 points) is also available in the instances that parents have not observed the behavior in question. Items can be summed to produce *quadrant* subsections (Seeking, Avoiding, Sensitivity, and Registration) or *sensory* subsections (Auditory, Visual, Touch, Movement, Oral, and Behavior). For this study we utilized the *quadrant* scores as measurements of four distinct sensory processing patterns. Within each quadrant, higher scores indicate more frequent sensory behaviors.

3.2.5 Statistical Analysis

Data were exported from REDCap and analyzed using Stata/SE (version 17.0; (StataCorp, 2021)). We examined the data for influential outliers and adjusted statistical testing to accommodate for non-influential outliers. No influential outliers were identified.

3.2.5.1 Demographics analysis

Participants were separated by group (SS and NSS) based on screening questions. Student's *t*-test or Chi-squared tests were used to compare groups on the demographic variables of age, sex, race, ethnicity, and geographic location to ensure these variables were similar across groups. Additionally, we examined rate of general medication use, medication or supplement use to aid sleep, and frequency of special education services (school based and outpatient) to further characterize our groups.

3.2.5.2 Characterizing sleep by group

Means and standard deviations of total scores and subsection or quadrant scores of each questionnaire were calculated and compared by group. To understand the significance of the differences between groups, Student's t tests or the non-parametric alternatives and Hedges' g effect size estimations for unequal groups were computed. Hedges' g is an effect size that is better suited for our small sample and unequal group sizes. Effect size interpretation for the social sciences when comparing group differences typically indicates $g > 0.41$ as a minimum effect size representing practically significant effect, $g > 1.15$ as a moderate effect, and $g > 2.70$ as a strong effect (Ferguson, 2009). Considering our multiple variables and comparisons, a probability level of $p < .01$ was set *a priori* to indicate significance.

3.2.5.3 Examining relationship between sensory processing patterns and sleep problems

For the second aim of this study, we examined the correlations between parent- and child-reported sleep problems and different sensory processing patterns for all of the children together. Sensory processing patterns scores were calculated using the SP-2 scoring criteria and correlated with the sleep questionnaires total scores. Child's age and sex were also correlated to examine the relationship between these variables and sensory processing patterns and sleep. All variables were correlated using Spearman's ρ with the probability level of $p < .05$ set *a priori* to indicate significance. We used Mukaka's guidance of correlation coefficient magnitude in medical research of 0.70-1.00 indicating high correlations, 0.50-0.70 indicating moderate correlations, 0.30-0.50 indicating low correlations, and < 0.30 indicating negligible correlations (Mukaka, 2012).

Finally, we examined the relationship between each sensory processing pattern and reported sleep behaviors for each group (SS and NSS) to examine if the presence of sensory sensitivities impacts the relationship between both parent-reported and child-reported sleep and sensory processing patterns. Scatter plots were used to visualize the data for each group and a fitted line was drawn for each group to represent the magnitude and direction of the relationship between each sensory processing pattern and sleep total score. Due to our small sample size, we were unable to quantify the amount of variance in reported sleep each sensory quadrant explained in each group, however we can visualize the data to inform future larger studies (Figures 4 and 5).

3.3 Results

3.3.1 Demographics

A total of 57 parents and children were consented for this study, 23 in the SS group and 34 in the NSS group. Prior to the completion of the study, one participant asked to be withdrawn due to a family move and one participant was lost to follow-up, resulting in 22 participants in the SS group and 33 in the NSS group. All participants were recruited between September 2021 and December 2021 when families were transitioning into the school year during the COVID-19 pandemic. Children were reported to have had at least 2 weeks of school prior to starting our study to ensure some adjustment to their new schedule.

The groups were similar in child age, parent age, and child sex, but differed on racial and ethnic diversity (Table 2). Children with SS also had more diversity in location (urban, suburban, and rural). Additionally, most of the participants in both groups were living in the mid-west or eastern areas of the United States; however, the SS group did have one participant in the south and two participants in the west.

Parents of children with SS reported diagnoses of anxiety (13%), trauma (13%), behavior-related diagnoses (e.g., Oppositional Defiance Disorder; 8.6%), and developmental delay (4.3%). While none of the children in this study had a diagnosis of ADHD or Autism, two children with SS were reported to take Straterra or Ritalin daily (common ADHD medications). Additionally, two children were reported to take Prozac and Zoloft (common antidepression medication) however no children were reported to have a diagnosis of depression. Within the group of children with NSS, one child was reported to have a diagnosis of anxiety (3%) and one was reported to have asthma (3%). The only medications reported to be taken for children in the NSS group were allergy medication, multivitamins, magnesium and Vitamin D supplements, and melatonin. All other children in the NSS group did not report a diagnosis that impacts their daily life.

Table 2 Participant Characteristics

	SS Group (n=22)	NSS Group (n=33)	*p* value
Parent Age (SD)	38.36 (3.57)	37.33 (4.59)	.487
Child Age (SD)	7.46 (1.44)	7.46 (1.65)	.999
Child Sex†			.375
Male (%)	14 (64%)	17 (52%)	
Female (%)	8 (36%)	16 (48%)	
Child Race			
Black/African American, Hispanic	2 (9%)	0 (0%)	.078
Black/African American, Non-Hispanic	4 (18%)	0 (0%)	.011*
White/Caucasian, Hispanic	1 (5%)	0 (0%)	.216
White/Caucasian, Non-Hispanic	12 (55%)	30 (91%)	.002**
Other/Multiple	4 (18%)	3 (9%)	.322
Geographic location			
Urban	9 (41%)	3 (9%)	.005*
Suburban	9 (41%)	24 (73%)	.018*
Rural	4 (18%)	6 (18%)	.999
Child use of melatonin for sleep (%)†	7 (32%)	3 (9%)	.032*
Special Education Services†			
Children receiving special education services (%)	10 (45%)	5 (15%)	.013*
Children receiving outpatient therapy services (%)	8 (36%)	2 (6%)	.004**

Note: Students *t* test performed unless otherwise indicated.
† Chi Squared test performed
* $p< .05$, ** $p <.01$, *** $p< .001$

Another key difference between the groups was the number of children using medications or supplements to support sleep. Melatonin was used significantly more frequently for children with SS (n=7/22, 32%) than children with NSS (n= 3/33, 9%, χ^2= 4.58, p= .032). Parents who reported use of melatonin used doses that ranged from 0.5 mg to 2.5 mg, taken 30 to 60 minutes prior to bed.

While we did not directly ask about adoption during our study, 5 children with SS were reported to have been adopted. No children with NSS were reported to have been adopted, however parents were not directly asked. Additionally, more children with SS received special education services at school (SS= 45%, NSS = 15%, χ^2= 6.11, *p*= .013) and outside of school (SS= 36%, NSS = 6%, χ^2= 8.15, *p*= .004). These services included occupational therapy, physical therapy, speech therapy, and therapies from psychologists and psychiatrists. Parents did not specify the goal areas of these services; however, it was indicated that all children had not received interventions related to sleep in the past or currently.

3.3.2 Characterizing sleep

3.3.2.1 Child's perception of sleep

A total score of the SSR was compared between groups to characterize a child's perception of their sleep (Table 3). These data met all assumptions for parametric testing and therefore were compared using Student's *t*-test. Children with SS scored significantly higher (i.e. indication of increased difficulties) in overall sleep scoring compared to children with NSS ($Mean_{SS}$ = 42.18, SD_{SS} = 8.26, $Mean_{NSS}$ = 33.55, SD_{NSS} = 6.71, $t(53)$= -4.26, p < .001, g= 1.17). When examining subsection scores, we found a statistically significant difference between the bedtime ($t(53)$= -3.68, p < .001, g= 1.01) and sleep behavior (U= -3.63, p < .001, g= 1.23) subscales. In addition to the questions included in the total score, children were also asked '*do you have trouble sleeping?'* as part of the SSR. For children with SS, 64% (14/22) indicated that they had trouble sleeping. Only 21% of children with NSS (7/33) indicated that they had difficulty sleeping (χ^2= 6.49, p= .011).

3.3.2.2 Parent's perception of child's sleep

To characterize a parent's perception of their child's sleep, we calculated and compared the total score of the CSHQ by group. Due to the non-normality of these data, we used non-parametric Mann-Whitney *U* tests to compare groups (Table 3). Parents reported a statistically significant difference in overall sleep, with children with SS scoring higher (indication of increased difficulties higher; $Mean_{SS} = 54.91$, $SD_{SS} = 10.00$) than children with NSS ($Mean_{NSS} = 45.12$, $SD_{NSS} = 7.27$; $U = -3.41$, $p = .001$, $g = 1.11$). Further analysis of subsections indicated that parents of children with SS identified higher frequencies of bedtime resistance, sleep onset delay, sleep anxiety, night awakenings, and parasomnias. Both groups scored similarly on sleep duration, sleep disordered breathing, and daytime sleepiness subsections. Ninety-one percent of total scores for children with SS exceeded the cut-point of 41 (J. Owens, A. Spirito, & M. McGuinn, 2000). Interestingly, 67% of total scores for children with NSS exceeded the cut-point, a higher rate than what is reported in the literature (Markovich, Gendron, & Corkum, 2015).

3.3.2.3 Correlation between parent and child sleep

We examined the relationship between parent and children reported sleep by group and found that children with SS and their parents had very low, non-significant correlations between their reported of sleep ($\rho = 0.14$, $p = .526$). Children with NSS and their parents showed a moderate and significant positive correlation between their total scores ($\rho = 0.64$, $p < .001$).

Table 3 Comparison of groups on sleep variables

	SS Group (n=22)	NSS Group (n=33)	*p* value	Hedges' *g*
Sleep Self Report total score†	42.18 (8.26)	33.55 (6.71)	< .001**	1.17‡‡
Bedtime†	22.45 (4.78)	12.97 (4.19)	<.001**	1.01‡
Sleep behavior	12.68 (3.05)	9.64 (2.01)	<.001**	1.23‡‡
Daytime sleepiness†	7.05 (1.84)	5.94 (1.58)	.021	0.66‡
Children's Sleep Habits Questionnaire total score	54.91 (10.00)	45.12 (7.27)	<.001**	1.11‡
Bedtime Resistance	9.64 (2.66)	7.61 (2.32)	.001*	0.83‡
Sleep onset delay	2.09 (0.81)	1.45 (0.56)	.003*	0.95‡
Sleep duration	5.05 (2.01)	4.12 (1.39)	.095	0.56‡
Sleep anxiety	7.41 (2.40)	5.64 (2.12)	.004*	0.79‡
Night waking	4.82 (1.87)	3.70 (0.92)	.018	0.81‡
Parasomnias	10.68 (2.42)	8.42 (1.52)	<.001**	1.17‡‡
Sleep disordered breathing	3.59 (1.01)	3.39 (0.70)	.493	0.24
Daytime sleepiness	11.64 (3.90)	10.79 (2.70)	.557	0.26
Sensory Profile 2				
Seeking†	55.41 (20.99)	31.36 (11.61)	<.001**	1.50‡‡
Avoiding	57.00 (18.04)	32.24 (11.47)	<.001**	1.72‡‡
Sensitivity	50.14 (16.00)	27.76 (9.15)	<.001**	1.81‡‡
Registration†	49.45 (16.09)	30.88 (10.16)	<.001**	1.45‡‡

Notes: Means presented with standard deviations in parentheses with higher scores indicating higher frequencies of problem behavior. Non-parametric Mann-Whitney *U* test used until indicated. Hedges' *g* corrected for uneven groups was used to calculate effect size.
† Student's *t* test was used
‡ Effect size interpretation for social sciences typically is as follows (Ferguson 2009):
‡*g*> 0.41 minimum effect, ‡‡*g*> 1.15 moderate effect, ‡‡‡*g*>2.70 strong effect
* p< .01, ** p< .001

3.3.3 Relationship between sleep and sensory processing patterns

3.3.3.1 Characterizing sensory processing patterns in each group

Children with SS and NSS differed significantly on all four quadrant scores of the SP-2, with children with SS scoring significantly higher for each quadrant score (Table 3). Twenty (91%) children with SS scored higher than at least 1 standard deviation (or "More than others" on the tool) from the mean on one of the quadrants, and 11 (50%) scored 2 standard deviations (or “Much more than others”) from the mean on at least one quadrant.

On average, children with NSS scored within one standard deviation from the mean in all sensory quadrants. However, 8 children (24%) with NSS had at least one quadrant score falling one standard deviation above the mean, and 2 participants (6%) scored higher than 2 standard deviations above the mean on a quadrant score, one scoring 2 standard deviations higher in the low registration quadrant and the other scoring 2 standard deviations higher in both the avoiding and sensitivity quadrants.

3.3.3.2 Correlations between sleep and sensory processing patterns

We then examined the correlations between sleep and sensory variables by group. Two compilations of scatter plots are presented in figures 4 and 5. Figure 4 represents the correlation of parent-reported sleep by each sensory quadrant score by group and figure 5 presents the correlations between child-reported sleep and each sensory quadrant score. From these scatter plots and fitted lines, potential differences in the magnitude and significance of the relationship between reported sleep problems and sensory processing patterns can be explored.

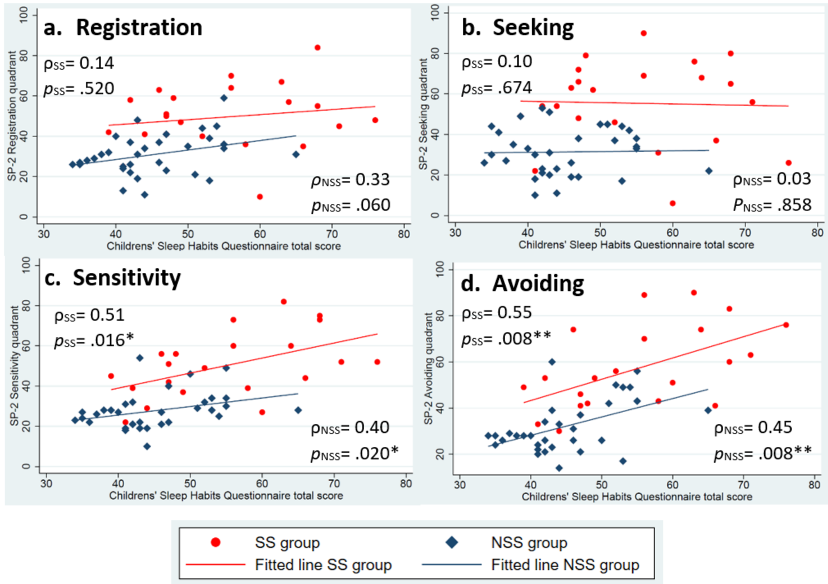

Figure 4 Scatter plots of parent-reported sleep (Children's Sleep Habits Questionnaire) and sensory processing patterns (Sensory Profile-2 quadrant scores)

Note: Spearman's ρ correlations and *p*-values presented for each group. * $p< .05$, ** $p< .01$, *** $p< .001$

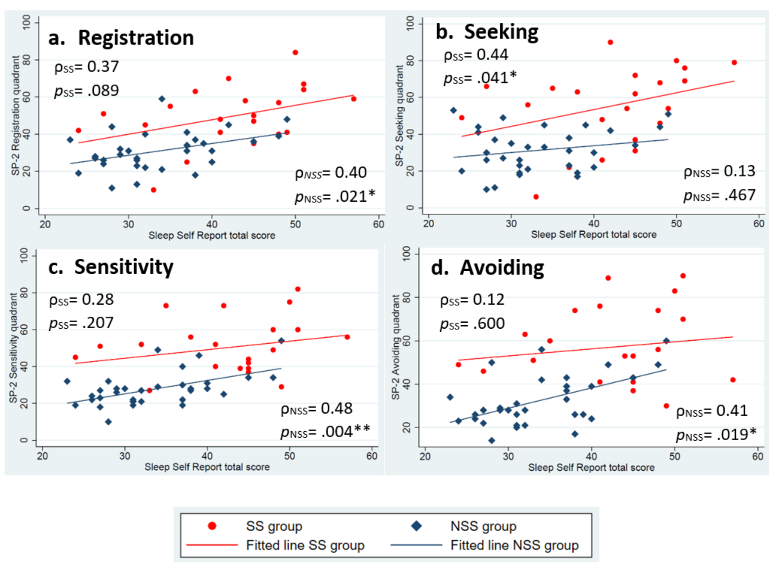

Figure 5 Scatter plots of child-reported sleep (Sleep Self Report) and sensory processing patterns (Sensory Profile-2 quadrant scores).

Note: Spearman's ρ correlations and *p*-values presented for each group. * $p< .05$, ** $p< .01$, *** $p< .001$

Aligning with our hypothesis, both groups had statistically significant associations between parent-reported sleep and low neurological threshold patterns (figure 4c and 4d). For child-reported sleep, a significant association was found in low neurological threshold patterns for only children with NSS (figure 5c and 5d). Contrary to our hypothesis, low neurological threshold patterns were not significantly associated with child-reported sleep for children with SS. Interestingly, children with SS identified a significant relationship between sensory seeking and reported sleep (figure 5b).

Additionally, we compared the magnitude of the associations within each sensory processing pattern by group. Using parent-reported sleep behaviors, larger correlations were found for children with SS compared to children with NSS for all sensory patterns except the low registration pattern. This aligns with our hypothesis and suggests that sensory processing is slightly more strongly associated with sleep behaviors in children with SS compared to peers. Child-reported sleep, however, was found to be more strongly associated with high neurological threshold patterns for children with SS (figure 5a and 5b) and low neurological threshold patterns for children with NSS (figure 5c and 5d).

Additionally, a larger variability can also be seen in children with SS compared to children with NSS, as evident by the larger spread of data in this group. We see a shift towards higher scores on both of the sleep variables and each of the sensory processing pattern scores for children with SS in these plots, indicating that children with SS more frequently endorse the sensory and sleep behaviors noted in these questionnaires.

3.4 Discussion

First, this preliminary cross-sectional, observational study adds to the science by characterizing sleep behaviors in a novel group: children with sensory sensitivities (SS) who do not have a diagnosis of autism or attention-deficit hyperactivity disorder. We compare these data to children without sensory sensitivities (NSS) to understand the areas in which these groups differ. We found significantly increased sleep difficulties (e.g., more frequent bedtime resistance, parasomnias, sleep anxiety) for children with SS compared to children with NSS. The current results align with previous findings in neurodiverse children; studies have found higher prevalence of sleep problems in children with ADHD (Langberg et al., 2020; Mimouni-Bloch et al., 2021) and autism (Manelis-Baram et al., 2021; Souders et al., 2017). Both of these groups have high rates of co-occurring sensory processing patterns that negatively impact daily life (Dellapiazza et al. 2021; Ghanizadeh 2011; Ausderau et al. 2016; AOTA 2013).

Second, we noted that parents reported a small to moderate and significant correlation between the lower neurological threshold patterns in both groups. Parents of children with SS reported slightly larger correlations than parents of children with NSS, aligning with our hypothesis that sensory processing patterns are more strongly associated with sleep difficulties for children with SS. When examining child-reported sleep correlations, we found that only children with NSS report similar small, significant, and positive correlations between sleep behaviors and low neurological threshold patterns. Children with SS, on the other hand, report negligible correlations between sleep behaviors and low neurological threshold patterns and small-moderate correlations between sleep behaviors and the higher neurological threshold patterns, a finding that opposed our hypothesis. This could be reflective of the parent and child discrepancy of perception that is evident in the reported sleep measures, as the sensory questionnaire was only completed by parents.

As other sleep research has found, we see interesting discrepancies between parent and child reported sleep (Judith A. Owens, Maxim, Nobile, McGuinn, & Msall, 2000; Short, Gradisar, Lack, Wright, & Chatburn, 2013). As research continues to explore sleep in pediatric populations, it is critical to incorporate both parent and child reported perspectives of sleep to construct a more complete picture of the components of sleep. Using these two methods, we can see that while both parents and children identify higher rates of sleep difficulties for children with SS compared to children with NSS, parent and child reports correlate with different sensory processing patterns.

3.4.1 Relationship between sleep and sensory processing

Characterizing the relationship between sleep and sensory processing patterns has been of recent interest in the pediatric sleep research community. Rajaei et al. (Rajaei, Kalantari, Azari, Tabatabaee, & Dunn, 2020) recently published a large, cross-sectional study with typically developing children in Tehran correlating the Persian version of the CSHQ with Sensory Profile quadrant scores. They found small but highly significant correlations between CSHQ total scores and all sensory processing patterns.

Recent studies have also identified similar findings in other diagnostic populations. Manelis-Baram and colleagues (Manelis-Baram et al., 2021) highlight similar significant correlations between parent-reported sleep (CSHQ) and sensory processing patterns in young children with autism prior to the pandemic. More frequent endorsement of sensory processing behaviors has also been correlated with more frequent parent-reported sleep problems for children with ADHD (Mimouni-Bloch et al., 2021).

While research continues to home in on specific relationships between sensory processing patterns and sleep in children, our findings of higher reported sleep difficulties for children with SS compared to peers suggests that a sensory sensitive pattern could be a key component to understanding the high rates of sleep problems in children (Deliens & Peigneux, 2019; Hollway & Aman, 2011; Mazurek & Petroski, 2015; S Reynolds et al., 2011).

3.4.2 The impact on the occupation of sleep

Sleep is a critical occupation that requires a skilled transition from wakefulness to sleep (American Occupational Therapy Association, 2020). Our results indicate that children with sensory sensitivities struggle with independence in this transition. More specifically, there is emerging evidence that children with reported low neurological threshold patterns, or those with sensory sensitivities and sensory avoidance, show the largest relationship with poor sleep outcomes (Rajaei et al., 2020; Shochat et al., 2009; Thomas et al., 2015). Being that sleep is foundational to a child's health, growth, and development, sleep should routinely be part of care for children with sensory sensitivities.

3.4.3 Strengths, limitations, and future directions

An important strength of this study was the comparison of children with SS to a peer group with NSS. This allows us to account for some of the current historical (e.g., COVID) and temporal (e.g., time of year) factors that otherwise might influence our outcomes of interest. We also used validated questionnaires that are widely used to characterize sleep and sensory processing patterns, a strength to consider when applying our findings with the larger body of literature.

Our study does have limitations that are important to consider. Our study uses a small sample size that lacked racial and ethnic diversity to mirror the United States' demographic make-up. A larger, more diverse sample in future research will further uncover the relationships between sleep and sensory processing patterns. Our groups also were significantly different in their geographic location and urbanicity. These variables can lead to differences in exposure to a myriad of environmental sensory stimuli like nighttime light and environmental noise that could negatively influence sleep in children who are more attune to sensory stimuli.

Our groups also differed in their use of medications or supplements to support sleep. We found a significantly higher rate of melatonin use for children with SS compared with children with NSS. This could be reflective of the significantly higher rates of sleep behaviors noted for children with SS. Parents and children who identify higher rates of sleep behaviors may turn to medication and supplements more readily to address these problems. It is interesting that despite the higher rates of melatonin use, children with SS still report higher sleep behaviors. Future research could examine melatonin use and its perceived effects for children with SS compared to children with NSS.

It should be noted that three children in the SS group were taking medications that may impact their sleep (Straterra, Prozac, and Ritalin/Zoloft). There were also a similar number of children in both groups taking allergy medication which may impact sleep for these children. Future research should document more information regarding medication timing and effects parents and children note regarding their daily medication.

Additionally, in this study we purposefully sampled children who were reported to have sensory sensitivities. While this allows for a strong sample of children with lower neurological threshold, children with predominately high neurological thresholds may have been excluded, biasing our findings. Future research should include children with a variety of sensory processing patterns to better understand correlations with sleep.

An important consideration with this study is the timeline of data collection, which took place between September 2021- December 2021, during the COVID-19 pandemic (Delta variant predominance) in the United States. All but one of our participants were attending school in person at the time of data collection, however some reported having to recently quarantine at home due to COVID exposure or infection. While the effects of COVID on child sleep are still being explored, some studies conducted at the beginning of the pandemic show an increase in overall sleep duration and sleep quality during the early pandemic (Sharma et al. 2021). However, in our data, we show high rates of sleep problems reported in both children with SS and NSS at this time, which may be a result of the higher level of stress and schedule variabilities due to COVID exposure or illness and quarantine restrictions.

Children's sleep habits do not occur in a vacuum, but in a dynamic family context; this context is critical for pediatric sleep researchers to remember (Dahl & El-Sheikh, 2007; L. J. Meltzer & Montgomery-Downs, 2011). Children with poor sleep often impact the family functioning, just as family functioning can impact a child's sleep (L. J. Meltzer & Montgomery-Downs, 2011). In this study we did not measure family functioning, parental stress, or overall feelings of burden related to child sleep problems. Future research may consider the family dynamic and parental stress and the impact of poor child sleep on family functioning.

This is one of the very few studies characterizing sleep in children with sensory sensitivities who do not have a diagnosis of autism or ADHD and therefore this study lays the groundwork for future studies characterizing sleep using objective sleep measures like actigraphy or polysomnography. These measurement tools can provide additional information that can support development of targeted sleep intervention for children with each sensory processing pattern. Additionally, exploration of circadian rhythm timing for children with different sensory processing patterns would be an interesting aspect to consider for future research.

3.5 Conclusion

Good sleep is critical for childhood development and overall health. We have found evidence that children with sensory sensitivities experience higher rates of sleep difficulties that can be captured by parent- and child-reported questionnaires. Further, we show positive correlations between sensory processing patterns and both parent- and child-reported questionnaire total scores. When examining correlations within each group, we found significant, positive relationships between parent-reported sleep difficulties and low neurological threshold patterns (e.g., sensitivity and avoiding) for both groups. These data indicate children who are reported to have more frequent sensory-related behaviors endorse more frequent bedtime problems. We believe our study provides a step towards uncovering specific sleep intervention targets and will contribute to improvement in everyday care for children with sensory sensitivities.

4.0 Characterizing rest-activity rhythms and sleep for children with sensory sensitivities

This chapter describes a cross-sectional, observational study examining rest-activity rhythms and sleep period variables for children with and without sensory sensitivities. This chapter has been developed into a manuscript and is currently in preparation for submission to a scientific journal.

4.1 Introduction

Sleep is a critical pillar of health and has a strong influence on general wellbeing (Spruyt, 2019). Insufficient sleep can increase a child's risk for a myriad of negative health outcomes and contribute to delays in cognitive development, emotional regulation, and physical growth (Beebe, 2011, 2016; Bonanno et al., 2019; Cook et al., 2020; James & Hale, 2017; Virring, Lambek, Jennum, Møller, & Thomsen, 2017). Characterizing multidimensional sleep health in children with neurodevelopmental disorders or neurodivergence has been of particular interest in recent calls for research (Beebe, 2016; Meltzer et al., 2021; J Owens & Mindell, 2006). Published literature suggests that children with neurodevelopmental disorders (e.g., autism, attention deficit-hyperactivity disorder, fetal alcohol syndrome) are at risk for high rates of sleep problems (Cohen, Conduit, Lockley, Rajaratnam, & Cornish, 2014; Díaz-Román, Hita-Yáñez, & Buela-Casal, 2016; Hollway & Aman, 2011; Singh & Zimmerman, 2015). Existing studies find that 65% of children with attention deficit-hyperactivity disorder (ADHD) and up to 80% of children with autism report significant sleep problems (Beth A Malow et al., 2006; S Reynolds et al., 2011; K. B. van der

Heijden et al., 2018). These rates are notably higher than rates of sleep problems in the general pediatric population, which have been reported to be as high as 20% (Calhoun et al., 2014).

Research has pointed to a connection between poor sleep and sensory sensitivities that may explain the high rates of sleep problems in these neurodiverse populations (Appleyard et al., 2020; Deliens & Peigneux, 2019; Foitzik & Brown, 2018; Lufi & Tzischinsky, 2014; Mazurek & Petroski, 2015; Mimouni-Bloch et al., 2021; Shochat et al., 2009; Souders et al., 2017; Tzischinsky et al., 2018; Vasak et al., 2015). Children with sensory sensitivities intensely perceive sensory information gathered from the environment (e.g., the sound of a plane, the texture of their clothes) or from internal sensations (e.g., the stretching of their bladder, or movement of their stomach), often resulting in a fight-flight-freeze autonomic response (Dunn et al., 2016; Greven et al., 2019; L. J. Miller et al., 2007). Sensory sensitivity is one type of atypical sensory processing pattern that can impact daily participation in activities (Dunn et al., 2016; L. J. Miller et al., 2007). A positive relationship has been found between parent-reported poor sleep and atypical sensory processing patterns in the general population (6, 29). More specifically, sensory sensitivity seem to be common sensory patterns that are related to poor sleep across different pediatric populations like autism (Deliens & Peigneux, 2019; Manelis-Baram et al., 2021; Mazurek & Petroski, 2015), ADHD (Lufi & Tzischinsky, 2014; Manelis-Baram et al., 2021), and the general pediatric population (Fernández-Pires et al., 2021; Rajaei et al., 2020).

4.1.1 Measuring sleep health

Sleep health is defined as a multidimensional construct that includes sleep behaviors, satisfaction with sleep, daytime alertness, sleep timing, sleep efficiency, and sleep duration (Buysse, 2014; Meltzer et al., 2021). Assessing the multiple dimensions of sleep health requires multiple measurement tools. Polysomnography, actigraphy, and retrospective sleep questionnaires are the three most prevalent tools used to measure sleep in pediatric populations (Lam & Shea, 2016). Polysomnography is the gold standard of sleep measurement and requires one or two nights spent in a sleep lab while connected to many wires that monitor brain activity during sleep. Activity monitoring through the use of a wearable device, also called actigraphy, offers a less burdensome and invasive way to capture sleep characteristics based off of movement. Sleep questionnaires, completed by parents or children, are most widely used to provide a retrospective account of sleep. The literature examining sleep health for children with sensory sensitivities has almost exclusively relied on parent-reported questionnaires.

Actigraphy provides a longitudinal and movement-based estimate of rest-activity rhythms and sleep period variables like sleep efficiency, total time in bed, total time asleep, and wake after sleep onset (Calogiuri, Weydahl, & Carandente, 2013). Rest-activity rhythms have recently become of interest in research, as they provide a measurement of a person's 24-hour rhythms in the free-living environment (J. A. Mitchell et al., 2017). These rhythms characterize average activity across the day and night and give indication of a person's timing and "shape" of patterns of active and inactive (sedentary or sleep) times within the 24-hour period. Blunted rest-activity rhythms have been linked to poor health outcomes like high body mass index, fatigue, and inattention and hyperactivity in pediatric children (Qian et al., 2021; Rogers et al., 2020; Ulset et al., 2021). Rest-activity rhythms can provide information to target interventions aimed to improve sleep and overall health outcomes.

Previous findings have identified significant sleep disturbances for children with sensory sensitivities compared to peers using parent- and child-reported retrospective questionnaires (Hartman, McKendry, Soehner, Bodison, & Bendixen, 2022). In this study, we present longitudinally collected actigraphy and sleep diary data for children with sensory sensitivities compared to peers without sensory sensitivities. We aim to characterize and compare movement-based rest-activity rhythms and sleep period variables to expand the understanding of differences experienced by children with sensory sensitivities compared to peers. Aligning with parent and child-reported differences for children with sensory sensitivities (Hartman et al., 2022; Singh & Zimmerman, 2015), we hypothesize that children with sensory sensitivities will show evidence of more sleep fragmentation, (as seen by lower sleep efficiency and higher wake after sleep onset) and longer time needed to fall asleep.

4.2 Methods

4.2.1 Participants

Children between 6 and 10 years old in the United States and their families were recruited to take part in this research study between September through December 2021. All caregivers spoke English, were willing to complete daily sleep diaries throughout the study period and reported participating in at least 4 nights of the bedtime routine each week. Participating children had not engaged in a behavioral sleep intervention in the past or presently.

We recruited two groups of children to participate in this study: children with sensory sensitivities (SS group) and children without sensory sensitivities or any developmental diagnosis (NSS group). Children recruited for the SS group were reported to have tactile and/or oral-tactile sensitivities by their caregivers, established by caregivers answering “yes” to 6 of the 8 tactile and oral-tactile sensitivity questions posed in the screening process (taken from the Sensory Profile-2 questionnaire, see Appendix B). A diagnosis of autism, attention-deficit hyperactivity disorder, or Down's syndrome excluded participants, as these diagnoses have different neurological and medical components that may impact sleep. Children recruited for the NSS group were reported by caregivers to not have sensory sensitivities that impact daily life and did not have a developmental diagnosis.

4.2.2 Protocol

Interested participants were consented and sent a demographics survey to complete electronically through the REDCap software program (Clinical and Translational Sciences Institute at the University of Pittsburgh Grant Number UL1-TR-001857, (Harris et al., 2019; Harris et al., 2009)). Participants were sent a wrist-worn activity monitor, the ActiGraph GT9X (ActiGraph Corp, LLC, Pensacola, FL), to wear all day and night for 2-weeks. During this data collection period, parents are given sleep diaries (either electronically or in paper form per their preference) to complete every morning and evening (Appendix C).

4.2.3 Outcome Measures

4.2.3.1 Demographics questionnaire

Demographics information was collected to characterize our participants. Questions about the caregiver and child age, caregiver relationship to child, child sex, child race and ethnicity, geographic location (urban, suburban, or rural) were asked. Additionally, caregivers were asked to report any diagnosis their child has that impacts their daily life. If children were taking medication, caregivers reported the type of medication and frequency of taking the medication.

Caregivers were also asked if they used medications or supplements to support sleep for their child, and if so, frequency and amount used.

4.2.3.2 Actigraphy

Actigraphy provides an indirect, objective, movement-based estimate of sleep and activity (Ancoli-Israel et al., 2003; Lisa J. Meltzer et al., 2016; Morgenthaler et al., 2007). The ActiGraph GT9X Link (ActiGraph Corp, LLC, Pensacola, FL) is a research-grade activity monitor that uses an internal accelerometer, gyroscope, and magnetometer to estimate sleep-wake patterns. Participants were instructed to wear the ActiGraph throughout the day and night for 14 days on their wrist, taking it off to charge as needed and when there was a possibility of getting wet. Data collection was set to 60 second epoch lengths. Upon completion of the data collection period, data were downloaded and cleaned in two different ways, for: (i) rest-activity rhythm calculation and (ii) sleep period variable calculation.

4.2.3.2.1 Rest-activity rhythms statistics

For rest-activity variable calculation, raw actigraphy data (vector magnitude or "counts") were cut into consecutive days of complete data (no more than 3 hours of missing data). These data were used to calculate rest-activity rhythm variables using RStudio (version 4.1.1, (Computing, 2021)) and two external packages: the RAR package, version 2.0.0, (Graves et al., 2021) and the nparACT package, version 0.8, (Blume, Santhi, & Schabus, 2017)). Rest-activity rhythms were characterized in three ways: (i) using sigmoidally transformed extended cosine models, (ii) non-parametric circadian rhythm analysis, and (iii) localized measures of rest-activity rhythms (specifically mean and standard deviation of 1 hour time bins; RAR package, version 2.0.0, (Graves et al., 2021)).

The extended cosinor model approach applies a series of sigmoidal transformations to a traditional cosine model to allow the curve of the model to be more square-like, which has been noted to be closer to the human rest-activity rhythms (Marler, Gehrman, Martin, & Ancoli-Israel, 2006). This approach generated 3 variables characterizing the timing of rest-activity rhythms that were of specific interest for this study: (i) average time of activity initiation in the morning (up-mesor), (ii) average time of activity peak (acrophase), and (iii) average time of activity off-set in the evening (down-mesor) (Marler et al., 2006; Smagula et al., 2017). All variables are presented in military clock time (e.g., 1400= 2:00pm).

Non-parametric rest-activity rhythms were calculated to assess the stability and variability of the children's rest-activity rhythms (Calogiuri et al., 2013). These variables include intradaily variability (IV), interdaily stability (IS), least active 5 hours (L5), most active 10 hours (M10), and relative amplitude (RA) (Calogiuri et al., 2013; Goncalves, Cavalcanti, Tavares, Campos, & Araujo, 2014). IV is a measure of fragmentation of the rest-activity rhythm (range from 0-2) with high values of IV indicating more sedentary activity during the day (e.g., naps) and higher nighttime activity. IS quantifies the synchronization of activity patterns to the light/dark cycle or other environmental cycles that inform the biological clock. IS is often used as a measure of strength or robustness of the circadian rhythm with a higher IS scores (range of 0-1) indicating a robust and synchronized circadian rhythm. L5 is the measure of activity during the least active 5 hours of the 24-hour period and M10 is the measure of activity during the most active 10 hours of the 24-hour period. The difference between M10 and L5 divided by their sum produces RA, which is another measure of the robustness of one's rest-activity rhythm, with higher numbers indicating a larger difference between active and sedentary (or sleep) periods and therefore a stronger rhythm.

For further discussion on these variables, see Mitchell and colleagues' review (J. A. Mitchell et al., 2017).

Finally, to visualize the rest-activity patterns, the localized means and standard deviations of activity (vector magnitude) were calculated in 1 hour time bins across the 24-hour period (Figure 6; (Krafty et al., 2019)).

4.2.3.2.2 Sleep period statistics

For the sleep period variable calculation, sleep periods were identified first using the Tudor-Locke algorithms and the manufacturer's ActiLife software (ActiGraph Corp., 2010, 2018). The nightly bedtime definition was set at 5 consecutive minutes of sleep and morning wake time was set to 10 consecutive minutes of activity. Next, the data were visually inspected and cleaned by the PI (AH) and research assistant (SM) using timing information gathered from the sleep diaries. Each complete sleep period was used to calculate average sleep efficiency (the number of minutes marked as asleep divided by the number of total minutes in bed; (Corp., 2019)), total time in bed, total sleep time, and wake after sleep onset using the Sadeh pediatric algorithm with the use of the manufacturer's ActiLife software (ActiGraph Corp., 2010; Sadeh, Sharkey, & Carskadon, 1994). The Sadeh pediatric algorithm has been shown to have high accuracy (91%) and high sensitivity (97%) for identifying if a child is sleeping or if a child is awake compared to polysomnography (Sadeh, 2011).

4.2.3.3 Sleep Diary

The sleep diaries are based off the consensus sleep diary core questions (Carney et al., 2012) and were adapted for this pediatric population. Sleep diaries are critical for capturing specific to the research questions or population needs and are frequently used in sleep studies. For this study, specific variables of interest were the timing of the start of bedtime routine, duration of nightly routine, timing of child settling down, and timing of child's sleep. These variables were extracted from the logs and compared across groups.

4.2.4 Statistical Analysis

Statistical analyses were conducted with Stata software version 17.0 (StataCorp, 2021) and RStudio (Computing, 2021). We characterized rest-activity rhythm and sleep period variables by examining means and standard deviations of the variables and comparing groups using Student's *t* test, or the nonparametric alternative, and Hedges' *g* effect size estimation for unequal groups. Effect size interpretation for the social sciences typically indicates $g > 0.41$ as a minimum effect size representing practically significant effect, $g > 1.15$ as a moderate effect, and $g > 2.70$ as a strong effect (Ferguson, 2009). A probability level of $p < .05$ was set *a priori* to indicate significance. Localized means of activity data across 1-hour time bins were plotted to visualize the rest-activity rhythms throughout the 24-hour period.

To test our hypothesis that children with SS have more segmented sleep, we specifically examined the comparison of sleep efficiency and wake after sleep onset variables to children with NSS. We also examined sleep onset latency to test our hypothesis that children with SS take a longer time to settle down and fall asleep. We measured sleep onset latency in two ways. First, we calculated the average time caregivers reported that it took their children to settle down and fall asleep on the sleep diary. Then, we calculated the difference between parent-reported sleep onset time and actigraphy estimated sleep onset time. We compared these sleep onset latency variables using Student's *t* test and Hedges' *g* effect size estimation.

4.3 Results

4.3.1 Demographics

In total, 57 individuals enrolled to participate in this study between September and December 2021 (COVID-19 pandemic, Delta variant prominence). Prior to completing data collection, one participant asked to be withdrawn due to moving out of the area, and one participant was withdrawn by the PI due to lack of communication. Two participants were unable to contribute actigraphy data to this study because their ActiGraphs were lost or had a malfunction during data processing. In total, 53 participants completed this study, 21 children with SS and 32 children with NSS. All caregivers that participated identified as parents and will be referred to as such for the remainder of this paper.

When examining the actigraphy data, three children with NSS were unable to have at least 3 consecutive days of data without more than 3 hours of non-wear time in order to be included for the rest-activity rhythm variable calculation, resulting in a comparison analysis with smaller groups (n_{SS}= 21, n_{NSS}= 29). Additionally, two children with SS and 10 children with NSS had missing data from the sleep diaries, resulting in an exclusion for the sleep diary-actigraphy comparison analysis and smaller groups for this analysis (n_{SS}=19, n_{NSS}= 23).

A complete report of demographics data can be found in Table 4. Both groups were similar in parent age, child age, child sex. The children with SS were more racially, ethnically, and geographically diverse compared to the children with NSS. Parents of children with SS reported diagnoses of anxiety (13%), trauma (13%), behavior-related diagnoses (e.g., Oppositional Defiance Disorder; 8.6%), and developmental delay (4.3%). Children with SS were reported to take multivitamins, allergy medication, and fiber supplements. One child with SS was reported to take Ritalin and Zoloft every morning (common ADHD and antidepression medication) and one child with SS reported taking Prozac in the evening (common antidepression medication), however no children were reported to have a diagnosis of ADHD or depression. Within the NSS group, one parent reported that their child had a diagnosis of anxiety (3%) and another one child was reported to have asthma (3%). The only medications reported to be taken for children with NSS were allergy medication, multivitamins, magnesium and Vitamin D supplements, and melatonin. No other diagnoses were reported for the other children with NSS.

Children with SS were reported to use sleep medication or supplements significantly more frequently that children with NSS. Melatonin was used significantly more frequently by children with SS (n=7/21, 33%) than children with NSS (n= 2/32, 6%, χ^2= 6.60, p= .010). All but one parents who reported use of melatonin used small doses (ranging from 0.5 mg to 2.5 mg) between 30 and 60 minutes prior to bed. One parent with a child with SS used a higher dose (10 mg) of melatonin for an antioxidative effect.

Table 4 Participant Characteristics for Rest-Activity Analysis

	SS Group (n=21)	NSS Group (n=32)	*p*-value
Parent Age (SD)	38.57 (3.52)	37.09 (4.45)	.206
Child Age (SD)	7.4 (1.56)	7.53 (1.46)	.723
Child Sex†			.083
Male (%)	12 (57%)	17 (53%)	
Female (%)	9 (43%)	15 (47%)	
Child Race and Ethnicity			
Black/African American, Hispanic	2 (10%)	0 (0%)	.075
Black/African American, Non-Hispanic	4 (19%)	0 (0%)	.010**
White/Caucasian, Hispanic	1 (5%)	0 (0%)	.213
White/Caucasian, Non-Hispanic	11 (52%)	30 (94%)	<.001***
Other	1 (5%)	0 (0%)	.213
Other/Multiple	2 (10%)	2 (6%)	.659
Geographic location†			
Urban	8 (38%)	3 (9%)	.012*
Suburban	9 (43%)	24 (77%)	.018*
Rural	4 (19%)	5 (16%)	.105
Use of melatonin for sleep support†	7 (33%)	2 (6%)	.010**

Note: Groups compared using Student's *t* test unless otherwise specified.
† Chi-squared test for categorical variables.
* $p<.05$, **$p<.01$, ***$p<.001$

4.3.2 Actigraphy variables

All of the participants were able to tolerate wearing a wrist-worn activity monitor without the need for adaptation due to sensitivities. Three children in the NSS group did not have more than 3 consecutive days of actigraphy data collected due to excessive missing data. When asked about their tolerance of wearing the watch, these children's parents reported that they had forgotten to put the watch back on after charging. There were no complaints about the watch bothering the children. One parent in the SS group shared that the only time their child mentioned being bothered by the watch was when the band got wet. Otherwise, the child was able to wear the watch without difficulty.

4.3.2.1 Rest-activity rhythm variables

The rest-activity rhythms of both groups show similar timing of activity (Table 5 and Figure 6). On average, all children rose around 7:30am (up-mesor), reached peak activity around 2:30pm (acrophase), and settled down slightly before 9:30pm (down-mesor). Using non-parametric analysis, we found that both groups showed a similar stability within the day (IS_{SS}=0.77, IS_{NSS}= 0.75) and low fragmentation during the day (IV=0.75 for both groups). The SS group was found to be less active during the most active 10 hours ($M10_{SS}$= 3,165; $M10_{NSS}$= 3,307) and more active in the least active 5 hours of the day ($L5_{SS}$= 298; $L5_{NSS}$= 252) than the NSS group, but these differences were not statistically significant. The relative amplitude of these active times was higher in the NSS group, indicating a slightly more robust rest-activity rhythm in this group, although the difference between groups was only minimally clinically significant.

Table 5 Parametric and non-parametric rest-activity rhythm variables

	SS group (*n*= 21)	**NSS group (*n*= 29)**	***p*-value**	**Hedges' *g* effect size**
Up-mesor timing ‡	7:33 (83 mins)	7:23 (47 mins)	.776	0.15
Acrophase timing ‡	14:29 (60 mins)	14:22 (51 mins)	.977	0.13
Down-mesor timing ‡	21:25 (67 mins)	21:20 (60 mins)	.821	0.08
IS	0.77 (0.09)	0.75 (0.11)	.330	0.20
IV	0.75 (0.15)	0.75 (0.13)	.953	0.03
RA	0.83 (0.07)	0.86 (0.05)	.136	0.45*
M10	3164.96 (550.48)	3307.22 (615.46)	.321	0.24
L5	298.43 (151.19)	252.40 (98.95)	.275	0.37

Note: Mann-Whitney test used for all variables due to non-normality of the data. Hedges' *g* corrected for unequal groups used for effect size estimation.
‡ These variables are presented in military time (e.g. 21:30 = 9:30PM)
* *g*> 0.41 indicating minimally practically significant

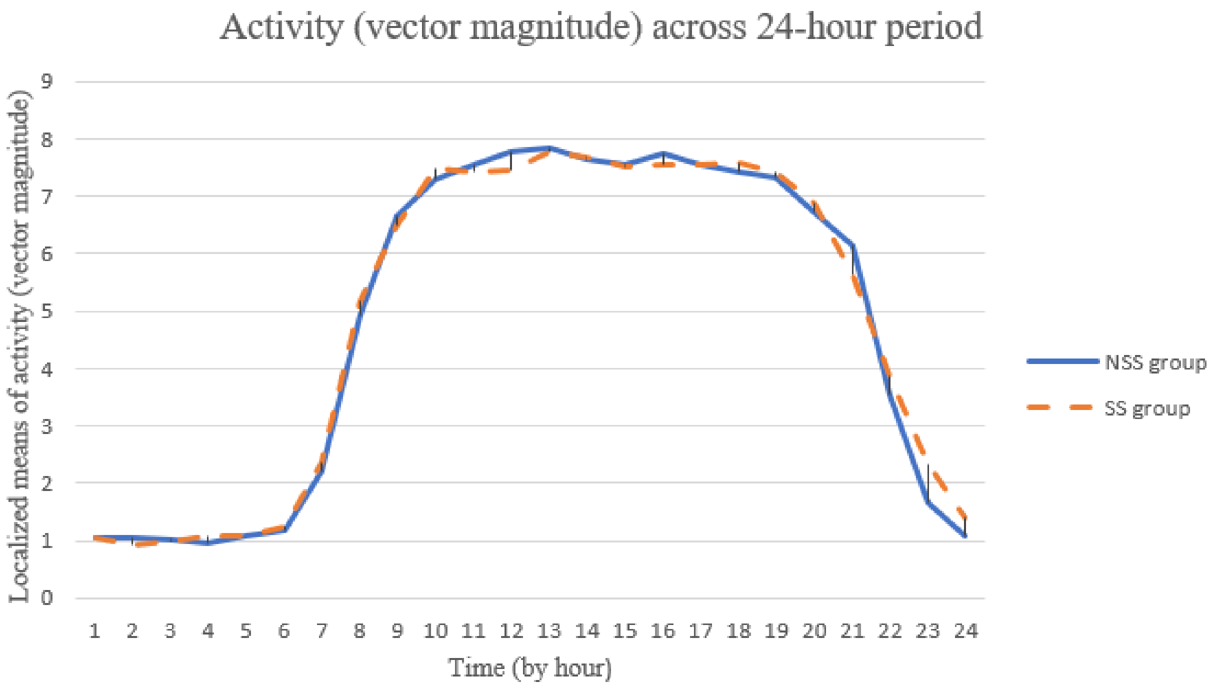

Figure 6 Localized means of activity across a 24-hour period

4.3.2.2 Sleep period variables

All 53 participants had at least 6 nights of complete sleep periods to analyze. On average, the SS and NSS groups show low sleep efficiency (78% and 77%, respectively). Overall, both groups spend similar time in bed, asleep, and awake after sleep onset (Table 6).

Table 6 Sleep period variables collected by actigraphy

	SS group (*n*= 21)	**NSS group (*n*= 32)**	***p*-value**	**Hedges' *g* effect size**
Sleep Efficiency	77.89 (5.12)	77.44 (5.36)	.760	0.09
Total Time in Bed	9 hours, 33 mins (38.13 mins)	9 hours, 46 mins (28.07 mins)	.160	0.40
Total Sleep Time (mins)	7 hours, 26 mins (35.50 mins)	7 hours, 33 mins (28.56 mins)	.437	0.22
Wake After Sleep Onset (WASO; mins)†	119.79 (33.46)	125.59 (33.44)	.440	0.17

Note: Standard deviations in parentheses. Student's *t* tests were used to compare means unless otherwise specified. Hedges' *g* corrected for uneven groups used for effect size estimation.
† Wilcoxon rank-sum test used to compare means due to non-normality

4.3.3 Sleep diary and actigraphy comparison

For participants who had sleep diary and actigraphy variables, we compared the time it takes for children in both groups to settle down and fall asleep (Table 7, Figure 7). These variables indicate that children in the SS group take a longer time to settle down and fall asleep (SS= 52.63 mins, *SD*= 38.31) compared to the NSS group (NSS= 26.19 mins, *SD*= 14.20, *p*= .075, *g*= 0.95). Comparing parent-reported and actigraphy-reported sleep onset, children in the SS group have actigraphy sleep onset times about 33 minutes later than their parent reported sleep onset (*SD*= 35.76). Children in the NSS group have a difference of 10.48 minutes (*SD*= 12.48), which indicates a small but potentially meaningful difference (*p*= 0.53, *g*= 0.87).

Table 7 Sleep diary and actigraphy comparison

	SPD group (*n*= 19)	**CON group (*n*= 23)**	***p* value**	**Hedges' *g* effect size**
Average time of sleep onset (Actigraphy)	21:52 (59 mins)	21:42 (28 mins)	.519	0.22
Average time to settle (Sleep diary)	21:00 (46 mins)	21:16 (30 mins)	.170	0.43*
Average time of sleep onset (Sleep diary)	21:19 (53 mins)	21:31 (31 mins)	.346	0.30
Difference between sleep onset between sleep diary and actigraphy	32.96 mins (35.76)	10.48 mins (12.48)	.053	0.87*
Difference between time to settle (sleep diary) and sleep onset (actigraphy)	52.63 mins (38.31)	26.19 mins (14.20)	.075	0.95*

Note: Times are reported in military time. All differences indicate that the sleep diaries report an earlier time than actigraphy. Student's *t* tests were used to compare means. Hedges' *g* corrected for uneven groups used for effect size estimation.
* *g*> 0.41 indicating minimally practically significant

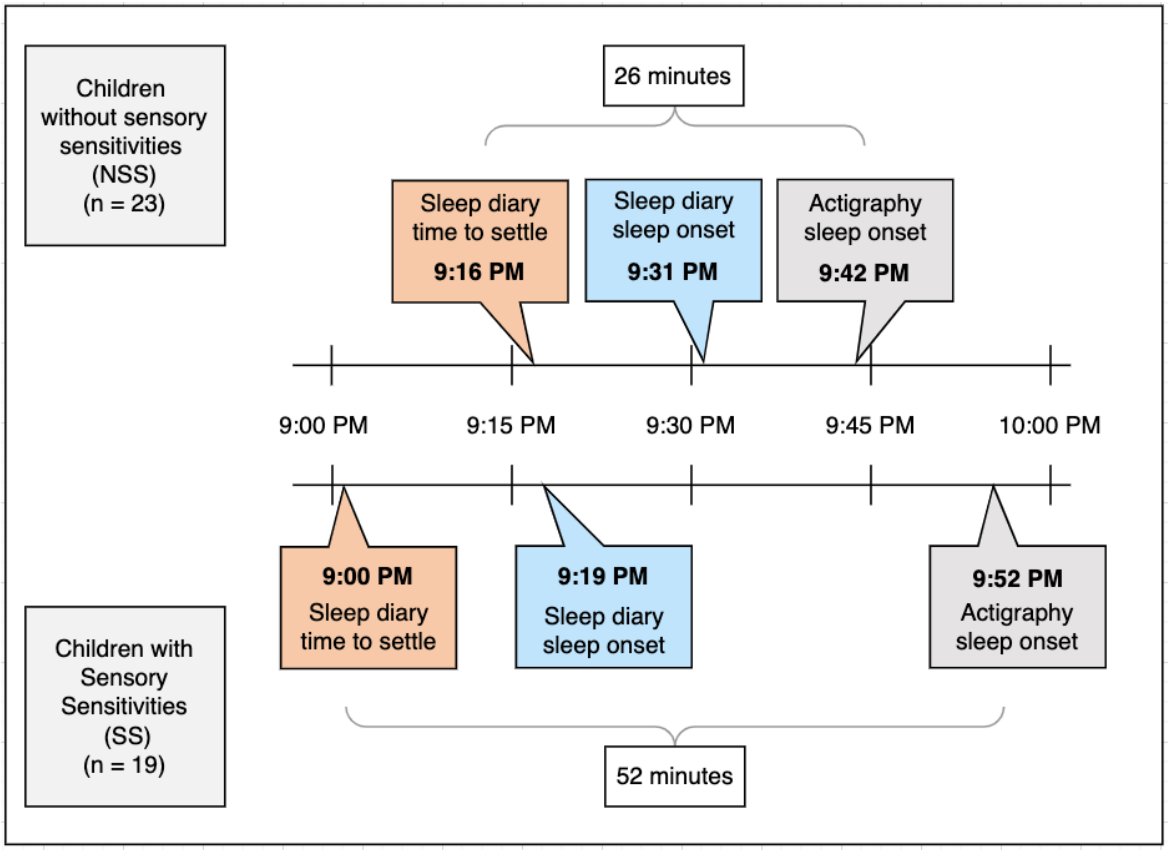

Figure 7 Timing of settling down and falling asleep per parent-reported sleep diary (in orange and blue) and actigraphy (in grey)

4.4 Discussion

This study presents rest-activity rhythm and sleep period variable analyses in children with and without sensory sensitivities. We add to existing knowledge by presenting a protocol that was well tolerated by children with tactile sensitivities. We found that children with sensory sensitivities show similar rest-activity rhythms and sleep period variables to their peers without sensory sensitivities. There is preliminary evidence that children with sensory sensitivities may take more time to settle down and fall asleep than their peers without sensory sensitivities; however, further study is needed.

4.4.1 Rest-activity rhythms in pediatric populations

Aligning our samples with published literature, we find that both children with and without SS in our study have similar rest-activity rhythms as children in a typical population (J. A. Mitchell et al., 2017). One interesting difference, however, is an elevated IS scores in our sample (IS_{SS}= 0.77, IS_{NSS}= 0.75) compared to published findings in neurotypical children (IS= 0.55; (J. A. Mitchell et al., 2017)) and children with ADHD (IS= 0.61; (Kristiaan B Van der Heijden, Smits, Someren, & Boudewijn Gunning, 2005). This indicates that our sample of children have daily circadian rhythms that more closely align with the light/dark cycle or environmental cues compared to other studies findings. Additionally, mean activity during the most active 10 hours of the day (M10) and least active 5 hours of the day (L5) were substantially higher in our samples than in published studies.

4.4.2 Sleep variables in pediatric populations

Exploring sleep period variables, our samples show indication of poorer sleep when compared to published actigraphy norms from large, non-clinical, pediatric samples. For example, children in the present study have sleep efficiencies between 77% and 78%. A large, systematic review and meta-analysis of actigraphy measured sleep indicate an average sleep efficiency of 86.3% (95% CI= 84.4-88.2) in children ages 3-18 years old (Galland et al., 2018). Additionally, the American Academy of Sleep Medicine published a consensus statement in 2016 recommending that children 6-12 sleep 9 to 12 hours of sleep to promote optimal health (Paruthi et al., 2016). In our sample, both children with and without sensory sensitivities had total sleep times substantially shorter than the recommendations (total average TST= 7.5 hours, *SD*= 0.5 hours). Unfortunately, past large reviews of pediatric sleep have found insufficient sleep to be pervasive in children, with an average of 8.24 hours of sleep each night for children between 6 and 8 year old (95% CI 7.83- 8.65) and an average of 8.07 hours of total sleep each night children between 9 and 11 year old (95% CI 7.88- 8.26; (Galland et al., 2018)).

The most significant finding of our study was the extended time children with sensory sensitivities needed to settle down to fall asleep (53 minutes). Interestingly, we see similar extended time spent settling down for children in neurodivergent populations. For example, sleep onset latency, measured using actigraphy, has been found to be longer in children with ADHD (32-49 minutes; (K. B. van der Heijden et al., 2018; Ziegler et al., 2021)) and in children with ASD (28-34 minutes; (K. B. van der Heijden et al., 2018)). This is substantially longer than both our non-sensory sensitive group, who took about 26 minutes to settle down and fall asleep, and neurotypical children in the larger, historic studies who have reported between 15-29 minutes of sleep onset latency (Elrod & Hood, 2015; K. B. van der Heijden et al., 2018; Ziegler et al., 2021)).

4.4.3 Actigraphy use in pediatric populations

In our previous study, we found significantly more sleep problems reported by parents and children with sensory sensitivities when compared to their peers without sensory sensitivities (Hartman et al., 2022). In this study, we find that these reported problems are not evident in the actigraphy variables under analysis. Both children with and without sensory sensitivities have similar rest-activity rhythms and sleep period variables. The presented analysis suggests that is it critical to consider multiple tools when characterizing sleep and activity patterns in children.

A number of studies in other pediatric populations have found actigraphy to be incongruent with other measurement tools, specifically subjective measures like sleep diaries and questionnaires (Werner, Molinari, Guyer, & Jenni, 2008). In a study conducted by Fernandez-Pires (Fernández-Pires et al., 2021), parent-reported sensory reactivity was found to be significantly associated with parent-reported sleep quality, not actigraphy-reported sleep duration, in young, typically developing school aged children (ages 3-7) in Spain. For children with ADHD, sleep concerns are well-established in subjective measures (K. B. van der Heijden et al., 2018), but are less evident in actigraphy and polysomnographic measures (De Crescenzo et al., 2016; Mullin, Harvey, & Hinshaw, 2011; Ruiz-Herrera et al., 2020).

4.4.4 Strengths, limitations, and future directions

A major strength of this study is the use of longitudinally collected actigraphy data for two groups. Having a comparison group allows for some control of historical (e.g., COVID-19 pandemic) and temporal (e.g., time of year, season) factors that otherwise might impact child sleep. These movement-based data give an objective view of patterns of rest and activity for children in their natural environment. We found actigraphy measurement to be well tolerated for a 2-week period for children with significant sensory sensitivities. We hope that these findings can promote the use of actigraphy in pediatric populations with similar sensory sensitivities.

It is important to recognize the limitations of this preliminary study prior to building upon the presented findings. This study utilizes a small sample size with considerable differences in racial, ethnic, and geographic diversity between groups. Further, significantly more children with

SS were taking melatonin for improved sleep compared to children with NSS. Due to the size of this study, it is difficult to understand the implication of high rates of melatonin and the impact on child sleep. We also note that two children in the SS group reported taking medications that may impact their sleep (Ritalin/Zoloft and Prozac). Future studies should consider examining medication use and timing more closely to understand the potential impact it may have on sleep. We look forward to future research that utilizes actigraphy measurement in a larger, more diverse samples.

As previously highlighted, the data for this study were collected between September and December 2021, when the Delta variant of COVID-19 was at its peak and prior to/during initial approval of pediatric COVID vaccines (approved for emergency use October 29, 2021 (Administration, 2021)). While all but one participant was attending school in-person, a number of children from both groups had COVID exposures, illnesses, and quarantining during data collection. As emerging research highlights the impact of COVID-19 on child sleep, the time period of this study is important to consider.

Our main finding was focused on the extended time children in the SS group took to settle down compared to the NSS group. Future studies using actigraphy in pediatric populations could consider different ways to better characterize the time parents and child spend settling down. In this study, we relied on parent's report of the time they indicated their child began to "settle down". In future research, we suggest interviewing parents and discussing what settling down means to them, when does this extended time settling down become problematic, and what aspects of the family dynamic or parent-child relationship drive how settling down happens.

Additionally, exploration of the differences in sleep period timing and settling down times between free days (non-school days) and school days may be an interesting analysis. Research suggests that social jet lag, or a difference in sleep timing on weekends that produces a 'jet lag' feeling, can impact overall health (Beauvalet et al., 2017). Children with sensory sensitivities often excel with predictable routines (Dunn, 2007) and therefore may be protected from social jet lag because their sleep timing may remain consistent despite the day of the week. Future research could explore if children or adolescents experience differences between sleep on weeknights and free nights and how this may impact their daytime functioning.

4.5 Conclusion

This study provides preliminary data describing rest-activity rhythms and sleep period variables in children with and without sensory sensitivities. While overall rest-activity rhythms and sleep variables were similar between groups, there was strong evidence that children with sensory sensitivities spend a longer time settling down to transition to sleep than peers without sensory sensitivities. We also provide evidence that wrist-worn actigraphy is tolerable and acceptable for children with sensory sensitivities. Daily parent-reported sleep diaries and a wrist-worn activity monitoring provides important, movement-based data that should be used in tandem with other measures of sleep health for future studies.

5.0 Pediatric occupational therapists' perspectives on sleep: An area of opportunity

This chapter describes a qualitative descriptive study examining pediatric occupational therapists' perspectives on the role of sleep health in their daily treatment. This chapter has been developed into a manuscript and is currently in preparation for submission to a scientific journal.

5.1 Introduction

Sleep health is an individualized pattern of sleep-wakefulness that is influenced by social and environmental demands and promotes wellbeing (Buysse, 2014). Good sleep health can be characterized by feelings of restfulness and energy during the day, timing of bedtime that aligns with social and environmental zeitgebers, or cues, (e.g., sleeping when it is dark, awake when it is light), and an adequate duration and high sleep efficiency (Buysse, 2014). There is strong evidence in the literature that good sleep health in children supports academic learning, mental health, immune health, and physical growth (Bathory & Tomopoulos, 2017; Bonanno et al., 2019; Chaput et al., 2016; Chien, Cheung, & Chen, 2019; James & Hale, 2017; Spruyt, 2019). Promoting good sleep health is considered foundational in healthcare therapies that promote development, like occupational therapy (American Occupational Therapy Association, 2020).

Despite the inclusion of sleep in many rehabilitation provider's frameworks, sleep has historically been overlooked in typical rehabilitation care (Colton & Altevogt, 2006; Tester & Foss, 2018; Valenza, 2011; Verschuren, Gorter, & Pritchard-Wiart, 2017). Specifically, there are too few professionals dedicated to addressing poor sleep health, too many people with co-morbid sleep problems within our health system, and a dearth of educational programs to educate health care professionals to incorporate sleep health promotion in the United States (Colton & Altevogt, 2006). In recent years, occupational therapy clinicians and scientists have highlighted the need for occupational therapists to address sleep concerns within routine care (Fung et al., 2013; Green, 2008; Tester & Foss, 2018). Specifically, *rest and sleep* are identified as functional occupations that are critical for health and active engagement in other daily occupations in the occupational therapy practice framework (American Occupational Therapy Association, 2020).

Significant sleep problems have been reported in 40-80% of neurodiverse children (Blackmer & Feinstein, 2016; Cortesi et al., 2010; Langberg et al., 2020; Romeo et al., 2021), a rate that is about twice as high as the general population prevalence of 20-30% (Maski & Owens, 2016; J. Owens, 2008). Considering that neurodiverse children often seek out occupational therapy services, sleep assessment and intervention should be common in occupational therapy treatment. However, in a recent survey conducted by Piller and colleagues, occupational therapists reported spending less than 25% of their intervention time on sleep concerns (Piller et al., 2020). Further, in this survey, occupational therapists indicated that they do not feel equipped to address the sleep concerns identified with their clients.

In this qualitative descriptive study, our objective was to more clearly understand the perspective of pediatric occupational therapists regarding the role of sleep health in routine care. The aims of this study were to explore: (i) therapists' experiences addressing sleep health during typical care, (ii) the role sleep plays in rehabilitation goals, (iii) therapists' confidence in addressing sleep concerns, and (iv) the supports and barriers therapists encounter related to addressing sleep health concerns for their pediatric clients.

5.2 Methods

A qualitative descriptive methodology (Sandelowski, 2000) was employed to explore pediatric occupational therapists' perspective on sleep health within their practice. Qualitative descriptive studies are based in the tenants of naturalistic inquiry in which researchers approach an event or group of people with a series of inquires without pre-determined theories or codes to apply. As such, these studies require researchers to not stray far from the data collected and resist applying interpretation to the words given by participants. This methodology was chosen for this study because we wished to develop a rich description of occupational therapist's perception of sleep health within their practice without influence or bias that might be presented when working with a theoretical model.

5.2.1 Participants

Currently practicing pediatric occupational therapists across the United States were invited to participate in this study. Therapists were recruited using emails to clinics and individuals across the nation. Recruitment was capped at 5 participants from the same metroplex and only one person from a clinic to increase variety of experiences. Therapists who indicated interest in the study were contacted via telephone to enroll in the study. All procedures, consent forms, and measures were approved by the University of Pittsburgh's Institutional Review Board (STUDY20090057).

5.2.2 Data collection

Hour-long semi-structured interviews were completed by the PI (AH) using a video conferencing software (Zoom). Interviews were recorded, except for instances where technology faltered (n=3) and interviews were completed over the phone. The PI is a pediatric occupational therapist with 10 years of experience in outpatient and inpatient settings. The PI acted as an interview tool, facilitating the discussion using a semi-structured interview guide with questions of interest to focus the conversation on the aims of this study (Table 8).

The semi-structured interview guide was developed by the PI (AH) and trialed with another pediatric occupational therapist (KC) prior to initiating the study. This guide was used to provide some initial structure for the interview and was based on the aims of this study. During the interview, participants were free to share additional information and the PI used probing questions to explore topics that came up in more detail.

Table 8 Interview Questions

General Interview Questions
What is your experience addressing sleep concerns with your clients?
How do you think a child's sleep impacts their life and the goal areas on which you work?
Tell me about how confident you are in talking about sleep with your clients and their caregivers.
What are the supports and barriers that impact your ability to address sleep concerns?

The interviewer took notes on the discussion and noted any thoughts or personal bias that became apparent during the discussion. For the first 8-10 interviews, the PI wrote an overall impression and general themes at the end of the interview in a reflection journal to clarify broad themes and ensure the interview guide questions were still appropriate.

Upon completion of the interview, therapists completed an online demographics questionnaire using REDCap software (Clinical and Translational Sciences Institute at the University of Pittsburgh Grant Number UL1-TR-001857). This questionnaire included questions about basic demographics about the therapists, their experience level as a clinician, current practice setting and location, and the age, race, and ethnicity of the children with whom they serve.

5.2.3 Data Analysis

The transcripts of the interviews, interview notes, reflection journal, and demographic questionnaire were all used during data analysis.

Interviews were transcribed using Zoom software (Otter AI) and then cleaned by the PI using the audio recording of the interview. Interview transcripts were transferred to Microsoft Excel documents for data analysis. A qualitative thematic analysis approach was taken to analyze the data. Thematic analysis is a method for identifying themes and patterns within the data that requires very little interpretation of the data, staying true to the original intent of the speaker (Braun & Clarke, 2006). This analysis method was chosen to provide a rich and detailed account of the perspectives of the participants without imposing *a priori* frameworks or hypotheses on the data.

Two researchers (AH, KC) read each interview, applied structural codes to identify sections of text that surrounded each question of the semi-structured interview, and added any additional concepts that were discussed. In the second round of coding, descriptive and *in vivo* coding methods were used to summarize emerging themes within each structural code. The researchers met twice monthly to review themes and ensure agreement. Concepts that were difficult or required more thorough discussion were brought to larger lab meetings with a third researcher (RB).

As interviews were coded, researchers moved the codes into a large descriptive matrix within Microsoft Excel with each structural code as its own tab. Within each workbook tab, preliminary categories were placed across the x-axis at the top and each participant was placed along the y-axis. Descriptive code and *in vivo* text were placed within the individual cells. Matrix analysis (Averill, 2002) allows for data to presented in a way that overarching themes can be discovered and interactions can be explored. As new categories were discovered, already coded interviews were reviewed to ensure the new category was not missed. To explore unique themes by specific setting, participants were grouped by the primary setting in which they worked. Unique themes that were setting-specific were identified.

All participants were sent an overview of major themes that emerged from the data. Participants were asked to confirm that their thoughts were captured within these themes. Sixteen of the twenty participants responded to this member checking, and all reported that their experience was appropriately captured.

5.3 Results

Twenty pediatric occupational therapists completed interviews (Table 9). The majority of the therapists identified as female (85%) and cisgender (95%). Ages of therapists ranged from 26-65 years old, with half of therapists falling between 26-35 years old. Therapists reported working in outpatient clinics (independent, associated with a hospital, or non-profit; *n*=17), early intervention (*n*=8), school systems (*n*=6), inpatient (acute and rehabilitation) hospitals (*n*=6), home health (*n*=2), and camp (*n*=1). Although some participants reported working at only one setting (*n*=8), many participants reported working at multiple settings, ranging from 2 (*n*=5) to 7 (*n*=1).

After overarching themes were developed, interviews were then separated by the therapist’s primary setting(s) and unique setting-specific themes were explored. Primary settings include outpatient (*n*= 14), early intervention (*n*= 6), school systems (*n*= 4), and inpatient hospital (*n*= 2). Within this analysis, setting-specific supports and barriers became apparent, along with novel themes about how sleep is viewed.

Table 9 Therapist demographic characteristics

Demographics Characteristics	All participants (*n*= 20)
Sex	
Male	3 (15%)
Female	17 (85%)
Gender	
Cisgender	19 (95%)
Non-binary	1 (5%)
Age Range (%)	
26-35 years	10 (50%)
36-45 years	6 (30%)
46-55 years	2 (10%)
56-65 years	2 (10%)
65+ years	0
Years of experience	
0-5 years	5 (25%)
6-10 years	8 (40%)
11-15 years	2 (10%)
15+ years	5 (25%)
Work setting (multiple answers accepted)	
In-patient hospital: acute care	4 (20%)
In-patient hospital: rehabilitation	5 (25%)
Outpatient clinic associated with a hospital	8 (40%)
Independent outpatient clinic	11 (55%)
School system	6 (30%)
Early intervention	8 (40%)
Home health	2 (10%)
Other	2 (10%)
Description of populations served (percent of clients treated)	
Child age range	
Less than 3 years old	31.90%
Preschool age (3-5 years)	26.22%
Elementary school (5-10 years)	27.42%
Middle School (11-13 years)	14.11%
High school or young adult (14+ years)	10.67%
Child race	
American Indian or Alaska Native	7.05%
Asian	9%
Black or African American	19.79%

Table 10 (continued)

Child race (continuted)	
Native Hawaiian or Other Pacific Islander	2.5%
White or Caucasian	70.16%
Child ethnicity	
Hispanic or Latinx	20.9%
Not Hispanic or Latinx	79.26%

5.3.1 Key themes of occupational therapists' perspectives regarding sleep health

Therapists voiced interest in discussing the role of sleep within routine care for their clients. They used words like "important", "complex", "individualized", and "fluid" to characterize sleep within a therapeutic setting. Therapists talked about how sleep impacts a person's occupations and overall development, using phrases such as "biggest life skill" and "essential" when expressing the importance of sleep health in the children they serve in the clinic. Therapists view sleep as a concept that is intricately woven throughout each member of the family unit, and therefore an intimate part of the lives of the children with whom they work.

Despite its importance, more than half of the therapists interviewed report that prior to this study, they did not regularly inquire about a child's sleep health as part of their practice. A variety of themes emerged describing the supports and barriers to addressing sleep. These themes fell into three broad categories describing: (i) personal factors, (ii) client/family factors, (iii) setting specific factors, and (iv) external factors (Figure 8).

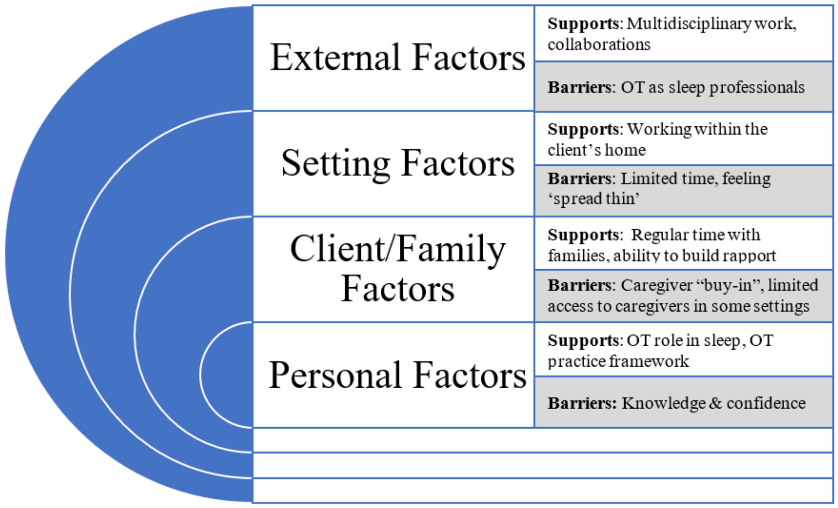

Figure 8 Factors impacting pediatric occupational therapists when addressing sleep

5.3.1.1 Personal factors

Therapists identified themes that were supportive of occupational therapy's role within sleep: *sleep is within our scope, occupational therapists can have a unique role in sleep intervention*. Themes that spoke of barriers were *more knowledge is needed, confidence varies among therapists,* and *a feeling of being "spread thin".*

When asked about occupational therapists' role surrounding sleep, therapists believed occupational therapists have a distinct role in addressing sleep concerns within the pediatric setting. "There are so many incorporations with sleep that's already embedded into being an OT, in the sense of like how OTs address things and how [sleep] is part of our daily routine. I think that's a primary reason why OTs need to be addressing sleep and why it's in our scope." (124)

Therapists also mentioned that the Occupational Therapy Practice Framework (OTPF; (American Occupational Therapy Association, 2020)) identifies *rest and sleep* as critical occupations to examine within occupational therapy practice. Therapists identified specific foundational skills that support their involvement in addressing sleep concerns in the clinic.

Specifically, knowledge of environmental adaptations, routines, clinical interviews, and sensory tools to support sensory processing were noted to be key in therapist's approach to supporting sleep health. Therapists who have past experiences addressing sleep shared that they have focused on environmental adaptations (e.g., opening blinds in hospital room during the day, using sound machines), bedtime routine building, parent education on good sleep habits, and sensory techniques for regulation prior to bedtime during sleep intervention sessions.

Despite sleep being within the OTPF, all therapists reported that the topic of sleep was not covered in their graduate schooling. Continuing education courses on sleep were noted to be difficult to find, however many therapists shared that they had not thought of looking for courses focused on sleep intervention prior to participating in this study. Therapists who had sought out sleep education shared that they learned about sleep intervention ideas from research articles, conference presentations, trainings from different disciplines (e.g., psychology), co-workers within and outside of occupational therapy, books, and internet searchers. Therapists felt that they lacked the depth of knowledge they needed to truly address the complex nature of sleep. "I cover sleep very superficially." (106) Specifically, therapists felt that, beyond routine changes or sensory techniques at bedtime, they were at a loss of what to do. "I wish that I knew what questions to ask. And then based on what information is given, I would need more assistance or like more research, more knowledge to know what suggestions to give or what path to go down… I'd panic going beyond the basics." (105)

Overall, over half of the therapists interviewed for this study voiced hesitancy surrounding sleep conversations with their clients and families. "In terms of my competency, no, I don't feel confident because I don't have the background knowledge for sleep." (111). Therapists who lack confidence tended to be less experienced. "I think the first couple years are so heady as far as like trying to analyze what's going on with the child that you see in front of you that I didn't ask a lot of questions about anything that was unseen. Honestly, it's like my brain was like just trying to process the bulk of it.” (116).

Some therapists do feel confident in their abilities to address sleep. These therapists are more experienced (from 6 years to 20+ years of experience) and identified experiences with past clients, their own children, and discussions with other professionals as key pieces that support their practice. “I would say my first 10 years of practice, I never even thought about sleep. But after having my own children I think I started thinking more like, this is important. This is definitely the biggest life skill they have because without sleep, everything is off. Eating is off, play is off. It was important. I ask [about sleep] far more now after becoming a mother than I did in the first couple years.” (102)

Across all settings, therapists shared that they often feel “spread thin” because of the many areas they are tasked with to address in therapy. Therapists share that they don’t always have the capacity to address sleep concerns in the way they wish they could. The idea of not having enough time- time to uncover sleep problems, time to fully address sleep concerns, time to educate themselves on best practice- was prevalent throughout the interviews. “The conversation [on sleep] is not a fast one and you're not getting the referral for poor sleep…And so I think that's why a lot of OTs use tidbits of like weighted blankets. Because the conversation is not a fast one.” (116).

5.3.1.2 Client or family factors

Therapists find that the families they work with are often “at the end of their rope” (102) and come into therapy with a list of pressing goal areas, often not involving sleep concerns. Regular caregiver involvement is critical for uncovering and intervening in sleep concerns. It is after building rapport and working on goal areas for months that sleep concerns can emerge as a foundational factor impacting progress in therapy. “And it's really fascinating that when we address sleep issues that very often other issues that seemed to be really big, start to be organized in a different way in the nervous system that's now able to kind of sooth and calm and re-center and recalibrate in sleep, the purpose of sleep. Then kids look really different once they're sleeping.” (118)

Identifying sleep as an area for intervention is sometimes difficult, due to limited access to caregivers (e.g., in the schools setting), difficulties building rapport with families, or limited “buy-in” from families to engage in behavioral changes to impact sleep. “[Parents] are very, very stressed and changing sleep routines requires a lot of effort of them, and rightfully, they're not ready to do that. Because it's a big-time investment to do a lot of the sleep kind of training and the sleep kind of programs that really work.” (101) Therapists said that the topic of sleep can feel very personal and sometimes families are not willing or ready to discuss sleep difficulties. “Sleep is intimate …. I’ll mention it, but if they don’t bite, then I drop it.” (121) Specifically, therapists said that caregivers may feel shame, judgement, or embarrassment about their sleep habits, leading caregivers to avoid bringing sleep concerns up.

5.3.1.3 Setting factors

The setting of therapy was another factor that could either support or limit a therapist’s involvement in sleep assessment and intervention. Some settings, like early intervention, were predominately supportive of occupational therapy’s involvement within sleep concerns. Other therapists in different settings found significant barriers to overcome when addressing sleep for their clients. We will highlight the themes within the settings in which our participants worked.

5.3.1.3.1 Outpatient setting: Independent, associated with a hospital, or non-profit clinics

Outpatient therapists shared a variety of experiences and perspectives related to addressing sleep health with their clients. When asked about sleep's impact on their practice, most therapists verbalized that sleep is important for development and can impact progress in the goal areas that are being addressed during therapy. Half of the outpatient therapists shared that they had specific questions that they ask parents to explore sleep within their evaluation or treatment sessions. No one reported use of a standardized sleep questionnaire or measurement tool within their practice. In two instances, a senior therapist with 20+ years of experience shared that they had been the driver of developing the evaluation electronic medical record and had purposely included a section on sleep, driven by the inclusion of sleep in the OTPF (American Occupational Therapy Association, 2020) and their own past experiences with sleep impacting their client's lives.

5.3.1.3.2 Early intervention

The early intervention (EI) setting allows for occupational therapists to be embedded into the home environment and form relationships with the client (children 0-3 years old in most areas) and their caregivers. EI therapists identify this physical setting of therapy as a critical support in addressing sleep within their treatment. Other supports include the "routines-based" interview that each family completes prior to starting therapy, the service coordinator who is available to help support therapists, and regular interdisciplinary meetings that allow for collaboration and mentorship. Additionally, some states have specific billing codes that allow for therapists to spend time educating families, which is critical in sleep intervention.

5.3.1.3.3 School systems

Occupational therapists who primarily work in the school system reported that sleep does not come up in their setting unless the child's performance in school seems to be impacted by daytime fatigue. Half of the school-based therapists shared that they had never thought about addressing the sleep health of their clients. School-based therapists who have thought about their client's sleep in the school setting report that sleep is often not a primary focus of therapy due to restrictions placed on goal areas (e.g., must be education related) and limitations in access to caregivers for evaluation and education purposes. As such, school-based therapists report they focus on education of the client's teacher and often do not try to impact the sleep health of their clients. "I think it's really just educating the teachers. Like when you see these kids come in a certain way [tired], I think we have to give them the grace for the day." (109)

School-based therapists shared that they feel like "crisis managers" (102) and are often called in to help a child when the teacher or other staff people are unsure how to proceed. "I would say I'm the most qualified to address [sleep], but that doesn't mean there shouldn't be someone more qualified to address it. There's just no one else I can think of in this role at this time." (112) When working with older clients (e.g., middle school, high school), some therapists found that education about sleep's impact on the body is an interesting topic for therapy. "Older kids love to hear about their body. They love to learn about cause and effect and what's going on." (109) Therapists connected the impact that poor sleep has on common problems seen in middle and high school, like sloppy handwriting, agitation, anxiety, and overall poor mental health. However, many therapists did not feel comfortable to address the depths of sleep concerns. "I just don't feel like I have enough knowledge in sleep to really help them dig into it." (109)

5.3.1.3.4 Inpatient setting: Acute care and rehabilitation

In the inpatient setting, occupational therapists work alongside other healthcare professionals to serve children and their families with complex situations and diagnoses. Inpatient therapists in this study worked in the pediatric intensive care unit, rehabilitation unit, oncology, and neonatal intensive care unit (NICU). Participants identified the critical role of sleep in the healing, growth, and development that is so important for the children with whom they work. However, when it comes to sleep intervention, inpatient clinicians noted that sleep was often not the focus of therapy unless they were working within the NICU. “I would say there's just other things that kind of take priority for us in an acute setting. Like their sleep- I think is a given that it's not going to be as great because they're in the hospital for all these other reasons.” (106) Clinicians identified aspects like the hospital bed, client and family stress, pain, and multiple nighttime interruptions due to medical needs all contributing to poor sleep in the hospital, most of which are unable to be changed by the therapist or client. “There's just so many things out of our control in my setting, like medications and pain level [of my clients].” (106)

In the NICU setting specifically, therapists report that they often discuss sleep concerns with parents primarily because it involved with the baby’s feeding routine, which is a common focus for occupational therapy in the NICU. “Sometimes, by asking about sleep, you can get a lot more information [about the child] a lot faster.” (110) Despite discussing sleep concerns, NICU clinicians, like other inpatient clinicians, report they do not write goals addressing sleep health. “I would say my goals are typically focused elsewhere. I don't do a lot of sleep goals.” (110)

5.3.1.4 External factors

External factors are factors outside of the occupational therapist and their practice setting that impact the perceived ability for the occupational therapist to assess and intervene on sleep areas. These themes were centered around the view other healthcare providers or caregivers of clients view occupational therapists. One predominate external factor that spoke of supporting occupational therapy involvement was *frequently working within a collaborative team.* A main external factor barrier was the perception that occupational *therapists are not being seen as sleep professionals.*

Therapists who work within a multidisciplinary team report learning across traditional discipline areas. A therapist's comfort with addressing sleep concerns seems to be related to the therapist's view of their role within the team. Therapists who felt that they were seen within their team as the sleep expert spoke confidently about addressing sleep concerns with their clients. “I've learned how to collaborate with [the team] in a really great way that I think supports the family where we're getting what we need medically but we're also getting the therapy that we needed at home.” (122) Therapists who mentioned having other clinicians on their team who address sleep (often a developmental specialist or psychologists) tended to speak about sleep not being their area of intervention. “No one's ever really taught [sleep education] to me […] I think there are other disciplines that I really appreciated their approaches, especially some of the behavioral approaches. I've appreciated hearing some of those and incorporating some of those strategies because I think that can be an important element sometimes.” (115)

Generally, therapists perceived that caregivers and other healthcare professionals did not see sleep as an aspect occupational therapists could address. “I don't think that they even know [sleep] is in our scope practice, to be honest. Like they see us more as a developmental specialist.” (110) One therapist put into words what it would take to move towards being seen as sleep experts: “We could [specialize in sleep] but it's going to require focus and also it would require a settings'…. I don't want to say *permission* but it's kind of *permission,* to see us in that role. They [other healthcare professionals] see us as feeding specialists. They're not looking to us for sleeping.” (106) Having the confidence to work within the medical team and advocate for the occupational therapy role in sleep intervention was a barrier noted by a number of participants across multiple settings.

5.4 Discussion

This qualitative descriptive study explores the perspectives of pediatric occupational therapists regarding the role of sleep health within their practice. Overall, therapists recognize the importance of sleep in their pediatric practice and believe occupational therapy has a critical role in addressing sleep health. However, many therapists report that they do not focus on sleep goals or use sleep outcome measures within their routine practice. During thematic exploration, we highlighted person, client/family, setting, and external factors that impact an occupational therapist's ability to examine sleep health with their clients.

More than half of therapists share that they are not confident with their knowledge surrounding the intricacies of sleep. The overwhelming majority of therapists interviewed reported a lack of education opportunities within their graduate programs and continuing education courses related to sleep. The Occupational Therapy Practice Framework (American Occupational Therapy Association, 2020) identifies sleep as a foundational occupation, and as such, occupational therapy graduate programs could be prime avenues for increasing sleep education for future therapists. Therapists also identify the need for continuing education courses focusing on more complex aspects of sleep and sleep intervention for therapists who want to specialize in sleep or require deeper knowledge in the area.

Pediatric sleep has been well-studied and frameworks to guide measurement and intervention have recently been presented (Allen, Howlett, Coulombe, & Corkum, 2016; Meltzer et al., 2021). Occupational therapy research can advance sleep research in special populations by merging sleep and occupational therapy frameworks to develop specialized care for children seen in the clinic (Ho & Siu, 2018).

5.4.1 Study limitations and future directions

This study represents the perspective from a small sample of pediatric occupational therapists who practice within the United States. While saturation of themes from our interview guide questions was achieved with a sample size of 20, we recognize that factors like geographic location, practice setting, and years of experience could influence a therapist's perspective. Future studies could explore a broader view of general occupational therapists or a focused view of setting, geographic location, etc. on a therapist's perspective.

Efforts were made to increase trustworthiness of the presented results including recruiting a sample of occupational therapists across the country, capturing interview data through multiple tools (transcripts, interview notes, and a reflexive diary kept by the interviewer), the use of multiple coders, and a final member check with major themes. We did recruit participants who volunteered for our study, which may have unintentionally resulted in a sample who is more interested with topic of sleep. Our sample was made up of predominately white, non-Hispanic, cisgendered females. We were able to include some participants who identified with underrepresented groups within occupational therapy (e.g., male, non-white, non-binary), however a more diverse sample of therapists could offer a more representative reflection of perceptions. Additionally, while we did have therapists who worked with clients of underrepresented populations (e.g., Native Alaskan, African American, urban school district), the majority of therapists treated children who were white, non-Hispanic (about 70% of clients across all therapists).

Our results highlight an opportunity for future education on sleep assessment and intervention for pediatric occupational therapists. While most therapists identified sleep as an important aspect of health for their clients, many said they lacked the education, confidence, tools, and opportunity to incorporate sleep intervention in their regular practice. Educators within universities and continuing education courses are called to disseminate existing knowledge surrounding sleep measurement and intervention. Sleep researchers are called to validate sleep measurement and intervention tools in special populations and disseminate findings to clinicians to advance sleep-focused intervention in the clinic. Advocacy for occupational therapy's role in sleep health intervention within and outside of the field is essential.

5.5 Conclusion

This study highlights a critical opportunity for occupational therapists, occupational therapist educators, and sleep researchers to improve care for children who receive occupational therapy services. Occupational therapists in this study identify specific barriers that limit their ability to address sleep concerns. Additionally, therapists identify a lack of education materials covering sleep in special populations.

6.0 Conclusion

It is well known that good sleep health is critical for development and health for children (Chaput et al., 2016; James & Hale, 2017; Spruyt, 2019). Emerging research has identified a potential relationship between sensory processing abilities and sleep health in school aged children (Appleyard et al., 2020; Foitzik & Brown, 2018; Shochat et al., 2009), adolescents with attention-deficit hyperactivity disorder (ADHD; (Lufi & Tzischinsky, 2014)), and children with autism (Manelis-Baram et al., 2021). Interestingly, there is limited data characterizing sleep health for children with sensory sensitivities outside of the diagnostic categories of ADHD and autism. Additionally, addressing sleep concerns is not often a focus in occupational therapy intervention for children (Piller et al., 2020). The presented body of work aims to expand the existing knowledge and work towards understanding the role sensory processing patterns play in sleep health and how to best support therapists in addressing sleep concerns.

We first outlined the existing research that discusses the role sensory processing has in sleep health (Chapter 2). From this examination, we presented a multifaceted study that utilizes subjective (parent- and child-reported questionnaires; Chapter 3) and movement-based (actigraphy; Chapter 4) sleep and activity measures to identify specific sleep health characteristics that are impacted for children with sensory sensitivities compared to their peers without sensory sensitivities. We also presented findings from semi-structured interviews with pediatric occupational therapy practitioners that explored perspectives of the role of sleep health in routine care as well as perceived supports and barriers that impact addressing sleep concerns (Chapter 5). As a whole, this dissertation was designed to provide the groundwork needed to determine whether children with sensory sensitivities have unique difficulties with sleep compared to children without sensory sensitivities. In this chapter we situate our findings in the larger body of research on pediatric sleep health and discuss implications for future work.

6.1 The role of sensory processing in sleep health

Emerging research has identified a potential common characteristic in poor sleeping children: atypical sensory processing (Foitzik & Brown, 2018). Our findings align with published research by determining significantly higher endorsement of sleep problems in the children with sensory sensitivities (SS), by both parent and child, when compared to peers without sensory sensitivities (NSS). Using our subjective and movement-based measurements, we can present a preliminary multifaceted profile of specific sleep health characteristics for our SS and NSS samples.

6.1.1 Sleep health profile for children with sensory sensitivities

Using the identified domains of pediatric sleep health (Meltzer et al., 2021), we align subjective and movement-based measurements of each sleep health domain (Table 10). Compared to the NSS group, children in the SS group and their parents individually report significantly more bedtime behaviors and lower satisfaction with child sleep. This aligns with the body of research that identifies discrepancies between groups of children with sensory sensitivities or atypical sensory processing patterns within diagnostic groups compared to peers (Lufi & Tzischinsky, 2014; Manelis-Baram et al., 2021). Most of these studies use parent-reported questionnaires to capture sleep behavior and satisfaction domains of sleep.

The domains of daytime alertness, sleep timing, efficiency, and duration were all similar across groups. This suggests that, in our small sample, sensory sensitivities may not be significant influencers on these aspects of sleep health. There is limited research that examines actigraphy based sleep in children with predominate sensory sensitivities. Research in pediatric populations with co-morbid atypical sensory processing has found mixed evidence on differences between diagnostic and control groups. For example, a meta-analysis examining actigraphy measured sleep in children with ADHD found strong evidence of similar sleep durations between groups (De Crescenzo et al., 2016). Within this analysis there was also moderate evidence of longer sleep onset latency and lower sleep efficiency in the ADHD group (high heterogeneity in each of these analyses limits strength of these findings; (De Crescenzo et al., 2016)). Similarly, in a meta-analysis of actigraphy and polysomnography studies examining sleep in children with ASD, strong and significant evidence of longer sleep onset and shorter sleep duration was found in the ASD group compared to peers (Elrod & Hood, 2015). Sleep efficiency was about 2% less in the ASD group, which was statistically significant, but may not be clinically meaningful. Additionally, high heterogeneity was found in the findings, specifically in the sleep duration and sleep efficiency studies, limiting the strength of these findings (Elrod & Hood, 2015).

Table 11 Sleep Health domains for children with and without sensory sensitivities

Pediatric Sleep Health Domain	Variables used to describe domain (type of outcome measure)	Outcomes for children with sensory sensitivities (SS group)	Outcomes for children without sensory sensitivities (NSS group)	*p* value	Effect size: Hedges' *g*‡ or Cramer's V^{V}
Behaviors	Sleep behavior subsection on SSR (questionnaire; higher score indicates more frequent negative behaviors)	12.68	9.64	<.001***	1.01‡
	Bedtime resistance subsection on CSHQ (questionnaire)	9.64	7.61	<.001***	0.83‡
Satisfaction	*Do you have trouble sleeping?* Question from SSR	64% answered *yes*	21% answered *yes*	.011*	0.34^{VV}
	CSHQ total score (questionnaire)	91% scored above the cut point†	67% scored above the cut point†	<.001***	1.11‡
Alertness	Rest-activity rhythms of M10 (actigraphy)	Average activity counts= 3164.96	Average activity counts= 3307.22	.321	0.24
	Daytime sleepiness subsection of CSHQ (questionnaire)	11.64 (3.90)	10.79 (2.70)	.557	0.26
Timing	Rest-activity rhythms of down-mesor (actigraphy)	21:25 (67 mins)	21:20 (60 mins)	.821	0.08
	Time of sleep onset (actigraphy)	21:53 (59 mins)	21:43 (28 mins)	.519	0.22
Efficiency	Sleep efficiency (actigraphy)	77.89 (5.12)	77.44 (5.36)	.760	0.09
Duration	Total sleep time (actigraphy)	7 hours, 26 mins (35.50 mins)	7 hours, 33 mins (28.56 mins)	.437	0.22

Note: CSHQ= Children's Sleep Habits Questionnaire, parent-reported. SSR= Sleep Self Report questionnaire, child-reported. On both of these questionnaires higher score indicates more frequent negative behaviors.

†The cut-point of the CHSQ total score is 41, scores that are above this threshold indicate clinically significant sleep problems (J. Owens, A. Spirito, & M. McGuinn, 2000).

‡ Effect size interpretation for Hedge's *g* (effect size for unequal groups): $^{‡}g$> 0.41 minimum effect, $^{‡‡}g$> 1.15 moderate effect, $^{‡‡‡}g$>2.70 strong effect

^{V} Effect size interpretation for Cramer's V (effect size estimate for χ^2 tests)= ^{V}Small effect= V>0.10, ^{VV}Medium effect= V>0.30, ^{VVV}Large effect= V>0.50

*p< .05, **p<.01, ***p<.001

6.1.2 Examination of sleep-onset latency

We specifically were interested in examining the variable sleep-onset latency within our samples because sleep-onset latency has been noted to be impacted for neurodivergent children like children with ADHD and ASD (De Crescenzo et al., 2016; Elrod & Hood, 2015; Wengel et al., 2011). We calculated sleep-onset latency by subtracting the average time a child starts to settle down from the average time of sleep-onset per actigraphy. Our findings provide preliminary evidence of significant sleep onset-delay for children with sensory sensitivities, who need on average almost 1 hour to settle down and fall asleep, compared to peers without sensory sensitivities, who need about 30 minutes to settle down (see chapter 4). This could have significant implications on both the child and parent's perception of sleep as well as overall family routine and stress. While sleep-onset latency is not directly represented in the pediatric sleep health domains presented by Meltzer (2021), it is incorporated in the sleep behaviors domain of sleep health and is incorporated in the sleep efficiency domain.

The domains of sleep timing, efficiency, and duration relied solely on actigraphy. The American Academy of Sleep Medicine Clinical Practice Guidelines highlights limited evidence in the use of actigraphy for measuring insomnia and sleep-wake disorders in children, especially children in developmental diagnostic populations (Smith et al., 2018). They provide a conditional recommendation to use actigraphy as one assessment tool when examining sleep in children, primarily due to the low-risk nature of actigraphy monitoring and despite the low quality of evidence. Research highlights the low agreement rates between actigraphy, diaries, and questionnaires for measuring child sleep patterns (Werner et al., 2008). Further, a meta-analysis of the effects of cognitive behavioral therapy for insomnia in adults, a gold standard in sleep intervention, found that changes in sleep are best captured through subjective measurements rather than more objective measures (polysomnography and actigraphy; (L. J. Mitchell, Bisdounis, Ballesio, Omlin, & Kyle, 2019)).

6.1.3 Informing future research

This small, observational study provides a foundation upon which future research can be conducted in larger, more representative samples. In this study, we use the pediatric sleep health framework which allows for sleep health data to be clearly organized in a way that specific sleep domains that are impacted become evident. These specified areas highlight opportunities for future research and targeted intervention. Our findings suggest that future research could examine the sleep behaviors that are unique to children with SS and contribute to the higher reported of sleep problems in this group. Qualitative interviews with both caregivers and children with SS could further pinpoint supports occupational therapists could provide to support sleep health in routine care. Additionally, future intervention research could examine the effectiveness of sleep intervention on the identified areas of sleep behaviors and satisfaction that are impacted in this population.

6.2 Addressing sleep health in routine healthcare

Another critical step taken in this work is examining the perspectives of pediatric occupational therapists to understand the supports and barriers impacting their abilities to address sleep in routine care. Sleep has been recognized as a critical occupation since the first occupational therapy framework (Roley et al., 2008). However, there is limited focus in research and clinical care on sleep within rehabilitation clinics (Tester & Foss, 2018). Using qualitative descriptive methods, we explored how sleep is viewed and intervened upon by pediatric therapists, the impact sleep has on goal areas, therapist's confidence with addressing sleep concerns, and supports and barriers experienced when addressing sleep with clients. This study is the first qualitative study to examine these questions and can provide preliminary guidance for future research and implementation.

The Consolidated Framework for Implementation Research (CFIR; (Damschroder et al., 2009)) offers a structure to start to organize our findings and present a clear way forward for research and implementation of intervention. This framework was developed using a review of prevalent theories describing influences on implementation. A total of 5 major themes emerged as foundations for a consolidated framework: Intervention characteristics, outer setting, inner setting, individual characteristics, and the process of implementation (Figure 9). The CFIR initially was used for research within the implementation phase or post-implementation, however Kirk and colleagues encourage the use of CFIR in research across the research spectrum, as it can help identify barriers to implementation prior to implementation. Applying our findings to the CFIR, we can begin to characterize supports and barriers in three of the framework domains: the outer setting, inner setting, and individual domains (see the red box in Figure 9).

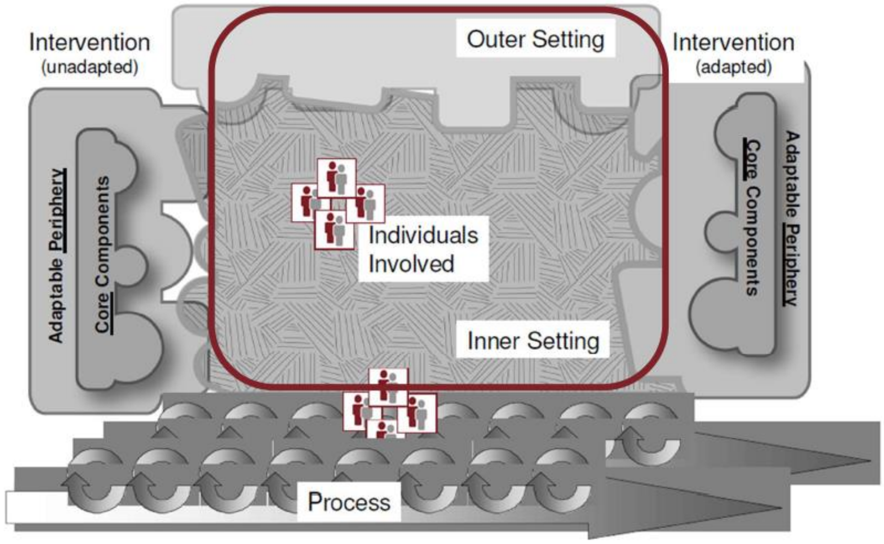

Figure 9 The Consolidated Framework for Implementation Research
CC BY ©2009, Damschroder et al., licensee BioMed Central Ltd.
Note: Red square added to highlight domains addressed within the qualitative findings of this study.

6.2.1 The outer setting of sleep intervention within pediatric occupational therapy practice

The outer setting refers to the larger context in which an organization resides (e.g., economic, political, or social context). Within this domain, we can examine the needs and resources available and needed for the implementation of the intervention of interest, the network of the organization, the pressure felt to implement (or not implement) the intervention, and policies or incentives in place that impact implementation. General themes of not being seen by the larger healthcare community as sleep experts and not receiving referrals for sleep concerns are potentially reflective of the outer setting's view of occupational therapy's role (or lack of role) related to sleep intervention. Therapists themselves share that sleep is an area in which they have limited experience in intervening, further impacting the outer setting's understanding of the occupational therapy skill set that can support sleep intervention.

Sleep has been within the occupational therapy practice framework since its inception (Roley et al., 2008). As such, therapists highlight that sleep is well within the role of a pediatric occupational therapist. Despite this, occupational therapists identified a number of barriers or needs that impact their ability to engage in sleep assessment and intervention. Therapists report that they are not seen as healthcare providers that could address sleep concerns and do not routinely receive referrals for poor sleep health. Therapists identified limited collaboration opportunities with other sleep-related healthcare professionals (e.g., psychiatry, psychology, neurology, sleep clinics). This could be related to the fact that most therapists in this study reported that they did not routinely ask about sleep, and therefore had limited experience in addressing sleep concerns or seeking out collaborations outside of their clinic or team.

6.2.2 The inner setting of occupational therapy

The inner setting within the CFIR refers to structural, political, and cultural contexts in which the intervention implementation will occur. This includes the network, culture, climate, and readiness for change of an organization. Within our findings, the unique setting specific themes spoke to inner setting supports and barriers that were perceived to impact implementation of sleep intervention. Therapists spoke of the setting of therapy to be either supportive, as in early intervention which takes place within the home, or a barrier, as in the school setting, to assessing and addressing sleep concerns. They also discussed the dynamics of the team either supporting or limiting their involvement in sleep intervention.

6.2.3 Individual domain of occupational therapists and sleep intervention

Characteristics of the individual therapist can influence the intervention implementation and success. Specifically, the CFIR describes the individual's knowledge and beliefs, self-efficacy, state of change, relationship and identity within the organization, and other personal attributes as important aspects of the individual domain. Within our findings, two overarching individual level themes paint a preliminary picture of the individual therapists and their readiness for implementation of sleep intervention: (i) opportunities for further education in sleep health and (ii) specific aspects of occupational therapy that lend itself to engaging in interventions that are personal, holistic, and health focused.

Occupational therapists identified a critical need for education covering sleep assessment and intervention in both graduate programs and for continuing education. Many therapists voiced discomfort or a feeling of a lack of knowledge surrounding sleep assessment and intervention for their clients. They also highlight the opportunity for continued research specifically examining sleep intervention in special populations that can drive clinical interventions. These findings suggest that additional education and research may need to precede larger sleep intervention implementation.

Occupational therapy involves an individualized connection between therapist and client. For pediatric clients, caregivers are often involved regularly in therapy goal setting and intervention. Therapists in our study identify having caregivers present for therapy sessions as critical for building the relationship that is needed in order to be able to ask about underlying sleep concerns that may contribute to difficulties in goal areas. Additionally, occupational therapists are well educated in routine building, environmental modification, and regulation techniques

(American Occupational Therapy Association, 2020), which are all aspects of pediatric sleep interventions (Allen et al., 2016).

6.2.4 Guiding future research towards implementation of intervention

Our findings start to characterize current supports and barriers that may impact future implementation of sleep intervention. However, there is considerable research that must be done prior to implementation of a broad sleep intervention as part of routine occupational therapy care. Future research is needed to identify the best sleep measurement tools that characterize areas of sleep health that are impacted for the populations treated in the occupational therapy clinic. Additionally, sleep interventions that target the areas of sleep health noted to be impacted in these special populations must be trialed. Further, clinical trials could examine the added benefit of sleep intervention to routine care in different clinical populations on goal areas and health metrics.

6.3 Conclusion

This dissertation builds a foundation upon which future research can build specified sleep interventions targeting sleep health concerns unique to children with atypical sensory processing patterns. Expanding the knowledge of the relationship between sensory processing patterns and pediatric sleep health can uncover both targets and tools for future intervention. Additionally, we present pediatric occupational therapists' perspectives related to their current abilities to assess and intervene in sleep for their clients. Future research is needed to develop an implementation plan for incorporating additional education and intervention guidance for occupational therapists.

Appendix A Publications, Presentations, and Awards from this Dissertation

The studies within this dissertation have been disseminated through the following publications and presentations. Awards are indicated in italics

Appendix A.1 Publications

Appendix A.1.1 Peer-Reviewed Manuscripts

1. Hartman, A.G., McKendry, S., Soehner, A., Bodison, S., Akcakaya, M., DeAlmeida, D., & Bendixen, R. Characterizing sleep differences in children with and without sensory sensitivities. Frontiers in Psychology [in press]. Doi:10.3389/fpsyg.2022.875766

2. Hartman, A.G., Caspero, K., Bodison, S., Soehner, A., Akcakaya, M., DeAlmeida, D., & Bendixen, R. Pediatric occupational therapists' perspectives on sleep: An area of opportunity [Manuscript in preparation].

3. Hartman, A.G., McKendry, S., Soehner, A., Bodison, S., Akcakaya, M., DeAlmeida, D., & Bendixen, R. Characterizing rest-activity rhythms and sleep for children with sensory sensitivities [Manuscript in preparation].

Appendix A.1.2 Peer-Reviewed Abstracts

1. Hartman, A., Bendixen R. (2021) Understanding the link: Sleep and sensory processing. American Journal of Occupational Therapy, 75(Supplement_2).

2. Hartman, A.G., Soehner, A, Smagula, S., McKendry, S., & Bendixen, R. (2022) Parent and Child Perception of Sleep for Children with Sensory Processing Difficulties. Sleep [Accepted, publication in preparation].

Appendix A.1.3 Invited Publications

1.Hartman, A.G., Bodison, S., & Bendixen, R. (2021) Sleep and sensory processing: Recognizing the relationship. SensorNet, 57, 25-28.

2.Hartman, A. (2021). Sleep and sensory processing: A critical relationship? SIS Quarterly Practice Connections, 6(4), 5–7.

Appendix A.2 Presentations

Appendix A.2.1 Peer Reviewed Presentation

1. Hartman, A. (2021) Sleep health in children with sensory processing disorder [Three Minute Dissertation Competition]. The University of Pittsburgh, virtual.

** This presentation won First Runner-up place and the People's Choice Award.*

2. Hartman, A. and Bendixen R. (2021) Understanding the link: Sleep and sensory processing [Short course]. American Occupational Therapy Association Annual Conference, virtual.

3. Hartman, A. and Bendixen, R. (2021). Work in progress: Sleep health in special pediatric populations. [Work in Progress Presentation] Occupational Therapy Summit of Scholars, virtual.

4. Hartman, A. (2021). Sleep Health in Children with Sensory Processing Disorder [Three Minute Dissertation Competition]. Occupational Therapy Summit of Scholars, virtual.

**This presentation tied for First place for the Three Minute Dissertation Competition.*

Appendix A.2.2 Interactive Poster Presentations

1. Hartman, A.G., McKendry, S., & Bendixen, R. (2021). Sleep health in children with sensory processing difficulties. Sleep and Circadian Research Day, Pittsburgh, PA.

2. Hartman, A.G., Soehner, A., Smagula, S.F., McKendry, S., & Bendixen, R. (2022) Parent and child perception of sleep for children with sensory processing difficulties. University of Pittsburgh's Occupational Therapy Colloquium, Pittsburgh, PA, virtual.

Appendix A.2.3 Invited Presentations

1.Hartman, A. (2019) The occupation of sleep [Lunch and Learn]. The Occupational Therapy Department at the University of Pittsburgh, Pittsburgh, PA.

2.Hartman, A.G. (2021) Understanding the link between sleep and sensory processing. Canadian Association of Occupational Therapists' Practice Evidence Webinar, virtual.

3.Hartman, A.G (2022) Understanding the link between sleep and sensory processing. Saturday Seminar Webinar through the Therapro Company, virtual.

Appendix B Screening Questions for Inclusion for the Sleep Health in Children Study

Sensory Over-responsivity screening questions taken from the Sensory Profile-2. A parent must answer ‘yes’ to at least 6 of the following questions in order to be included in the sensory sensitivity group:

1. Does your child show distress during grooming (for example, fights or cries during haircutting, face washing, fingernail cutting)?
2. Is your child particular about the types of clothing s/he will wear?
3. Does your child show an emotional or aggressive response to being touched?
4. Does your child become anxious when standing close to others (for example when in a line?)
5. Does your child rub or scratch a part of the body that has been touched?
6. Does your child gag easily from certain food textures or food utensils in his/her mouth?
7. Does your child limit his/herself to certain food textures?
8. Is your child a picky eater?

Appendix C Sleep Diary Example

The following pages are examples of the sleep diary questions used in this dissertation study. Parents of children in the study completed these questions either on paper or electronically each morning and evening reflecting on the previous day or night.

Appendix C.1 Morning Sleep Diary Questions

Date: ___________

***Good morning!* Please take a few minutes to answer some questions about your child's sleep last night so that we may better understand his/her sleep health and sensory processing abilities.**

Today is:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

To the best of your knowledge, did your child wear the ActiGraph last night?

☐ Yes, all night ☐ Yes, more than half of the night ☐ Yes, but less than half of the night ☐ No, not at all

Please note any comments, issues, or times you think your child took off the ActiGraph:

The following questions are about your child's sleep last night:

Did your child wake up in the middle of the night? ☐ Yes ☐ No ☐ Not sure

If yes:

My child woke up this many times after falling asleep, not counting their final awakening: ___________________

In total, I estimate these awakenings lasted: __________ minutes

Was there a time your child had to wake up (e.g., for school)? ☐ Yes ☐ No

If yes:

My child planned to wake up at: ___________ AM/PM

My child *actually* got out of bed at: ___________ AM/PM

If no:

My child's final awakening in the morning was at: _________ AM/PM

My child got out of bed to start the day at: _________ AM/PM

My child's final awakening was caused by: ☐ Alarm ☐ Other person ☐ Worries ☐ Bathroom ☐ Noises ☐ Just woke ☐ Text/Email/Electronic Notification

This morning (or upon waking) …

My child's mood was: Very Sad-------------------------- Normal -------------------------- Happy

☐ ☐ ☐ ☐ ☐

I think my child felt: Very tired ---------------------- Normal --------------------------- Energetic

☐ ☐ ☐ ☐ ☐

Appendix C.2 Evening Sleep Diary Questions

Date: ______________

Good Evening! Please take a few minutes to answer some questions about your child's daytime behaviors and bedtime process today.

Today is:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

To the best of your knowledge, has your child worn the activity watch today?

☐ Yes, all day ☐ Yes, more than half of the day ☐ Yes, but less than half of the day ☐ No, not at all ☐ I don't know

Please note any comments, issues, or times you think your child took off the ActiGraph:

What did your child do today? Select all that apply:

☐ Virtual learning ☐ In-person schooling ☐ After school activity ☐ Completed homework
☐ Home schooling ☐ Free play inside (no screen) ☐ Free play outside (no screen) ☐ Video/virtual interactive games
☐ Work/chores ☐ Passive screen time (TV, movie, etc)

Did your child engage in 30 minutes of physical activity today ☐ Yes ☐ No ☐ Not sure

Did your child take any naps today? ☐ Yes ☐ No

If yes…

How many naps did your child take? _____

In total, I estimate these naps lasted: _____ minutes

What time(s) did your child nap? _______________

What time did your child's bedtime routine start? __________PM

How long did it take to complete? ____________

What time do you believe your child settled down to fall asleep? __________PM

What time do you believe your child fell asleep? __________PM

How was your child's mood today? *Please select all that apply.*

☐ Happy ☐ Angry ☐ Sad ☐ Sensitive ☐ Attentive ☐ Well-rested
☐ Calm ☐ On edge ☐ Emotional ☐ Clumsy ☐ Distractable ☐ Tired/Groggy

Throughout the day…

	Very Sleepy		Normal		Alert
My child seemed to feel:	☐	☐	☐	☐	☐

	Poorly		As they normally do		Very well
Compared to a typical day for my child, they handled the sensory information from the environment:	☐	☐	☐	☐	☐

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