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THE IMPACT OF MODERN TECHNOLOGY AND ARTIFICIAL LIGHT ON INSOMNIA: EXPLORING THE ROLE OF BLUE LIGHT AND SCREEN TIME

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Abstract:

This paper explores the impact of modern technology and artificial light on insomnia, with a particular focus on the role of blue light and screen time. The

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physiological and psychological factors of sleep disturbances are examined, which include the disruption of circadian rhythm due to blue light exposure and how screen time affects brain activity. Blue light also disrupts the production of melatonin which causes delayed sleepiness and lowers the quality of sleep. In addition, this paper explores the effect of screen time on sleep architecture including changes to sleep stages and a decrease in deep sleep. Insomnia is also linked to psychological factors such as increased stress and poor sleep hygiene that are associated with excessive screen time. This paper will also offer practical solutions and the application to current issues, which emphasizes the limitation of screen time before bed and various strategies to reduce blue light exposure.

Keywords:

Insomnia, Artificial Light, Blue Light, Quality of Sleep

Introduction

Technology seems to have changed the pace of work, life, and interpersonal communication in modern times. These breakthroughs have led to a vast range of advantages, but they also raise concerns, especially regarding one's health and well-being. Against this backdrop, the most immediate of these challenges is insomnia, a sleep problem that impacts millions of people worldwide. Insomnia is an epidemic of the modern world with the number of cases rising significantly in the last few years due to excessive screen usage and artificial lights in our homes and offices. According to Carr (2001), screen times or screen usage has been categorized into two lower types (two hours per day) and excessive (four hours per day).

Artificial light, also known as blue light is the kind of light emitted from screen devices, which can also disrupt the body's circadian rhythm by suppressing melatonin, a hormone that works to regulate our sleep-wake cycles and cause sleepiness (Chellappa, 2020). This suppression may also result in a delay in the sleep onset, curtailed time in restorative sleep stages, like deep sleep (slow-wave sleep), and may extend time in lighter sleep stages. According to news from Free Malaysia Today (2024), South Africa spends the majority of their waking hours in front of screens. On average it is about nine hours and 24 minutes per day or 56.8%. As a result of long periods of exposure to these screens whether from laptops, smartphones or televisions, most average people wake up earlier and go to sleep later in most places in the world, as more and more time is spent in front of screens. This can increase neurosensory and body dysfunctions, making the sleep-wake cycle problematic. Thus, given the ubiquity of technology across all societies, the relationship between blue light, screen time, and insomnia has become an important area of investigation for research.

Insomnia is a sleep disorder marked by difficulties in initiating, maintaining, or achieving restorative sleep despite sufficient opportunities to rest (Roth, 2007). According to the International Classification of Sleep Disorders (ICSD-3), it is diagnosed when sleep issues occur at least three nights per week for three months or more, often leading to daytime

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impairments such as fatigue, irritability, and poor concentration (Morin et al., 2015). Insomnia is classified into three categories: chronic insomnia, which persists for over three months; short-term insomnia, lasting less than three months and often triggered by stress; and other insomnia disorders that impact sleep but do not meet these specific criteria (Kaur et al., 2023). According to Newsom and Singh (2024), blue light, which is emitted by electronic devices such as smartphones, tablets, and LED screens, significantly affects sleep patterns. This specific wavelength of light suppresses melatonin production, a hormone essential for signalling the body to prepare for sleep (Shechter et al., 2018). Research shows that blue light exposure in the evening can delay sleep onset, reduce sleep quality, and disrupt circadian rhythms, making it difficult to fall or stay asleep (Cajochen et al., 2011). This effect is amplified by modern lifestyles, as many individuals use electronic devices in the hours before bedtime. The disruption caused by blue light is a key factor contributing to insomnia in today's digital age.

Understanding the link between blue light and insomnia is vital for improving sleep quality. Reducing evening blue light exposure can be achieved by turning off devices, dimming screens, using blue light-blocking glasses, or employing red/orange lighting alternatives (Newsom & Singh, 2024). Public health campaigns promoting limited blue light exposure before bed can help prevent insomnia-related health issues and enhance overall well-being.

Methodology

A comprehensive and systematic online search was conducted through academic search engines including Google Scholar, PubMed and APA PsycNet. The keywords and phrases used to gather the papers included "sleep hygiene," "sleep quality," "insomnia," "blue light," "circadian rhythm" and "sleep disorder." Additionally, the Boolean operators (AND, OR) were utilized to help with the search.

Inclusion and Exclusion Criteria

All papers published between 2019 to 2024 were considered for this review. Additionally, this review consisted of participants from human, mice and flatworm subjects to further understand the circadian rhythm in mammals. To ensure academic validity, the papers selected were limited to research with original findings and comprehensive systematic review papers. Meanwhile, grey literature and student papers were excluded from the review. Additionally, papers published in non-English language and with no full-text availability were excluded.

Data Extraction

The data extraction strategy was conducted using a standardized form that was developed specifically for this review. This allowed for systematic synthesis of information, including key findings, subject details, limitation of research and significance of findings. The data was then compiled under relevant subthemes and the findings and key points were discussed.

Findings

Insomnia and Its Causes

According to the circadian rhythm theory, the hypothalamus, especially the suprachiasmatic nucleus (SCN), is the body's master regulator of the sleep-wake cycle, ensuring that internal circadian rhythms align with the external day-night cycle (Cao et al., 2023). The SCN processes light input via the retina, helping to synchronize key biological functions like sleep patterns,

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hormone production, and appetite. This coordination maintains a 24-hour rhythm, resetting daily with the morning light (Tsuno & Mieda, 2024; van Drunen & Eckel-Mahan, 2021). A critical aspect of the SCN's role involves controlling melatonin production mechanism in the pineal gland. Melatonin, a hormone that promotes sleep, typically peaks at night in response to dark environments. In this sense, exposure to light, especially blue light from screens suppresses melatonin levels, shifting the body's circadian rhythm and delaying sleep onset (Tsuno & Mieda, 2024; van Drunen & Eckel-Mahan, 2021). This artificial light acts as melatonin suppression, blocking the release of melatonin in the pineal gland as the SCN detects blue light emitting from screens at night. This mechanism disturbs the body's internal clock, misaligning circadian rhythms with the natural environment. As a result, this disruption can lead to sleep disorders like insomnia, as the body struggles to maintain its natural rhythm (Ma & Morrison, 2023; von Gall, 2022).

The effects of light on the SCN's control over melatonin are particularly problematic in today's world, where artificial light, such as from screens and artificial lighting, is often present late into the night. This extended exposure to light confuses the SCN, leading to an imbalance between the body's internal clock and external stimuli. For example, screen time before sleep suppresses melatonin, resulting in delays in falling asleep, reduced sleep quality, and potential long-term disruptions to overall health and well-being (Cao et al., 2023). The regulation of the sleep-wake cycle, including the SCN's role and its synchronization with light, resonates deeply with Islamic principles of balance and discipline. Islam emphasizes the importance of living in harmony with natural rhythms, such as waking at dawn for Fajr prayers and resting after Isha prayers at night. The importance of maintaining a regular circadian rhythm and preventing disruption to the SCN cannot be overstated. By aligning the body's sleep-wake cycle with the natural light-dark cycle, the body can maintain optimal health. Preventing exposure to artificial light, especially before sleep, is essential for supporting melatonin production, ensuring restful sleep, and mitigating disruptions like insomnia (van Drunen & Eckel-Mahan, 2021).

Blue Light and Circadian Rhythm Disruption

Blue light exposure, especially during the evening, significantly disrupts the circadian rhythm, which is the internal biological clock of the body that regulates the sleep-wake cycle. Such disruption is largely mediated by the intrinsically photosensitive retinal ganglion cells (ipRGCs) of the retina, which contain the photopigment melanopsin and are highly sensitive to blue light. When the ipRGCs are exposed to blue light, this sends a signal to the SCN of the hypothalamus, which is the brain's master circadian clock. Light exposure, especially around bedtime, tends to suppress melatonin secretion, which promotes sleep onset, delaying it and shifting sleep to later times. As a result, this phase shift may decrease total sleep time and deteriorate the quality of sleep, resulting in sleep disruptions, fragmented sleep, and desynchronization between the body's internal clock and the external environment. Such disturbances have been associated with a number of general health consequences, such as mood disorders, cognitive impairments, and metabolic disorders (Cajochen et al., 2011; Gooley et al., 2011; Lucas et al., 2001).

From an Islamic perspective, the concept of maintaining proper sleep and rest aligns with the importance of balance and discipline that are attributed to daily life. Islam encourages healthy regimens in which both the Qur'an and Hadiths emphasize rest and sleep during appropriate times. The Prophet Muhammad is reported to have recommended a regular pattern of sleep, going to bed and getting up in times that are not very far from natural circadian rhythms. This

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disruption of the circadian rhythm through excessive artificial light, especially blue light exposure before bedtime, goes against the natural order that Islam advances. Furthermore, the Qur'an has mentioned the creation of nighttime as a time for rest and the alternation of day and night as signs of God's wisdom (Qur'an, 78:10-11). In this way, it emphasizes following natural cycles to maintain health. Hence, the increasing issue of disruptions of circadian rhythm from blue light does suggest that a modern challenge can be counteracted by returning to a natural rhythm lifestyle advocated by the Islamic teachings of early nights and health discipline.

Screen Time and Brain Activity

In this modern world, technology and digital screens have been significantly integrated into people's everyday lives. However, people's reliance on digital devices raises serious concerns about how these devices affect the brain's activity and its influence on sleep. Long-term screen time has an impact on cognitive processes, brain mechanisms, and overall well-being. Addressing the negative effects of prolonged screen time especially in the evening is significant and requires the understanding of these processes.

The brain has a reward system that is primarily driven by dopaminergic pathways and it plays an important role in the relationship between screen time and brain activity. Dopamine plays a crucial role in time perception and reward processing, thus suggesting a similar mechanism as screen time and the rewarding feeling (Fung et al., 2021). Dopamine is released when using digital screens, especially for social media or gaming, which produces a rewarding experience. For example, features like social media notifications and content that are tailored by algorithms will provide users with intermittent rewards and keep them interested until late at night. This process is significantly similar to addictive behaviors and individuals will face difficulty in disengaging from screens, which will affect their sleeping time. The mesolimbic dopamine pathway will be repeatedly activated with the usage of digital screens and may lead to addiction and compulsive reward-seeking behavior (Popescu et al., 2021). Over time, this dependency can interfere with daily life as individuals prioritize screen time over other tasks. The addictive nature of screen time may disrupt the circadian rhythm and delay the release of melatonin. Therefore, falling asleep will become harder and the likelihood of insomnia is increased.

Screen activities like social media scrolling and gaming require significant cognitive engagement. As opposed to the relaxation required for a person to fall asleep, this overstimulation maintains the brain in an alert and active state. Neurotransmitters that are involved in focus and excitement which are dopamine and norepinephrine will stay high and inhibit the body's natural relaxing signals such as the melatonin and GABA release that will prepare the brain for sleep (Omond et al., 2022). Melatonin is a transmitter responsible for regulating sleep-wake cycles and circadian rhythms whereas GABA promotes sleep by inhibiting arousal neurons (Chaturvedi & Emery, 2024; Kennaway, 2021). Hence, this disturbance eventually makes it harder to maintain sleep cycles and increases insomnia symptoms. The use of digital screens is inevitable and many benefits come from these technologies. However, it is encouraged to use them in moderation just as Allah has commanded in Surah Al-A'raf verse 31 which is translated into the concept of balanced and moderation in every aspect of one's life. The use of screen time at night is often excessive and may cause physical, mental, and spiritual harm, which is contrary to the principle of balance in Islam.

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Impact on Sleep Architecture

Prolonged screen time can impact the sleep architecture which is the pattern of the sleep stages that occur throughout the night (i.e., REM and NREM). Excessive screen time particularly during the evening may interrupt the body's natural circadian rhythm by suppressing melatonin production. This suppression may also result in a delay in the sleep onset, and curtailed time in restorative sleep stages, like deep sleep (slow-wave sleep; SWS). NREM is divided into a few stages with slow wave sleep being the deepest process which occurs at stage three NREM. It is characterized by slow brain waves called delta waves and is an important part of recovering and repairing the body. In this phase, the body is dedicated to tissue repair, muscle growth, and immune system enhancement. Moreover, growth hormone is secreted during SWS, which assists with recovery from physical labor and injury while also promoting overall good health. Insufficient SWS exposure can lead to physical exhaustion, immune depression, and increased vulnerability to chronic diseases such as diabetes and coronary heart disease (Garbarino et al., 2021). In this regard, exposure to screens in the hour before bed may delay the onset of SWS and shorten its time frame, hindering the bodily repair processes (Caumo et al., 2020; Salsabila, 2022). This is aligned with what Prophet Muhammad (SAW) has said, "Allah made the early hours blessed for my ummah" (Sunan Ibn Majah, 2236) which discourages excessive wakefulness and late-night activities as there are many blessings in the morning. Similarly, modern sleep science advocates individuals to sleep early to help the body to undergo its restorative phase and wake up early, to fit with the natural circadian rhythm.

Based on Islamic perspectives, the division of day and night with the night is created for rest and the body's recovery, reflecting a sign of Allah's omnipotence. The Qur'an says in surah An-Naba (Quran, 78:9-11) which highlights that all human activities, including sleep, should be in harmony with the natural cycles of day and night, aligned with what scientific perspectives take into account regarding the importance of quality circadian rhythm. Overexposure to artificial light after sunset will go against the divine order and can derange both physiological and spiritual health. Other than that, in Islam, it is recommended to recite some specific supplications and Quranic verses before going to bed, which allows psychological tranquility and can help in entering deeper sleep even in the presence of blue light and other factors that interfere with sleep.

Moreover, the interruption from the blue light in REM sleep can affect memory consolidation. Research by Cousins and Fernandez (2019) has shown that insufficient REM sleep deteriorates both declarative memory (e.g., facts and events) and procedural memory (e.g., skills and tasks). This is because the REM stage is crucial in the sleep cycle to process and store memories. In this phase, our brains sort new information, replaying what we have learned and organizing it for storage. This process strengthens the connections between neurons, assisting in their transfer from short-term to long-term storage. The disruption in REM sleep during this phase of brain activity, can interfere with the consolidation and ultimately, create problems with recalling or holding onto this new information or newly acquired skills.

In most papers that discuss the impact of modern technology and artificial light on sleep architecture, one of the strengths that can be encountered is the study addresses important factors like light use duration and type of devices used and its effects on different sleep stages which are critical to understanding the bigger picture of technology and its effects on health. Besides, sleep architecture sensitivity to artificial light varies with individual differences such as chronological age, actigraphic-derived circadian phase (chronotype: morning or evening

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JISTM
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type) and pre-existing sleep disorder. However, not all studies take these variables into account, resulting in an incomplete picture of this literature, making this a limitation and gap of the study at once. Thus, future research directions can be proposed to investigate how those individual differences may contribute to or exacerbate sleep disorders like insomnia.

Psychological and Behavioral Contributions

Human behavior itself contributes a lot to the prevalence of insomnia. One of which is the new generational issue of doom scrolling. Doom scrolling is the tendency to constantly scroll through a series of fear-inducing news on your mobile phone (George et al., 2024). Due to the emergence of advanced technology, doom scrolling has been more popular among the community. After the pandemic of COVID-19, it is shown that doom scrolling has become more popular as people go on their phones to check on the news of the pandemic (Price et al., 2022). After COVID-19, it is shown that fear-inducing news has been more widespread across the internet as the internet has been one of the most convenient platforms to update the news. Doom scrolling negatively affects the sleep quality of an individual as seeing the bad news constantly before going to bed would increase the cortisol and adrenaline levels due to the stress-inducing materials keeping the body in the state of alertness and would disrupt sleep patterns (George et al., 2024). Because of this, the blue light emitted by mobile devices slows melatonin production which leads to poor sleep quality and poor sleep patterns (George et al., 2024). This acts as a domino effect. Doom Scrolling promotes even a bigger risk than the aforementioned. The apocalyptic news could promote stress and can lead to multiple problems such as intrusive thoughts, nightmares, and emotional disturbance that have the symptoms of PTSD which can lead to poor sleep quality (Price et al., 2022). This research also stated that during the pandemic timeline, the adolescents have spent over 4 hours consuming pandemic-related news showed a staggering 258% higher risk ratio for a trauma or stress disorder as MRI scans reported a threat in neuronal activity in the amygdala and the result also shows the hippocampus shrunken due to the stress and lack of sleep (George et al., 2024).

Aside from the behavior of doom scrolling, general stress could highly impact our sleep quality. Insomnia has been a common problem for college students (Ali et al., 2023). College students have several factors that affect their sleep schedule and later on, affect their sleep quality in general. The first one would be perceived stress which refers to how individuals perceive and interpret the stimulating events and risk factors in their life (Cohen et al., 1983). Perceived stress can negatively predict sleep quality for college students (Abdulla et al., 2023). The physiological evidence is that stress can induce the adrenal cortex and cortisol levels to rise. Due to the rise in the adrenal cortex and cortisol level, it will promote hyper-arousal within individuals which will later cause a significant psychological effect which later affects the sleep quality and merges as the symptom of insomnia (Lu et al., 2024). Research by Lu et al. (2024) indicated that Fear of Missing Out (FoMO) might be a significant variable in predicting insomnia among college students. Fear of Missing Out will lead to the proneness of media usage among adolescents making them addicted to social media which leads to overconsumption of social networks, particularly at night when it makes their quality of sleep disrupted. The desire to stay connected online makes it difficult for the students to manage their sleep schedule which leads to insomnia.

Discussion

It is evident from the research reviewed that the causes of insomnia are integrated and people nowadays are more susceptible to developing insomnia symptoms due to modern technology

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and artificial light. The reviewed articles also point out to the physiological mechanism underlying the circadian rhythm theory and melatonin suppression mechanism. Additionally, the behavioral and psychological understanding were also discussed.

Physiological Mechanisms

The research conducted by Lucas et al. (2001) and Tsuno and Mieda (2024) focus on explaining the effect of blue-wavelength light on the SCN, which is the brain's master circadian clock. The results across experimental research show that exposure to screens at night activates photosensitive retinal ganglion cells in the SCN which is very responsive and sensitive towards light. The consequence of this hypersensitive trigger to light is melatonin suppression, causing disruption in the normal circadian rhythm. Additionally, while experimental studies indicate that melatonin suppression and delayed sleep phases are caused by screens, other studies support this notion by providing neurobiological evidence linking photosensitive retinal ganglion cells to the SCN, which tie up the current physiological mechanism of insomniac-related symptoms (van Drunen & Eckel-Mahan, 2021; von Gall, 2022). It is also noteworthy to mention that individual differences might play an underlying factor in the mechanism explaining melatonin suppression mechanism and the circadian rhythm theory. A study by Ma & Morrison (2023) discusses that heightened susceptibility towards circadian disruption might vary across different sample populations, taking into account factors such as age, chronotype, exposure duration, and light intensity, with adolescents and evening chronotypes appearing particularly vulnerable. These variations highlight that while physiological mechanisms are consistent, their expression is moderated by individual differences.

Behavioral and Psychological Mechanisms

Interestingly, the effect of blue light on SCN is not the only root cause of sleep disruption. Studies have indicated that exposure to screens at night not only invites melatonin suppression but also contributes to insomnia through heightened cognitive and emotional arousal. The main focus of these studies is the social media contents that are consumed before bedtime that are interactive, emotionally aroused and rewarding such as reels, news consumption and gaming-related contents. The engagement with social media activates the dopaminergic pathways associated with motivation and reinforcement, prolonging wakefulness and delaying sleep initiation (Popescu et al., 2021; Omond et al., 2022). Interestingly, another study supporting this notion found that symptoms of insomnia are consistent even after blue light exposure is reduced and screen brightness is controlled, indicating that cognitive and emotional driven arousals may impact disruption to sleep quality (Newsom & Singh, 2024). These two studies combined create a framework in explaining insomnia through the dual-pathway model, which points to physiological circadian disruption, as well as cognitive and emotional arousal, both of which can be caused by excessive screen time usage before bedtime.

Application of past research to this current issue is important for the critical insights into why modern technology and artificial light are such powerful disruptors of sleep. This body of work, accordingly, has enabled a better understanding of the physiological mechanisms involved and has driven public health recommendations to limit screen time before sleep and to implement blue light-filtering technologies. For example, smartphone and computer manufacturers develop settings for the reduction of blue light, such as "Night Shift" or "Night Mode", that lower the amount of blue light emitted during evening hours. These interventions are informed by scientific research in the struggle that has been going on to minimize the effects that artificial light is having on sleep. In conclusion, applying previous findings to the current issue of

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insomnia highlights the complex relationship between blue light exposure and sleep disturbances. Therefore, as technology advances further in integral daily life, understanding and addressing the implications of this disruption will remain key to ensuring good sleep health and quality of life.

Limitations and Future Directions

To inform future studies on this topic, a few limitations and improvements will be discussed. Firstly, all studies reviewed are mainly correlational studies, with no control group, limiting the data from causal understanding. Due to this, the data stated acted as correlational results rather than a valid cause and effect attribution between insomnia and the factors abovementioned (Roth, 2007; Morin et al., 2015). Therefore, future research is encouraged to explore the variables related to sleep disturbances using a controlled and randomized design that can yield causal inferences. Additionally, a longitudinal study of circadian disruption may inform better intervention plans as longitudinal studies can produce dense data on the factors related to insomniac-related symptoms, which are limited for cross-sectional studies. Therefore, this review encourages future researchers to conduct mixed-method and longitudinal design studies that integrate objective sleep measures with behavioral and contextual data, particularly across diverse age groups and chronotypes.

Conclusion

In conclusion, modern technology and artificial light, especially blue light emitted by digital screens have a significant impact on insomnia and sleep in general. This technology, interfering with the circadian rhythm and melatonin suppression, leads to trouble falling asleep, shorter sleep duration, and lower sleep quality. Additionally, excessive screen time increases alertness in brain activity and emotional arousal especially right before bed. Moreover, the psychological effects of screen use include increased stress and anxiety as a result of the constant exposure to stimulating content such as on social media or entertainment platforms. The individual may fall into a never-ending cycle of sleep deprivation created by these psychological factors in addition to the physiological disturbances caused by blue light.

It is very essential to acknowledge the significant role that technology and artificial light play in disrupting our sleep patterns to address this issue. In this sense, initiatives beyond individual levels should be prioritized such as public sleep health education, promotion of healthy technology use before bedtime, and the integration of digital well-being features into modern devices. In the same effort, research regarding this topic must be continued to complement the already existing literature, especially focusing on longitudinal studies and intervention-based experiments to clarify long-term outcomes and evaluate effective prevention as well as intervention strategies.

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