SLEEP AND LANGUAGE IN TYPICAL AND ATYPICAL DEVELOPMENT

By

TRICIA RENEE HINDLEY

A Thesis Submitted to The Honors College

In Partial Fulfillment of the Bachelors degree
With Honors in

Neuroscience and Cognitive Science

THE UNIVERSITY OF ARIZONA

MAY 2015

Approved by:

Dr. Jamie Edgin
Department of Psychology

Abstract

Sleep physiology changes across development from infancy to adulthood. Sleep and language-learning also change during development and into adulthood. This literature review identified several important correlations between quality of sleep and development. Sleep disruption can detrimentally affect language learning for all individuals. However, atypically developing individuals who have intellectual disabilities face distinctive challenges that sleep issues may further affect.

Introduction

Sleep is vital to maintain adequate physical and mental health. Problems with sleep can arise any time during childhood or adulthood, while others may never experience issues. Abnormalities in sleep often arise from health related impairments in psychological or physical form. Sleep disturbances affect the ability to function during wake periods. Individuals who lack proper sleep are often more agitated, lack energy, and show reduced executive function. A reduction in verbal ability, decision making, and ability to learn are all correlated with lack of sleep (Adams, 2009). The ability to learn and improve verbal skill is especially important during development for proper language acquisition and communication.

Atypical populations, such as individuals with Down syndrome, Williams Syndrome, and Autism Spectrum Disorder often experience unique communication and language challenges compared to their typically developing peers. These differences have been associated with sleep disturbances, such as obstructive sleep apnea and waking up frequently throughout the night (Breslin, 2014, and Goldman et al., 2009). This literature review will evaluate the relationship between sleep and language across development. The goal of this review is to determine if sleep affects language and learning differently in infants and children than in adults. It will also evaluate how sleep disruption affects language and learning in typical and atypical populations.

Sleep

Sleep Characteristics

Sleep naturally cycles into different neural states known as stages. In all stages, the body is unresponsive and homeostasis and cognitive processes are restored. While the purpose of sleep has not been clearly defined, the general structure of sleep is understood and used to determine how sleep influences other physical and psychological processes. Sleep patterns are consistent across typical healthy adults. Sleep stages consist of non-rapid eye movement (nREM) stages 1-3 and rapid eye movement (REM) (Werth et al, 1996). Each stage was identified due to their distinct physiological differences, such as brain activity variation.

While there is not a clear definition of sleep onset, it is generally associated with the physiological characteristics of nREM sleep stage one. Different physiological recordings and tasks are used to identify the onset of sleep. Electromyograms, electrooculograms, electroencephalograms (EEG), as well as behavior tasks involving sensory skills are used to identify different stages of sleep (Carskadon and Dement, 2011).

The initial sleep cycle, nREM stage 1, is the lightest stage of sleep lasting between 1-7 minutes. It serves as a transition period between consciousness and deeper stages of sleep. An individual in nREM stage 1 sleep is easily awoken by soft noises thus defined having a "low arousal threshold" (Carskadon and Dement, 2011). While some bodily movements occur, a majority of movements begin to cease. Furthermore, EEG of brain activity indicates a mix of frequency waves present including theta and alpha waves. Simple behavioral tasks can be completed during nREM stage 1 due to the task's "automatic" behavioral nature. Participants showed a delayed response or ignored the task completely during visual and auditory cues, but olfactory cues showed a response in nREM stage 1 (Carskadon and Dement, 2011).

In stage two of sleep, more stimulation is required to induce arousal. Lasting 10 to 25 minutes, this stage exhibits a variation in EEG patterns that include sleep spindles and K-complexes, which are involved in memory consolidation. The transition from stage 2 to stage 3 occurs by a gradual transition to high voltage slow wave activity (SWA) (Carskadon and Dement, 2011). Stage 3 comprises 20-49% of the cycles and lasts 3 to 8 minutes in the first cycle (Colten and Altevogt, 2006). Slow wave sleep (SWS) occurs during stage three and it is the most difficult to wake someone during stage three relative to the other stages.

REM sleep may only last a few minutes during the first cycle, but it becomes longer after each cycle. Early sleep is rich in SWS, while late sleep is rich in REM (Rasch and Born, 2013). Most dreams occur during REM sleep, which is when muscle movement ceases (Colten and Altevogt, 2006). Both SWS and REM sleep are important for “brain plasticity” and interruption during this time can be detrimental to development. Quality and duration of sleep vary based on several factors including age, health and wellness, and sleeping conditions.

Sleep disturbances can inhibit typical development by interrupting important processes that occur during sleep. Recall the importance of SWS and REM presence during sleep previously discussed. Several sleeping problems can develop during childhood regardless of how much a parents tries to keep their child’s schedule routine. Just like other actions, sleep is a behavior that has to be learned, and when a child is too dependent on the parent, problems can ensue during weaning of parent involvement during sleep (Tiernay, 2013). A problem associated with learning how to sleep is the ability to self-soothe. Because the child is not getting ample sleep at night, it is likely to be associated with problems during the day such as inability to focus and irritability. During a night’s sleep, there is a period known as ‘brief arousal’ that occurs around 1-2 hours after falling asleep. At this time, certain behaviors occur, such as touching one’s face, rolling around, and sitting up. More erratic behavior includes sleep walking and terrors, and some thrashing. All of these behaviors can affect a child's ability to sleep, and their daytime behavior as a result. In order to screen for these problems, some clinicians perform an assessment using "BEARS", which stands for bedtime issues, excessive daytime sleepiness, awakenings, regularity and duration of sleep, and snoring (Owens and Dalzell, 2005). It is also important to consider the health of the individual or change in medication, and any recent stressors like a new family member. Each factor plays a role in sleep quality. It is important to keep a child's routine as consistent as possible. This entails having a similar bedtime routine every night and going to bed at the same time each night, as well as planning for potential bedtime issues like misbehaving. Even with proper "sleep hygiene", children can have sleeping problem.

Due to sleeping disturbances, some individuals can develop insomnia, which is associated to a number of other sleep disorders, including "bedtime resistance (occurs in 25-50% of preschools age children, sleep associations, ADHD, depression/anxiety, substance abuse, and delayed sleep phase (circadian rhythm disorders)" (Tiernay, 2013). Insomnia in children begins with the lack of structure by parents (Tiernay, 2013). When there is inconsistency in bedtime rules and not a set bedtime, children often stall or refuse to go to bed. Furthermore, some children struggle to sleep unless there are a set of conditions that must occur, such as a blanket or toy. Some of these conditions are not beneficial for long term sleep behavior. For example, parent contact like rocking or feeding, and watching television are not sustainable bedtime routines throughout childhood. Other issues with sleeping include circadian rhythms during the early sleep phase, the time spent in bed is too long, there is excessive napping in the morning or just too much napping in general, not a typical sleep/waking cycle, or there are disruptions to enable the onset of sleep and disruptions of sleep, such as noise or light. A treatment to insomnia includes creating a routine, keeping bedtime set to a specific time, retaining non-sleep activities to locations other than the bed, and limiting sleep to one area, such as the child's bed. Other treatments include raising awareness to the child about their sleeping issues and then rewarding them for fixing their sleeping issues. For insomnia relating to anxiety or depression, it is best to set up behavior therapy appointments in order to diagnose the root of emotional issues. As will be discussed during typical development and sleep, it is vital to have healthy sleep habits in order to utilize the skills reinforced by certain stages of sleep.

Sleep in Development

Sleep plays an important role in development, such that cognitive function and learning are affected. Thus, characteristics of sleep change across development from infancy to adulthood. Typical sleep patterns in infants (0-12 months) include active, quiet, and intermediate stages of sleep; intermediate sleep may be a part of active or quiet stages. From birth to 12months, time between each sleep stage increases, as well as a better presence and distinction between stages. However, there is a decrease in total time slept; a reduction from 64% of a 24 hour period to 50 to 55% of a 24 hour period (Crabtree and Williams, 2009).

Sleep duration in toddlers (1-5 years) decreases overall and shows the most change after the second year. Environmental changes including preschool influence the difference in sleeping patterns. Several studies show conflicting values of how much sleep toddlers get per night. While one study found an average of 13.5 hours of sleep in a 24 hour period, another indicated as much as 12-15 hours in a 24 hour period, which is just as much as infant sleep (Crabtree and Williams, 2009). It is likely these differences occur due to the variation in activities from ages 1-5 years. A decrease in napping is associated with, but not limited to, environmental changes during development such as daycare or parent scheduling, cultural differences, and developmental expectations of parents (Crabtree and Williams, 2009).

Sleep during middle childhood (6-12 years) starts to develop more discrete physiological stages. Polysomnography indicates a decrease in sleep duration, SWS percentage, and REM latency. However, sleep stages are more structured and begin to model adult sleep stages. On average, children sleep around ten hours in a 24 hour period, but that value decreases toward age 12. Additionally, gender and ethnicity influenced sleep patterns. Females, ages 6-7, tend to spend more time in nREM stage 1 per cycle than boys. White children spend more time in nREM stage one and less time in nREM stage 2 per cycle compared to African American children across the same age (Crabtree and Williams, 2009). Furthermore, EEG data indicates changes with brain connectivity within and across hemispheres, albeit small changes (Tarokh et al., 2010).

Adolescents (12 to 18 years) show a decrease in sleep to about 7.5 to 8 hours a night and go to bed much later compared to the sleep patterns during middle childhood. On average, school-aged children go to bed around 10pm, while adolescents go to bed at midnight or later. The changes in sleep patterns reflect environmental changes, such as school responsibilities like homework, sports, or employment. Adolescents also tend to sleep and rise later with age; with a difference of up to 4 hours a night. In regards to polysomnography, REM latency and SWS decline from that of childhood (Crabtree and Williams, 2009). There is also an increased coherence across hemispheres, and increased coherence with the right hemisphere (Tarokh et al., 2010). Coherence indicates a state of the brain where it performs optimally, thus during development, the brain is able to improve performance.

Sleep rhythms and networks mature and change during the course of development (Chu et al., 2013). EEG recordings were analyzed from 384 participants from the age of 0-18 years, who demonstrated typical neurological development. The results of this study found that cortical rhythms vary between ages. Lower frequencies occur most often in infancy, but are present in all ages. The difference in cortical bands has shown importance for development because it is thought that different frequencies are associated with different neural functions like learning. It was also determined that across development, cortical rhythms are region specific. SWS also changes across childhood into adolescence (Kurth et al., 2009). These findings indicate important neurological changes that occur during sleep and how that influences the way children development.

While all of these changes occur during development, they begin to normalize to the sleep characteristics outlined in the above section. In some cases, sleep is interrupted and hinders the natural rhythm of sleep from nREM stages 1-4 and REM sleep. When this occurs, several problems can occur, and cause lifelong changes to the individual. Some issues include learning and language disabilities that are pervasive and salient across development.

Sleep and Language

Typical Development

Characteristics of sleep vary across development. These variations are also associated with changes in learning and language. Particular sleep patterns have been associated with typical development. Several studies also indicate that the quantity and quality of sleep influence language skill and ability. Sleep and development also affect learning and memory consolidation. During development, the brain matures its sleeping patterns and vary between children (9 or 10 years old), adolescents (15 or 16 years old), and adults (20-23 years old) (Tarokh et al. 2010). There are also changes in experience-dependent plasticity across development, which is demonstrated through the changes in slow-wave sleep activity (Wilhelm 2014). Experience -dependent plasticity is important for learning and is thought to occur primarily during childhood. This plastic state is thought to be represented by the presence of SWA during sleep.

Research has shown the significance of sleep even in infancy. Compared to infants that did not nap, infants that napped were able to abstract an artificial language (Gomez et al., 2006). Forty-eight infants were randomly assigned to a nap, no-nap, or nap-control condition. The nap and no-nap groups were exposed to familiarization stimuli of their artificial language in high variability, while the control was exposed in low variability. Each group was tested on the same version of the language. Results indicate an increase in looking-time difference between trials and the first test first trial for the nap group compared to the no-nap group. These findings support the presence of abstraction for the artificial language presented. The ability to abstract an artificial language is important as a developmental step because it indicates plasticity and learning. Furthermore, sleep enables infants to establish word meanings to specific objects (Friedrich et al., 2015). It is evident that the presence of sleep spindles is also important for learning semantics and brain-plasticity during sleep.

Communication and reading to toddlers is important, but sleep has been deemed just as important for learning (Williams and Horst, 2014). Toddlers, ages 3.5, were either read a story prior to a habitual nap, or read a story without a nap. The toddlers that napped were able to learn words as well as the toddlers who were read the same story twice. However, toddlers who were read two different books and did not take a nap were unable to learn words as efficiently as the other two groups. These findings may be due to whether napping was habitual; toddlers who habitually took naps may have traits associated with learning words that non-napping toddlers do not possess. When children begin to learn and integrate new words, sleep becomes a crucial step in the process for recalling these words. Thus, sleep consolidation improves word learning by reading storybooks with children before rest. A potential explanation to the neurological processes involved during rest is the presence of sleep spindles (Kurdziel et al., 2013). Sleep spindles are a burst of brain activity that occurs during stage two of sleep that is associated with integrating new information with existing knowledge (Tamminen et al., 2010). Kurdziel et al. demonstrated that children in preschool who habitually napped midday were better equipped to learn in the afternoon compared to children who did not nap. Learning ability was measured by recalling information learned prior to the nap. There was also an indication that, unlike the findings by Williams and Horst, napping was only beneficial to children that habitually napped compared to those that did not normally nap. This research suggests the increase in sleep spindle density associated with naps serves an important function during childhood; a period in which the brain has increased plasticity.

Children (7-12 years) also exhibit sleep as an important part of the "learning system" for language (Henderson et al., 2012). Fifty-three children were exposed to non-words and non-word competitors. It was only after sleep that they were able to identify the non-words. In addition, unlike adults, they showed declarative memory consolidation associated with sleep, but not procedural memory. These findings indicate that sleep also plays a role in the consolidation of vocabulary during childhood.

Children, adolescents, and adults were given a visuomonitor adaption task while EEG recordings of their brain activity were compiled to analyze sleep behavior after a novel learning task. It was shown that SWA had the most changes in children and children have the highest experience-dependent plasticity; this declines as you age. These findings indicate the importance and presence of sensitive periods in a child's life where learning and sleep are critical. Sleep is vital for adults as well as for the developing brain. Adolescents who have poor sleep habits are more prone to behavioral problems and attentional deficits (Williams et al., 2013). Thus, it is important to analyze sleep during development and how it affects behavior. Determining what causes poor sleeping habits can help improve other domains of development, such as learning.

Sleep remains an important part of learning into adulthood. A recent study by demonstrated the importance of sleep and memory processing that help facilitate language acquisition (Batterink et al., 2014). Participants were subjected to a hidden linguistic rule while learning two-word phrases and presented with novel words. The adults who had more SWS and REM during their 20 minute nap were more reactive to the hidden linguistic rule when exposed to the second set of phrases. Thus, sleep, and specifically interactions between SWS and REM, affects language-learning and memory. A study of grammar also indicates the link between rest and higher grammar acquisition (Nieuwenhuis et al., 2013). This study investigated the effect time had on the ability to learn a set of grammar rules. It was determined that the participants who were able to sleep understood the grammar rules better than those who did not sleep. How the brain interprets language, or spoken words changes with sleep (Dumay and Gaskell et al., 2007). Participants were presented with 48 two-syllable triplet words and given two opportunities to recall the words freely. Those who were able to get a full nights rest experienced competition from previously learned words, which indicates sleep's involvement with plasticity in language learning. Polysomnographic data also support the important roles that sleep plays with language-learning (Gaskell et al., 2014). Participants who were able to sleep showed evidence of SWS activity with its associated implicit constraint learning. Thus, sleep, and specifically SWS, is a critical role for linguistic plasticity. There is also a relationship between sleep stages and memory consolidation (Fogel and Smith, 2006). After three overnight sleep studies using EEG, it was verified that different stages of sleep are more important for memory consolidation than others. Participants with a higher density of sleep spindles during stage 2 of sleep were 15.8% better at a memory dependent task. These data indicate that sleep is important, and certain stages of sleep deem more important for language learning.

Atypical Development

Atypical development can inform us on the role of sleep on learning. Many intellectual disabilities interfere with sleep, thus interfering with important developmental processes. Intellectual disabilities involved with sleep disturbances that will be discussed in this review include Down syndrome (DS), Williams Syndrome (WS), and Autism Spectrum Disorder (ASD).

Down syndrome

Individuals with DS face unique sleeping difficulties. DS is a genetic disorder caused by a mutation in chromosome 21. This mutation causes several differences including distinct facial features, and a number of health complications involving the brain, cardiovascular, and endocrine system (Allen et al., 1999). Although sleep disturbances are common for individuals with DS, the level of disturbance varies between individuals. There are also distinct differences between DS and typically developed (TD) individuals. Disturbances have been documented through both individuals with DS and mouse models.

Mice with the hSOD1 transgenic line KT or APP gene are used to mirror the genetic differences that human DS possesses (Colas et al., 2004). EEG recording from DS mice indicates differences in sleep pattern compared to healthy controls. Compared to control mice, DS mice had a decrease in paradoxical sleep (PD, also known as REM), during dark periods in a given 24 hours, and an increase during lights off. A reduction in PS can reflect some of the cognitive deficits that occur with DS. Thus, this finding supports that the hSOD1 transgenic line KT or APP gene is an appropriate DS mouse model. Additional research using Ts65Dn and Ts1Cje mice strains to model DS showed more sleeping abnormalities compared to control mice (Colas et al.

2008). DS strain Ts65Dn showed more similarities to DS in humans, such as an increase in waking during sleep and decreased nREM. While these findings may not parallel human DS research results, it is important to consider these findings in order to find potential treatments to the learning deficits associated with sleep in DS.

Many studies have researched sleep abnormalities in humans with DS. Sleep abnormalities are often associated with obstructive sleep apnea (OSA), which is occurs when breathing starts and stops irregularly. Obstructive breathing results in periods of limited or no oxygen reaching the brain and frequent arousal. Both result in sleep disturbances that affects the typical progression of sleep stages (Breslin et al. 2014). Thirty-eight individuals with DS were analyzed with ambulatory polysomnography during sleep and the Arizona Cognitive Test Battery (ACTB), which assessed cognitive ability. Results indicated a negative correlation between cognitive ability and OSA symptoms. Because of the sleep disruption, children with DS also tend to have a decrease in SWS and increase in nREM Stage 1, indicative of sleep fragmentation. Sleep fragmentation in children with DS and OSA results in a lower verbal IQ and less cognitive flexibility than children with DS without OSA, as determined by ACTB. Polysomnographic data support that sleep fragmentation affects intellectual skill (Andreou et al., 2005). Twelve participants with both DS and varied intensities of sleep apnea were given the Mini-Mental state test and the Raven Progressive Matrices (RPM). They found a correlation between increased sleep apnea and decreased visuoperceptual skills. These interruptions begin to transgress into school performance (Gozal, 1998). More severe sleep disordered breathing is associated with poorer school performance in children. It is important to note that learning is interrupted in both typical and atypically developing children that have disordered breathing during sleep (Fernandez and Edgin, 2013). Polysomnography research indicates that the impact obstructive sleep has on sleep architecture varies based on its intensity (Yin et al., 2013). Six hundred and nineteen school-aged children drawn from the typical population that contributed to the sleep study were classified as healthy controls, primary snoring (PS), mild OSA, or moderate to severe OSA. The more important finding was that PS had increased N1 sleep and wake after sleep onset (WASO) compared to healthy controls. Because neurocognitive function is increasingly hindered with more severe breathing obstruction, PS may be threatening. If PS if possibly detrimental to cognition, then it is definitely important to consider how moderate to severe OSA affects cognition and language learning in individuals with DS.

Because sleep is such a vital part to language-learning, individuals with DS do not reach the same language milestones as TD children partly due to sleep disruption that is often associated with sleep apnea. Executive functions necessary for language are impacted by sleep disruption in DS (Chen et al., 2013). Twenty-nine adolescents and young adults with DS participated in the study, which analyzed the correlation between OSA and prefrontal cortex dysfunction. Results indicated that increased body mass correlated to an increase in reported sleep apnea symptoms. An increase in sleep apnea symptoms also resulted in a decrease in executive function. These findings establish important correlations and suggest weight loss solutions. There is also a question as to whether increased sleep disruption is associated with future cognitive decline like dementia and Alzheimer's. Despite further questioning, it is suggested that executive function impaired by sleep disruptions related to DS may also affect language learning that occurs during sleep (Edgin et al., under review). Twenty-nine toddlers with DS were assessed in regards to their sleep behavior and language development. Sleep was analyzed using the actigraphy actiwatch and a sleep habit questionnaire. The Macarthur-Bates Communicative Development Inventory and utterances analyzed through the Language Environment Analysis (LENA) were used to measure the status of language development for each toddler. Results indicated 66% of participants with sleep efficacy scores 80% or less, which is expected based on previous studies. Results also suggest that language learning is poorer in children with DS who have higher levels of sleep disruption compared to TD children. Because these findings also indicate a sleep-related language learning problem at an earlier age than previously thought, health and educational intervention is important for earlier ages. Alternatives to reasoning behind these findings include the possibility of hypoxia-related learning detriments. Although this explanation cannot be ruled out, it more likely SWS disturbances are responsible for the correlation (Edgin et al., under review).

As stated, individuals with DS generally experience cognitive decline throughout their life, which may be correlated to sleep disturbances. Poorer sleep may be associated to an increase in cognitive decline, especially relating to Alzheimer's disease (AD) (Fernandez and Edgin, 2013). Sleep fragmentation is more prevalent in DS than TD individuals. There is also increased hypoxia associated with OSA that causes brain damage. Because intermittent hypoxia is frequent in DS, its affects are similar to AD, with an increase in Aβ production. These results are detrimental to language later in life such that neural pathways associated with language that are already affected by DS are further impaired by AD-like symptoms that can damage brain tissue.

Williams Syndrome

WS is a neurodevelopmental genetic disorder that occurs due to small gene deletions in chromosome seven. The syndrome manifests a number of physical abnormalities including “elf-like” facial features, and issues with the cardiovascular and renal systems (Udwin and Yule, 1990). They possess unique societal behaviors such as friendliness to strangers, and have issues with general learning and visuospatial skills. However, they generally have enhanced verbal skill (Udwin and Yule, 1990). Individuals with DS also experience sleep abnormalities, which is common among developmental disorders.

Few studies have looked at sleep behavior and WS. However, there is an indication that individual with Williams Syndrome experience daytime sleepiness due to their sleep patterns (Goldman et al., 2009). Actigraphy and a sleep journal were recorded for twenty-three participants with WS aged 17 to 35. Results indicated that more than 29% of participants that were experiencing daytime sleepiness woke at least once during the night; 65% woke two or more times during the night. Actigraphy data indicated 74.4% sleep efficiency and an average of 56 minutes of WASO. These data suggest daytime sleepiness is due to a number of different sleep disturbances common for individuals with WS, such as periodic limb movements, and bladder control issues including nocturia. Due to minimal research involving sleep patterns and WS, there is potential for more information regarding this topic.

Comparatively, DS and WS have similar sleep abnormalities that may transfer to attentional problems during the day (Ashworth et al., 2014). Twenty children with DS and 22 children with WS, in addition to 41 TD children had their sleep patterns measured by actigraphy with the actiwatch, and heart rate and SpO2 measured by Masimo Radical 8 monitors. The Raven's Colored Progressive Matrices (RCPM) measured intelligence of participants and a designed continuous performance attention task (CPT) determined attention and impulsivity of participants. Results indicated attentional deficits prevalent in both DS and WS. There was also a correlation between higher CPT scores and increased sleep quality, and more SpO2 among TD children. These results were not found in children with DS or WS. When looking at the experiment one could expect individuals with DS to experience the poorest CPT performance related to poor sleep quality because they experience more sleep disturbances than WS and TD children, but this was not the case (Fernandez and Edgin, 2013). However, these findings are still important because it is one of the first to investigate sleep quality and performance in DS and WS.

Autism Spectrum Disorder

Unlike DS and WS, ASD is not genetic and does not have a definitive cause. Despite its unknown cause, there are still developmental abnormalities present that manifest differently. While some individuals with ASD experience language-learning and communication difficulties, others may not show any language impairment at all (Rice et al., 2005). There are also varying levels of sleep difficulties that may reflect attentional problems during the day (Malow et al., 2006). Twenty-one children with ASD had their sleep recorded with polysomnography, and their behavior measured through the behavior check list. Results indicated that children with ASD who slept "better" were less likely to have affective problems, and were better at social interactions during the day. These findings support the importance of sleep quality related to behavior. However, it is not clear if symptoms of ASD affect sleep quality, or if symptoms of ASD are further exacerbated by sleep deprivation. Regardless, sleep disturbances are known to influence cognition, and may be involved in language and communication problem with ASD.

For those that do experience language communication difficulties, they still may have nonverbal communication skills and relatively unhindered intelligence. ASD is diagnosed by having impairments with social interaction, communication, and specific behaviors or interests (Rice et al., 2005). It is also important to note the ASD is on a “spectrum”, such that some individuals with ASD experience more severe qualities compared to others. For example, Asperger Syndrome, a mild form of ASD, experiences limited intellectual disabilities, while individuals with ASD and fragile X syndrome are severely intellectually disabled. It has also been shown that up to 50% of children with ASD are nonverbal (Rice et al., 2005). The presence of so many nonverbal individuals in the ASD population is problematic, and there needs to be more research on this disorder. Because ASD has not been linked to any genetic traits, further research has been stinted. However, if ASD is compared to other language disorders such as DS and WS, similarities and differences between them may lead to new findings.

Discussion

Research involving sleep and sleep stages has been studied for an extended time, thus being consistent. However research involving the importance of the different stages and the content within each stage varies. For example, the associations between sleep spindles in SWS and learning have not been proven. However, multiple studies support this association and deem it necessary research further (Fogel and Smith, 2006). By looking at the specific qualities of sleep stages that affect learning, researchers may be able to pinpoint those moments during sleep and maximize for increased language learning and memory.

Different models have been used to look at sleep-wake architecture, including mice models. These models enable testing for potential genetic modifications that could alleviate or eliminate the health and intellectual deficits associated with sleep disturbances, such as DS. While DS mouse models parallel many of the detriments associated with DS in humans, it may be difficult to transpire the findings to an actual human study; its transition to human subjects would need to be ethically sound. There is also the consideration that some mice strains do not properly resemble DS characteristics in humans. As mentioned previously, two DS mouse models showed different sleep physiology despite both being genetically modified to have DS (Colas et al., 2008). Thus, the use of animal models to conduct DS research is beneficial, but more research needs to be conducted in order to correlate the findings to humans.

It is important to talk about language problems and sleep among individuals with DS, WS, ASD, and other intellectual disabilities because language and communication are closely correlated to cognitive ability (Rice et al., 2005). Sleep disruption may detrimentally affect cognitive processes that are already negatively impacted by neuronal processes impaired by the disability. Eliminating sleep disturbances and improving quality of sleep with not alleviate all of the intellectual disabilities, but it could vastly improve their quality of life.

After researching sleep and language among typical and atypical populations, future research would including looking at other intellectual disabilities that involve atypical development, such as Fragile-X syndrome and compare sleeping patterns. Sleep behavior of individuals with ADHD would also be of particular interest due to its similarity to attentional and behavioral deficits of other intellectual disabilities like DS, WS, and ASD.

References

Adams, J. A. (2011). Sleep and Language Development. *Research Papers.* Paper 39.

Allen, M. I., Fung, J., & Jurenka, S. B. (1999). Health care concerns and guidelines for adults with Down syndrome. *American Journal of Medical Genetics, 89: 2*, 100-110.

Andreou, G., Galanopoulou, C., Gourgoulianis, K., Karapetsas, A. & Molyvdas, P. (2002). Cognitive status in Down syndrome individuals with sleep disordered breathing deficits (SDB). *Brain and Cognition, 50*, 145-149.

Ashworth, A., Hill, C. M., Karmiloff-Smith, A., & Dimitriou, D. (2014). The Importance of Sleep: Attentional Problems in School-Aged Children With Down Syndrome and Williams Syndrome. *Behavioral Sleep Medicine*, 1-17.

Batterink, L. J., Oudiette, D., Reber, P. J., & Paller, K. A. (2014). Sleep Facilitates Leaning a New Linguistic Rule. *Neuropsychologia*, 1-11.

Breslin, J., Spano`, G., Bootzin, R., Anand, P., Nadel, L., & Edgin, J. (2013). Obstructive sleep apnea syndrome and cognition in Down syndrome. *Developmental Medicine & Child Neurology*, 1-8.

Carskadon, M. A., & Dement, W.C. (2011). Monitoring and staging human sleep. In M.H. Kryger, T. Roth, & W.C. Dement (Eds.), *Principles and practice of sleep medicine, 5*, 16-26.

Chen, C. C., Spano`, G., & Edgin, J.O. (2013). The impact of sleep disruption on executive function in Down syndrome. *Research in Developmental Disabilities, 34*, 2033-2039.

Chu, C. J., Leahy, J., Pathmanathan, J., Kramer, M. A., & Cash, S. S. (2013). The maturation of cortical sleep rhythms and networks over early development. *Clinical Neuropsychology*, 1-32.

Colas, D., London, J., Gharib, A., Cespuglio, R., & Sarda, N. (2004). Sleep-wake architecture in mouse models for Down syndrome. *Neurobiology of Disease, 16*, 291-299.

Colas, D., Valletta, J. S., Takimoto-Kimura, R., Nishino, S., Fujiki, N., Mobley, W. C., & Mignot, E. (2008). Sleep and EEG features in genetic models of Down syndrome. *Neurobiology of Disease, 30*, 1-7.

Colten, H. R., & Altevogt, B. M. (2006). Sleep Physiology. *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem,* Institute of Medicine (US) Committee on Sleep Medicine and Research.

Crabtree, V. M., & Williams, N. A. (2009). Normal Sleep in Children and Adolescents. *Child and Adolescent Psychiatric Clinics, 18*, 799-811.

Dumay, N., & Gaskell, M. G. (2007). Sleep-Associated Changes in the Mental Representation of Spoken Words. *Psychological Science, 18:1*, 35-39.

Edgin, J. O. (under review). Sleep Disturbance and Expressive Language Development in Preschool-Age Children. *Child Development*.

Fernandez, F., & Edgin, J. O. (2013). Poor Sleep as a Precursor to Cognitive Decline in Down syndrome: A Hypothesis. *Alzheimer's disease and Parkinsonism, 3:2*.

Fogel, S. M., & Smith, C. T. (2006). Learning-dependent changes in sleep spindles and Stage 2 sleep. *Sleep Research, 15*, 250-255.

Friedrich, M., Wilhelm, I., Born, J., & Friederici A. D. (2015). Generalization of Word Meanings during Infant Sleep. *Nature Communications*, 1-9.

Gaskell, M. G., Warker, J., Lindsay, S., Frost, R., Guest, J., Snowdon, R., & Stackhouse, A. (2014). Sleep Underpins the Plasticity of Language Production. *Psychological Science*, 1-9.

Goldman, S. E., Malow, B. A., Newman, K. D., Roof, E., & Dykens, E. M. (2009). Sleep patterns and daytime sleepiness in adolescents and young adults with Williams syndrome. *Journal of Intellectual Disability Research, 53:2*, 182-188.

Gomez, R. L., Bootzin R. R., & Nadel L. (2006). Naps Promote Abstraction in Language-Learning Infants. *Psychological Science, 17:8*, 670-674.

Gozal, D. (1998). Sleep-Disordered Breathing and School Performance in Children. *Pediatrics, 102:3*, 616-620.

Hart, E. E. (2011). A Comparative Analysis of the Patterns of Language Development between Children with Williams syndrome and Children with Down syndrome. *Boston College University Libraries*, 1-65.

Henderson, L. M., Weighall, A. R., Brown, H., & Gaskell, M.G. (2012). Consolidation of vocabulary is associated with sleep in children. *Developmental Science*, 1-15.

Kurdziel, L., Dudos, K., & Spencer, R. M .C. (2013). Sleep spindles in midday naps enhance learning in preschool children. *PNAS, 110:43*, 17267-17272.

Kurth, S., Jenni, O. G., Riedner, B. A., Tononi, G. T., Carskadon, M. A., & Huber R. (2009).

Malow, B. A., Marzec, M. L., McGrew S. G., Wang, L., & Henderson, L. M. (2006). Characterizing sleep in children with Autism Spectrum Disorders: A multidimensional approach. *SLEEP, 29: 12*, 1563-1571.

Nieuwenhuis, I. L. C., Folia, V., Forkstam, C., Jensen, O., & Magnus Peterson, K. (2013). Sleep Promotes the Extraction of Grammatical Rules. *PLOS ONE, 8:6*, 1-10.

Owens, J. A., & Dalzell, V. (2005). Use of the BEARS sleep screening tool in a pediatrics residents' continuity clinic: a pilot study. *Sleep Medicine, 6:1*, 63-69.

Rasch, B., & Born, J. (2013). About Sleep's Role in Memory. *Physiological Reviews, 93*, 681-766.

Rice, M. L., Warren, S. F., & Betz, S. K. (2005). Language symptoms of developmental language disorders: An overview of autism, Down syndrome, fragile X, specific language impairment, and Williams syndrome, *Applied Psycholinguistics, 26:1*, 7-27.

Tamminen, J., Payne, J. D., Stickgold, R., Wamsley, E. J., & Gaskell, G. M. (2010). Sleep spindles is associated with the integration of new memories and existing knowledge. *The Journal of Neuroscience, 30: 43*, 14356-14360.

Tarokh, L., Carskadon, M. A., & Acherman, P. (2010). Developmental Changes in Brain Connectivity Assessed Using the Sleep EEG. *Neuroscience, 171*, 622-634.

Tiernay, C. D. (2013). Developmental Perspectives on Common Sleep Problems. *Penn State Children's Hospital*, 1-16.

Udwin, O, & Yule, W. (1991). A Cognitive and Behavioural Phenotype in Williams Syndrome, *Journal of Clinical and Experimental Neuropsychology, 13:2*, 232-244.

Williams, J. A., Zimmerman, F.J., & Bell, J. F. (2013). Norms and Trends of Sleep Time Among US Children and Adolescents. *JAMA Pediatrics, 167:1*, 55-60.

Williams, S. E., & Horst, J. S. (2014). Goodnight Book: Sleep Consolidation Improves Word Learning via Storybooks. *Frontiers in Psychology*, 1-44.

Yin, Z., Ting, A. C., Simon, L. H., Kate, C. C. C., Crover, H., Kwok, W. Y., & Martin, L. A. (2013). Sleep architecture in school-aged children with primary snoring. *Sleep Medicine*.