HIGH SCHOOL EDITION
Journal of Student Research
Volume 13 Issue 2 (2024)

Effects of Light on Sleep Patterns and Circadian Rhythms

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ABSTRACT

Although humans spend an increasingly considerable amount of time in front of light emitting diode (LED)/digital screens, little research has been conducted focusing on the effects of artificial light on circadian rhythm and sleep. A current theory suggests that exposure to light, artificial or natural, outside of daytime hours has a detrimental effect on the neurobiology of an individual. Furthermore, artificial light from these screens or at a larger scale, light pollution, defined as excessive outdoor artificial light, can affect the circadian rhythms. The central pacemaker in the brain, known as the suprachiasmatic nucleus (SCN) controls various essential biological processes. Current evidence suggests different wavelengths of light have contrasting impacts on SCN activity and subsequent circadian rhythms. Alterations to circadian rhythms can have a profound impact on sleep and mood. Therefore, understanding how artificial light impacts SCN function is critical for determining the psychological and biological consequences. This paper reviews the effects that artificial light has on the brain, and breaks down the biological and psychological processes that control sleep and mood.

Background

Humans are diurnal, are used to light exposure during the daytime, and darkness at night. Over the course of our evolution, humans have adapted to be active during the daytime when the sun is out, and to sleep when it is dark, and many biological processes are modulated by this pattern of wakefulness and sleep. However, the invention of electricity and eventually, digital devices, introduces a challenge to this physiologic pattern. Nowadays, humans are exposed to more and more nighttime light through phones, television, and indoor lighting. However, the impact of nighttime light exposure on various biological processes in the body is poorly understood. Critical studies have demonstrated that light exposure outside of normal daytime hours can lead to a variety of major health problems, stemming from the disruption of circadian rhythms.

Circadian rhythms are our internal clocks that follow a 24 hour cycle that respond to light changes in our environment and regulate alertness and sleepiness, with physical, behavioral and mental changes [1]. Light influences circadian rhythms by altering activity in the suprachiasmatic nucleus (SCN), the central pacemaker in the brain [2]. The SCN is a structure located in the anterior part of the brain that controls many neurological processes in the body and is the main regulator of circadian rhythms. To function effectively, the SCN needs to be synchronized with solar time, information gathered via the central visual system, more specifically the retina [3]. The SCN receives input from retinal ganglion cells in the eye, which communicate information about light in the environment to the brain [3]. These signals alter activity in the SCN to influence circadian rhythms.

As light strongly modulates circadian rhythms, exposure to light outside of normal daytime hours can have a negative impact on health. Disruption to circadian functions that depend on these rhythms lead to major health consequences including decreased sleep efficiency, impaired cognitive performance, and increased disease risk {3}. Taken together, these can contribute to psychiatric, metabolic and neurological diseases such as Alzheimers and parkinsons. The SCN also controls the release of hormones through connections to other glands

such as the pineal gland, therefore, light-mediated disruption of SCN function has the ability to influence not just brain activity, but other organ systems in the body [2].

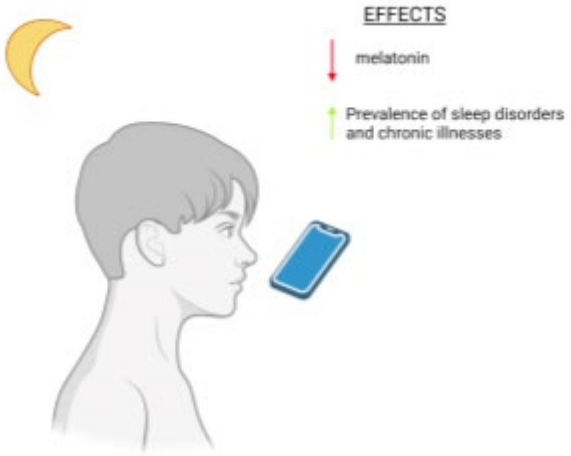

Figure 1. How light disrupts the circadian rhythm (made with BioRender)

Sleep Disruption

One important hormone controlled by the SCN is melatonin, which regulates sleep by helping with the timing of circadian rhythms {4]. Melatonin levels are cyclic, meaning they are lower during the day and higher at night. Exposure to light suppresses melatonin secretion, which although advantageous during the day, is detrimental at night. It has been proposed that exposure to artificial light at night can suppress melatonin secretion and therefore make it harder to fall asleep, disrupting the overall sleep wake cycle. Nighttime light exposure can also suppress the activity of neurotransmitters in the brain such as gamma-aminobutyric acid (GABA), which enables the body to relax and fall asleep by inhibiting neural transmission and reducing neuronal excitability [5]. Overall, exposure to artificial light outside of daytime hours can lead to suppression of melatonin and other neurotransmitters, which leads to sleep disruption.

Sleep is a critical component of overall health, and disruption of normal sleep-wake cycles by artificial light exposure can have negative effects on health and wellbeing. Besides increased daytime sleepiness, sleep disruption can lead to many other health consequences. For example, sleep disruption has been linked to increased fight or flight response and stress reactivity [6, 7]. While it is not well understood how circadian rhythms modulate stress responses in the body, it is widely accepted that activity of the hypothalamic-pituitary-adrenal or HPA axis, the system in the body that controls stress responses, varies by the time of day [7]. Further, some studies suggest that the circadian rhythm influences the levels of various neurotransmitters in the brain that activate the HPA axis to generate a stress response in the body [7]. In this way, sleep disruption can impact stress levels by altering neurotransmission in the brain that drives stress. In adults, this may manifest as symptoms such as increased stress, pain sensitivity, and decreased performance in the short term [6].

Further, chronic sleep disruption can also lead to long term effects by contributing to the progression of neurodegenerative diseases such as Alzheimers, Huntingtons, and Parkinson's Diseases [8]. During the day, brain cells produce a waste product known as beta-amyloid, which is found in the fluid between the cells. Under normal circumstances, it is thought that this waste is removed from the brain during sleep. However, lack of sleep has been shown to impede the removal of beta-amyloid, leading to elevated beta-amyloid levels. This elevation causes a buildup of beta-amyloid, which then forms plaques, which disrupt the communication between neurons and can lead to Alzheimer’s Disease. A recent study found that beta amyloid increases 5% after losing a night of sleep, compared to getting a full 8-9 hours of rest. Scientists also found that study participants

with increases in beta amyloid levels, had worse moods after losing sleep {9}. Therefore, it's important to be aware of sleep disruption in terms of both immediate and long-term effects across a lifetime.

In adolescents, the effects may vary, as sleep disruption is thought to have an effect on psychosocial health, performance in school and risk taking behaviors [6]. Untreated sleep disruption, though, can also be the main cause of mood disorders.

Light Therapy

An effective way to reduce sleep disruption and potentially help with sleep problems related to Alzheimers and insomnia as well is light therapy. Bright light therapy is used to gradually shift sleeping patterns and shift them to a normal state. This process, known as phototherapy, uses timed light to delay the biological clock of the patient. The source of the light can be very bright such as a full spectrum light or even natural outdoor light {10}. Untreated sleep disruption, though, can also be the main cause of mood disorders[10].

Impact on Mood

In addition to causing sleep disturbances, mis-timed light exposure can impact mood by directly influencing neurotransmission in the brain, and by causing misalignment of the body's internal clock with solar time. Multiple studies have shown an increased prevalence of depression in night shift workers compared to daytime workers and other analyses have shown that night-shift workers are 40% more likely to have depression than day shift workers {11}. This is thought to occur because bright nighttime light can cause overactivation of the amygdala, a brain region that is critical for emotions, resulting in anxiety, stress, and changes in mood [12]. Further, it has been shown that light can directly modulate the activity of neurotransmitters that are important for mood regulation, including serotonin [4]. In this way, extreme exposure to nighttime light that interferes with circadian rhythms may be a factor of mood disorders such as bipolar disorder, PTSD and depression [13]. Therefore, it's important to consider nighttime light as a critical factor in mental health disorders in the form of neurotransmission.

Another important factor to consider is the effect nighttime light has on the sleep wake cycle and how it shifts this whole cycle. Along with these changes, misalignment of the circadian rhythm with solar time, also known as phase shift, may also lead to anxiety issues {11}. A phase shift in circadian rhythms means that your sleep-wake cycle shifts earlier or later in the day, based on environmental conditions {14}. Exposure to light in the night will delay this cycle, pushing it to later in the day. A balance between sleep and light exposure, as well as the alignment of circadian rhythms to the sleep-wake cycle can positively influence mood through the day. Further, it has been reported that changes to sleep patterns are also prevalent in depression.

Conclusion

Artificial light exposure, especially at night time can have substantial pathological impacts on our physical and mental health. While the full extent remains unknown and further research is required, this is a developing public health crisis. Considering the extent to which we are exposed to screens at night, which can directly affect normal biological function in everyday life, we need to better understand the underlying pathophysiology. Nighttime light can disrupt circadian rhythms leading to sleep disruption, which is a critical component of overall health. These disruptions can lead to many consequences as well, affecting mood and contributing to disease risk. While technology is an essential part of daily life and it helps us with speeding up many tasks in everyday life, we should be aware of the health consequences of staring at screens and the impact life can have on our overall health. However, there are many steps we can take to improve our well-being. Simply making

the effort to turn off unnecessary lighting during hours when not needed is a great step to improve our health [15]. It's important to note that though many say that swapping blue colored light with warmer colors and turning on night shift mode on devices will help prevent negative outcomes, it's more so the timing of light than the type of light that affects sleep and well-being [15].

Acknowledgments

I would like to thank my advisor for the valuable insight provided to me on this topic.

References

[1] U.S. Department of Health and Human Services. (n.d.). Circadian rhythms. National Institute of General Medical Sciences. https://nigms.nih.gov/education/fact-sheets/Pages/circadian-rhythms.aspx. Retrieved 08/08/2023.
[2] Tahkamo, Leena et al. (12/08/2018). Systematic review of light exposure impact on human circadian rhythm. Chronobiology International. nigms.nih.gov/education/fact-sheets/Pages/circadian-rhythms.aspx. Retrieved 08/08/2023.
[3] Hastings, Michael et al. (08/2018). Generation of circadian rhythms in the suprachiasmatic nucleus. Nature Reviews Neuroscience. https://dpl6hyzg28thp.cloudfront.net/media/s41583-018-0026-z_ZhM3Dud.pdf. Retrieved 08/08/2023.
[4] Blume, Christine, et al. (09/2019). Effects of Light on Human Circadian Rhythms, Sleep and Mood. Somnologie. https://doi.org/10.1007/s11818-019-00215-x. Retrieved 08/08/2023.
[5] Allen, Mary J., et al. (26/07/2020). GABA Receptor. Nih.gov, StatPearls Publishing. www.ncbi.nlm.nih.gov/books/NBK526124/#:~:text=Gamma%2Daminobutyric%20acid%20(GABA). Retrieved 08/08/2023.
[6] Medic, Goran, et al. (19/05/2017). Short- and Long-Term Health Consequences of Sleep Disruption. Nature and Science of Sleep. www.ncbi.nlm.nih.gov/pmc/articles/PMC5449130/, https://doi.org/10.2147/nss.s134864. Retrieved 08/08/2023.
[7] Koch, C.E., et al. (08/09/2016). Interaction between Circadian Rhythms and Stress. Neurobiology of Stress. https://doi.org/10.1016/j.ynstr.2016.09.001. Retrieved 08/08/2023.
[8] Hastings, Michael H, and Michel Goedert. “Circadian Clocks and Neurodegenerative Diseases: Time to Aggregate?” Current Opinion in Neurobiology, vol. 23, no. 5, Oct. 2013, pp. 880–887, https://doi.org/10.1016/j.conb.2013.05.004. Accessed 18 Dec. 2019.
[9] (23/04/2018). Sleep Deprivation Increases Alzheimer’s Protein. National Institutes of Health (NIH). www.nih.gov/news-events/nih-research-matters/sleep-deprivation-increases-alzheimers-protein#:~:text=Impaired%20sleep%20has%20been%20associated.
[10} “Bright Light Therapy.” Stanford Health Care (SHC) - Stanford Medical Center, stanfordhealthcare.org/medical-conditions/sleep/advanced-sleep-phase-syndrome/treatments/bright-light-therapy.html. Accessed 3 Sep. 2023.
[11] Epstein, Lawrence. (13/05/2023). Why Your Sleep and Wake Cycles Affect Your Mood. Harvard Health Blog. www.health.harvard.edu/blog/why-your-sleep-and-wake-cycles-affect-your-mood-2020051319792. Accessed 08/08/2023

[12] Ressler, Kerry J. (15/06/2010). Amygdala Activity, Fear, and Anxiety: Modulation by Stress. Biological Psychiatry. www.ncbi.nlm.nih.gov/pmc/articles/PMC2882379/, https://doi.org/10.1016/j.biopsych.2010.04.027. Retrieved 08/08/2023.
[13] Bedrosian, T A, and R J Nelson. (01/2017). Timing of Light Exposure Affects Mood and Brain Circuits. Translational Psychiatry. https://doi.org/10.1038/tp.2016.262. Retrieved 08/08/2023
[14] Mansbach, Peter. (14/10/2021). Phase Response Curve - Circadian Sleep Disorders Network. Www.circadiansleepdisorders.org, www.circadiansleepdisorders.org/info/PRC.php#:~:text=A%20phase%20shift%20in%20your. Retrieved 08/08/2023.
[15] Tracy, Samantha. (10/2023). I Can't Sleep… Can You Turn off the Lights?. Science in the News. sitn.hms.harvard.edu/flash/2020/i-cant-sleep-can-you-turn-off-the-lights/#:~:text=Exposure%20to%20artificial%20light%20disrupts. Retrieved 08/08/2023.