Spring 5-19-2023

Sensory processing impacts on sleep patterns in children with neurodevelopmental disorders during the COVID-19 pandemic

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Sensory processing impacts on sleep patterns in children with neurodevelopmental disorders during the COVID-19 pandemic

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A dissertation submitted in partial fulfillment

Of the requirements for the degree of

Doctor of Philosophy

In

Clinical Psychology

Seattle Pacific University

School of Psychology, Family, & Community

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DEDICATION

I dedicate this project to my mother and father. Their guidance, love, and boundless support have been a guiding light and touchstone for me throughout this process. They have instilled in me a curiosity, desire to learn, hunger to grow, and space for compassion throughout my life. I use these values and lessons every day in all areas of my life.

ACKNOWLEDGEMENTS

I would like to thank the neurodevelopmental disabilities' community of families, self-advocates, researchers, and teachers that serve to grow the understanding of how to best support those with developmental disabilities. I would also like to thank my research vertical team, especially my cohort mate Vanessa Zhou, for staying community focused and creating this project during the height of the COVID-19 pandemic. Additionally, I would like to express my gratitude to my dissertation committee for their dedication, support, and guidance to my overall professional development throughout my graduate career.

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ABSTRACT

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The COVID-19 global pandemic in 2020 introduced a sudden disruption to the people's daily routines, including changes to sleep schedules and, thus, sleep quality. Generally, children with developmental disabilities (DD), such as autism spectrum disorder (ASD), experience higher levels of sleep difficulties compared to typically developing youth. These sleep difficulties have been linked to social and emotional abilities, cognitive development, and adaptive functioning. One component found to impact sleep behaviors is sensory processing differences. Individuals with ASD and other DDs exhibit greater levels of these sensory concerns. The current study sought to understand how the sleep behaviors of ASD and DD youth changed during the pandemic, and further how these populations may have differed in those changes. Sleep patterns during the pandemic were also examined with respect to the role that sensory differences may have had within sleep changes. In line with previous research, I hypothesized that children with ASD would experience more sleep patterns changes (i.e., duration, onset time, wake time, quality). Additionally, in line with a dimensional approach, I hypothesized that higher sensory differences would moderate the relation between diagnosis and sleep duration changes, such that those with heightened sensory concerns would experience decreases in sleep duration regardless of diagnosis. The current sample was comprised of 55 youth (ages 1 to 18) with ASD and other DDs, and their parents. Changes in sleep was measured by a shortened version based on the Children's Sleep Health Questionnaire (CSHQ; Owens et al., 2000) and sensory processing differences were measured by the Short Sensory Profile (SSP; McIntosh et al., 1999). No significant difference was found between ASD and DD youth with regards to sleep changes. A trending moderating effect of sensory scores was seen on diagnosis and sleep duration changes. This was further explored to reveal a significant main effect of high sensory seeking on decreased sleep during the pandemic, indicating a need for increased focus on providing more intervention-level supports for sensory-seeking youth with DDs during times of global stress. Additionally, these results support a need for future studies on impacts of stressors on those with sensory concerns and DDs.

Keywords: autism spectrum disorders; developmental disabilities; sensory processing; COVID-19; sleep

CHAPTER I - INTRODUCTION

Starting in late 2019, an outbreak of the COVID-19 coronavirus strain spread across the globe in what was later categorized to be a global pandemic. In response to dramatic increases in identification and deaths as a result of the pandemic, the United States issued a series of closures in March of 2020 that forced the majority of families to attend school and other services virtually (Gao & Scullin, 2020; Mervosh et al., 2020). Families with neurodevelopmental disabilities, including those with autism spectrum disorder (ASD) were among the many who experienced social, environmental, and family impacts of these closures.

ASD is a neurodevelopmental disorder broadly described by persistent difficulties with social communication and social interaction alongside patterns of restricted and repetitive behavior and interests. Recent estimates indicate that the global prevalence of ASD is 70 out of 10,000 individuals. Of children with ASD, nearly 83% have been diagnosed with an additional mental or developmental disorder including attention deficit hyperactivity disorder, mood and anxiety disorders, and obsessive-compulsive disorder (Joshi et al., 2013; Levy et al., 2010).

Sleep is an especially important area of development. For example, sleep plays a critical role of allowing time for the brain to consolidate memories, cleanse neurological fluids, repair the central nervous system, and allow the recuperation of the mind and body (Davis et al., 2004; Reddy & van der Werf, 2020). When individuals do not have enough sleep, there can be detrimental effects on their social and emotional development, their daily planning and working memory, and their overall cognitive functioning. Children with developmental disabilities, especially ASD, have been found to have heightened levels of sleep deficits compared to their typically developing peers (Lai et al., 2019; Souders et al., 2009). Overall, the sleep challenges experienced by children with developmental disabilities have life-long impacts that can compound on top of pre-existing mood and cognitive differences.

Children with ASD have several diagnostic characteristics that have been linked to sleep difficulties, including communication and transition difficulties, and atypical melatonin regulation cycles (Bourgeron, 2007). One feature that is particularly prominent in ASD, sensory processing differences, has been linked to decreased sleep quality and quantity for these individuals as well as those with several other developmental disabilities (Reynolds et al., 2012). Sensory processing differences are seen most often in children with ASD, with estimates ranging up to 95%, but are also seen at higher levels in other developmental disabilities when compared to typically developing populations (Cheung & Siu, 2009; Tomchek & Dunn, 2018).While studies have indicated that children with ASD are most commonly effected by this link between sensory and sleep, very little research has explored the role that sensory challenges play in sleep patterns above and beyond children's diagnostic status alone. Given the high level of prevalence of sensory processing differences in many communities with developmental disabilities, it is important to consider when attempting to distinguish areas of atypical development and the effects on sleep difficulties.

The purpose of the current study was to explore the impact of the COVID-19 pandemic on the sleep patterns of children with ASD and other developmental disabilities. Further, this study investigated the magnitude of the role of sensory processing differences on sleep difficulties in these different diagnostic categories. This paper provides a review of background information on ASD and other developmental disabilities to better understand the function of diagnostic status and specific diagnostic characteristics, such as sensory processing differences, on sleep changes during the COVID-19 pandemic. Sleep was explored as a primary feature of development in typically developing populations and autistic populations. Finally, an ecological systems model of sleep was explored with respect to sleep before and during the COVID-19 pandemic.

Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a neurodevelopmental disorder defined by persistent social communication and social interaction difficulties alongside patterns of restricted and repetitive behavior and interests. While all individuals with ASD display some degree of social and emotional differences, it is common to see a variety of profiles that can present with different levels of cognitive functioning, adaptive functioning, and speech abilities.

Clinical Presentation of Autism Spectrum Disorder

Historically, ASD was first defined by Kanner in 1943 as a behavioral phenotype of "severe delays in language and cognitive skills" (Hill et al., 2016, p. 6). Over time, the definition of autism broadened to focus on the impact of communication deficits alongside ritualistic behaviors and interpersonal difficulties (Rutter, 1968). Beginning in the 1980's autism began to include less severe phenotypes, including pervasive developmental disorder - not otherwise specified (PDD-NOS) and high functioning autism in those without an intellectual disability. In the following decade, the diagnostic category of autism shifted once again to include Asperger's Disorder (AD), a term for autism which was originally introduced by Hanz Asperger around the same time as Kanner (Asperger, 1944; Wing, 1981). At that time, individuals with AD were considered to have "less severe early symptoms, a milder developmental course and better outcome than high-functioning autism" (Ozonoff et al., 2000, p. 29).

Most recently, the release of the Diagnostic and Statistical Manual of mental illness, fifth edition, text revised (DSM-5-TR; American Psychiatric Association, 2022) combined all previous iterations of disorders within the autism spectrum into one diagnosis, entitled autism spectrum disorder. ASD can be diagnosed with additional classifiers of associated language or cognitive impairments. This singular diagnosis is defined as the presence of persistent deficits in three areas of social communication and interaction in addition to restricted and repetitive behaviors or interests that must be present at an early developmental age.

The three main areas of social communication and social interaction deficits are seen in challenges in social emotional reciprocity, nonverbal communication, and development and maintenance of social relationships. Difficulties in social emotional reciprocity are often displayed through a child's difficulties initiating or responding to social interactions, carrying on a back-and-forth conversation, sharing of thoughts, interests, or emotions with others (DSM-5-TR; American Psychiatric Association, 2022). Deficits in nonverbal communication are often seen through decreased use of integrated nonverbal communications, such as eye contact, body language, gestures, or facial expressions within verbal communication (Steyn & Le Couteur, 2003). Social relationships frequently suffer from deficits in the development, understanding, and maintenance of these relationships, this may be demonstrated through difficulties in adjusting behavior to various contexts, engaging in imaginative play, making friends, or an overall decreased interest in others.

For diagnosis, children must also display at least two of the following areas of restricted and repetitive behaviors: a) stereotyped or repetitive motor movement (e.g., lining up of objects), object use (e.g., indiscriminately dropping or flipping objects) or speech (e.g., echolalic or idiosyncratic phrases); b) insistence on sameness, cognitive rigidity, or difficulties with transitions; c) restricted or fixated interest in unusual objects, or perseverative interests, and hyper- or hypo-reactivity to sensory input. These symptoms as described in the DSM-5-TR must also result in impairment in multiple domains of social and adaptive functioning. A diagnosis of ASD through the DSM-5-TR criteria also allows for specifications of an intellectual or language impairment, a medical or genetic condition, an association with another neurodevelopmental or behavioral disorder, or the presence of catatonia.

Common Comorbid Diagnoses

In addition to the core diagnostic features listed previously, there are several common diagnostic features that emerge from the diversity of phenotypic profiles. Many individuals with ASD have behavioral problems, including aggression, irritability, hyperactivity, and self-injurious behavior, such as head banging, biting, and scratching (Steyn & Le Couteur, 2003). Additionally, medical issues such as gastrointestinal, cardiac, endocrinological, autoimmune, and sleep disorders are frequently present (Aldinger et al., 2015; Atladóttir et al., 2009; Ferguson et al., 2017; Schendel et al., 2016). Additionally, 83% of individuals with ASD qualify for an additional comorbid mental or developmental disorder (Levy et al., 2010). Most common comorbid diagnoses include attention-deficit-hyperactivity disorders, mood and anxiety disorders, and obsessive-compulsive disorder (Joshi et al., 2013).

Prevalence

Over the past decade global prevalence rates of ASD have increased. A meta-analytic study from 2000 to 2016 indicated current global prevalence rates to be 70 out of 10,000 (Myers et al., 2019). Reported rates included in this analysis ranged from rates of 1.4 per 10,000 (Al-Farsi et al., 2011) to 264 per 10,000 (Kim et al., 2011). Increased rates over the past decade are predicted to be in part related to better detection methods and increased awareness among the general population (Hill et al., 2016). Additionally, others theorize that rates are increasing due to changes in genetic vulnerability and environmental impacts (Schieve et al., 2012).

Development of Sleep in Typically Developing Populations

Sleep is a crucial aspect of daily functionality. It allows for the recuperation of the mind and body, repair of bodily tissues, consolidation of acts of learning and memories, cleansing of the neurological fluid transport systems, and central nervous system repair (Davis et al., 2004; Reddy & van der Werf, 2020). Many aspects of sleep are critical to child development, making the definition of sleep within development an equally critical and complex task. In most studies, sleep is reliably measured through subjective methods, such as interviews, questionnaires, and sleep diaries, or through more objective methods of actigraphy and polysomnography. Most commonly, duration is considered to be the primary domain used when determining an individual's sleep health in research and clinical settings. However, other significant parameters include sleep quality, consistency, chronotype (e.g., optimal time of wakefulness), frequency of daytime sleepiness, and bedtime routines (El-Sheikh & Sadeh, 2015). Understanding the foundation of childhood sleep is crucial, especially considering that during the first decade of life, children spend more time asleep than awake (Galland et al., 2012).

Patterns and Stages of Sleep Regulation

While sleep is a state of "decreased responsiveness and interaction with the environment", there are high levels activity occurring on a neurologic and physiologic level (Davis et al., 2004, p. 65). Sleep follows an ultradian rhythm of four stages of non-rapid eye movement (NREM) and one stage of rapid eye movement (REM) that repeat throughout the sleep period. The first stage of sleep is considered the transitional stage between wakefulness and sleep and is characterized by reduced bodily movement and responsiveness. This stage comprises two to five percent of the total sleep period. Following this stage is a period of true sleep onset that comprises 50% of the total sleep duration. Stage two is comprised of decreased eye movements, reduced muscle tone, and deceleration of respiratory and circulatory systems. The third and fourth stages comprise 20% of total sleep and are defined by slow-wave sleep in which the heart rate decreases further, and the breath becomes slow and rhythmic. These four stages of NREM sleep are followed by a period of REM sleep often associated with a state of dreaming, muscle paralysis, and is a crucial time for consolidation of learning and memories. The REM stage becomes increasingly longer throughout the night and once complete, will restart the process at stage one.

The nightly pattern of falling asleep and staying asleep is controlled by two primary processes, the circadian rhythm and the homeostatic process. The circadian process is an internal pattern that triggers sleep and wake periods in the body based on a light to dark cycle. This process drives the need to sleep when it is dark and awake when there is light. However, many things can affect this rhythm beyond the light in the room including light exposure prior to sleep, mealtimes, ambient temperature, noise, bedtime routines, pain, and medications (Davis et al., 2004). The circadian rhythm is similar to other bodily functioning cycles such as hormone secretion, temperature regulation, and sensory processing (Harrington & Mistleberger, 2000; Mistleberger & Rusak, 2000). In addition to the body's response to environmental cues, the body also responds to the internal need for sleep through the homeostatic process, in which the body's requirement for sleep increases during waking hours and replenishes during sleeping hours. An individual's need for sleep differs depending on their age and ranges from seven hours in adults to seventeen hours of sleep for newborns (see Table 1).

Table 1 *Amount of sleep recommended by age*

Age	**Amount of Sleep Recommended per 24 hours**
Newborn (0-3 months)	14-17 hours
Infant (4-11 months)	12-15 hours

Toddler (1-2 years)	11-14 hours
Preschool (3-5 years)	10-13 hours
School Age (6-13 years)	9-11 hours
Teen (14-17 years)	8-10 hours
Young Adult (18-25 years)	7-9 hours
Adult (26-64 years)	7-9 hours
Older Adult (65+)	7-8 hours

Note. Based on 2021 National Sleep Foundation recommendations (Hirshkowitz et al., 2015)

Importance of sleep on development

While organizations like the National Sleep Foundation have researched and disseminated the recommended amounts of sleep throughout development, children aged five to 12 years obtain an average of three hours less than the 10 hours of sleep recommended by the National Sleep Foundation (Van Dyk et al., 2016). Additionally, there are a variety of sleep disorders that are considered independent diagnoses by the psychological community, ranging from insomnia to nightmare disorders (DSM-5-TR; American Psychiatric Association, 2022). Substandard amounts of sleep, or sleep deficit, alongside sleep disorders, can have a variety of adverse effects on development including impacts on social and emotional development, cognitive functioning, and day-to-day executive functioning.

Social and Emotional Development. Sleep deficits have been shown to have a negative impact on social and emotional functioning and development, specifically on an individual's mood, anxiety, emotion regulation, and emotional recognition (Goldstein et al., 2013; Goldstein & Walker, 2014; Zohar et al., 2005). Sleep loss in otherwise healthy individuals was shown to lead to an increased anticipatory responding and hyper-reactivity to stressful stimuli (Goldstein et al., 2013). This effect was further amplified in those with trait-anxiety. In addition to this hyper-responsivity, sleep loss also leads to a significant increase in an individual's subjective levels of perceived threat when observing others' facial expressions (Van Der Helm et al., 2010). Further, individuals who have experienced a sleep deficit often have an amplified negative emotional reaction to disruptions in their daily routines and decreased ability to outwardly express their internal emotional state (Minkel et al., 2011; Zohar et al., 2005).

Disruption in daily sleep patterns not only disrupts capacity to socially and emotionally function, but it can also be disruptive to development of these capabilities in childhood and adolescence. Dysregulation of emotional responses following decreased sleep can affect temperament as early as infancy (Gómez & Edgin, 2015). Further, sleep loss in preschool and elementary aged children is related to higher rates of behavioral problems, positive and negative outbursts, and less optimal adjustment to the increased demands and transitions in the school environment (Bates et al., 2002; Berger et al., 2012; Smedje et al., 2001). Sleep deprivation through adolescence has been linked to psychological distress and the development of mental health illnesses, such as anxiety and depression (Glozier et al., 2010; Tarokh et al., 2014). In sum, sleep loss is not only detrimental to daily social and emotional functioning but exacerbates long term effects on social and emotional regulation skills that can last throughout development into adulthood.

Cognitive Development. Throughout childhood and adolescent development, sleep is a crucial process in the maturation of the brain and building pathways for adequate learning and memory (Astill et al., 2012; Feinberg & Campbell, 2010). Researchers have found that fragmented sleep leads to a decreased ability to attend to information, perform on cognitive measures, and make decisions in individuals that are otherwise healthy (Sadeh et al., 2002; Van Dongen et al., 2004). This impact on neurological development is apparent starting as early as the first days of life. Freudigman and Thoman (1993) found that measurements of infant sleep-wake times were significantly correlated with early neurobehavioral organization at six months. This relation between sleep and cognitive ability continues well into school-age and adolescence, in which shorter sleep durations and sleep schedule irregularities can predict poorer academic achievement (Wolfson & Carskadon, 1998). Overall, sleep is crucial for the development and continual growth of cognitive abilities that have far-reaching impacts in daily life and academic realms.

Behavioral Regulation. Lastly, sleep plays a crucial role in the ability to regulate one's own behavior. Behavioral regulation is often an external display of internal impacts. The previously explored effects of suboptimal sleep on emotional regulation, social interaction, and the ability to attend and make decisions can be readily seen in external behaviors. This can be seen as early as the first days of life. Infants with more difficult temperaments experienced higher levels of sleep difficulties during the first four days after delivery (Novosad et al., 1999). Avi-Sadeh and colleagues (Sadeh et al., 2002) found that this continues well into childhood based on higher reports of behavior problems by parents of children with fragmented sleep compared to those with less sleep interruptions. Furthermore, a bidirectional relation between externalizing behavioral problems and sleep can be seen as children age. As children experience greater disruption to their sleep, they display a higher frequency of externalizing behaviors, which then influences their quality of sleep (Quach et al., 2018). Thus, the impact of insufficient sleep is not only critical but has exponential consequences as behavior becomes harder to regulate over time.

Sleep in ASD Populations

While many sleep disorders can be diagnosed independently of mental health diagnoses, sleep problems are also seen as diagnostic criteria (e.g., major depressive disorder) or secondary related features for several disorders. Both diagnoses of sleep disorders and reported sleep problems have been found to be more common in those with ASD compared to the general population. A meta-analysis by Lai and colleagues reported that sleep disorders such as insomnia and night waking, were found in 13% of those diagnosed with ASD compared to only 3.7% of the general population (Lai et al., 2019; Souders et al., 2009). Disturbed sleep based on parent report and actigraphic sleep data was seen in between 66.1 to 66.7% of children with ASD (Souders et al., 2009). While sleep can be impacted by numerous biological, psychological, social, and environmental factors, pilot studies have linked high autism severity ratings and difficulties with social abilities with decreased total sleep time (Devnani & Hegde, 2015).

Common Sleep Problems in ASD

Individuals with ASD experience a wide variety of sleep disturbances. Given the broad areas of sleep difficulties and disorders previously discussed, it will be crucial to understand how autistic individuals are impacted. Subjective parent reports indicate that children with autism most commonly struggle with high levels of bedtime resistance, delayed sleep-onset, anxiety about sleeping and sleep schedules (e.g., not sleeping in own bed), waking during the night time, and decreased sleep quality (i.e., restlessness) and duration (Cortese, Wang, et al., 2020; Williams et al., 2004). Polysomnography readings of children with ASD indicated that several parental concerns were supported, including decreased sleep time, longer sleep-onset latency, decreased sleep quality, and nighttime awakenings.

Etiology and Impact of Sleep Problems in ASD

Many factors of lifestyle and biologic origin can impact sleep habits regardless of diagnosis. This leaves many to wonder why those with ASD are more commonly impacted with sleep problems. It is considered best practice to consider this problem from a biopsychosocial standpoint. Neurologically, those with autism have been found to have atypical regulation of melatonin, a neurotransmitter that is critical for establishing and maintaining regular sleep-wake cycles (Bourgeron, 2007). Not only is melatonin atypically regulated in those with ASD, researchers have found that specific genes associated with circadian rhythms, known as clock genes, have been linked to a decreased effect of melatonin on synaptic changes during the sleep-wake cycle in those with autism (Richdale & Schreck, 2009).

From a psychological viewpoint, core and associated features of ASD have been found to have a direct impact on sleep behaviors. Several key features of autism, such as social and communication differences, rigidity in routines and stereotypic behaviors, have all been theorized to play a role in sleep behaviors. One of the most impactful of these is social and communication differences. Developmentally, sleep and wake patterns and routines throughout the day are often learned through their association with specific social and environmental cues, such as meal, self-care, and play times (Pandi-Perumal et al., 2007). The difficulties in interpreting and internalizing social cues and patterns seen in individuals with ASD may interrupt or lessen the role that these social cues play on sleep routines (Richdale & Schreck, 2009). This theory was further supported by Malow and colleagues (Malow et al., 2006) who found that individuals with an autism diagnosis and sleep difficulties had higher levels of reciprocal social interaction difficulties on the Autism Diagnostic Observation Schedule (ADOS, Lord et al., 1999).

In addition to the impact of core diagnostic symptoms, there are many features that often accompany a diagnosis of ASD, such as sensory processing differences and high levels of externalizing behaviors. These associated traits have been theorized to play a large role in sleep quality and routine. Children with increased levels of challenging behaviors throughout the day often have difficulty with regulating their emotions and energy levels during night-time routines (Williams et al., 2004). Additionally, higher levels of hyperactivity that are common in those with increased externalizing behaviors, which is common in individuals with ASD, often create more fluctuating activity levels throughout the day (Bauminger et al., 2010). These fluctuations can disrupt typical sleep-wake patterns and exacerbate mood dysregulation and add to the psychosocial impacts of autism on the individual and the family structure (Cortese, Wang, et al., 2020). Additionally, autistic populations have a higher percentage of additional psychopathological diagnoses, such as anxiety and depression than the general population (Levy et al., 2010). As such, they may have increased vulnerabilities to sleep difficulties seen in populations with anxiety and depression.

Finally, behaviors seen within the home cannot be considered without factoring in the context of the home environment. This includes factors ranging from sleep hygiene practices to parental styles and child-rearing views. Previously discussed diagnostic features of ASD and concurrent diagnoses have an impact on the child and the larger family system. Higher levels of parent-reported sleep difficulties in children with autism have been associated with decreased family functioning, especially in the domains of parental and sibling stress, marital discord, interrupted and decreased levels of sleep for other family members, and decreased positive parenting styles (Devnani & Hegde, 2015; Meltzer & Mindell, 2007; Robinson & Richdale, 2004; Wiggs & Stores, 2004). Thus, the impact of sleep becomes bidirectional. As sleep disturbances rise, family structures decline, psychological distress and externalizing behaviors increase, the child's affected neurological systems become increasingly taxed, and sleep continues to decrease. This cycle illustrates the necessity of considering the multidimensional etiological nature of developmental disabilities on sleep. This bidirectional relation between sleep and externalizing behaviors can also be related to high levels of sensory processing differences (O'Donnell et al., 2012). As such, an exploration of sensory processing differences in developmental disabilities will be helpful in investigating the sleep difficulties so commonly seen in these children. To fully understand their impact on sleep, sensory processing differences will be explored in the broader developmental disabilities' population and the autistic population before dissecting the role they play in sleep patterns.

Defining Sensory Sensitivity

Sensory processing can be defined as an individual's ability to detect and perceive a sensory input and spans multiple modalities, including visual, auditory, olfactory, tactile, and gustatory processing (Schulz & Stevenson, 2019; Sinclair et al., 2019). Sensory sensitivity occurs when an individual perceives a sensory stimulus to be overly desirable, aversive, overwhelming, or underwhelming. Reactions to these perceptions are used to sort the individual's processing into sensory seeking, sensory hypersensitive, or sensory hyposensitive categories (Sinclair et al., 2019). For example, a child with a hypersensitivity to sound would perceive a noise to be louder than a peer without an auditory hypersensitivity.

One of the most widely used sensory processing models is Dunn's model of neural sensitivity and self-regulation (Dunn, 2007). This theory posits that sensory processing patterns result from interactions between an individual's threshold for neurological sensory processing and their behavioral responses to these stimuli. For those with a lower threshold, a very low amount of sensory stimulation will activate the individual's neurological system. Following this pattern, those with higher thresholds require a higher level of stimulation to activate their internal sensory processing neurological system. When responding to stimuli, individuals may take an active or a passive behavioral strategy, such that more active responses indicate higher levels of self-regulatory strategies to control the type and amount of sensory stimulation received (Dunn, 2007). This model delineates four categories of sensory processing patterns: (a) low registration individuals with high thresholds and passive behavioral responses (e.g., hyporesponsivity); (b) sensation seekers – those with higher thresholds and active response systems; (c) sensory sensitivity – individuals with lower thresholds and passive behavioral responses and self-regulations strategies; (d) sensation avoiders – individuals with a lower thresholds and active behavioral avoidance responses to sensory stimuli (Dunn, 1997).

When collecting data about children, information about a child's life outside the lab must be gathered through third-party reporters such as parents or caregivers. Measuring an internal response through the report of an outside observer brings challenges as to whether the questionnaire is actually measuring the perception or the reaction. Several questionnaires rely on behavioral responses to sensory stimuli, or sensory responsivity, rather than the internal sensory sensitivity of the child (Schulz & Stevenson, 2019). While it would be ideal to understand the sensory sensitivity, or the internal processing of the sensory stimuli as overwhelming or underwhelming, it is not realistic to include this as a factor in a study focusing on populations with varying levels of functional independence and ability to answer questions about their internal experience.

Sensory Sensitivity in Autism Spectrum Disorders

A common diagnostic component to ASD is sensory abnormalities, so much so that up to 95% of children with ASD exhibit sensory symptoms (Tomchek & Dunn, 2018). These features are so frequent in the autistic population that diagnosticians often use sensory processing information to help differentiate children with ASD from those with other clinical diagnoses (Baranek et al., 2007). Most common sensory processing concerns in individuals with autism include an overresponsivity to tactile sensations, hypersensitivity or underresponsivity to sounds, and hypersensitivity to food textures or smells (Baranek, 1999; Cheung & Siu, 2009; Osterling &

Dawson, 1994). The weak central coherence theory of ASD suggests that individuals with ASD often exhibit a more detail-focused processing style that may contribute to decreased central processing abilities (Frith, 2003). This focus on details rather than the global situation or stimuli is thought to diminish an individual's ability to attend to and understand broader meanings from a situation where sensory stimulation is involved. For example, if an individual with an auditory hypersensitivity hears a loud sound, they are more likely become focused solely on the noise rather than to notice where it came from and what else is happening around them. This detailed focus and sensitivity to portions of a situation, such as a loud noise, may then have a great impact on an autistic individual's ability to process the situation.

Sensory Sensitivity in Developmental Disorders

While sensory sensitivities have been integrated into the diagnostic criteria for autism, it is commonly seen in a variety of developmental disorders. Sensory processing differences have been found in children diagnosed with ADHD, a fetal alcohol spectrum disorder, fragile X syndrome, and an intellectual disorder (Baranek, 1999; Engel-Yeger et al., 2011; Ghanizadeh, 2011; Parush et al., 2007; Wengel et al., 2011). When compared to typically developing populations, both children with ASD and other developmental disabilities are reported to have higher levels of sensory features (Cheung & Siu, 2009). However, there are very few studies that contrast sensory symptoms seen in those with ASD compared to those with non-ASD developmental disabilities. A meta-analysis by Ben-Sasson and colleagues (2009) found that only four studies compared autistic samples with children with other developmental disabilities. In those four studies, rates of sensory processing differences were primarily focused on children with ASD and did not further distinguish types of developmental disabilities in comparison groups. This is largely due to low sample sizes and high levels of comorbidity between populations of developmental disabilities. The authors of this meta-analysis found that children with autism experienced higher rates and more complex presentations of sensory processing differences when compared to those with another developmental disability (Ben-Sasson et al., 2009). This finding further supports the need for increased understanding of the levels of sensory differences that are experienced by populations with developmental disabilities other than autism. By differentiating the effects of sensory processing differences of those with developmental disabilities, we can better understand the impact of specific diagnostic features. This feature-level focus allows for an adjustment to a more dimensional stance that supports a more holistic approach of an individual's characteristics, such as sensory processing, rather than categorical approaches, such as ASD versus ADHD. Dimensional stances focused on an individual's profile allows for the greatest level of specialized support when developing treatment plans for families. Specifically, when considering difficulties with sleep, treatments focused on sensory differences are often only considered for those with ASD despite the presence of sensory processing challenges in most developmental disabilities.

Problematic Sleep and Sensory Processing Differences

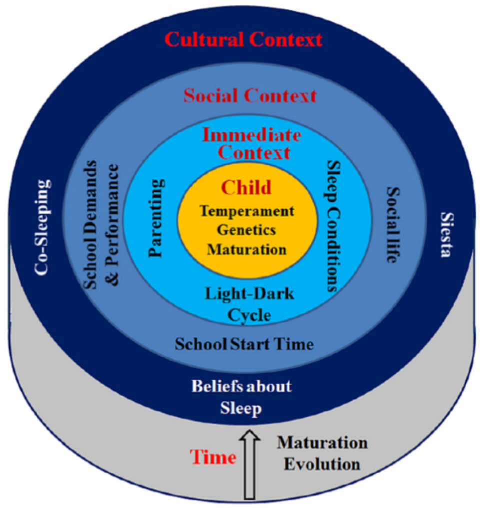
As discussed above, sleep concerns have been found to be highly prevalent in populations with neurodevelopmental disabilities. Many of these groups experience heightened levels of sensory processing differences (Ben-Sasson et al., 2009). It has been posited that these high levels of sensory-related differences contribute to the sleep problems seen in these groups, especially when individuals experience over-arousal or hypersensitivity to sensory stimuli (Milner et al., 2009; Reynolds et al., 2012). Higher levels of sensory processing difficulties are correlated with increased time required to settle into night-time rest, shorter overall duration of sleep periods, and decreased sleep quality (Sharfi & Rosenblum, 2015; Vasak et al., 2015). The link between sleep disturbance and sensory processing has been seen throughout the lifespan in several diagnostic categories, including ASD, ADHD, and fetal alcohol spectrum disorder (Lufi & Tzischinsky, 2014; Mazurek & Petroski, 2015; Milner et al., 2009; Sharfi & Rosenblum, 2015; Wengel et al., 2011). While at lower rates than that of the neurodevelopmental disability community, sleep and sensory difficulties are seen in typically developing populations as well (Engel-Yeger & Shochat, 2012; Milner et al., 2009; Shochat et al., 2009). This widespread evidence of relational patterns between these two areas suggests that sensory processing differences may have an additive effect on the impact of neurodevelopmental diagnostic status on sleep patterns.

Sleep and sensory processing are biologically linked in many ways. Even prior to the start of the sleep cycle, researchers have found impacts of sensory processing differences. Milner and colleagues (2009) gathered electroencephalograph (EEG) readings in adults that indicated poor sleepers showed impairments in sensory gating during pre-sleep wakefulness. The research team measured the P50 amplitude of the EEG scan during a paired-click paradigm, a process of presenting two successive clicking sounds during the pre-sleep process. When presented with the two clicks, individuals with high levels of sensory gating, or decreased sensitivity to sensory stimuli, attend less to a second click than the first click. However, those who were identified to be poor sleepers continued to attend to this second click, indicating that they have lower levels of sensory gating abilities. The findings of this paired-click paradigm analysis indicated that those who were identified to be poor sleepers showed significant differences in how they processed sensory stimuli. Additionally, researchers have been able to use biological methods of gauging emotional and physiological distress by measuring levels of cortisol, a hormone released by the hypothalamic pituitary adrenal (HPA) axis in response to stress (Tyrka et al., 2007). Reynolds and colleagues (2012) found that by utilizing behavioral parent report of sensory symptoms and salivary cortisol samples, they were able to predict which children would have a poor night's sleep with an accuracy of 85.7%. This suggests that biologically, both sleep and sensory modulation processes are positively related to the internal regulation of stress and that parent-reported sensory processing differences can be a helpful indicator for understanding sleep patterns. The correlations between behavioral, physiological, and hormonal effects of sensory processing on sleep patterns indicate the importance of considering sensory processing when measuring problematic sleep patterns.

Ecological Systemic Model of Sleep

While the importance of sleep on development and overall mental health is not disputed, there can often be barriers to finding successful methods for improving sleep functionality and quality. This is largely due to the impacts of multiple environmental micro- and macro- systems that play a bidirectional role on sleep. This ecological systemic model of sleep, based on the Bronfenbrenner's ecological systems theory and the Sameroff transactional systems developmental model, was developed by El-Sheikh and Sadeh in 2015 to account for the multiple contexts that must be considered when examining sleep patterns (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994; Fiese & Sameroff, 1989; Sameroff, 2009). As seen in Figure 1 from El-Sheikh and Sadeh's monograph on sleep, a child's sleep can be influenced by internal and external systems. Internally, the child's own temperament, genetics, and maturational level determines their biological baseline sleep levels. Their baseline sleep is further shaped by the external immediate context of the home environment and parenting techniques, as well as the social and cultural context of school and social schedules and the more distal overall cultural view of sleep schedules.

Figure 1. The ecological systemic model of sleep (figure from El-Sheikh & Sadeh, 2015)



The ecological systemic model of sleep accounts for many external and internal variables on sleep development; however, it does not take into account the distinct role of external stressors on the child's contexts. Environmental and social cues seen in the immediate and social realms have been found to fluctuate substantially with stress levels (Fortunato & Harsh, 2006). Stressful life events in adolescent populations have been negatively correlated with time spent in slow wave sleep, which has been connected with memory consolidation, regulation of growth hormones, regeneration of energy levels used during the daytime, immune support, and cleaning of metabolites in the cerebral spinal fluid (Léger et al., 2018; Williamson et al., 1995). Further, the childhood stress-sleep cycle does not operate independently of other external systems. When children experience decreased sleep, this significantly impacts maternal stress, which in turn increases child stress levels and further impacts sleep quality (Hoffman et al., 2008; Meltzer & Mindell, 2007). While stress in these studies were mainly focused on everyday occurrences, the recent global pandemic contributed to high levels of stress to the environmental, social, and individual contexts (Gao & Scullin, 2020).

The Global Coronavirus Pandemic

In late 2019, a novel strain of coronavirus disease (COVID-19) was first reported in Wuhan, China (Gao & Scullin, 2020). By March of 2020, the COVID-19 outbreak had spread worldwide and was officially categorized as a pandemic by the World Health Organization (WHO). Within the first three months of its presence in the United States, the country quickly rose to one of the most severely impacted areas globally, with over two million cases and over 110,000 COVID-19 related deaths (*WHO Director-General's Opening Remarks at the Media Briefing on COVID-19 - 11 March 2020*, n.d.). Throughout March of 2020, the United States began a process of closures that began with schools on March 13 and shelter-in-place polices by March 24. While these policies varied by state, closures became a norm throughout the following year (Mervosh et al., 2020).

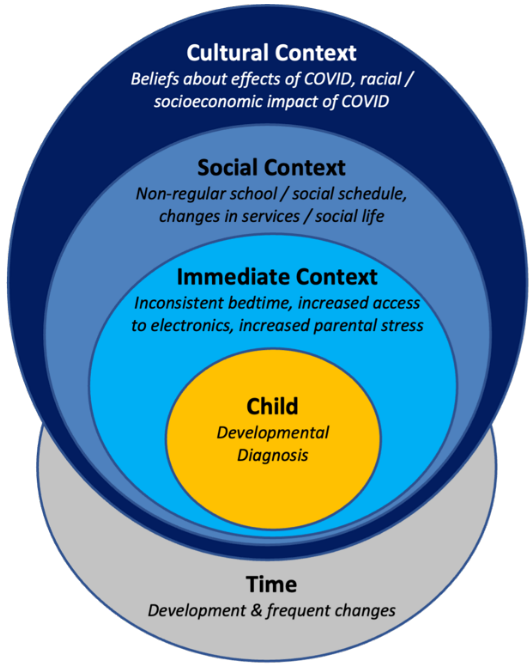
Very soon after closures began, researchers began to focus on the environmental, social, and individual effects of COVID-19 safety precautions. Several authors noted that environmental and social changes as a result of the pandemic were significantly affecting sleep duration and quality in the general population (Blume et al., 2020; Wright et al., 2020). Early estimates indicated that at least 25% of the general population experienced decreased quality of sleep due to stress, adverse impacts of life changes and caregiving supports, and the presence of COVID-related symptoms (Gao & Scullin, 2020). However, some studies reported that changes in sleep were not uniformly experienced when study populations were diversified to include those with previously experienced sleep difficulties. Kocevska and colleagues (2020) found that one in four of those who had poor sleep prior to the pandemic experienced an improvement in sleep quality and those that had generally positive sleep patterns experienced the opposite effect during closures. This was an unexpected pattern that the researchers continued to explore through identifying potential differences in emotional responses to lockdown. As predicted, the researchers found that patterns of sleep quality were negatively associated with negative affect and worry indicating that the emotional response to lockdown was a better indicator of sleep changes. What was becoming clear is that the effects of closures had varying levels of impact on sleep for different populations.

This variation is especially important to consider in developing populations. The impact of prior health-related disasters and confinement responses have been found to cause children and their families to experience high levels of stressful and traumatic events (Sprang & Silman, 2013). During early closure phases in Italy and Israel, caregivers reported an overall decrease in quality of their children's sleep (Dellagiulia et al., 2020; Zreik et al., 2021). Around 30% of mothers reported that their children were experiencing decreased sleep quality and very few reported positive sleep changes during the closures (Zreik et al., 2021). Similar findings were reported across Europe, with main risk factors of caregiver's overall stress level and protective factors of service levels and presence of siblings and pets in the home (Markovic et al., 2021). Despite information regarding individuals and children in the general population, little information has surfaced regarding the effects on groups with developmental disabilities, who are already significantly impacted by sleep difficulties compared to typically developing populations.

A COVID-Informed Ecological Systems Model of Sleep

It is clear that there are impacts of the global pandemic on multiple areas of life and emerging evidence of significant impacts on sleep. The previously explored ecological systems model of sleep (El-Sheikh & Sadeh, 2015) will to be helpful in understanding how large global stressors, such as the COVID-19 pandemic, influence sleep from a systemic viewpoint. As seen in Figure 2, global stressors impact each context of the sleep model.

Figure 2. COVID-19 Impacts on the ecological systemic model of sleep



At an immediate context level, families have experienced inconsistent bedtimes or bedtime routines, increased access to screen-based devices, and increased parental stress (Cortese et al., 2020; Kong, 2021; Markovic et al., 2021; Ribner et al., 2021; Shorey et al., 2021). Regarding daily screen usage, reliance on technology for education as well as to entertain children during workdays have resulted in increased child engagement in screen engagement by nearly an hour compared to their pre-COVID usage (Ribner et al., 2021). In addition to these home-based changes, the social context significantly decreased in the availability of schools, social activities, and services that have been discontinued or significantly changed due to stay-at-home procedures (Loades et al., 2020; Mervosh et al., 2020; Shorey et al., 2021). At a broad level, children's cultural contexts were challenged as the United States took stances on issues such as family beliefs about COVID policies and pandemic-related governmental practices (Earnshaw et al., 2020). Additionally, families of racial and socioeconomic minority groups have experienced inequitable levels of impacts as a result of the pandemic. Early estimates indicated that black populations in the United States were disproportionately affected by COVID, with 58% of national deaths and 52% of national COVID diagnoses, likely due to social conditions and systemic racism (Millett et al., 2020). In addition to medical impacts, minority populations, such as Latinx, experienced higher levels of unemployment due to COVID-19 (18.2%) compared to Caucasian populations (Couch et al., 2020; Fairlie et al., 2020). With effects seen at all external contexts in the ecological systems model of sleep, it is important to understand how the internal context of the child is influenced. El-Sheikh & Sadeh's (2015) model indicated the importance of child temperament, genetics, and maturation, which in the COVID-informed model translates to the child's diagnosis, developmental level, and perception of their own world.

The Current Study

As previously described, the COVID-19 pandemic has shown varying levels of impact on sleep quality and quantity. The majority of the research focus has been drawn to typically developing adults and children (Dellagiulia et al., 2020; Zreik et al., 2021). Changes in sleep patterns can easily lead to increased levels of sleep deficits, which have a negative impact on development of cognitive skills, social and emotional functioning and regulation, and mood and anxiety symptoms (Goldstein et al., 2013; Goldstein & Walker, 2014; Zohar et al., 2005). Children with developmental disabilities, especially those with ASD, have up to four times the amount of sleep difficulties seen in the typically developing community (Lai et al., 2019). Additionally, we know that children with ASD have increased resistance to and difficulty with transitions and change, which have been common events during the pandemic (Loades et al., 2020; Mervosh et al., 2020; Shorey et al., 2021). Increased levels of transitory difficulties and resulting internalizing and externalizing behaviors have been connected to increased levels of caregiver stress, which has also been seen to be negatively correlated with child sleep quality

(Hoffman et al., 2008; Markovic et al., 2021; Meltzer & Mindell, 2007). Overall, this conglomeration of heightened risk factors for impacted sleep call for an increased understanding of the influence of the COVID-19 pandemic on sleep quality for those with developmental disabilities. The current study seeks to understand the influence of the pandemic closures on sleep in populations with developmental disabilities and to further distinguish between the varying levels of effects on children with ASD compared to their peers with other developmental disabilities.

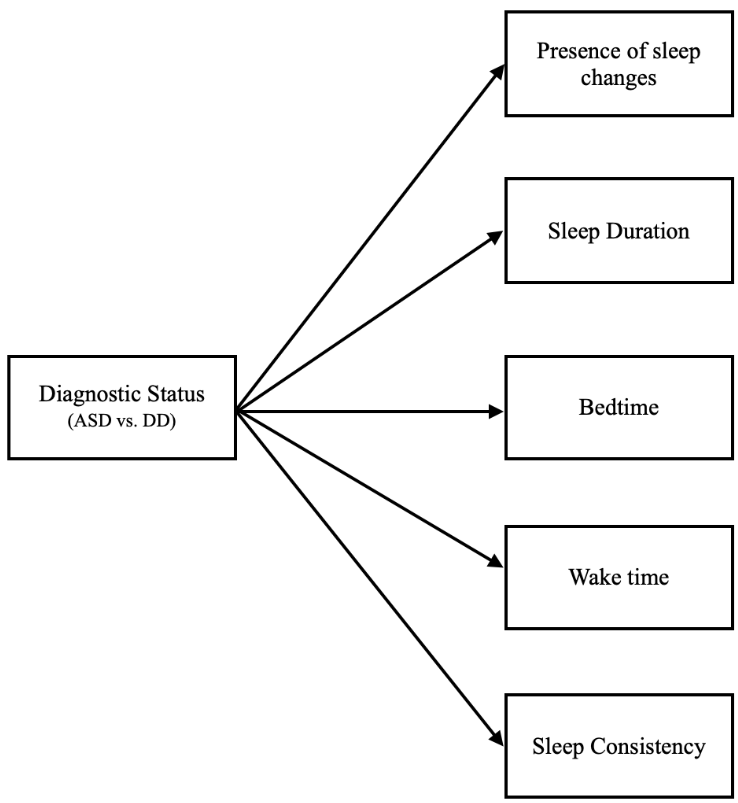
Further, there have been many studies relating sensory processing differences to sleep difficulties. Sensory processing differences have been linked to sleep throughout the lifespan in several populations with developmental disabilities diagnoses, such as ASD, ADHD, and fetal alcohol spectrum disorder (Lufi & Tzischinsky, 2014; Mazurek & Petroski, 2015; Milner et al., 2009; Sharfi & Rosenblum, 2015; Wengel et al., 2011). While at lower rates, this negative relation has also been seen in the typically developing community (Engel-Yeger & Shochat, 2012). As a part of exploring the impact of the pandemic on sleep in developmental disabilities communities, it is important to consider the role of sensory processing difficulties. The current study seeks to understand the potential moderating role of sensory processing differences on COVID-19 related sleep changes. Investigating this relationship will help us understand how sensory processing differences exhibited by children with neurodevelopmental disabilities may have influenced the changes in sleep patterns experienced by these children at the start of the pandemic.

Hypotheses

The current study examined the difference in sleep changes at the start of the COVID-19 pandemic in children with ASD and with other developmental disabilities. Further it examined the moderating role of sensory processing differences on the relation between diagnostic status and sleep changes.

Hypothesis 1. In general, children with developmental disabilities have been found to have heightened sleep difficulties compared to typically developing children. Within developmental disabilities populations, children with ASD have been found to have significantly higher levels of sleep difficulties than other children with DDs (Krakowiak et al., 2008). I hypothesized that children with ASD would have higher levels of sleep difficulties across five dimensions of sleep at the start of the COVID-19 pandemic compared to their peers with other developmental disabilities.

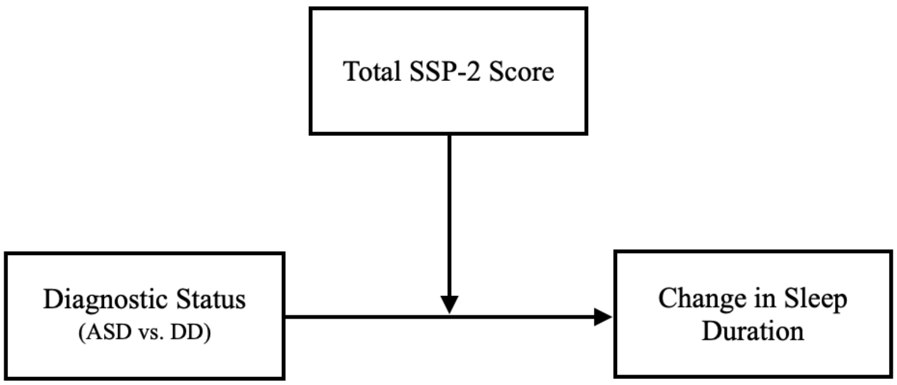
Figure 3. Visual model of the primary analysis to test the first hypothesis



Hypothesis 2. Many developmental disabilities have been associated with high levels of sensory processing differences, which have been shown to negatively impact sleep quality and

duration (Reynolds et al., 2012). I hypothesized that sensory processing differences would play a moderating role in the relation between diagnostic status and increased changes in sleep duration at the start of the COVID-19 pandemic, such that sleep duration changes would be more common in children with heightened sensory processing differences regardless of their developmental disability diagnostic category.

Figure 4. Visual model of the moderation analysis to test the second hypothesis



CHAPTER II - **Method**

Participants

The current study was part of a follow-up study examining the lived experiences of individuals with and parents of children with developmental disabilities during the COVID-19 pandemic. Participants for the current study were 55 parents of children between the ages of 1 and 18 years old. Parents served as reporters on their own and their children's behavior. As illustrated in Table 2, children had a mean age of 10.75 years old, with a range of 1 to 18, and the majority, 78.2%, were male. Thirty-two children in this sample had a diagnosis of ASD (12.5% female, 3% nonbinary; mean age = 10.75 years). Seventeen of these children had an additional diagnosis (ADHD = 13, LD = 8, Seizure Disorder = 1, ID = 1, Other = 6). The remaining 23 children in the sample (30.4% female; mean age = 9.86 years) had a developmental disability other than autism (ADHD = 6, Cognitive disability = 2, multiple diagnoses = 12, other = 3). About half of the full sample, 49.1% (ASD: 43.7%, DD: 56.5%), identified as Caucasian, 5.5% Hispanic/Latinx (ASD: 9.4%, DD: 0%), 1.8% Asian American (ASD: 0%, DD: 4.3%), 10.9% (ASD: 9.4%, DD: 13.0%) African American, and 32.7% (ASD: 37.5%, DD: 26.1%) reported that they had more than one racial identity. Household income ranged from $0 to more than $150,000, with nearly half of participants, 47.3%, earning over $100,000 (ASD: 40.6%, DD: 56.5%). Parental education level varied with 3.6% that completed high school (ASD: 6.2%, DD: 0%), 3.6% that completed vocational training (ASD: 6.2%, DD: 0%), 14.5% completed some college course work (ASD: 12.5%, DD: 17.4%), 7.3% earned an associate's degree (ASD: 3.1%, DD: 13.0%), 25.4% earned a bachelor's degree (ASD: 31.2%, DD: 17.4%), 3.6% completed some post-undergraduate work (ASD: 3.1%, DD: 4.3%), 23.6% earned a master's degree (ASD:

28.1%, DD: 17.4%), 1.8% that earned an applied or professional doctorate degree (ASD: 0%, 4.3%), and 23.6% that earned a doctorate degree (ASD: 9.4%, DD: 26.1%).

Table 2 *Demographic information by diagnostic groups*

	Total Sample (n = 55)	ASD (n = 32)	Other DD (n = 23)
Gender			
Male	43	27	16
Female	11	4	7
Non-binary	1	1	0
Race/Ethnicity			
Caucasian	27	14	13
Hispanic/Latinx	3	3	0
African American	6	3	3
Asian	1	0	1
Caribbean	0	0	0
More than one race	18	12	6
Caucasian	*14*	*10*	*5*
Hispanic/Latinx	*7*	*5*	*2*
African American	*3*	*3*	*1*
Native American/ Alaskan Native	*5*	*3*	*2*
Middle Eastern	*1*	*0*	*1*
Asian American	*3*	*2*	*1*
Pacific Islander	*1*	*1*	*0*
Mean Age in years (range)	10.38 (1 – 18)	10.75 (3-18)	9.86 (1-17)
Family Income			
$0 - $9,999	4	4	0
$10,000 - $24,999	3	3	0
$25,000 - $49,999	11	6	5
$50,000 - $74,999	3	1	2
$75,000 - $99,999	5	3	2
$100,000 - $149,999	11	4	7
More than $150,000	15	9	6
No answer	3	2	1
Parent Education Level			
Some high school	0	0	0
High school diploma or equivalent	2	2	0
Vocational training	2	2	0
Some college	8	4	4

Associate degree	4	1	3
Bachelor’s degree	14	10	4
Some post-undergraduate work	2	1	1
Master’s degree	13	9	4
Specialist degree	0	0	0
Applied or professional doctorate degree	1	0	1
Doctorate degree	9	3	6
Child Diagnosis			
Autism Spectrum Disorder	15	32	-
ADHD	6	-	6
Cognitive Disability *(Down Syndrome, ID)*	2	-	2
Other	3	-	3
Multiple Diagnoses	29	17	12
ASD	*17*	*17*	-
ADHD	*21*	*13*	*8*
Cerebral Palsy	*1*	*0*	*1*
Deaf or Hard of Hearing	*3*	*0*	*3*
Learning Disability	*13*	*8*	*5*
Seizure disorder	*2*	*1*	*1*
Stutter	*0*	*0*	*0*
Cognitive Disability	*6*	*1*	*5*
Other	*9*	*6*	*3*

Procedure

This study utilized cross-sectional data from a larger web-based survey on the experience of the developmental disabilities’ community in the United States during the COVID-19 pandemic. Eligibility criteria for this survey included being 18 years of age or older, living in the United States at the time of the survey, and having a diagnosed developmental disability or having a child with a developmental disability. Data were collected across a 13-week period from April to July of 2020. Participants completed an initial survey that was approximately 20 to 35 minutes in length. At the end of the initial data collection, participants were given the opportunity to be involved in four follow-up surveys, taking place at two weeks, four weeks, six weeks, and one year post initial data collection. Upon completion of the initial survey, participants were entered into a raffle drawing for a $25 Amazon gift card. A second raffle drawing for a $25 Amazon gift card was offered to those who completed the follow-up surveys.

Measures

COVID Sleep Questionnaire

Quality and quantity of sleep was determined by questions based on the Children's Sleep Health Questionnaire (CSHQ; Owens et al., 2000) . Due to the time required for the larger study, questions were shortened and modified to focus on sleep changes that were experienced at the onset of the COVID-19 pandemic rather than to diagnose overall sleep disorders in the studied population. This procedure was modeled after a similar study by Wu and colleagues (2017) in which researchers assessed sleep duration, quality, and habits with simple, comparative questions (i.e. "During the past month, when has your child usually gone to bed on a weeknight?"). In the current study, four areas of sleep were assessed: duration, time of sleep onset, time of waking, and consistency of these sleep parameters throughout the week.

Respondents were asked to report if and when their child's main service (i.e., school or day care) was shut down due to the COVID-19 pandemic. Following this, they were asked if any of the four areas of sleep described above had changed following decreased in-person services through their school or daycare. If respondents reported change in sleep, they were given additional questions on the affected sleep parameter prior to and after change in services (i.e. "Specify the average amount of time that your child slept during the night *before* the start of the COVID-19 pandemic and/or school or day care shut down" and "Specify the average amount of time that your child slept during the night *after* the start of the COVID-19 pandemic and/or school or day care shut down"). Depending on how many areas of sleep were impacted, the respondent would provide between 4 and 12 responses.

While questions presented in the abbreviated format were altered for length and were directed at changes caused by the pandemic, the questionnaire content was based on the CSHQ. The CSHQ is a retrospective, 45-item caregiver questionnaire that has been validated for children aged 4 to 10. The CSHQ was standardized on a community sample of 469 parents of school-aged children and a clinical sample of 154 parents of children with sleep disorders (Owens et al., 2000). The focus of the questionnaire is on identifying clinical sleep complaints and behavior in young children, specifically in the domains of behaviors during bedtime, sleep onset, sleep duration, sleep-related anxiety, sleep-time behaviors (i.e., night wakings, sleep-disordered breathing, and parasomnias), morning waking, and daytime sleepiness. Domains on the CSHQ are rated on a three-point scale within the context of a "typical" recent week, with higher scores indicating higher frequency of the behavior or complaint. Some items are reverse scored to support this pattern.

The foundational study of the CSHQ indicates that it has a test-retest reliability range of .62 to 0.79 and an internal consistency range from .68 (community sample) to .78 (clinical sample) (Owens et al., 2000). Internal validity of the subscales in the CSHQ ranged .36 to .70 in the community sample and 0.56 to 0.93 in the clinical sample, and were all significant at $p < .01$, excepting the sleep-disordered breathing subscale in the clinical sample. Discriminant validity of the CSHQ total score was demonstrated by comparing the community and clinical samples for each item and subscale at a significance level of $p < 0.001$. The clinical group had higher levels of sleep problems than the community sample in all items, except for one (i.e., "Wakes by self"). Additionally, all items were significant at the $p < 0.001$ significance level excepting three items in the Daytime Sleepiness subscale. The CSHQ developers generated a cut-off score to indicate concern for disordered sleep at 41 using a Receiver Operator Characteristic Curve analysis. This analysis indicated that the cut-off total score correctly yielded a specificity of 0.72 and a sensitivity of 0.80.

Short Sensory Profile

The Short Sensory Profile (SSP; McIntosh et al., 1999) is a parent report measure comprised of 38 questions targeted at identifying behaviors commonly associated with abnormal responses to sensory stimuli, or sensory responsivity. The items on the SSP were selected from the measure's longer counterpart, the Sensory Profile (SP; (Dunn, 1999), due to their high discriminative power of detecting atypical sensory processing. The SP was standardized on 1,115 children aged 3 to 10 (Dunn, 1997). The shortened questionnaire takes around 10 minutes to complete and thus is commonly recommended for research protocols due to decreased time burden on participants (Dunn, 1999; McIntosh et al., 1999). The items chosen for the SSP are scored on a zero to four scale, with higher scores indicating higher impairment, and can be analyzed in either a total score of sensory differences or any of seven factor scores (tactile sensitivity, taste/smell sensitivity, movement sensitivity, auditory filtering, low energy/weak, under-reactive/seeks stimulation, and visual/auditory sensitivity).

The originating study of the SSP indicates that it has a reliability of .90, a discriminant validity greater than 95%, and a factor-level internal consistency range from .70 to .90 across three samples (Tomchek & Dunn, 2007). Internal validity of the factors in the SSP ranged .25 to .76 and were all significant at $p < .01$. Discriminant validity of the SSP total score was demonstrated by comparing scores of age and gender matched children with and without Sensory Processing Disorders (SPD). Those with SPD were found to have greater sensory abnormalities on the SSP than their typically developing peers. Additionally, scores on the SSP were significantly correlated with abnormal physiological electrodermal reactivity in response to sensory stimuli (McIntosh et al., 1999).

The developers of the SSP have released an updated edition, entitled the Short Sensory Profile – Second Edition (SSP-2; (Dunn, 2014), however there have been few studies released regarding the psychometric properties of this version. In addition to the strong psychometric properties of the SSP, this measure has also been adapted for several different languages and cultures, including Chinese, Indian, Israeli, Malay and Polish versions (Benjamin et al., 2014; Chojnicka & Pisula, 2019; Ee et al., 2016; Engel-Yeger, 2010; C. Y. Y. Lai et al., 2011).

CHAPTER III - **Results**

Power Analysis

Two a priori power analyses were conducted using G*Power software to compute the necessary sample sizes needed for adequate statistical power in the two proposed analyses (Faul et al., 2007). The primary analysis for this study compared sleep changes in children with ASD to those in children with other developmental disabilities at the start of the COVID-19 pandemic. This analysis required a power analysis for an independent groups t-test with an alpha level of .05 and a power level of 0.8. Sample sizes of 620, 102, and 42, respectively, would be required to detect small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) effects in this proposed analysis. Data collected during the COVID-19 pandemic resulted in a sample size of 55 individuals, which resulted in a Cohen's d of 0.56 or a medium powered analysis.

The secondary analysis focused on the moderating effect of sensory processing differences on the relation between developmental disability status and COVID-19 related sleep changes required a linear multiple regression a priori power analysis. Four variables, diagnostic status, SSP-2 score, sleep duration residual changes, and the moderation variable, were entered as predictors into the power analysis. Results indicated that respective sample sizes of 550, 77, and 36, would be required for a small ($f^2 = 0.02$), moderate ($f^2 = 0.15$), and large ($f^2 = 0.35$) Cohen's f^2 effect size to be achieved. Due to impacts of longitudinal attrition, only 19 of the 55 individuals included in the primary analysis provided information about their child's sensory processing differences. Therefore, the secondary analysis was determined to best be utilized as an exploratory analysis used to understand potential trends that could be followed up in future studies.

Analytic Plan

The primary set of analyses focused on understanding the sleep changes seen at the start of the COVID-19 pandemic in a sample of children with ASD compared to a sample of children with other developmental disabilities. Due to mixed nature of continuous and categorical data (as can be seen in Table 3), the principal research question was addressed using a series of independent samples t-tests and simple linear regressions. Five primary outcomes were compared between the two samples: (a) presence of any changes in sleep patterns (a variable calculated by counting the number of variables parents reported to have changed); (b) changes in sleep duration; (c) changes in time of sleep onset; (d) changes in time of waking; and (e) changes in overall sleep consistency.

Table 3 *Analytic methods for primary research question*

Analysis	Variables	Analytic Method
1.1	Comparison of overall changes in sleep patterns between ASD and DD groups	Independent samples *t*-test
1.2	Relation between diagnostic status and change in sleep duration	Linear regression
1.3	Relation between diagnostic status and change in bedtime	Linear regression
1.4	Relation between diagnostic status and change in waketime	Linear regression
1.5	Relation between diagnostic status and change in sleep consistency	Linear regression

The secondary analysis explored the moderating effect of sensory processing differences on the relational patterns identified in the primary analysis, thus providing insight into the differentiating role of sensory processing and diagnostic status as the driver in pandemic-related sleep impacts. A moderation analysis was conducted with a predictor variable of diagnostic status, a moderating variable of a total score from the SSP-2, and an outcome variable of the change in sleep duration (Figure 4). With the addition of melatonin use and child age as control variables, trending significant moderation effects at a 0.1 level indicated that further post hoc analyses would be beneficial. These tertiary post hoc analyses were completed to determine effects of each of the previously discussed sensory processing domains on changes to sleep duration at the beginning of the COVID-19 pandemic.

Data Preparation

The data collected for these analyses were primarily focused on identifying areas of perceived change, such that questions asked parents to report information on whether changes were seen in child sleep from before and after the start of the pandemic for multiple diagnostic groups. Change scores often fall into an area of statistical concern due to differences between individual baseline scores and the reliability of these scores on calculating changes in groups. This statistical conundrum, Lord's paradox, is the assertion that "differences between scores tend to be much more unreliable than the scores themselves" (Kisbu-Sakarya et al., 2013; Lord, 1956).

Given Lord's paradox, one of the recommended methods for comparing differences in individual changes by group involves calculating a residual change score. Literature focused on contrasting different methods of data preparation for analyses involving change scores revealed that the use of residual change scores resulted in the ability for analyses to support differential power despite conditions of imbalanced baseline and reliability scores (Kisbu-Sakarya et al., 2013). Residual change scores for the analyses in this study were calculated by regressing the post-pandemic score (Y) on the pre-pandemic score (X) without accounting for diagnostic status. This process results in a total regression coefficient for Y on X to be used in subsequent linear regression analyses.

Descriptive Analyses

Descriptive statistics for the study variables are summarized in Table 4. Potential covariates were identified through correlational analyses between key study variables (see Table 5). Age and melatonin usage were included as possible covariates. Age significantly correlated with a key study variable, sleep domain change. Specifically, increased age was associated with a greater amount of sleep domains changed during the pandemic. Sleep domain change was also significantly correlated with residual change scores for child waketime and consistency. As expected, additional significant correlations were seen between several of the sleep domains.

Table 4 *Means, standard deviations, and ranges for quantitative study variables*

	Means (*SD*) [range]		
	Total (*n* = 55)	**DD** (*n* = 23)	**ASD** (*n* = 32)
Sleep Domains			
Quantity of domain changes	2.16 (1.41) [0, 4]	1.91 (1.24) [0, 4]	2.34 (1.52) [0, 4]
Residual duration change	-0.003 (1.01) [-1.60, 3.53]	-0.13 (0.70) [-1.51, 2.01]	0.09 (1.19) [-1.60, 3.53]
Residual bedtime change	-0.002 (1.01) [-1.64, 5.97]	-0.16 (0.57) [-1.42, 1.48]	0.11 (1.23) [-1.64, 5.97]
Residual waketime change	-0.007 (1.02) [-2.93, 3.03]	-0.15 (0.95) [-2.09, 2.67]	0.10 (1.07) [-2.83, 3.03]
	Total (*n* = 18)	**DD** (*n* = 7)	**ASD** (*n* = 11)
Sensory Domains			
Seeking/Seeker	17.71 (5.57) [5, 26]	17.00 (2.38) [13, 21]	18.20 (7.12) [5, 26]
Avoiding/Avoider	27.50 (6.97) [13, 38]	28.29 (5.71) [22, 36]	27.00 (7.87) [13, 38]
Sensitivity/Sensor	32.29 (6.60) [19, 43]	33.57 (1.90) [31, 36]	31.40 (8.54) [19, 43]
Registration/Bystander	18.94 (6.06) [10, 30]	17.57 (5.32) [12, 26]	19.90 (6.62) [10, 30]
Sensory Total	35.5 (8.45) [23, 53]	33.57 (5.19) [26, 39]	36.90 (10.19) [23, 53]
Behavioral Total	61.2 (13.61) [28, 81]	62.86 (6.34) [54, 70]	60.18 (16.96) [28, 81]

Note. *SD* = standard deviation; ASD = Autism Spectrum Disorder; DD = Other Developmental Disabilities

Table 5 *Correlational table of study variables*

Variable	1	2	3	4	5	6	7	8
1. Diagnostic Group[1]	-							
2. Child Age	0.09	-						
3. Melatonin[2]	0.14	0.06	-					
4. Sleep Change Sum	0.15	0.26*	-0.08	-				
5. Duration RCS	0.11	0.25	0.21	0.10	-			
6. Bedtime RCS	0.14	0.13	-0.11	0.19	0.40**	-		
7. Waketime RCS	0.12	0.20	0.07	0.32*	0.34**	0.52**	-	
8. Consistency RCS	0.19	0.11	0.07	0.41**	0.08	0.49**	0.55**	-
9. SSP-2 Sensory Score	0.20	0.09	0.08	-0.29	-0.27	-0.23	-0.13	-0.08

Note. RCS = Residual Change Score; SSP-2 = Short Sensory Profile-Second Edition; [1] Diagnostic Group is a binary variable (0 = Other Developmental Disabilities, 1 = ASD); [2] Melatonin use is a binary variable (0 = no melatonin use, 1 = melatonin use); $p < .05$, $p < .01$

Tests of Hypotheses

Primary analyses: Differences in sleep change by diagnosis

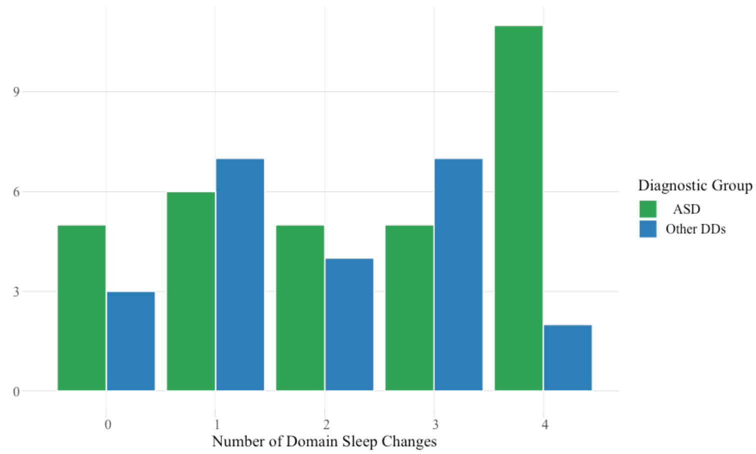
Analysis 1.1: Changes in sleep patterns by diagnosis. An independent-samples t-test was conducted to evaluate the hypothesis that children with a diagnosis of ASD would experience change in a larger number of sleep domains compared to children with other developmental disabilities. As shown in Table 6, groups did not differ significantly, $t(53) = 1.12$, $p = 0.27$, with a 95% confidence interval ranging from -0.34 to 1.20. Children with ASD (M = 2.34, SD = 1.52) showed a similar amount of change in sleep domains during the COVID-19 compared to youth with other developmental disabilities (M = 1.9, SD = 1.24). The difference between these groups was relatively small (d = 0.31). While this analysis indicated no significant difference between group means, there did appear to be more children with ASD that experienced change in all four domains assessed (ASD n = 11, TD n = 2) as seen in Figure 5. While this difference is not reflected within the main group differences, it is valuable to note that there may be room for future resources looking at the difference in variability between autistic youth and their peers with DDs.

Table 6 *Sample descriptives using students' two sample t-test for equality of means*

	ASD		DD					
	M	*SD*	*M*	*SD*	*t*-test	*df*	*p*	*d*
Sleep Domain Changes	2.34	1.52	1.91	1.24	1.12	53	0.27	0.31

*$p < .05$

Figure 5. Histogram plot of group differences in number of sleep domains.



Analysis 1.2: Residual change in sleep duration. Normality was assessed for the sleep duration residual change scores prior to conducting a linear regression. Visual analysis indicated that the data are over peaked, such that there is a large cluster of residual change scores between no change in sleep and loss of one hour of sleep (*M* = -0.003, median = -0.16). This slightly abnormal curve suggests that a bootstrapped linear regression should be completed to evaluate and assist with normality. A non-significant change in standard error and coefficients following a bootstrap analysis implied a non-significant amount of data atypicality, which provided confidence in the linear regression analysis. The hypothesis that an autism diagnosis predicts more change in sleep duration during the pandemic was tested through a simple linear regression analysis. Contrary to hypotheses, this relationship was not statistically significant (see Table 7). Further, diagnosis explained a small amount of the variation in sleep duration changes (R^2 = 0.01).

Analysis 1.3: Residual change in bedtime. Normality was also assessed for the sleep bedtime residual change scores prior to conducting a linear regression. Similarly, histogram plots indicated that the data were over peaked, such that there was a large cluster of residual change scores between no change in time of sleep onset and one hour later in the night (*M* = -0.002, median = -0.19). A non-significant difference between the residual creation and following bootstrap indicated that data atypicality was non-significant and would not impact further regression analyses. The hypothesis that those with ASD would experience greater change in bedtime during the pandemic was tested through a simple linear regression analysis. Contrary to hypotheses, this relationship was not statistically significant (see Table 7) and had a small effect size (R^2 = 0.02).

Analysis 1.4: Residual change in waketime. Over-peaked normality was also seen in residual changes in waketime. This pattern indicated that there was a large cluster of residual change scores between no change in time of sleep onset and one hour later in the night (*M* = -0.006, median = -0.23). Further, bootstrap comparison once again indicated non-significant effects of this data pattern and supported further regression analysis. The hypothesis that those with ASD would experience greater change in waketime during the pandemic was tested through a simple linear regression analysis. Contrary to hypotheses, this relationship was not statistically significant (see Table 7). Effect sizes of this analysis indicated that diagnosis explained a small amount of variance within sleep onset changes (R^2 = 0.02).

Analysis 1.5: Change in sleep consistency by diagnosis. For the final simple linear regression analysis, previous steps of checking normality resulted in similar over-peaked data pattern in which a large cluster of residual change scores indicating a slight decrease in sleep quality (*M* = -0.007, median = -0.24). Bootstrap comparison indicated non-significant effects of this data pattern and supported further regression analysis. The hypothesis that children with ASD would experience less consistency in their sleep patterns during the pandemic compared to children with other developmental disabilities was assessed through a simple linear regression. Contrary to hypotheses, this relationship was not statistically significant (seen Table 7). Similar to the previously conducted analyses, the effect size remained small, indicating that there was little variance in sleep consistency explained by diagnosis ($R^2 = 0.04$).

Table 7 *Regression analyses linear regression models 1.2, 1.3, and 1.4*

Model	Outcome	*b*	*SE*	*t*	*p*	R^2	*Fit*
1.2	Sleep duration	0.22	0.28	0.81	.42	0.01	$F(1,53) = 0.66$
1.3	Bedtime	0.27	0.28	1.01	.32	0.02	$F(1,53) = 1.01$
1.4	Waketime	0.25	0.28	0.91	.37	0.02	$F(1,53) = 0.82$
1.5	Consistency	0.40	0.28	1.44	.16	0.04	$F(1,53) = 2.07$

* $p < .05$

Secondary Analysis: Moderated Hierarchical Linear Regression

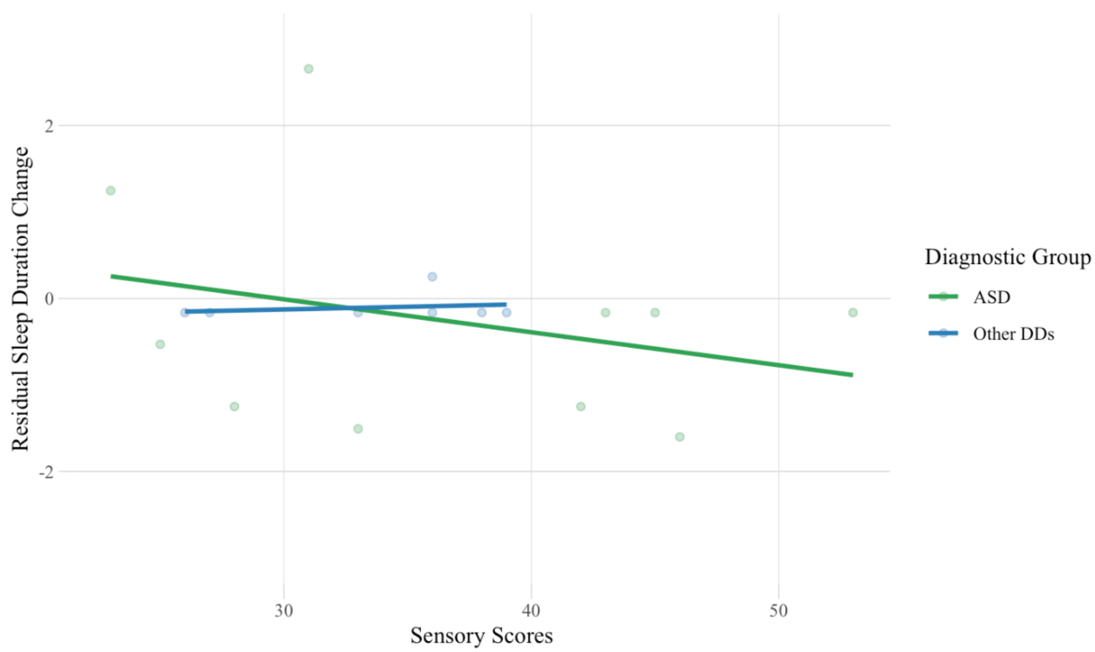
As previously described, a moderated hierarchical linear regression was utilized to understand the moderating effect of sensory processing differences (as measured by the raw sensory score on the Short Sensory Profile, Second Edition) on the relation between diagnostic group and change in sleep duration during the COVID-19 pandemic. This model controlled for the effect of melatonin medication usage and child age. The results of the regression analysis indicated that sensory score and diagnostic status did not account for a significant amount of the variability in residual sleep duration change, $R^2 = .49$, $F(5, 11) = 2.16$, $p = .13$ (see Table 8). There was a trending direct effect of child diagnosis ($b = 5.64$, $t = 1.89$, $p = .086$) and no direct effect of sensory score ($b = 0.10$, $t = 1.36$, $p = .201$) on residual sleep duration change when melatonin usage and age was accounted for. In contrast, child sensory scores had a moderating effect on the relation between child diagnostic status and residual sleep duration change that trended towards significance, $B = -0.17$, $t = 0.09$, $p = .077$. This suggested that individuals with ASD experienced marginally decreased levels of sleep duration as sensory scores increased when compared to their peers with other developmental disabilities, as illustrated by Figure 6. Further, the moderation model of sensory processing score on diagnostic group explained a large amount of the variance in sleep duration change ($r^2 = 0.49$).

Table 8 *Regression analyses of sensory score and diagnostic status on sleep duration change*

Predictor	*b*	*SE B*	*t*	*p*
(Intercept)	-4.36	2.81	-1.55	.149
Melatonin	1.53	0.61	2.51	.029**
Age	0.05	0.05	1.21	.253
Diagnostic Group [a]	5.64	2.99	1.89	.086*
SSP-2 [b] Sensory Score	0.10	0.08	1.36	.201
Diagnostic Group [a] x Sensory Score	-0.17	0.09	-1.95	.077*
R^2	.49			
$F(5,11)$	2.16			0.13

* $p < .1$, ** $p < .05$
[a] DD = 0, ASD = 1; [b] SSP-2 = Short Sensory Profile, Second Edition

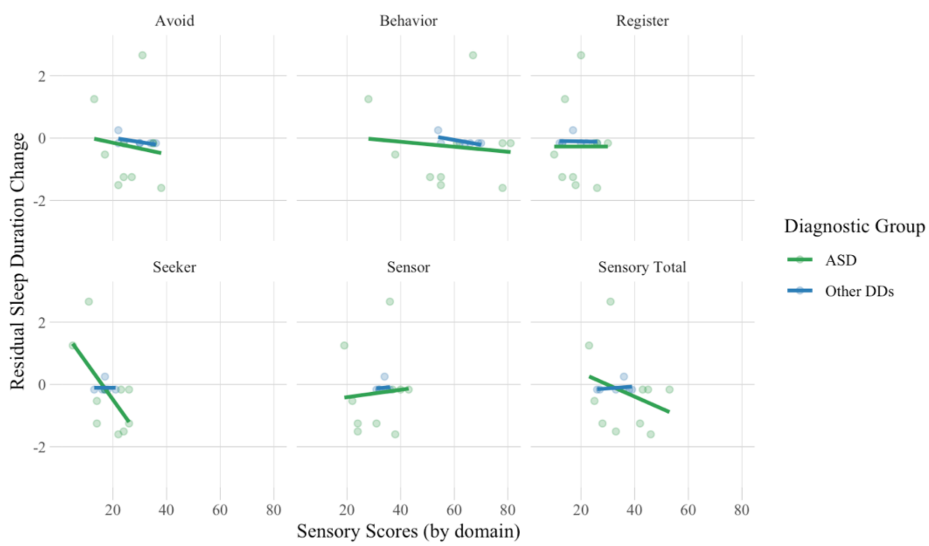
Figure 6. Moderating role of sensory raw score on sleep duration changes by diagnosis



Tertiary Analyses: Post Hoc Analyses

The previously described marginal significant effect along with the large effect size of the secondary analysis indicated the utility in exploring broader effects of the four domains of sensory processing that are measured by the broadband sensory score of the SSP-2. Previous literature has found impacts of sensory processing types on child sleep patterns, especially in children with higher sensor and seeking profiles (Rajaei et al., 2020; Vasak et al., 2015). These past findings indicated utility in conducting a post hoc analysis of the SSP-2 domain impacts score on sleep. The SSP-2 includes a sensory composite score, which can be broken down into four sensory processing domains (i.e., Avoid, Register, Seeker, Sensor), and a behavior composite score that indicates the impacts of sensory differences on an individual's behavior. Visual analysis (as seen in Figure 7) of the four sensory processing domains, behavior composite, and sensory composite was performed to direct further post hoc analysis. These visualizations suggested that there was reason to expect a greater change in sleep duration in children who experienced higher levels of sensory seeking.

Figure 7. Post hoc comparison of sleep duration changes by diagnosis and sensory domain



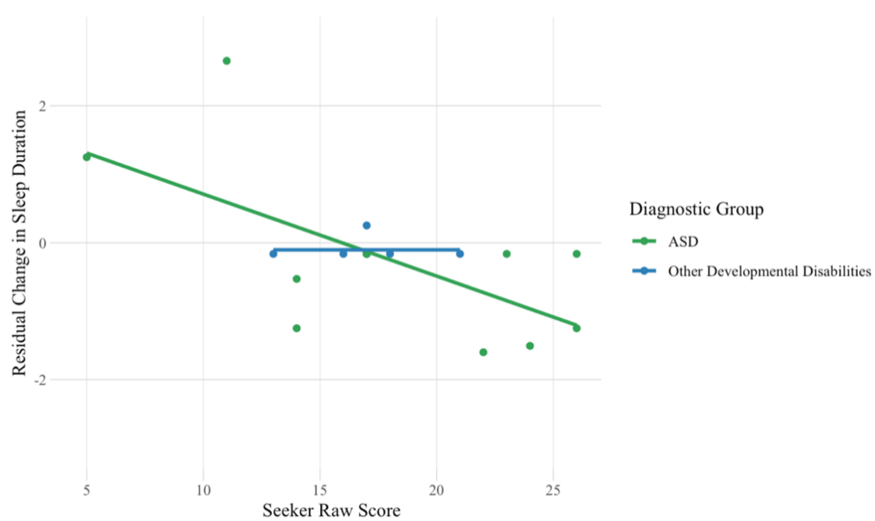
A tertiary post hoc analysis included a hierarchical linear regression with a moderating variable of sensory seeking. Prior to this analysis, the sensory seeking raw variable was centered to reduce structural multicollinearity. This regression analysis resulted in a significant direct effect of sensory seeking on residual sleep duration change in the second hierarchical level of the regression analysis in which the interaction term was not included, (b = -0.63, t = -3.38, p = .005), as seen in Table 9. This main effect, as visualized in Figure 8, indicates that as sensory seeking scores increases, the residual change in sleep duration became more negative. A main effect was not seen for diagnostic group at this level (b = -0.11, t = -0.29, p = .777). A significant effect was also seen for the control variable of melatonin (b = 1.21, t = 2.45, p = .031) but not for child age (b = .007, t = 0.22, p = .828). This model explained a large amount of the variance sleep duration residual change scores (R^2 = 0.61).

Table 9 *Hierarchical regression main effects' level of analysis for centered sensory seeking score and diagnostic status on sleep duration change*

Predictor	*b*	*SE B*	*t*	*p*
(Intercept)	-0.43	0.41	-1.03	.321
Melatonin	1.21	0.49	2.45	.031**
Age	0.007	0.03	0.22	.828
Diagnostic Group [a]	-0.11	0.36	-0.29	.777
SSP-2 [b] Sensory Seeking Score [◊]	-0.63	0.18	-3.38	.005***
R^2	0.61			
F(4,12)	4.65			0.02**

* p < .1, ** p < .05, *** p <0.01
[a] DD = 0, ASD = 1; [b] SSP-2 = Short Sensory Profile, Second Edition
[◊] variable was centered

Figure 8. Post hoc interaction plot of diagnosis and sensory seeking levels as predictors of change in residual sleep duration change



Upon the addition of the sensory seeking and diagnostic status interaction term in the third hierarchical level of regression, the main effect significance of sensory seeking diminished (*b* = -0.002, *t* = 0.004, *p* = .997) as can be seen in Table 10. The main effect of diagnostic status on residual sleep duration change remained non-significant (*b* = -0.18, *t* = -0.48, *p* = .639). Additionally, the interaction term indicated a non-significant moderating role of seeking on the relation between diagnostic status and residual sleep duration change score (*b* = -0.67, *t* = -0.92, *p* = .375). Significant effect of the control variables remained the same at this third level of analysis such that melatonin was a significant control variable (*b* = 1.21, *t* = 2.44, *p* = .033) and age was not (*b* = .008, *t* = 0.22, *p* = .831). Such changes in results upon the addition of the interaction term indicate that these results are considerably impacted by low power and sample size. However, the addition of the interaction term accounts for only 3% more of the variability in sleep duration change. This indicates that while the moderation is not significant, the evaluation of the effect of sensory seeking on sleep duration change, without the consideration of diagnostic status, may be a more valuable way to understand these data.

Table 10 *Hierarchical regression interaction term level of analysis for centered sensory seeking score and diagnostic status on sleep duration change*

Predictor	*b*	*SE B*	*t*	*p*
(Intercept)	-0.35	0.42	-0.82	.43
Melatonin	1.21	0.49	2.44	.033**
Age	0.008	0.03	0.22	.831
Diagnostic Group [a]	-0.18	0.38	-0.48	.639
SSP-2 [b] Sensory Seeking Score [◊]	-0.002	0.70	0.004	.997
Diagnostic Group [a] x Sensory Seeking[◊]	-0.67	0.73	-0.92	0.375
R^2	0.64			
$F(5,11)$	3.84			0.03**

* $p < .1$, ** $p < .05$, *** $p < 0.01$
[a] DD = 0, ASD = 1; [b] SSP-2 = Short Sensory Profile, Second Edition
[◊] variable was centered

CHAPTER IV - **DISCUSSION**

The current study sought to understand the impact of the COVID-19 pandemic on sleep behaviors in children with developmental disabilities. The first portion of this study involved 55 participants with ASD (n = 32) and other developmental disabilities (n = 23) between the ages of one and 18 years old. It was hypothesized that children with ASD would have higher levels of difficulties in all five measured domains of sleep (amount of sleep domain changes, sleep duration, bedtime, waketime, and consistency) at the start of the COVID-19 pandemic compared to their peers with other developmental disabilities. The second portion of this study focused on the role of sensory processing differences in these children by examining the role of different sensory profiles beyond that of diagnostic status alone in changes of sleep duration. Due to sample attrition, this portion of the study involved 18 individuals with ASD (n = 11) and other developmental disabilities (n = 7). The hypothesis for this secondary analysis was that sensory processing differences would have a moderating effect on the relation between diagnostic status and changes in sleep duration, such that the relation between sleep duration changes and developmental disability would be more prevalent in children with heightened sensory processing differences regardless of presence of ASD diagnosis. Additional exploratory questions related to impacts of different sensory processing domains on change in sleep duration were also examined. The following section includes interpretations and clinical implications of the study findings, as well as strengths and limitations of the study and suggestions for future research.

Interpretation of Results

No Difference in Sleep Changes Between Diagnostic Groups

The hypothesis that children with ASD would experience greater changes in sleep domains during the COVID-19 pandemic compared to peers with other developmental disabilities was not supported by this study. Sleep domains were further broken down to understand specific differences between diagnostic groups in areas of potential sleep changes during the pandemic. Similarly, no significant differences between those with ASD and other DDs were found in measured domains of sleep: duration, bedtime, waketime, and sleep quality. Results of previous literature collected outside of the pandemic led to primary hypotheses based on the concept that those with developmental disabilities, especially ASD, would be disparately impacted by the changes created by global stressors like the COVID-19 pandemic. Therefore, the current outcomes of these analyses were unexpected especially due to previous literature supporting higher levels of sleep deficits in autistic populations compared to their counterparts with non-autistic NDDs based on biological, behavioral, and sensory differences (Lai et al., 2019; Souders et al., 2009). While this result is surprising when viewing developmental disabilities from a categorical lens, findings from these preliminary analyses may fit well within a dimensional stance that focuses on individual characteristic profiles rather than on diagnostic label alone.

The majority of academic, research, and clinical classification systems are rooted within diagnostic or categorical systems, such as the Diagnostic Statistical Manual (DSM) or the International Classification Diagnostic system (ICD). Clinically, these systems are used to categorize patterns of difficulties to guide support and intervention options. In research domains, categorical viewpoints are utilized to design study sampling, analysis procedures, and theoretical stances (Astle et al., 2022). However, this stance can lead to sampling criteria that excludes heterogeneity, complexity, and overlapping characteristics within those with NDDs, and thus exaggerates findings among the different diagnostic categories of NDD (Astle et al., 2022). Over the past decade, emphasis has shifted towards a more dimensional, transdiagnostic approach. A dimensional viewpoint is grounded in the focus on "a specific phenotype or a hypothesized shared underlying mechanism, rather than at a diagnostic group" (Finlay-Jones et al., 2019, pg. 98). This dimensional approach well supports the literature on high comorbidity across NDDs as well as the similarities of concerns among those with NDDs (Craig et al., 2016; Weyrauch et al., 2017). When considering results from the first set of analyses from this dimensional viewpoint, it indicates that additional differences could be gained from analyzing differences in sleep behaviors by characteristic differences, such as sensory processing, rather than by diagnosis alone.

Trending Moderating Role of Sensory Differences on Sleep Duration Changes

When revisiting literature on factors related to sleep disturbances, a key feature common among several developmental disabilities, including ASD, ADHD, fetal alcohol spectrum disorder, and fragile X, is sensory processing differences (Reynolds et al., 2012). While sensory processing differences are most commonly associated with a diagnosis of ASD, those with other NDDs have higher levels of sensory differences compared to typical populations (Cheung & Siu, 2009). This study sought to understand the relation between diagnostic status and sleep during the pandemic from a more dimensional standpoint by focusing on the impact of sensory processing differences, especially given the prevalence of sensory processing difficulties in NDDs and the higher disturbance in sleep within those with sensory processing difficulties. I hypothesized that sensory processing differences would have a moderating effect on the relation between diagnostic status and increased sleep changes at the start of the COVID-19 pandemic. This hypothesis was marginally supported. Initial results indicated that child sensory processing score on the SSP-2 and diagnosis were not significant predictors of sleep change at the start of the pandemic. However, the addition of melatonin and age as control variables resulted in a trending significant effect for child diagnosis. Furthermore, when these control variables were included, the moderating role of SSP-2 sensory score on the relation between diagnosis and sleep duration change showed trending significance. As both age and use of melatonin are known influences on duration of sleep (Brzezinski et al., 2005; Buckley et al., 2020; Iglowstein et al., 2003), this addition to the analysis better illuminates non-confounded impacts of sensory processing patterns on child diagnosis and sleep duration. Children with ASD and higher levels of parent-reported sensory processing differences had greater reductions in sleep duration compared to those with other developmental disabilities at the beginning of the pandemic. This finding is well supported by the literature focused on correlations between sensory processing differences and increased sleep onset duration, shorter overall duration, and decreased sleep quality (Sharfi & Rosenblum, 2015; Vasak et al., 2015).

Given that these results were trending in nature, this leads one to wonder about the impact of the pandemic on sleep from a more dimensional nature to better understand the characteristics of children with DDs that are making children more vulnerable to global stressors. The finding that the addition of sensory processing scores marginally moderated the relation between diagnosis and sleep duration whereas the initial t-test analyses were not significant revealed a need for further exploration. Additionally, previous research findings indicate the importance of recognizing the role of sensory processing on sleep characteristics in all developmental disabilities (Cheung & Siu, 2009). These factors all strengthened the creation of an alternate hypothesis that sleep duration changes would be more common in children with heightened sensory processing differences regardless of their developmental disability diagnostic category.

Impact of Sensory Seeking Processing Differences on Sleep Duration Changes

Sensory processing, as defined by Dunn (1997), has four main types of processing patterns: registration, sensation seeking, sensory sensitivity, and sensation avoidance. The secondary moderation analysis of this study was conducted using the total sensory processing score on the SSP-2. Tertiary post hoc analyses were conducted to identify dimensional impacts of these four sensory processing types on the relation between developmental disability and perceived change in sleep duration. Initially, a visual analysis of data indicated that a potential significant impact of sensory seeking behaviors on sleep within those with ASD and other DDs. When conducting a hierarchical linear regression with sensory seeking scores as a moderating factor, there were mixed results. Within the process of multi-level regression, a significant main effect emerged between sensory seeking scores and residual sleep duration changes. When interpreted alongside the non-significant main effect of diagnostic status on sleep duration, this leads one to believe that it was the characteristic of high sensory seeking that influenced parent-reported differences in sleep duration during the COVID-19 pandemic. This finding is supported by previous literature that indicates those with high levels of sensory seeking have worsened sleep habits and significantly shorter nighttime sleep duration (Rajaei et al., 2020). This research is based on the idea that sensory seeking is created through a high neurological threshold and an increased need for self-regulation (Brown et al., 2008). This finding has been replicated in children with FASD (Fjeldsted & Hanlon-Dearman, 2009) and atopic dermatitis (Fjeldsted & Hanlon-Dearman, 2009). Additionally, a study of children in infancy and toddlerhood found that higher sensory seeking was correlated with increased levels of time to settle during sleep routines

(Vasak et al., 2015). When considered within the context of the COVID-19 pandemic and resulting closures of schools, daycares, and activities outside of the home, it is reasonable to expect that those with higher sensory seeking needs, upon having lost stimulating activities and environments, would experience higher disruption to activity levels and therefore have impacted sleep behaviors.

Within the tertiary post hoc analysis' third level of the hierarchical regression model, the interaction term of diagnostic status and sensory seeking was added to the model to illuminate the moderating role of sensory seeking. With this addition, the main effect of sensory seeking dissipated alongside no significant moderation of sensory seeking and diagnostic status. Firstly, this indicates that there was no moderating effect of sensory seeking on the relation between diagnosis and reported residual sleep duration change during the COVID-19 pandemic. However, it is unexpected that the main effects should diminish to such a degree. This outcome can be viewed through a variety of lenses. Primarily of note, it should be restated that these exploratory analyses were conducted on a small sample with low power that may impact the results of a high-level moderation analysis. Additionally, upon inspection, there seemed to be a greater variability in the sensory data of those with ASD over those with other DDs. As detailed 39% (*M* = 18.2, *SD* = 7.12, range = 5 to 26) in the ASD group as compared to the coefficient of variation of 14% (*M* = 17, *SD* = 2.38, range = 13 to 21) in the broader development disability group. Further, this difference in variability is seen in all sensory domains, including the total sensory score (ASD CV = 28%, DD CV = 15%). Considering the lower sample size and high variability between groups, these analyses should be carefully considered due to their overall low power. Nevertheless, the significant main effect of sensory seeking on change in sleep duration in the moderation analysis along with prior research on sensory processing suggests there may be reason to place higher levels of trust in the significant relation between sensory seeking and sleep duration rather than only the moderating effects. This suggestion is supported by the minimal level of variance explained by the inclusion of the interaction term to the model. This could be interpreted to mean that sensory seeking should not be considered as a moderator, but rather as a main indicator of changes observed by parents in sleep duration patterns across developmental disabilities.

Clinical Implications

The results of this study have many clinical implications for families of children with developmental disabilities. Of primary importance is the need to focus on sleep concerns within the broader neurodevelopmental disabilities' community rather than focusing only on those with a diagnosis of ASD. While previous literature focuses on specific differences between those with and without ASD with regards to sleep behavior, the results of this study indicated that there was no significant difference in COVID-related sleep changes between ASD and their counterparts with non-ASD developmental disabilities. The outcomes of the primary analyses instead, could lead mental health and medical care providers towards a dimensional approach to sleep concerns and additional impacts of global stressors. Early studies from the COVID-19 pandemic indicated that 25% of the general population and 30% of caregivers within the general community indicated decreased sleep quality. This suggests that more dimensional characteristics of individuals, such as sensory processing, individual externalizing and internalizing symptoms, and rigidity, may hold greater influence over one's sleep quality and duration during times of societal stress and change.

Additional exploratory analyses that utilized this dimensional approach indicated that sensory processing differences, specifically sensory seeking, may be an important indicator of those who are more vulnerable to changes in sleep duration when experiencing changes to their surrounding systems and environments. This may be a crucial factor to focus clinical screenings and interventions, as sensory differences are common within the neurodevelopmental disabilities' community at large (Cheung & Siu, 2009; Reynolds et al., 2012). In addition to higher sensory demands or processing differences, these sleep deficits negatively impact social and emotional functioning and development, which further disrupts family structure and increases neurological burden for these children creating a negative cycle (Goldstein et al., 2013; Goldstein & Walker, 2014; O'Donnell et al., 2012; Zohar et al., 2005). While these analyses were underpowered, the trending results of the role sensory processing differences, specifically sensory seeking, on sleep behaviors suggests a need for further research of a dimensional approach.

With regards to intervention opportunities, this study indicates the importance of expanding sensory-related supports to families regardless of diagnosis. While there are numerous supports provided through occupational therapy both in and out of school environments, the closure of support systems left many of these families without services at the start of the pandemic. The lack of support to these systems indicates a need for development of home-based and telehealth options that can be well utilized by families in times of global stressors that impact availability of resources. While these are not ideal methods in which to deliver services, the improvement of these services also has the additional benefit of increasing access to services in resource-low and rural communities.

Strengths and Limitations

The current study had several strengths. First and foremost, the study data were collected from a community sample across the United States. This allowed for a wider variety of individuals to be included from broader geographic, ideological, and characteristic qualities. Further, individuals were recruited via a cross-syndrome design that included individuals with co-occurring diagnoses within the neurodevelopmental disabilities' continuum (Astle et al., 2022). This sampling technique allows for the potential of comparing diagnostic groups as well as the ability to consider transdiagnostic viewpoints and insights. The less stringent criteria of allowing co-occurring diagnostic profiles also provides opportunities to increase diversity and representativeness of characteristics within a population (Astle et al., 2022). Prior to this study, both the method comparing ASD and other developmental disabilities and the later adapted dimensional approach had yet to be explored within the literature with respects to sleep, sensory processing, and global stressors. Further, sleep impacts in these populations during the COVID-19 pandemic had not yet been explored thus making this study an important contribution to the literature. Lastly, data were collected at the beginning of the COVID-19 pandemic which allowed researchers to explore immediate impacts of restrictions on families and children.

There were also several limitations to this study. While broader sampling techniques allowed for greater diversity, it also introduced complexities that reduced controllability over accuracy of diagnostic categorization as well as reduced our ability to sample equally amongst groups. Additionally, the sample size for sensory processing information was impacted due to study attrition rates. These lower samples sizes significantly affected power and the ability to fully explore research questions based on sensory processing. The use of researcher-adapted questionnaires to measure sleep, while allowing for specific research questions to be met, were not validated by previous research, and therefore represent a limitation to the external validity of this study. Additionally, due to the unexpected nature of the pandemic, reports of baseline sleep characteristics and behaviors prior to the pandemic were not able to be attained. Therefore, scores representing changes from baseline were based on parent recollection and comparison. It is possible that this introduced measurement error of sleep pattern changes due to potential bias in caregivers indicating any changes perceived following the beginning of the pandemic. Lastly, there was no typically developing comparison group included in this study. The lack of a group of typically developing children within this study's sample limited the ability to understand how sleep changes experienced by children with DDs differed from those experienced by those without DDs during the pandemic.

Conclusions and Future Directions

This study sought to explore the impacts of the COVID-19 pandemic on the sleep behaviors of children with neurodevelopmental disabilities. The study findings with regards to comparing change in sleep domains in children with ASD and with other DDs were not significant, indicating no group differences in parent-reported changes in sleep onset, waketime, duration, and quality. However, the study did support emerging findings of the role of sensory processing differences on the relation between diagnosis and sleep duration differences during the beginning of the COVID-19 pandemic. This was particularly true for those with high levels of sensory seeking. Although findings with regards to sensory processing differences were underpowered, results encourage further exploration of a dimensional focus on sensory processing effects on sleep behavior change amidst global stressors.

Further research would benefit from exploring different categories of sensory processing among different neurodevelopmental disability diagnoses and diagnostic clusters with respect to environmental stress on sleep. Additionally, there is a need for longitudinal research to further clarify the long-lasting changes in sleep throughout a global stressor as well as post-return to services. Furthermore, improved understanding of sensory processing and sleep may better inform and improve treatment targets and mechanisms as virtual and home-based intervention options grow in the future.

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APPENDIX A - Descriptive Table of Sleep Data by Diagnostic Group

	ASD		DD	
	Before	After	Before	After
Quantity of domain changes				
0	5		3	
1	6		7	
2	5		4	
3	5		7	
4	11		2	
Sleep Duration				
No changes	16	16	16	16
Under 4 hours	0	2	0	0
5 to 6 hours	3	2	0	1
6 to 7 hours	0	0	0	0
7 to 8 hours	5	1	0	2
8 to 9 hours	2	2	4	1
9 to 10 hours	4	6	2	1
10 to 11 hours	0	3	1	2
Over 11 hours	2	0	0	0
Bedtime				
No changes	18	18	11	11
Before 7:00 PM	2	0	0	0
7:00 - 8:00 PM	0	1	4	1
8:00 - 9:00 PM	4	0	4	4
9:00 - 10:00 PM	4	2	4	2
10:00 - 11:00 PM	3	3	0	3
11:00 - midnight	1	2	0	1
After midnight	0	6	0	1
Waketime				
No changes	18	18	13	13
Before 6:00 AM	1	1	0	1
6:00 - 7:00 AM	7	0	9	2
7:00 - 8:00 AM	5	0	1	4
8:00 - 9:00 AM	0	3	0	1
9:00 - 10:00 AM	0	5	0	0
10:00 - 11:00 AM	1	4	0	1
After 11:00 AM	0	1	0	1
Sleep Quality				
No changes	19	19	15	15
Very consistent	6	1	3	1
Somewhat consistent	6	3	5	5
Somewhat inconsistent	0	2	0	1
Very inconsistent	1	7	0	1