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Mechanisms Underlying the Effects of Electronic Media on Sleep and Corresponding Interventions

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Abstract. Screen-based electronic products have become an indispensable part of modern daily life. Using mobile phones, tablets and similar devices before bedtime has evolved into a common habit across all age groups worldwide. Based on epidemiological investigations, sleep scale statistics and human physiological monitoring data, this paper discusses various adverse effects caused by improper use of electronic devices at night. Data indicate that prolonged pre-bed screen exposure delays sleep onset and reduces total sleep duration. It also disturbs natural sleep rhythms and triggers daytime fatigue as well as emotional fluctuations. Drawing on existing findings in photophysiology, neuroscience and behavioral psychology, this study identifies three major influencing pathways. Short-wavelength blue light emitted by screens interferes with the synthesis and secretion of melatonin. Audiovisual content on digital platforms tends to keep the nervous system in a constant state of excitement. Irregular electronic device consumption gradually breaks the body's stable circadian rhythm. This study proposes targeted interventions in three areas, including personal behavioral constraints, equipment and environmental optimization, and long-term lifestyle cultivation.

Keywords: Electronic devices, Blue light, Melatonin, Sleep quality, Circadian rhythm

1. Introduction

Sleep sustains multiple physiological functions of the human body. It also regulates cognitive ability and emotional status, so sound sleep acts as a fundamental guarantee for physical and mental well-being [1]. Driven by the progress of information technology, mobile phones, laptops and other electronic devices have gained widespread popularity. These tools are applied extensively in study, office work and leisure activities. Using electronic screens before going to bed has gradually become a prevailing social phenomenon. Relevant statistical records show that more than 90 percent of the domestic population accesses electronic devices within one hour prior to sleep. Minors generally spend a relatively long time on such products every day [2]. Along with the universal popularity of electronic devices, sleep conditions among global residents have declined year by year. A series of surveys reveals that teenagers nowadays have much shorter sleep time compared with their peers a century ago. In Chinese universities, the detection rate of sleep disorders has reached 25.7 percent. Problems such as difficulty in falling asleep and chronic insomnia have spread among people of all age brackets [3].

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Research in photophysiology and neuroscience shows that light delivers multiple non-visual physiological effects beyond basic visual functions. Photosensitive cells on human retinas show extreme sensitivity to short-wavelength blue light from electronic screens. These cells take part in the regulation of melatonin secretion and human circadian rhythm [4]. Most mainstream electronic devices on the current market are equipped with LED screens. Man-made blue light released continuously during device operation has turned into a major physical factor disturbing regular sleep. Meanwhile, short videos, online games, social updates and other content stimulate the nervous system and emotions, which further worsens sleep disorders [1].

Numerous research teams at home and abroad have carried out controlled experiments with professional tools including the Pittsburgh Sleep Quality Index, polysomnography and actigraph. The results show that device usage duration, content categories and product types have different effects on sleep conditions [5, 6]. Research on the combined effect of multiple mechanisms and systematic intervention plans remains insufficient. This paper takes pre-bed use of electronic devices as the core research subject. It analyzes negative impacts and explores the underlying mechanisms, before constructing a complete intervention system. The conclusions can fill deficiencies in existing studies, help the public standardize device use and improve sleep quality, and provide a reference for follow-up research in related fields.

2. Negative impacts of electronic devices on sleep

Data collected from cross-sectional surveys, laboratory-controlled trials, and long-term population tracking reveal that pre-bed use of electronic devices affects sleep as reflected in subjective feelings, physical indicators, and daily behavioral patterns. The severity of adverse effects varies greatly with usage duration, screen content and application scenarios [1]. This paper discusses the impacts of electronic devices on human sleep from three perspectives: subjective sleep experience, objective sleep architecture, as well as bedtime procrastination and emotional disorders.

2.1. Decline of subjective sleep experience

Current evaluation of subjective sleep conditions mainly relies on standardized sleep scales and daily sleep logs. Integrated data from multiple investigations suggest that pre-bed screen use impairs sleep experience and raises the risk of insomnia [5]. Special surveys targeting young adults find that people who use electronic devices in bed are more likely to develop insomnia than those who stay away from screens before sleep. A positive correlation exists between screen time and sleep risks. Each extra hour spent on electronic devices before bedtime increases the possibility of sleep disorders. People who stick to such habits tend to suffer from listlessness, poor concentration and physical exhaustion during daytime [3].

Content displayed on screens serves as a key variable that changes the degree of harm. It is found that browsing social media and watching movies and TV programs have stronger negative effects than soothing audio and relaxing videos.

This phenomenon indicates that emotional arousal triggered by different content directly determines the influence on sleep [7].

2.2. Damage to objective sleep structure

Polysomnography is widely recognized as the standard monitoring tool in sleep research. It can accurately record sleep onset latency, total sleep duration, sleep efficiency and the proportion of

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different sleep stages [6]. Multiple research teams have adopted this tool to conduct comparative experiments, separating participants into two groups: one group used mobile phones or tablets before bedtime while the other read printed books. These experiments have drawn consistent conclusions that participants with screen exposure took much longer to fall asleep. The intense light emitted by screens and digital information disrupt the transition from wakefulness to sleep [8].

Using electronic devices reduces rest time. Entertainment activities on screens have no definite end and often cut into sleep hours. This problem is particularly prominent among children and teenagers with weak self-control. Some adults choose to get up late to compensate for lost sleep. This method, however, fails to repair disturbed circadian rhythms, so the human body cannot get sufficient rest [9]. Light from screens disrupts sleep cycles and reduces the proportion of slow-wave sleep and rapid eye movement sleep, the two main stages of deep sleep. Even if total sleep time meets the normal standard, the body cannot complete physical repair. Nighttime screen use also increases the frequency of awakenings during sleep and reduces overall sleep efficiency [8].

2.3. Occurrence of bedtime procrastination and emotional problems

Bedtime procrastination has become a common behavioral issue in modern society. Excessive engagement with electronic devices acts as the main trigger of this problem [10]. Self-control gradually declines after a full day of work and study, so people are less able to resist temptation at night. Entertainment content on electronic devices is highly attractive and addictive. Many people continue to use devices even when they know they should rest. Some individuals regard electronic products as a way to relieve life pressure and release negative emotions, so they intentionally delay bedtime.

A vicious cycle exists between bedtime procrastination and insufficient sleep. Sleep loss leads to mental fatigue and further weakens self-control on the next day. People find it harder to put down electronic devices at night, and procrastination becomes more serious [10]. Long-term improper use of electronic devices before sleep increases the incidence of anxiety and depression. A two-way interaction exists between device use and sleep disorders. Poor sleep drives people to use screens passively on screens, while excessive screen use worsens sleep conditions [1].

3. Core mechanisms of electronic devices affecting sleep

Based on studies on light effects, sleep physiology, arousal theory, and behavioral psychology, researchers have identified three core mechanisms that explain how electronic devices interfere with sleep. These mechanisms do not operate independently. They interact and overlap, leading to various sleep-related problems [1].

3.1. Blue light inhibits melatonin secretion

Melatonin is synthesized and secreted by the pineal gland. It is a vital hormone that induces sleep and maintains circadian rhythms [4]. Melatonin secretion rises naturally in dark environments and brings about drowsiness. Strong light, especially short-wavelength blue light, significantly hinders the synthesis and release of melatonin. Photosensitive cells on human retinas are most sensitive to blue light from LED screens. Human eyes become more sensitive to light after dark, which amplifies the inhibitory effect of screen blue light [2].

Melatonin suppression is cumulative. The inhibitory effect rises sharply when single screen use lasts for two hours or longer [1]. Cool light with high color temperature creates stronger suppression

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than warm light. This accounts for the greater harm of high-brightness screens to nighttime sleep [4]. Insufficient melatonin directly results in difficulty in falling asleep and shallow sleep.

3.2. Audio-visual stimuli cause excessive brain arousal

Audiovisual content on electronic devices activates the arousal mechanism. It keeps the brain and body in an excited state and disrupts the calm atmosphere required before sleep [1]. Online games, thriller videos, trending news and dramatic programs feature fast scene changes, powerful sound effects and complicated emotional conflicts. They raise arousal levels physically and psychologically.

From a physical perspective, intense audio-visual stimuli speed up heart rate and activate cerebral nerves. Muscles and the nervous system stay tense, preventing the body from relaxing and falling asleep naturally. From a psychological perspective, complicated plots and abundant information cause excitement, tension and anxiety. Checking social messages repeatedly also adds to mental stress. Even after people stop using electronic devices, the excited brain cannot calm down quickly. Continuous neural excitement disturbs the whole sleep process and lowers sleep quality. Differences in arousal intensity among content explain the different impacts of screen activities on sleep [7].

3.3. Irregular use disturbs circadian rhythms

Human circadian rhythms are regulated by natural light and follow the day-night cycle [4]. Prolonged use of luminous screens at night equals extra exposure to artificial light. This exposure disrupts the body's day-night judgment and triggers circadian phase shifts [2]. Short-term nighttime screen use directly delays bedtime and disrupts daily schedules. If bad usage habits persist, the shifted circadian rhythm may become fixed and develop into chronic sleep disorders. Mental excitement at night and drowsiness in daytime are typical symptoms of such rhythm disturbance.

Bedtime procrastination worsens schedule chaos and reduces sleep hours [1]. Abnormal light exposure combined with irregular device use disrupts daily routines and threatens sleep health in the long term.

4. Comprehensive intervention measures

Based on the above working mechanisms and practical research findings, this paper constructs a multi-level intervention system from three dimensions: personal behavior management, equipment and environmental improvement, and long-term lifestyle development. The overall plan covers emergency protection, long-term correction, and daily maintenance, and is scientifically sound and practical.

4.1. Personal behavior adjustment

Adjusting personal habits is the most convenient and effective intervention method. People are advised to stop using all screen devices at least one hour before bedtime. If work or academic tasks necessitate screen access, each continuous usage session should be restricted to 30 minutes at most. Immersive entertainment activities must be avoided in such cases [1]. Users should also choose appropriate screen content. Competitive games and thrilling videos should be kept away before sleep. Gentle audio and relaxing videos are recommended to reduce neural and emotional arousal [7].

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People should never use electronic devices in bed. Separating rest areas from entertainment helps eliminate the psychological link between beds and screens, to relieve bedtime procrastination [10]. Those who rely on electronic devices to relieve pressure and loneliness can replace screen time with meditation, deep breathing and gentle stretching. This method fundamentally reduces passive late-night activities.

4.2. Equipment and environment optimization

This part focuses on physical protection to reduce negative impacts brought by blue light and intense light. Users can activate night mode, dark mode and blue light filtering functions on mobile phones, computers and tablets. These built-in functions reduce the output of short-wavelength blue light through software settings [4]. Screen brightness should be lowered when using devices at night. Strong light must be prevented from shining directly into eyes, and screens should not be used in completely dark rooms. Low-brightness warm lamps can be placed indoors to reduce the contrast between screens and surroundings.

For people who need to use screens for long hours at night, blue light blocking glasses or protective films can provide additional protection. Placing mobile phones and tablets far away from beds before sleep also reduces the chance of casual use at night.

4.3. Healthy habit cultivation

Developing long-term healthy lifestyles is a key solution for repairing disturbed circadian rhythms. A fixed schedule of bedtime and wake-up time should be maintained every day, including weekends and holidays. Stable daily routines help restore regular melatonin secretion and normal circadian rhythms [4]. People can form exclusive pre-bed rituals. Reading printed books, soaking feet in warm water and listening to soft music can take the place of pre-bed screen use. Fixed relaxation procedures send sleep signals to the brain and form conditioned reflexes for falling asleep.

Adequate exposure to natural light in daytime optimizes circadian rhythms and improves melatonin efficiency at night. Moderate physical exercise is beneficial, while strenuous workouts are not allowed within two hours before sleep to prevent physical overexcitement [1]. Reasonable arrangement of daily work and study prevents task backlog and late-night work with electronic devices.

5. Conclusion

Electronic devices have become essential tools in modern society. Nevertheless, improper pre-bed screen use brings comprehensive harm to human sleep quality. Such behaviors delay sleep onset, shorten sleep duration, and disrupt normal sleep structure. They also lead to bedtime procrastination, daytime fatigue and various emotional problems. The degree of harm varies with screen content, usage duration and application scenarios. Highly stimulating content and in-bed device use produce the most severe consequences.

Three interconnected mechanisms explain the above phenomena. Blue light suppresses melatonin secretion. Audio-visual content triggers excessive neural excitement. Irregular daily activities disrupt circadian rhythms. These factors interact with one another and continuously threaten sleep health. There is no need to abandon electronic devices completely. Multi-level intervention strategies can effectively reduce adverse impacts. Standardizing personal usage behaviors and optimizing equipment and environments deliver immediate protection effects. Keeping fixed schedules and

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healthy pre-bed habits works for long-term sleep improvement. Joint efforts can minimize the negative influences of electronic devices.

Sleep is the foundation of physical and mental health. In the digital era, establishing proper device use and maintaining regular routines is critical for balancing electronic device use and high-quality sleep. Current research in this field has limitations. Research samples fail to cover all population groups. Studies on two-way causal relationships and neural pathways are still inadequate. Future research can carry out targeted experiments on different groups, explore new intervention methods and promote interdisciplinary cooperation. In-depth studies will provide more scientific guidance for the public to build healthy lifestyles.

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