The Relationship Between Sleep Deprivation and Brain Health

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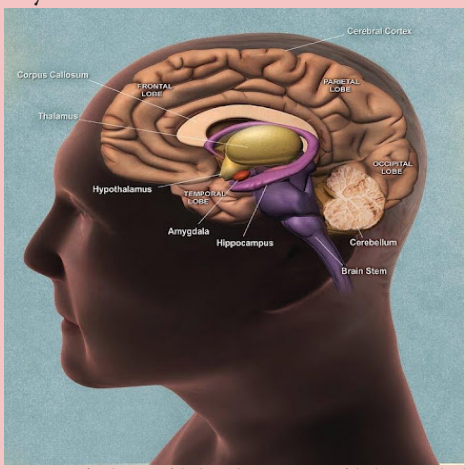
Sleep deprivation is a national issue affecting teenagers and adults. The Center for Disease Control and Prevention (CDC) reports that 35.2% of adults and 68.8% of teenagers get less than the recommended amount of sleep per night (2017). Ideally, teens should get around 9.5 hours of sleep, while adults should get 7-9 hours ("National Institute of Neurological Disorders and Stroke," 2019). Sleep deprivation is measured considering both the quality and the amount of sleep an individual obtains per night. Thus, people who wake up several times throughout the night are considered sleep deprived. The causes of sleep deprivation can be voluntary or involuntary. While some people may choose to stay awake, others may have sleep disorders that prevent them from falling asleep. In both cases of sleep deprivation, people face decreased cognitive capacity and increased risk for neurological disorders.

Sleep-related neurons are located in the brainstem, pineal gland, basal forebrain, amygdala, hypothalamus, and thalamus ("National Institute of Neurological Disorders and Stroke," 2019). The NINDS explains that the suprachiasmatic nuclei in the hypothalamus process light signals to regulate sleep, so that sleepiness aligns with nighttime darkness as part of the body's circadian rhythm. The circadian rhythm is the body's regulatory system that synchronizes sleep-wake cycles with daytime and nighttime and functions through hormone regulation. For instance, the pineal gland releases melatonin - a well-known hormone used in the signaling pathway for inducing sleep. The timing of hormones and neurological activity is essential for the body to induce and maintain sleep. A dark environment causes the body to secrete melatonin because the circadian rhythm coordinates sleepiness with nighttime. Then, the circadian rhythm halts production of melatonin and increases secretion of other hormones when the body needs to wake up from sleep during the daytime.

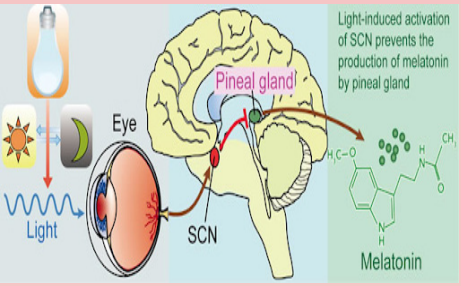


Caption: Left side view of the brain locates regions of the brain involved in sleep-related functions.

Sleep consists of nonrapid eye movement (NREM) and rapid eye movement (REM) cycles (Jacobson, 2020). NREM is the first sleep cycle, and people spend most of their time in this cycle. NREM also consists of three phases: N1, N2, and N3. An article by Kate Jacobson explains that the NREM cycle synthesizes ATP energy for the brain, decreases heart rate and internal temperature, and heals the body of toxic metabolites. Then, the production of acetylcholine transitions the brain into the REM cycle. REM sleep is the cycle that features peak brain stimulation and the occurrence of dreams. Research also suggests that REM sleep has cognitive benefits and can decrease feelings of depression or anxiousness. Thus, losing the recommended amount of REM sleep could have negative consequences on the brain.

A sleep survey asked teenagers to assess the importance of getting enough sleep each night and to report behavior leading to sleep loss. The respondents cited social media, video game, and TV usage as major factors of their sleep deprivation (Quante et al., 2019). Along with acting as a sleep distraction, electronic devices have light-emitting diodes (LED) with blue light, which interferes with sleep. In nature, sunlight is necessary for healthy sleep cycles so that the hypothalamus can establish the body's circadian rhythm. Researchers Wu et al. conducted a study to examine the effects of blue light exposure on sleep in mice (2021). Mice were split into a white group and a blue group. The white group was exposed to an hour of white light per day, while the blue group was exposed to an hour of blue light per day. The results showed that the blue light group mice slept and

woke at later times than the white light group. In humans, electronic use before bedtime prevents the onset of sleep and promotes feelings of tiredness in the morning.



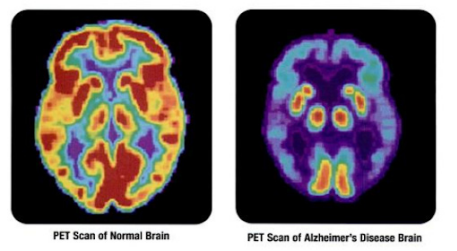
Caption: Light and eye receptors regulate the circadian rhythm. Darkness causes the pineal gland to produce melatonin and induce sleep. Artificial blue light can delay the production of sleep promoting hormones and prevent sleep onset.

In addition to individual habits, sleep disorders are also a major factor in sleep deprivation. Insomnia is a sleep disorder that makes it hard for a person to fall asleep. A medical study estimates that 33% of adults have chronic insomnia (Bhaskar et al., 2016). Additionally, the researchers found that 27% of respondents that had insomnia were previously undiagnosed, suggesting that insomnia may be an underdiagnosed condition. A paper from Levenson et al. characterizes insomnia as a "hyperarousal" of the mind, meaning that overstimulation of the brain before bedtime prevents someone from falling asleep (2015). Currently, little is known about the specific chemical and cellular processes behind insomnia, but theories suggest that a region or family of neurons may be primarily responsible for it. For example, damage or removal of the thalamus, raphe nuclei, and mediobasal preoptic area caused insomnia in experiments with nonhuman subjects. Other experiments show that the hypothalamus and left dorsomedial frontal cortex led to insomnia in several human patients suffering from brain damage.

Causes of sleep deprivation can be voluntary or involuntary, but the effects of sleep deprivation can be similar in both groups. Sleep deprivation may cause a decreased attention span, which is an important trait for participating in work or school activities (Alhola and Polo-Kantola, 2007). Several sleep deprivation studies use "speed and accuracy" to define an individual's attention span, and many of those studies concluded that sleep deprivation decreases speed, accuracy, or both during the experiment. These findings imply the detrimental effects of sleep loss on test performance in students: an inability to work fast and accurately during a test could result in a lower score.

Sleep deprivation also negatively impacts memory capacity, which can disrupt learning. A study by Heckman et al. analyzed the effects of sleep deprivation on memory in mice (2020). The sleep-deprived mice were put in a testing cage to accustom them to their new surroundings. Two items were placed randomly in the cage so that the mice could learn the items' positions. After 10 minutes, the mice were taken out of the testing cage and put into their holding cage. Then, the researchers moved one of the objects in the testing cage to a new location to test the amount of time needed for the mouse to notice the change. Compared to rested mice, the researchers concluded that the sleep-deprived mice had a lower capacity for creating and using their memory in navigating the cage.

In addition to cognitive deficits, sleep deprivation is associated with depression. The CDC sleep survey shows that 22.9% of sleep-deprived adults reported having depression while 14.6% of well-rested adults reported having depression (2017). An article from Harvard Health Publishing also reports that 65% to 90% of depressed adults have a sleep disorder, implying that sleep disorders, like insomnia, can put an individual at risk for developing depression (2019). The development of Alzheimer's disease has also been linked to sleep deprivation (Bishir et al., 2020). Alzheimer's disease involves the deterioration of neurons and cognitive decline. Stress leads to an increased risk of Alzheimer's disease, and sleep deprivation can lead to increased stress, indicating that prolonged sleep deprivation may increase an individual's risk of Alzheimer's disease. Sleep deprivation also decreases the activity of proteins that keep neurons alive, which would lead to neural degeneration and inflammation. Neuron inflammation is involved with stroke onset, so extensive sleep loss can have fatal consequences.



Caption: The PET scans demonstrate the difference between a healthy brain and a brain with Alzheimer's disease. Alzheimer's disease causes neural degradation and increases risk for sleep deprivation.

Sleep deprivation may lead to health issues, so scientists have made extensive progress in treating sleep-related problems. Doctors are equipped to diagnose and treat sleep disorders in patients that show symptoms. Diagnostic tests may include monitoring the patient's brain or heart activity during sleep, or inquiring into the patient's family history of sleep disorders (Abad and Guilleminault, 2003). Treatments vary depending on the type and severity of the disorder: some patients need drugs, like melatonin, for healthy sleep while others require nonmedicinal therapy. Other lifestyle changes, such as decreasing the use of stimulants like caffeine, limiting blue light exposure before bedtime, and maintaining a consistent sleep schedule can help prevent sleep deprivation.

In conclusion, sleep deprivation can be detrimental to overall brain health. Short-term effects include symptoms like reduced cognition, but long-term effects like depression and Alzheimer's disease are life-altering. Sleep deprivation is widespread among adults and teenagers alike, so the effects of sleep deprivation can also negatively impact performance in school and work settings. Fortunately, recognition of sleep deprivation is the first step to changing sleep habits,

such as minimizing blue light before bedtime, or working with a doctor to overcome sleep disorders.

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