

## Application of biophilic natural lighting to reduce blue spectrum exposure in dark rooms on children's sleep quality

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received July 07, 2023 Received in revised form Sept. 07, 2023 Accepted November 22, 2023 Available online December 01, 2023</p> <p><i>Keywords:</i> Biophilic natural lighting Blue light Excessive use Gadgets Sleep quality</p> <p>*Corresponding author: Safial Aqbar Zakaria School of Housing, Building and Planning, Universiti Sains Malaysia Email: <a href="mailto:ssafial@usm.my">ssafial@usm.my</a> ORCID: <a href="https://orcid.org/0000-0002-8299-6387">https://orcid.org/0000-0002-8299-6387</a></p>	<p>Technology plays an essential role in people's lives, and gadgets have become a prevalent trend for information and communication. However, excessive gadget use among children can have negative side effects. Children often spend extended periods of time engaged with gadgets, disregarding screen brightness and maintaining a close distance to the screen. Some parents resort to gadgets as a quick way to pacify their children during tantrums. To address the challenges posed by advanced technology, this study aims to observe and interview parents with children aged 5 to 12. According to UC Davis Health in California, blue light, which is emitted by electronic devices, has the shortest wavelength and the highest energy. It can disrupt the production of melatonin, the hormone that regulates sleep. Exposure to blue light in a dark room, such as when children use electronic devices at night, further disrupts their sleep patterns. To mitigate this, the study will explore the implementation of biophilic natural lighting, which mimics the lighting found in nature. The goal is to create a harmonious and healthier environment that connects children with the natural world, promoting their well-being. By conducting a case study involving workers in biophilic and non-biophilic environments and a dark room is not an ideal choice for playing with gadgets, the study aims to investigate how biophilic natural lighting can reduce the exposure to blue spectrum in dark rooms, particularly for children. The ultimate objective is to determine the impact of biophilic natural lighting on children's sleep quality and propose effective lighting strategies to improve their overall sleep quality. The results of this study will demonstrate the significant improvement in children's sleep quality with the implementation of biophilic natural lighting, providing valuable design guidelines for creating healthier environments for children.</p> <p><i>Keywords:</i> Biophilic natural lighting, blue light, Excessive use, Gadgets, Sleep quality.</p>

### Introduction

Biophilia means "a love of nature". Biophilic design is the way in which architects incorporate nature into building spaces to contribute to the health and well-being of occupants (Nugroho 2021). Biophilic natural lighting will be focused in this study to reduce blue spectrum exposure especially in dark rooms on children. Biophilic

natural lighting refers to the use of natural light in indoor spaces to enhance human well-being and connection with nature. The concept of biophilia, which suggests that humans have an innate affinity for nature and natural elements (Karima, Firzal, and Faisal 2020; Bahauddin, Prihantmanti, and Ong 2021). By allowing natural light to penetrate indoor spaces, it creates a connection between the indoors and outdoors, providing a

sense of openness and a visual connection of nature. Nowadays, technology is growing. Children are also exposed to gadgets at a young age. Parents are not aware of the negative effects that their future children will face if they spend a long time playing with gadgets (Tirayoh and Dja'far 2021). Gadget devices emit blue spectrum which is dangerous to health. Moreover, it is played in a dark area. This 'comfort zone' should be avoided. Blue light has the shortest wavelength and the highest energy energy that can reduce the production of melatonin (UC Davis Health in California). Basically, they spend a lot of time with their gadgets while ignoring the screen brightness and having a very near screen distance from their eyes. A healthy circadian rhythm tells the brain to be awake during the daylight hours and to sleep at night. A child's circadian rhythm begins developing around 3-4 months of age. (National sleep foundation 2018).

This study to investigate the impact of biophilic natural lighting on children's sleep quality. Children who are exposed to gadget devices will cause their sleep cycle to be disturbed (Hai 2019). It is because the exposure of the gadget has caused a reduction in the secretion of the hormone melatonin. It is dangerous in dark spaces because the exposure will give a signal to the brain as if it were daytime. Melatonin helps us sleep naturally and it typically rises in the evening as we approach bedtime. With less melatonin being produced at bedtime, kids may be less sleepy, unable to fall asleep, or not sleep as well (Dr. Aujla (2021)). So, to improve their sleep quality, researcher will propose the effective lighting for children to improve their sleep quality. Natural light plays an important role in setting the rhythm of people's internal clocks (National Sleep Foundation 2018).

#### Literatur review

##### Children and sleep

(Dr Rajini Sarvananthan), consultant development paediatrician.

How much sleep is needed? Children need different amounts of sleep according to their age. They are advised to follow the guidelines given below to ensure children get enough rest:

Age: 3-6 years old;

The duration of sleep (per day): 10-12 hours.

At this age, sleeping during the day is not necessary. Let the children sleep for a while but keep the same bedtime/wake: Age: 7-12 years old  
The duration of sleep (per day): 10-11 hours

At this age, mske sure that the children sleep at 9pm to get enough rest.

##### Technology's impact on sleep

(Dr. Michael Breus, PhD, DABSM, FAASM)  
Clinical psychologist, sleep medicine expert (Breus 2023).

Nowadays, technology used to facilitate education, communication, and entertainment, and technological devices have become a crucial element of navigating daily life. Some devices may interrupt or negatively impact sleeping patterns. These include laptops, tablets, smartphones and televisions. All of this that which features screens that emits blue light. Overexposure to blue light in the evening can make it more difficult to fall and remain asleep. Studies shows that screen time before bed can increase the amount of time it takes to fall asleep, reduce sleep quality, and affect attentiveness the following day. In the long term, nightly exposure to light in the evening may increase the risk of certain sleep disorders and cancers.

Technology can affect sleep on multiple levels: (1) Interference with circadian rhythm: exposure to blue light suppresses the production of melatonin, a hormone that includes sleepiness. This is actually an advantage during the day because it keeps people feeling alert and refreshed. However, melatonin release in the evening helps people relax before their bedtime. Suppression of melatonin can cause to stay up later and sleep less than you normally would; (2) Excessive brightness in sleeping areas: household LED lights also emit blue light. Though do not stare directly into people like smartphones, and other devices. It is important to dim other bedroom lights or switch to warm lighting to reduce to blue light before sleeping; (3) Overly stimulating content: Studies have found that exciting or violent video games increase heart rate, make it harder to fall asleep, and impair sleep quality. This may have a stronger impact on sleep.

["The Effects of Exposure to Natural Light in the Workplace on the Health and Productivity of Office Workers: A Systematic Review Protocol" 2010](#)

(JBI Library of Systematic Reviews)

Humans spend a lot of time indoors, especially using computers for work and leisure, leading to a more sedentary lifestyle. Office workers are a significant part of both the healthcare and

business sectors. Managing human resources efficiently and sustainably benefits businesses, employees, and the wider economy. By minimizing costs is important, particularly during economic crises, while global awareness of environmental responsibility and resource conservation grows. Considering the productivity of human resources and the costs of building and maintaining structures, it is logical to create healthy and sustainable environments that enable employees to function optimally in the long term. The objectives of this review are to examine studies evaluate offices with windows to the external environment which permit the entry of natural on the health and productivity of the workers as monitored by output, staff turnover, sickness and absence from work and measures of their health status. Sunlight consists of UVA and UVB radiation, with UVA contributing to skin cancer and UVB enabling vitamin D synthesis. Spending a few minutes outdoors daily allows the body to produce adequate vitamin D, even if received through glass windows. Vitamin D deficiency has been linked to various ailments, including cancers, multiple sclerosis, and cardiac abnormalities. Reduced sunlight exposure has also been associated with health issues like reduced melatonin levels, stress, sleep deprivation, and alter menstrual cycles. Exposure to natural light offers multiple benefits, including vitamin D synthesis and regulation of circadian rhythm. Sunlight triggers melatonin production, vital for maintaining a healthy sleep-wake cycle. Seasonal Affective Disorder (SAD) is a condition associated with reduces sunlight exposure in higher latitudes, leading to mood changes, lack of energy, and sleep difficulties. Humans require bright daylight exposure during the day and complete darkness at night for optimal sleep, happiness, and overall well-being. Sunlight exposure is undoubtedly beneficial, but determining the right amount remains a challenge.

#### Blue light and melatonin

Melatonin is a hormone that promotes feelings of sleepiness, and blue light suppresses the production of melatonin. Humans need to maintain a sleep-wake cycle based around the rising and setting of the sun. When someone exposed to natural light from the sun, melatonin levels are low during the day, then increase in the evening following sunset, after that reach their

peak in the middle of the night and lastly gradually decrease until morning. Exposure to blue light during the day from sunlight or other sources is a healthy promoter of energy and concentration. However, using devices that produce artificial blue light in the evening and night time disrupts children's natural sleep-wake cycle by tricking the brain into not producing melatonin before sleep.

Blue light can be especially harmful to children's sleep.

Sleep is a critical aspect of health. This research will be focus on children because they are still too young and sensitive. When they watched more television, used a computer, played video games, or used smart phones before bedtime not only experienced disruptions to sleep quality and quantity, but were also more likely to be overweight. This will be another health effect for them. This will be worse when they play gadgets in a dark room or at night. It will interfere with the melatonin hormone that controls their sleep time. When their sleep is disturbed, they will be tired and easily feel angry or hot-tempered. This is certainly not good at such a young age. This study found that there is a difference for the kid's rating of simulating interior scenes. These interior scenes will be placed in a dark rooms and bright rooms. A dark room is a comfort zone for children to play gadgets because it does not glare and hide from the knowledge of parents to play gadgets for a long time while, bright room due to the observation of sunlight entering the space from the window can reduce exposure to blue light and at the same time children's bodies can absorb Vitamin D from the sun source. So, researchers will apply biophilic natural lighting in dark rooms to reduce the blue spectrum radiation from gadgets to children for their sleep quality (Tosini, Ferguson, and Tsubota 2016).

#### Method

This section discusses research methods and methods of obtaining information and data. This method is used to ensure that the objectives of the study can be achieved according to valid and reliable data. To collect primary data, field observation and key informant interviews were carried out. In addition, a case study is done to

collect secondary data. After that, all the data is analysed and discussed.

#### Structured interview

A structured interview will be conducted through questionnaires to parents who have children aged 6 to 12 years in Malaysia as the main target group to obtain primary sources and a more realistic view related to the topic being studied in close relation to the current scenario which is children who are addicted in gadgets (I et al. 2018). The 5 questions raised in this study revolved around these aspects:

- Q1. How often does your child use gadgets such as smartphones, tablets or computers on a daily basis?
- Q2. What activities do you notice your child engaging in on gadgets? (e.g., gaming, social media, video streaming)
- Q3. Have you noticed any difficulties your child faces in falling asleep or staying asleep after using gadgets?

- Q4. Do you encourage your child to have a “screen-free” period before bedtime? If yes, how long is this period?
- Q5. When your child is playing with gadgets, do you pay much attention to the lighting around your child? Whether it is a dark or bright space

#### Observation

Through this study, the researcher observes the situation around children who often play with gadgets. The researcher conducts structured observation where the researcher observes behaviour and events in a controlled and structured environment. In this observation, a set of instructions includes a list of behaviours to be observed and ways to record the data. It allows researchers to compare and analyse behaviour consistently among children.

**Table 1.** List of observes doing observational studies

Part 1: gadgets available at home	Part 2: distance and lighting	Part 3: outdoor activities
1. Hand phone	8. The distance between the child's vision and the gadget.	11. Self-defense arts
2. Computer/Laptop	9. Type of home lighting when kids see their gadget etc. at night.	12. Football
3. Internet access	10. Type of room light.	13. Fishing
4. I-pad		14. Playground
5. Digital camera		
6. Game (Playstation, hand-held game etc.)		
7. DVD player		

#### Case studies

A dark room is not an ideal choice for playing with gadgets

Using gadgets before bedtime is harming kids' sleep. Children might have trouble falling asleep or is waking up during the night, because of exposed of gadgets before bedtime (German Press Agency 2021). There are many argue by many experts for years about the advantages and disadvantages of using technological goodies in daily life. Gadgets seem to be easing to life nowadays, but the situation sharply changes when the topic comes to sleep. Electronic media use by children generally results in less sleep and many cases poor sleep as well. (Danish National Institute of Public Health, University of Southern Denmark in Copenhagen) reported in a systematic review of previous studies. The display of blue light emitted by electronic devices such as gadgets, can disrupt the production of melatonin and interfere with healthy sleep rhythms. This can



cause trouble sleeping, sleep disturbances, and a feeling of not being awake at night. As an alternative, it is recommended to avoid using gadgets before bed and the bedroom should be dark and quiet to help sleep quality and help melatonin production.

#### Subjective impression of an office with biophilic design and blue lighting

A workplace is a place where employees spend their time working for their survival (Xie et al. 2022). The environment in the indoor space should always be healthy so that the workers are always healthy. The main part of this study has been conducted to examine the benefits of bringing nature indoors, which focus on access to daylight (with or without view) and indoor plants. The application of biophilic design in this study is because employees are exposed to computers throughout their working hours (Kellert and Calabrese 2016). So, with this biophilic design, it

can reduce exposure to blue light. Daylight through windows has an essential impact on human health and well-being as it regulates their biological clock and influences their psychological states. This study is an exploration to investigate people's subjective impressions of an office with the two interior design strategies. There are two patterns in this study were represented namely, "visual connection with nature" and dynamic and diffuse light". This study aims to collect people's ratings and rankings of four simulated interior scenes of a private office using an online survey. From a biological perspective, melatonin is especially suppressed by short-wavelength (blue shifted) light, influencing the circadian rhythm. Disruptions to the circadian rhythm can further cause mood disorders. The superiority of short wavelength light on sleepiness reduction due to melatonin suppression. This research sheds light on the positive impact of biophilic design strategies on office space perception and highlights the negative influence of blue lighting. The findings provide valuable insights for creating satisfying and conducive office environments. However, further research in real-world settings and addressing the limitations identified in this study are necessary to strengthen the understanding of these effects.

**Table 2.** The four rendered scenes of an office with different interventions

Rendered scenes	People's impressions
 <p>Office (a) Baseline</p>	The baseline office was devoid of a biophilic design with typical white lighting.
 <p>Office (b) Blue Lighting</p>	Regarding blue lighting, previous studies have suggested its positive effects on alertness, cognitive performance, and emotion through a non-visual pathway. Blue lighting had a detrimental impact on participants'

Rendered scenes	People's impressions
 <p>Office (c) Indoor Plants</p>	Indoor plants proved to significantly enhance participants' perception of the simulated office, making it appear more lively, interesting, cheerful, appealing, and brighter compared to the baseline office. This suggests that participants' brightness perception is not solely influenced by light intensity.
 <p>Office (d) Daylight and View</p>	Access to daylight and an outdoor view outperformed indoor plants in all examined perceptual categories. Participants perceived the office space to be brighter, more spacious, and more comfortable with daylight and view access. However, it may not always be feasible or cost effective to provide daylight and view access in existing spaces without windows.

## Result and discussions

The analysis and findings presented in this study are based on comprehensive research approach that integrates interviews, observations, and case studies. By employing a multi-method approach, researcher aimed to gather rich and diverse data that would provide a holistic understanding of the research topic. By combining these methods,

researcher aimed the data, validate the findings, and provide a comprehensive analysis.

Children's assessment of spaces with biophilic design and blue lighting

Biophilic design, originating from the concept of biophilia, hypothesizes that humans have an innate connection with nature. This notion into the design of a built environment. To address the research gap from this study, application on biophilic natural lighting towards children is more effective because children who are emitted from blue light exposure in dark areas are very dangerous and their health level will be low. When children are exposed to blue light, it is important to ensure natural lighting from window openings and wide spaces so that blue light does not fill a narrow space. Researchers found a gap between previous studies to evaluate children who play electronic devices between dark and small rooms and bright rooms with natural light and views. The concept of 'biophilic' natural lighting is very strong to prove that studies on office workers and studies on children are good to practice. A study of these two spaces where children spend their time for playing gadgets. The environment in the indoor spaces should always be healthy so that the kids are always healthy. The application of biophilic design in this study is because children are exposed to gadgets throughout their daily life. So, with this biophilic design, it can reduce exposure to blue light (Juntti 2018).

The results of observations and interviews from respondents

Upon the identification of the above mentioned questions and the selection process of interviewees, 5 respondents who have children between the ages of 5 and 12 were further approached and interviewed as presented in table 3.

**Table 3.** Interviewees details

Interviewees	Background
1. Jamariah binti Ahmad	A full-time housewife for 15 years who has had 3 children among them aged 13 years, 8 years, and 3 years.
2. Noraniza binti ahmad	A housewife after quitting her job because she wants to take care of 3 children aged 8 years, 6 years and 1 year.

Interviewees	Background
3. Norhayati binti Kassim	A housewife and runs a small business to support 3 children who are 14 years old, 10 years old and 4 years old.
4. Yusmawati binti Abdullah	A person who works for the government and has 4 children aged 12 years, 10 years, 8 years and 1 year.
5. Faziera binti Dahlan	A person who works as a bank officer who has a child who is 5 years old.

This interview and observation session is conducted simultaneously by the observer. Most of the respondent said that their children played gadget in various spaces. According to Jamariah (respondent 1), her 13-year-old son was in the dormitory, while 8-year-old and 3-year-old lived with her. Her 8-year-old son often plays on her mobile phone when she comes home from school until the evening and will continue at night. While her 3-year-olds often watches television like cartoons. What can be observed here, the environment around them is hand phones and televisions. According to respondent 1, her son would play on her mobile phone in the living room together with his younger brother who was watching television. It is true that looking at electronic devices in bright areas can reduce blue light radiation, but it is also not good for their health when asked about outdoor activities, they are less exposed by playing with friends. So, they prefer to spend time with gadgets. According to Noraniza (respondent 2), her children will play on her mobile phone when they come home from school to look at social media and games and will stop playing in the evening because friends invite them to play outside the house. This family has a laptop, television and mobile phone. What can be observed, the interior of the house for respondent 2 is quite dark because less daylight enters the interior space and finally they have to switch on fluorescent lights during the day to get enough light. Sometimes, her children play mobile phones in dark areas because of the heat emitted from the lamp.

According to the researcher, the exposure of blue light to the child of the third respondent, Norhayati binti Kassim, is the most dangerous because she will give gadgets such as tablets to her 4-year-old child before going to bed. According to her, she was very tired because she managed the house and managed a small business. So, to ensure to rest at night, she will give the

gadget to her son to sleep. Their bedroom environment does not have any light when sleeping except for the light from the gadget. The sight distance is also very close to her son. Her son would fall asleep on her own and the gadget would still be lit. The bright screens and engaging content can over stimulate children's brains. It is not an easy way to sleep but makes it challenging for them to relax and calm their mind to sleep.

For respondents 4 and 5, there is not much difference between them because they both work and use gadgets as a medium to calm their children. According to Yusmawati, they play PlayStation in a dark room while specially designed with LED lights with the aim of getting the 'mood' to play. Naturally, the installation of LED lights in a dark room while playing PlayStation is not very dangerous in terms of health. However, too much blue light display emitted by LED lights can affect their sleep patterns. As discussed, blue light exposure can interfere with the production of melatonin, which is a hormone that helps regulate the sleep cycle and waking up from sleep. According to Yusmawati again, when they play the PlayStation at night, the next morning it is very difficult for them to wake up to get ready for school. This proves that the display of blue light has affected the quality of their sleep. For the last respondent, Faziera binti Dahlan, her 5-year-old son was exposed to gadgets such as mobile phones. This respondent realized that her daughter likes to cry and it is difficult to control the situation, the gadget is the last option to calm her daughter down by watching the YouTube application. This is not good when young children have been brought up with gadgets.

The influence of biophilic natural lighting in a dark room on children's sleep quality

Based on the case study, which is a comparison between 4 types of scenes in the interior of the office, it shows that 'biophilic' design is a good design to use. The use of biophilic natural lighting in dark rooms can help mitigate this effect by providing a more balanced and soothing light environment. Research has shown that natural light exposure during the day can improve circadian rhythms and increase overall sleep quality (Kritikos 2020). Additionally, exposure to natural light can reduce the amount of blue light exposure at night, as the body becomes more sensitive to natural light cues that signal onset of sleep. By incorporating

biophilic natural light sources into the design of a space, the negative impact of blue light exposure on sleep quality can be reduced. One study found that children who were exposed to natural daylight during the day and dim light in the evening had significantly better sleep quality than those who were exposed to bright light during the day and blue light from electronic devices at night (Summer and Vyas Nilong 2023). Another study found that children who slept in a room with a skylight had more restful sleep than those who did not (Journal of clinical sleep medicine 2014).

In conclusion, incorporating biophilic natural lighting into the design of dark rooms can be an effective strategy for reducing blue light exposure and improving the sleep quality of children. By taking advantage of natural light sources and designing spaces with biophilic natural lighting in mind, designers can create more healthful and supportive environments for children's growth and development (Veitch 2005).

## Conclusions

In conclusion, the application of biophilic natural lighting in dark rooms can effectively reduce blue spectrum exposure and positively impact children's sleep quality. Blue light or blue spectrum, especially from electronic devices, has been found to suppress the production of melatonin, a hormone that promotes sleepiness. By incorporating natural daylight into dark rooms, create a sleep environment that aligns with human natural sleep-wake cycle and supports healthy sleep patterns. So, exposure to natural daylight during the day and dim light in the evening leads to better sleep quality in children compared to bright light during the day and blue light exposure at night.

Based on the findings, some suggestions for applying biophilic natural lighting to reduce blue spectrum exposure in dark room and improve children's sleep quality: (1) Incorporate windows or skylights. Introduce natural daylight into the room by installing windows or skylights, which allowing the entry of sunlight during the day. This exposure to natural light helps regulate the body's internal clock and enhances the production of melatonin; (2) Limit electronic device usage: Encourage children to avoid using electronic devices, such as smartphones, tablets, and televisions, in the evening or at least an hour

before bedtime. These devices emit blue light that can disrupt sleep patterns; (3) Establish consistent sleep routines: Encourage a consistent sleep schedule and bedtime routine for children, including dimming the lights in the room gradually leading up to bedtime. This signals the body to start producing melatonin and prepares kids for a restful sleep.

By implementing these suggestions, parents can optimize the benefits of biophilic natural lighting, reduce blue spectrum exposure in dark rooms, and enhance children's sleep quality (Boubekri et al. 2014).

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## Author(s) contribution

**Nur Atiqah Ahmad** contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

**Safial Akbar Zakaria** contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.