Light Behind Bars: How light impacts mental health in prisons

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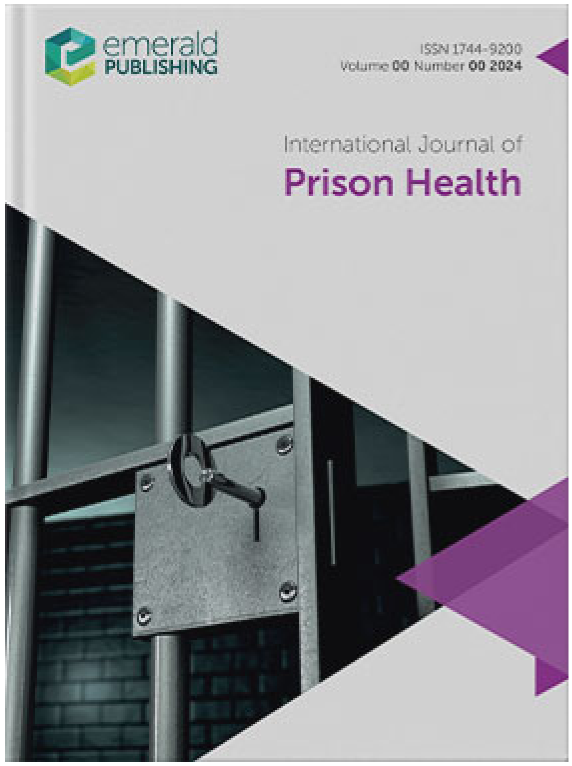

Light Behind Bars: How light impacts mental health in prisons

Journal:	*International Journal of Prison Health*
Manuscript ID	IJOPH-11-2024-0074.R1
Manuscript Type:	Research Paper
Keywords:	Non-visual, Circadian, Prison design, Mental health, Rehabilitation, Daylight

Light Behind Bars: How ~~Light Impacts Mental Health In Prisons~~light impacts mental health in prisons

Abstract

Purpose:

~~The purpose of this~~This paper ~~is to synthesise~~synthesises literature on ~~the~~ non-visual effects of light ~~and the~~in prison ~~environment, highlighting the~~ environments, drawing attention to disconnect between research evidence and current practices. ~~By confronting research findings with existing prison conditions, it~~It aims to guide prison designers and ~~authorities~~decision-makers toward ~~adopting~~ lighting strategies that ~~protect~~ better support inmates' mental health and ~~support~~ rehabilitation ~~outcomes..~~.

~~*Design/methodology/approach*~~

Methodology/Approach:

A focused literature search was conducted from June to October 2024 using Google Scholar and PubMed ~~to identify~~, targeting peer-reviewed studies ~~relevant to~~ published between 1985 and 2024. Included studies addressed the ~~following topics:~~ non-visual effects of light~~,~~, related to circadian rhythm ~~and light~~, mental health ~~and light, daylight exposure and natural light~~, artificial ~~light,~~and natural lighting ~~design in prisons~~, stress ~~and~~, aggression ~~related to lighting, rehabilitation and prison environments, melatonin~~, and hormonal regulation~~, and psychosocial and architectural interactions~~. Only English-language studies providing empirical or theoretical insights relevant to confinement settings were considered. Studies focused solely on visual performance, non-human subjects, or lacking health implications were excluded. Keyword combinations were refined iteratively, though some relevant interdisciplinary work may have been missed due to indexing or terminological variations.

Findings:

~~This paper highlights~~Neglecting the ~~impact~~role of ~~neglecting natural and artificial light~~ lighting in prison design ~~on inmates'~~contributes to poor psychological ~~well-being. Insufficient natural light~~outcomes. Limited access to daylight and ~~poorly managed~~ the overuse of artificial lighting ~~exacerbate mental health issues. The widespread use of~~ with high blue light content ~~in prison lighting disrupts~~disrupt circadian ~~rhythms, leading to~~ regulation, worsening sleep ~~deprivation and hormonal imbalances. In contrast, prioritising natural light access and implementing balanced,~~ , mood, and mental health. Conversely, designs that maximise daylight exposure and use adjustable artificial lighting with appropriate spectral qualities can ~~improve mood,~~ promote emotional stability, reduce aggression, and support ~~circadian health, fostering better mental health and social outcomes in prison.~~rehabilitation.

Original Value

This paper bridges the gap between lighting design, environmental psychology, and prison reform. By focusing on how light affects inmates' psychological health and rehabilitation, it ~~contributes new~~offers insights into how prison design can be improved to foster well-being.

Keywords:

Non-visual; Circadian; Prison design; Mental health; Rehabilitation; Daylight; Artificial lighting

Introduction:

Research in environmental psychology has consistently shown that environmental stimuli significantly affect cognition, stress, mood, and overall behaviour (Babin *et al.*, 2003; Hoffmann *et al.*, 2008; Knez, 2001). These studies underscore the importance of the physical environment in shaping how people think, feel, and act. ~~While~~However, while much of this research has focused on settings like workplaces and hospitals, its implications are especially crucial in prisons, where the environment can ~~have profound effects on~~ create suboptimal conditions that undermine rehabilitation by fostering environments detrimental to inmates' psychological and physiological well-being~~ and rehabilitation outcomes.~~. In this context, both natural and artificial light ~~plays~~play a critical role~~, as it has been demonstrated to impact mood, stress levels, and cognitive performance. Thus, light~~ and should be ~~carefully considered in~~thoughtfully integrated into prison design as an architectural tool to promote ~~better~~ mental health and support rehabilitation.

Although people may not always be aware of it, living with limited or no access to natural light for extended periods of time can lead to both physical and psychological consequences. ~~The~~Indeed, the connection between light and human health was not fully understood until the early 2000s when the discovery of a third type of photoreceptor ganglion in the retina revealed how light influences psycho-biological functions (Berson *et al.*, 2002). This discovery has spurred extensive research into the effects of light on circadian rhythms and overall well-being, which has important implications for environments where people are confined for long periods of time, such as prisons. Proper management of daylight and the selection of artificial light sources on these facilities can significantly improve the conditions for both inmates and staff, yet these factors are often overlooked in current prison designs.

Research on the effects of light on mood and behaviour has been well-documented in workplace environments, where both natural daylight and artificial lighting have been found to improve mood, productivity, and overall performance (Hoffmann *et al.*, 2008; Knez and Kers, 2000; Leichtfried *et al.*, 2015). For instance, studies by Boyce (2003) have shown that daylight can positively affect ~~employee's~~employees' mood and has tangible financial benefits for organisations. Similarly, in hospitals, the right lighting has been linked to better patient and staff well-being, and even reduced recovery times (Joarder and Price, 2013; Joseph, A., 2006). These findings highlight the power of light to improve outcomes in environments that support healing and performance, making it clear that prisons~~—~~, where conditions often exacerbate stress and aggression~~—~~, could benefit from similar approaches.

The well-established relationship between light and the circadian rhythm has also led to significant findings on its impact on psychological and mental health disorders. Research has demonstrated that light influences sleep quality, and alertness, and can alleviate symptoms of insomnia, depression, and even suicide (Czeisler and Gooley, 2007; Kamphuis *et al.*, 2014). In the context of prisons, where many inmates experience mental health issues exacerbated by confinement, proper lighting could help mitigate these problems by regulating circadian rhythms and improving overall mental health.

However, despite the wealth of evidence regarding the psychological and physiological benefits of light, a gap exists in its application to prison design. This gap prevents prison authorities and facility designers from making informed decisions that could improve inmates' mental health and rehabilitation prospects. Consequently, many prison lighting systems are designed with a focus on security and restriction, rather than well-being, which only serves to reinforce the challenging and often harmful environment for inmates.

The purpose of this paper is to consolidate the existing knowledge on how light affects human mental and psychological health and to explore how improper management of daylight and artificial lighting can exacerbate conditions in prisons. Based on this, ~~I~~this paper will propose recommendations for integrating this knowledge into prison design to improve the well-being of inmates. The paper will first explain the properties of light, the human perception of colour and brightness, and the non-visual effects of light on circadian rhythms. Next, ~~we~~it will examine the psychological and mental health challenges faced by prisoners and how light can help alleviate these issues. ~~We~~It will then discuss the role of lighting design in shaping prison environments and its effects on inmate well-being. Finally, the paper will provide recommendations for integrating light into prison design to optimise rehabilitation outcomes and improve conditions for inmates.

What is light?

Light is just a small part of a larger phenomenon known as electromagnetic radiation (ER), the process by which energy moves through space. Electromagnetic radiation encompasses a wide range of types, categorised into seven main components: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

Every second, the Sun—like all stars—emits vast amounts of energy that radiate outward in all directions as ER. This energy travels through space in waves of all seven types simultaneously, interacting with everything it encounters, from planets and moons to meteors.

These waves vary greatly in the lengths of each full cycle, a property known as wavelength. Some are incredibly short, such as gamma rays, with wavelengths smaller than 0.01 nanometres, while others, like radio waves, can stretch to 100 kilometres or more.

Electromagnetic radiation (ER) is perceived by humans (and other animals) through specialised sensors in the retina of the eye. However, these sensors are not capable of detecting the entire range of ER wavelengths. Instead, they are sensitive only to a ~~specific~~very narrow band of wavelengths, measuring approximately 380 to 780 nanometres—a range ~~we refer~~usually referred to as visible light.

The ~~retina contains three types~~discovery of light-sensitive sensors ~~for~~in the retina, responsible for detecting electromagnetic radiation ~~(ER), known as~~ and sending this information to the brain for interpretation, is attributed to Carl Bergmann in 1854 (Thibos, Lenner, & Thibos, 2023). He identified two distinct types of photoreceptor cells~~. Two of these,~~: cones and rods~~, are part of the~~. These cells make visual ~~system and play a crucial role in transmitting information to the brain's visual cortex,~~perception possible by enabling the ~~perception of~~brain to form images and ~~the decoding of~~interpret colours. Named for their shape ~~when observed~~ under a microscope (van Bommel, 2006), cones are responsible for detecting colour sensitivity, while rods are primarily involved in detecting brightness and enabling vision in low-light conditions.

Because daylight comprises a broad range of wavelengths within the visible spectrum, our brain decodes this as bright white light. When these wavelengths encounter an object, some are absorbed while others are reflected, depending on the material's reflective and absorptive properties. The reflected light reaches the eye, where cones and rods detect the new combination of wavelengths, and the brain, after processing this information, associates the result with specific colours.

Artificial lights, in contrast, do not always produce the same colours in objects because light sources are usually composed of waves highly concentrated in some areas of the visual spectrum, with a minimum or even without any presence of some wavelength existents in daylight. This absence of several parts of the visual spectrum affects colour perception ~~throw~~through the variation of visual information sent to the brain by rods and cones.

The concept of Correlated Colour Temperature (CCT) of light

Although colours are ultimately subjective perceptions, ~~we~~scientists categorise different types of light by associating each wavelength within the visible spectrum with a specific Correlated Colour Temperature (CCT). CCT represents the temperature of an idealised object, called a "black body," which absorbs and emits all colours of light perfectly. To understand this, imagine heating a piece of metal until it starts to glow. As the temperature rises, the metal changes colour, starting from red, moving to orange, and eventually to blue, depending on how hot it gets. This idealised "black body" would glow in a similar way, and the temperature at which it glows a particular colour is measured in Kelvin (K) (Boyce, 2003).

Therefore, light with shorter wavelengths in the visible spectrum, such as violet, around 400 nm, and blue, around 450–500 nm, ~~-~~is associated with higher correlated colour temperatures (CCTs), typically exceeding 5000 K, which gives it a "cool" appearance. In contrast, longer wavelengths like red, around 650–700 nm, and orange, around 600 nm, correspond to lower CCTs, often below 3000 K, creating a "warm" tone. Between these extremes, wavelengths in the green and yellow range, approximately 500–600 nm, contribute to intermediate CCTs, such as 4000–5000 K, resulting in a "neutral" white light. This correlation arises from how human vision interprets the mixture of spectral energy, shaping the perceived colour tone of light sources.

Nonvisual effect of ~~lighting~~light

While this mechanism of colour detection and decoding has been understood since the 1850s, the broader impact of light on physiological functions in humans and animals was only discovered in 2002 (Berson *et al.*, 2002). This breakthrough came with the identification of a third type of photoreceptor in the retina, distinct from the visual system. Known as the intrinsically photosensitive retinal ganglion cell (ipRGC), this photoreceptor contains a photopigment called melanopsin, which is most sensitive to short wavelengths of visible light, peaking at approximately 480 nm in the blue region of the spectrum (Lucas *et al.*, 2014). Although ipRGCs account for just 1% to 5% of the total ganglion cells in the mammalian retina, it has been shown ~~that~~ they play a crucial role in regulating non-visual biological processes, including melatonin production, body temperature, cortisol secretion, and alertness (van Bommel, 2006).

The information captured by ipRGCs is sent to the Suprachiasmatic Nuclei, situated not in the visual cortex but in the centre of the brain~~.~~ (see Figure 1). These signals are processed and transmitted to the pineal gland, which regulates various psychobiological functions by secreting hormones and controlling the sleep-wake cycle, which is commonly known as the circadian rhythm (Braun *et al.*, 2009). It is important to mention that ipRGCs can detect radiation of bluish 480 nm ~~of~~ light even when the eyes are closed, sending signals to the Suprachiasmatic Nuclei even during sleep hours.

Insert Figure 1 here

Caption: Light and its physiological links (Image by the author)

In the late evening, when it becomes dark, and the proportion of bluish light is minimal or inexistent, Melatonin production rises, promoting healthy sleep. Conversely, during the early morning, the proportion of 480 nm bluish light is high, and the detection of this light by the ipRGCs results in the suppression of melatonin to induce alertness (Boyce, 2003; Lucas, 2014).

On the other side of the cycle, the production of cortisol hormone is also regulated by the detection of bluish light through the ipRGCs~~.~~ (Boyce, 2003; Figueiro, 2010). In the early morning, when the brain detects that daylight contains sufficient bluish light, it activates the mechanism to produce cortisol, which in turn increases blood sugar levels~~ enhancing~~, enhances the immune system, thus creating alertness and preparing the body for the day's activity. Because of this, cortisol is called the hormone of stress. After this peak, cortisol levels gradually decrease throughout the day, reaching their lowest levels in the evening and night, just before sleep.

~~Disruption~~The disruption of~~ this~~ circadian rhythm has been linked to various challenges in people's daily ~~life~~lives. Research has extensively explored how inadequate light exposure schemes can contribute to disorders such as insomnia (Lack *et al.*, 2023, 2023; Walker *et al.*, 2020), depression (de Leeuw *et al.*, 2023; Samanta and Bagchi, 2024; Zhang *et al.*, 2024), and anxiety (Boiko *et al.*, 2022). For example, Lack *et al*~~(~~. (2023) found that sleep onset insomnia is associated with later-timed circadian rhythms and can be treated with morning bright light therapy to shift rhythms to an earlier timing. A 2024 longitudinal study on 543 participants found significant associations between depression severity and circadian rhythm features, such as heart rate peak timing and sleep duration (Zhang *et al.* 2024). ~~Similarly,~~Further evidence by Samanta and Bagchi (2024) ~~reported~~shows that circadian rhythm disruption causes impaired neurotransmitter release, altered melatonin and cortisol rhythms, metabolic dysfunctions, and neuroinflammation, all of which contribute to the development of psychiatric disorders, including depression.

In prison environments, where artificial lighting is often constant or poorly regulated, exposure to light at night (LAN) typically falls within the range of 100–300 lux, which is enough to alter circadian rhythms and negatively affect mood (Walker et al., 2020). Despite the lack of direct circadian studies in prison environments, a longitudinal study conducted in the similarly demanding environment of healthcare facilities underscores the potential for intense work schedules to disrupt circadian rhythms. This study, involving 833 medical interns tracked for over 52,000 days, demonstrated a significant increase in circadian misalignment between their central oscillator and sleep midpoint, rising from 1.67 to 2.19 hours during demanding schedules (Lee et al., 2024). This misalignment was strongly associated with depressive symptoms such as disturbed sleep, poor appetite, and overeating. These findings are relevant to prison populations, where both inmates and staff are exposed to erratic light–dark cycles and high stress. Moreover, individuals with altered melatonin and cortisol rhythms, such as those with autism spectrum disorder, are particularly sensitive to circadian disruption, linked to greater mood disorder severity (Fishbein et al., 2021). This suggests that managing lighting conditions in correctional facilities could play a critical role in supporting mental well-being.

This is important for the analysis of prison design because, as ~~we will see~~it is shown in the next section, conditions such as insomnia, depression, anxiety, and other mental health issues are disproportionately higher among incarcerated individuals, and these conditions can be produced or exacerbated by disruptions to their circadian rhythm.

~~These conditions can be produced or exacerbated by disruptions to their circadian rhythm, which, as mentioned earlier, can be the result of exposure to inadequate lighting schemes.~~

Psychological and Mental Health Issues in Prison Populations

Prison environments are characterised by harsh living conditions and social isolation, and this has a profound impact on inmates' psychological well-being (Jewkes, 2015). The confinement, combined with the loss of autonomy, creates an atmosphere that fosters stress, anxiety, aggression, and hostility, undermining efforts at rehabilitation (Griffin and

Hepburn, 2013). Several studies have highlighted the association between the physical conditions of prisons and the mental health of inmates. For instance, Morris *et al.* (2012) found that features of the prison environment contribute significantly to misconduct and psychological strain, with negative effects often outweighing the potential rehabilitative benefits.

The relationship between the built environment and inmate behaviour is complex, with certain design flaws exacerbating psychological distress. Deprived prison conditions, such as a lack of sufficient illumination in certain areas during dark hours or the proliferation of shadow mould in areas where daylight doesn't reach, can also aggravate this distress. Research by Lahm (2008) indicates that aggression in inmates is often more pronounced in deprived prison conditions, with such aggression being a strong predictor of violent behaviour, including inmate-on-inmate assaults. The design of prison cells and common areas, therefore, plays a crucial role in either mitigating or amplifying mental health challenges.

In addition to social and environmental stressors, a lack of exposure to natural light and poor artificial lighting conditions are significant factors in prison-related psychological issues. ~~Long~~As mentioned above, long-term exposure to inadequate lighting can disrupt circadian rhythms, leading to sleep disorders, anxiety, and depression, all of which are prevalent among prisoners (Bernhofer *et al.*, 2014; Joseph, A., 2006). ~~The~~In this regard, the impact of light on psychological health is well-documented in other institutional settings, such as healthcare facilities, where it has been shown to affect mood, behaviour, and recovery times (Joarder and Price, 2013). In prison settings, the limited access to daylight and reliance on artificial lighting, particularly with high blue light proportions, can have a similar detrimental effect on inmates' mental well-being.

Additionally, studies on sleep disorders in prison populations suggest a strong connection between poor sleep quality and increased aggression, depression, and suicidal tendencies (Elger, 2003; Kamphuis *et al.*, 2012). For example, a study by Carli *et al.* suggests a significant link between sleep problems and suicidal behaviour in prisoners (Carli *et al.*, 2011). With mental health disorders, including major depression, being prevalent in prison populations (Fotiadou *et al.*, 2006), the design of prison environments, particularly in relation to lighting and sleep conditions, becomes an important factor in addressing these issues. This is essential not only for improving the psychological well-being of inmates but also for enhancing the overall rehabilitation process. However, while research into the impact of light on mental health continues to grow, it is clear that considerations of these findings in prison design, particularly in lighting and natural light access, could play a key role in mitigating these issues.

The Role of Light in Prison Design and Its Effects

In prison environments, light plays a critical role in shaping both the physical and psychological well-being of inmates. Proper lighting design in prisons is not only a matter of functionality but also affects the health, safety, and overall quality of life for prisoners. This section explores the significant effects of natural and artificial lighting in confinement institutions, with a focus on how they influence inmates' physical health, mental well-being, and behaviour.

Natural Light and Its Impact in Prison

Natural light should be an essential component of prison design~~,~~ because it provides inmates with essential cues for the passage of time and contributes to their psychological well-being. As mentioned above, the lack of exposure to daylight in prison cells and communal areas can lead to various negative effects such as sleep disruption and mental health-related issues. A deficiency of natural light can disrupt sleep patterns, leading to sleep deprivation, irritability, and cognitive dysfunction (Figueiro and Rea, 2010). This is especially concerning in high-security facilities where daylight exposure may be limited due to the architectural design or security constraints. When light deprivation is chronic, as in the case of solitary confinement cells, this can lead to an increased risk of depression, anxiety, and stress (Bertani *et al.*, 2021). Studies in other institutional settings have shown that exposure to natural light helps reduce symptoms of mental health disorders, improving inmates' mood and reducing aggression (Aslanoğlu *et al.*, 2021; Kuchenbecker *et al.*, 2023; Madvari *et al.*, 2023~~) .~~). In prisons, where the emotional stressors are already high, a lack of natural light can exacerbate mental health issues.

Environments that maximise natural light can enhance inmates' mood, reduce aggression, and improve overall mental health outcomes (Figueiro *et al.*, 2023). Incorporating elements in prisons, such as windows with views to the outdoors or skylights in common areas, can have significant therapeutic effects, providing inmates with much-needed connections to the outside world (Dilani, 2008; Jimenez *et al.*, 2021; Ulrich, 1984).

Artificial Light and Its Effects in Prison

Artificial lighting, while necessary for nighttime visibility and security, can also play a crucial role in the psychological and physical environment of a prison. However, its design and quality can have both beneficial and detrimental effects. A growing body of evidence suggests that artificial light with high blue light content—often used in prison lighting—can significantly impact sleep patterns (Guyett *et al.*, 2024; Tsai *et al.*, 2024). As mentioned above, exposure to blue light during the evening can suppress the production of melatonin, the hormone responsible for regulating sleep, leading to difficulties falling asleep and maintaining restorative sleep cycles. This disruption is particularly concerning in prisons, where the confined nature of the environment means that sleep disturbances can have wide-ranging consequences on inmates' health~~.~~ (see Figure 2).

Insert Figure 2 here.

Caption: Artificial light exposure (Image and pictures by the author)

Although artificial lighting in prisons is essential for security and daily operations, its selection often prioritises cost and visibility over inmate well-being (Urrutia-Moldes, 2022). Different light sources are used in prison settings, each with unique impacts on health and performance. The intensity and placement of artificial lighting can influence inmates' stress levels and behaviour (Soler and Voss, 2021). Harsh, overly bright lighting can lead to discomfort, irritability, and heightened aggression (Schlangen and Price, 2021). In contrast, a more nuanced approach to artificial lighting, with dimmable or adjustable systems, ~~can~~could help mitigate these negative effects by offering inmates control over their environment (Giggins *et al.*, 2019).

Halogen lighting, still used in security-sensitive areas in many developing regions, emits a spectrum rich in warm tones~~,~~ (see Figure 3), which are less disruptive to circadian rhythms compared to other sources (Chao *et al.*, 2020). However, its application is usually limited to motion-activated devices and floodlights, where exposure is brief and intermittent. This minimises its direct circadian impact, though the harsh contrast of sudden brightness may cause momentary stress or agitation, particularly in environments where security responses are frequent (Soler and Voss, 2021).

Metal halide lamps, commonly used for outdoor perimeters and dormitory facades, emit bright, omnidirectional light with a significant proportion in the blue wavelength around 480 nm. This blue light strongly suppresses melatonin production, disrupting inmates' sleep-wake cycles when used for prolonged nighttime illumination (Chen *et al.*, 2021). In prisons, where these lamps often remain on through the night, inmates could experience chronic circadian disruption~~. The resulting~~, and sleep deprivation ~~contributes~~, as a consequence of bluish light during night hours (Schlangen and Price,2021), could be contributing to heightened stress, irritability, and long-term mental health issues, including anxiety and depression ~~(Schlangen and Price,2021).~~.

High-pressure sodium (HPS) and low-pressure sodium (LPS) lamps, widely used in economically constrained settings for pathways and exterior areas, emit light spectra that have varying effects on biological rhythms. HPS lamps produce a pinkish-orange glow, while LPS lamps emit a monochromatic yellow light. While these spectra are less disruptive to melatonin suppression than blue-rich light sources, the poor light quality can indirectly affect mental health by creating dim, visually uncomfortable environments (Wieduwilt *et al.*, 2020). This low-quality illumination can amplify feelings of disorientation, unease, and stress in inmates (Samaan *et al.*, 2024).

Fluorescent lighting, the most common choice for interior spaces such as cells, corridors, and communal areas, poses significant risks to inmates' circadian health and mental well-being. Fluorescent lights often emit a limited spectral range (see Figure 3) and include intermittent spikes in blue wavelengths, which can suppress melatonin when inmates are exposed for long periods of time (Liu *et al.*, 2018). Prolonged exposure—common in cells where inmates spend up to 23 hours a day—can lead to circadian misalignment, sleep disorders, and hormonal imbalances (Guyett *et al.*, 2024). Combined with the flicker effect inherent in some fluorescent fixtures, this exposure contributes to headaches, visual discomfort, and heightened stress levels, potentially deteriorating mental health.

LED lighting, increasingly adopted in prison retrofits and new builds, offers the potential to reduce circadian disruption if designed and implemented with appropriate spectral considerations (Giggins *et al.*, 2019). LEDs are highly versatile and can be engineered to emit spectra that minimise blue light exposure during nighttime. However, the lack of standardisation across manufacturers means the specific effects on circadian rhythms and mental health can vary~~.~~ (see Figure 3). In poorly designed systems, blue-rich LEDs can have similar disruptive effects on sleep cycles and hormonal regulation as metal halide lamps, compounding issues of insomnia, stress, and mood disorders.

(Insert Figure 3 here)

Caption: Relative energy spectrum of different sources of light (Image by the author)

The cumulative effect of detrimental environments, such as inadequate lighting design in prisons, extends beyond individual discomfort. Chronic circadian disruption and poor mental health could be contributing to increased aggression~~,~~ and impaired cognitive function, potentially reducing chances for rehabilitation, although the relation between circadian function and aggression is not yet clear (Todd and Machado, 2019).

Having properly designed lighting systems in communal and residential areas can help to improve mood and reduce the feeling of confinement and stress. Therefore, providing inmates with the ability to regulate lighting to simulate natural light cycles, through dynamic lighting systems that adjust throughout the day, is vital. This approach can help maintain circadian rhythms and improve inmates' well-being, making artificial light a tool not just for visibility but for promoting better sleep patterns and psychological health (Harrison *et al.*, 2020).

Environmental Design and Psychological Health in Prison

~~The~~A range of international studies confirms that mental health issues are highly prevalent in prison populations. In Malaysia, 42.2% of inmates at Kajang Prison were found to have clinical depression, with higher prevalence among males and those convicted of violent offences, especially when social support was lacking (Yaacob et al., 2022). In Australia, 80% of prisoners were diagnosed with a psychiatric illness compared to 31% in the general population (Butler et al., 2006). A Greek study found that 78.7% of male inmates had a diagnosed mental disorder (Fotiadou et al., 2006), while in Chile, the rate of major depression among prisoners was 6.1%, notably higher than the 3.7% in the general male population (Mundt et al., 2013). Among juvenile detainees internationally, the risk of psychosis is about 10 times greater than among their peers in the general population (Fazel, Doll and Långström, 2008). Furthermore, 27.8% of correctional officers in California reported symptoms of depression, and 11% had experienced suicidal ideation or attempts (Lerman et al., 2021).

In this context, the design of the prison environment~~—~~, particularly the ~~incorporation of~~ integration of natural and artificial light~~—~~, can ~~contribute~~play a key role in reducing environmental stressors that are contributing to ~~the reduction of~~ violent behaviour and heightened stress among inmates~~.~~ and staff.

Architectural strategies that emphasise well-lit spaces, access to daylight, and quality of artificial lighting can lead to a reduction in Aggressive Behaviour and promote Social Interaction and Rehabilitation (Wener, 2012). Studies suggest that prisons with better lighting conditions, including sufficient daylight exposure and the reduction of harsh, constant artificial lighting, experience less inmate violence (Wener, 2012, 2000). This may be due to improved mood regulation, reduced psychological stress, and better sleep. Similarly, environments with adequate lighting facilitate greater social interaction among inmates, which is essential for rehabilitation and reducing feelings of isolation. Well-lit communal areas can encourage social activities, improve mental well-being, and reduce the psychological burdens associated with incarceration.

Existing research highlights that lighting, especially natural daylight, can play a crucial role in the psychological and physiological health of inmates. According to a report from 1982 by the U.S. Department of Justice, correctional administrators found that well-designed lighting improves inmate morale and behaviour, while poor lighting has been linked to increased stress, anxiety, and disruption of circadian rhythms (Chism, 1988). Moreover, the design guidelines published by the American Institute of Architects recommend access to natural light in correctional facilities due to its known benefits for mood regulation, circadian alignment, and reduction of institutional stress (AIA Academy of Architecture for Justice, 2013). In legal contexts, prolonged exposure to artificial lighting, especially continuous illumination, has been challenged on human rights grounds due to its association with sleep disruption and psychological harm (Haney, 2006).

The Importance of Holistic Design in Prison Lighting

Following the recommendations of design made by WELL Building Standards for buildings in general (~~WELL, no date),~~International WELL Building Institute, n.d.), a comprehensive approach to prison lighting should consider not only the quantity of light but also its quality, colour temperature, and variability. The prison environment should be designed with consideration for:

- Daylight Availability: Maximising natural light through architectural features such as windows, courtyards, and skylights.

- Control over Artificial Lighting: Offering inmates some level of control over the lighting in their cells and common areas to create a sense of autonomy and reduce stress.

- Lighting Design for Safety and Well-being: While maintaining the safety and security of the prison, lighting should be designed to support the physical and psychological health of inmates, reducing the negative impacts of light deprivation and poor artificial lighting.

Recommendations for Integrating Light into Prison Design

The integration of light into prison design requires a careful balance between ensuring security, promoting rehabilitation, and safeguarding the mental and physical health of inmates. Evidence from various studies highlights the critical role light plays in regulating circadian rhythms, reducing stress, and improving overall well-being. Based on this evidence, this section outlines recommendations for incorporating light into prison design, emphasising strategies for maximising its therapeutic potential while meeting the operational needs of correctional facilities.

1. Enhancing Natural Light Exposure

Natural light is vital for circadian rhythm regulation and the psychological well-being of inmates. Studies like those by Joseph *et al.* (2006) and Bernhofer *et al.* (2014) demonstrate the benefits of increased daylight exposure in healthcare settings, such as improved recovery times and better circadian entrainment. Similar principles can be applied to prisons, where inmates often face limited access to daylight due to architectural constraints.

To address this, prison designs should include larger, unobstructed windows in cells and communal areas, allowing ample daylight to penetrate interior spaces. While bars and steel nets often block natural light, alternative security measures, such as shatterproof transparent materials, can maintain security without impeding light. Common areas, such as libraries, workshops, and recreational spaces, should be strategically positioned to maximise exposure to natural light, particularly during daylight hours.

Outdoor spaces should also be optimised for daylight access. Expanding the use of open courtyards or secure outdoor zones can allow inmates to experience sunlight directly. Establishing policies for regular outdoor activities, such as exercise or group programs, would further ensure inmates benefit from daylight exposure, supporting both their mental health and physical well-being.

2. Optimising Artificial Lighting for Health Benefits

Given that inmates often spend long hours indoors, artificial lighting becomes a critical aspect of prison design. Studies by Lucas *et al.* (2014) and Boyce (2003) highlight the effectiveness of well-designed artificial lighting in alleviating depression, improving mood, and promoting circadian entrainment.

To harness these benefits, prisons should adopt dynamic lighting systems that mimic natural daylight cycles. For instance, artificial lights with adjustable colour temperatures and intensities can simulate the gradual changes in daylight, supporting inmates' biological clocks. Morning lighting with cooler temperatures (e.g., 4000–5000 K) can promote alertness and productivity, while evening lighting with warmer tones (e.g., 2700–3000 K) can help inmates wind down and prepare for restful sleep. Additionally, care must be taken to provide adequate lighting in areas where inmates read, work, or engage in recreational activities, ensuring optimal visibility without creating glare or discomfort.

Artificial lighting should also avoid prolonged exposure to high levels of blue-enriched light at night, as studies by Gooley *et al.* (2010) indicate its potential to disrupt melatonin production, leading to poor sleep quality. Night lighting designs should focus on dim, warmer tones that are less likely to interfere with sleep patterns, especially in cell areas.

3. Designing for Psychological Comfort and Rehabilitation

Prison lighting designs must also consider the psychological effects of light. Findings by McCloughan *et al.* (1999) and Knes (1995) highlight how different light characteristics can influence mood and behaviour. Warmer lighting can create a calming environment, reducing hostility, while cooler tones can improve focus and productivity.

To incorporate these insights, lighting schemes in communal areas, such as dining halls or classrooms, should use neutral or cooler light to foster a sense of purpose and engagement. Conversely, relaxation areas could benefit from warmer tones to provide comfort and reduce stress. Additionally, lighting designs should account for individual differences, such as gender-specific preferences, ensuring that lighting contributes positively to all inmates' experiences.

Implementing a tiered lighting system that offers varying light levels and colours based on activity type and time of day can provide inmates with a sense of normalcy and control over their environment. Allowing inmates limited control over personal lighting, such as bedside lamps or dimmers, can further enhance their sense of autonomy, which is often lacking in confinement settings.

4. Balancing Security with Light Integration

While natural and artificial light can significantly improve health and well-being, prison designs must also prioritise safety and security. This often presents challenges, as traditional security measures can conflict with optimal lighting strategies.

To address this, architects and prison managers should adopt innovative security solutions that allow for light access without compromising control. For example, translucent materials like frosted or polycarbonate glass can maintain privacy and security while allowing daylight to enter. Skylights or clerestory windows positioned above reach level can also increase light penetration without creating security vulnerabilities.

Artificial lighting systems should include centralised controls to ensure lights can be adjusted quickly in emergencies, maintaining staff visibility and safety. Motion-sensor lights in hallways and outdoor areas can enhance security while reducing unnecessary energy consumption.

5. Monitoring and Adjusting Lighting Strategies

The success of lighting strategies in prisons depends on continuous monitoring and adaptation. Periodic assessments of lighting conditions and their impact on ~~inmate's~~inmates' health and behaviour should inform necessary adjustments. For instance, if inmates report frequent sleep disturbances or heightened aggression, modifications to lighting schedules or designs may be required.

Additionally, staff training is essential to ensure proper implementation and maintenance of lighting systems. Correctional officers and facility managers should understand the importance of light for inmate well-being and know how to optimise lighting systems for therapeutic benefits.

6. Collaborative Design Approaches

Finally, designing effective lighting strategies for prisons requires collaboration between architects, lighting designers, and behavioural health experts. By involving multiple stakeholders, prisons can create environments that meet both security requirements and inmates' health needs. Evidence from studies like the Stanford prison experiment underscores the importance of creating humane living conditions that balance confinement with rehabilitation goals. Collaborative design efforts should prioritise evidence-based practices, integrating findings from existing research into practical, implementable solutions.

Barriers to Implementation

While these recommendations offer a clear path toward healthier prison environments, implementing them is not without challenges. Budgetary constraints often limit the ability of correctional facilities to invest in architectural retrofits or advanced lighting systems. Logistical barriers, such as retrofitting older buildings, coordinating between departments, and the additional complexities of working in prison settings, can also complicate efforts. Additionally, there may be institutional resistance due to longstanding priorities around security, where any perceived change may face pushback.

To overcome these barriers, it is essential to frame lighting improvements not only as enhancements to well-being but also as investments in long-term rehabilitation, reduced healthcare costs, and safer environments for both inmates and staff. Pilot programs, phased implementations, and partnerships with research institutions may offer practical ways to trial and evaluate lighting strategies before making it standard practice. Acknowledging these challenges and planning for them would strengthen the case for making prison lighting a priority in future design and policy decisions.

Conclusion

Since the discovery of a special type of light-sensitive cell in the eye, called intrinsically photosensitive retinal ganglion cells (ipRGCs), research has greatly expanded our understanding of how light influences human biological and psychological functions~~, particularly in regulating circadian rhythms and improving mood and overall psychological well-being.~~. In ~~the context of prisons, inadequate~~prison environments, where natural light ~~exposure~~is often limited and ~~the overreliance on~~ artificial lighting dominates, this delicate balance can ~~disrupt circadian rhythms, leading to~~be disrupted. As a result, inmates may experience sleep ~~disorders, heightened~~ problems, increased anxiety, and ~~increased~~ even greater levels of aggression~~ among inmates~~.

This paper has ~~demonstrated~~shown the significant impact that lighting can have on the mental health and rehabilitation of prisoners. Despite considerable progress in understanding the psychological benefits of light, there remains a notable gap in its application within prison settings.

To address these challenges, ~~we have~~this paper has proposed several key recommendations: enhancing natural light exposure, optimising artificial lighting for health benefits, designing for psychological comfort and rehabilitation, balancing security with light integration, monitoring and adjusting lighting strategies, and adopting collaborative design approaches.

In conclusion, integrating evidence-based lighting designs in prisons has the potential to improve the psychological well-being of inmates, reduce aggression, and enhance rehabilitation outcomes. By incorporating these recommendations, prison environments can shift towards supporting inmate health and rehabilitation, ultimately leading to better outcomes for both inmates and staff.

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Light Behind Bars: How Light Impacts Mental Health In Prisons

Abstract

Purpose:

The purpose of this paper is to synthesise literature on the non-visual effects of light and the prison environment, highlighting the disconnect between evidence and practices. By confronting research findings with existing prison conditions, it aims to guide designers and authorities toward adopting lighting strategies that protect inmates' mental health and support rehabilitation outcomes..

Design/methodology/approach

A focused search was conducted using Google Scholar and PubMed to identify studies relevant to the following topics: non-visual effects of light, circadian rhythm and light, mental health and light, daylight exposure and natural light, artificial light, lighting design in prisons, stress and aggression related to lighting, rehabilitation and prison environments, melatonin and hormonal regulation, and psychosocial and architectural interactions.

Findings:

This paper highlights the impact of neglecting natural and artificial light in prison design on inmates' psychological well-being. Insufficient natural light and poorly managed artificial lighting exacerbate mental health issues. The widespread use of high blue light content in prison lighting disrupts circadian rhythms, leading to sleep deprivation and hormonal imbalances. In contrast, prioritising natural light access and implementing balanced, adjustable artificial lighting can improve mood, reduce aggression, and support circadian health, fostering better mental health and social outcomes in prison.

Original Value

This paper bridges the gap between lighting design, environmental psychology, and prison reform. By focusing on how light affects inmates' psychological health and rehabilitation, it contributes new insights into how prison design can be improved to foster well-being.

Keywords:

Non-visual; Circadian; Prison design; Mental health; Rehabilitation; Daylight; Artificial lighting

Introduction:

Research in environmental psychology has consistently shown that environmental stimuli significantly affect cognition, mood, and overall behaviour (Babin *et al.*, 2003; Hoffmann *et al.*, 2008; Knez, 2001). These studies underscore the importance of the physical environment in shaping how people think, feel, and act. While much of this research has focused on settings like workplaces and hospitals, its implications are especially crucial in prisons, where the environment can have profound effects on inmates' psychological well-being and rehabilitation outcomes. In this context, light plays a critical role, as it has been demonstrated to impact mood, stress levels, and cognitive performance. Thus, light should be carefully considered in prison design to promote better mental health and rehabilitation.

Although people may not always be aware of it, living with limited or no access to natural light for extended periods of time can lead to both physical and psychological consequences. The connection between light and human health was not fully understood until the early 2000s when the discovery of a third type of photoreceptor ganglion in the retina revealed how light influences psycho-biological functions (Berson *et al.*, 2002). This discovery has spurred extensive research into the effects of light on circadian rhythms and overall well-being, which has important implications for environments where people are confined for long periods of time, such as prisons. Proper management of daylight and the selection of artificial light sources can significantly improve the conditions for inmates, yet these factors are often overlooked in current prison designs.

Research on the effects of light on mood and behaviour has been well-documented in workplace environments, where both natural daylight and artificial lighting have been found to improve mood, productivity, and overall performance (Hoffmann *et al.*, 2008; Knez and Kers, 2000; Leichtfried *et al.*, 2015). For instance, studies by Boyce (2003) have shown that daylight can positively affect employee's mood and has tangible financial benefits for organisations. Similarly, in hospitals, the right lighting has been linked to better patient and staff well-being, and even reduced recovery times(Joarder and Price, 2013; Joseph, A., 2006). These findings highlight the power of light to improve outcomes in environments that support healing and performance, making it clear that prisons—where conditions often exacerbate stress and aggression—could benefit from similar approaches.

The well-established relationship between light and the circadian rhythm has also led to significant findings on its impact on psychological and mental health disorders. Research has demonstrated that light influences sleep quality, and alertness, and can alleviate symptoms of insomnia, depression, and even suicide (Czeisler and Gooley, 2007; Kamphuis *et al.*, 2014). In the context of prisons, where many inmates experience mental health issues exacerbated by confinement, proper lighting could help mitigate these problems by regulating circadian rhythms and improving overall mental health.

However, despite the wealth of evidence regarding the psychological and physiological benefits of light, a gap exists in its application to prison design. This gap prevents prison authorities and facility designers from making informed decisions that could improve inmates' mental health and rehabilitation prospects. Consequently, many prison lighting systems are designed with a focus on security and restriction, rather than well-being, which only serves to reinforce the challenging and often harmful environment for inmates.

The purpose of this paper is to consolidate the existing knowledge on how light affects human mental and psychological health and to explore how improper management of daylight and artificial lighting can exacerbate conditions in prisons. Based on this, I will propose recommendations for integrating this knowledge into prison design to improve the well-being of inmates. The paper will first explain the properties of light, the human perception of colour and brightness, and the non-visual effects of light on circadian rhythms.

Next, we will examine the psychological and mental health challenges faced by prisoners and how light can help alleviate these issues. We will then discuss the role of lighting design in shaping prison environments and its effects on inmate well-being. Finally, the paper will provide recommendations for integrating light into prison design to optimise rehabilitation outcomes and improve conditions for inmates.

What is light?

Light is just a small part of a larger phenomenon known as electromagnetic radiation (ER), the process by which energy moves through space. Electromagnetic radiation encompasses a wide range of types, categorised into seven main components: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

Every second, the Sun—like all stars—emits vast amounts of energy that radiate outward in all directions as ER. This energy travels through space in waves of all seven types simultaneously, interacting with everything it encounters, from planets and moons to meteors.

These waves vary greatly in the lengths of each full cycle, a property known as wavelength. Some are incredibly short, such as gamma rays, with wavelengths smaller than 0.01 nanometres, while others, like radio waves, can stretch to 100 kilometres or more.

Electromagnetic radiation (ER) is perceived by humans through specialised sensors in the retina of the eye. However, these sensors are not capable of detecting the entire range of ER wavelengths. Instead, they are sensitive only to a specific band of wavelengths, measuring approximately 380 to 780 nanometres—a range we refer to as visible light.

The retina contains three types of sensors for detecting electromagnetic radiation (ER), known as photoreceptor cells. Two of these, cones and rods, are part of the visual system and play a crucial role in transmitting information to the brain's visual cortex, enabling the perception of images and the decoding of colours. Named for their shape when observed under a microscope (van Bommel, 2006), cones are responsible for colour sensitivity, while rods are primarily involved in detecting brightness and enabling vision in low-light conditions. Because daylight comprises a broad range of wavelengths within the visible spectrum, our brain decodes this as bright white light. When these wavelengths encounter an object, some are absorbed while others are reflected, depending on the material's reflective and absorptive properties. The reflected light reaches the eye, where cones and rods detect the new combination of wavelengths, and the brain, after processing this information, associates the result with specific colours.

Artificial lights, in contrast, do not always produce the same colours in objects because light sources are usually composed of waves highly concentrated in some areas of the visual spectrum with a minimum or even without any presence of some wavelength existents in daylight. This absence of several parts of the visual spectrum affects colour perception throw the variation of visual information sent to the brain by rods and cones.

The concept of Correlated Colour Temperature (CCT) of light

Although colours are ultimately subjective perceptions, we categorise different types of light by associating each wavelength within the visible spectrum with a specific Correlated Colour Temperature (CCT). CCT represents the temperature of an idealised object, called a "black body," which absorbs and emits all colours of light perfectly. To understand this, imagine heating a piece of metal until it starts to glow. As the temperature rises, the metal changes colour, starting from red, moving to orange, and eventually to blue, depending on how hot it gets. This idealised "black body" would glow in a similar way, and the temperature at which it glows a particular colour is measured in Kelvin (K) (Boyce, 2003).

Therefore, light with shorter wavelengths in the visible spectrum, such as violet, around 400 nm, and blue, around 450–500 nm, is associated with higher correlated colour temperatures (CCTs), typically exceeding 5000 K, which gives it a "cool" appearance. In contrast, longer wavelengths like red, around 650–700 nm, and orange, around 600 nm, correspond to lower CCTs, often below 3000 K, creating a "warm" tone. Between these extremes, wavelengths in the green and yellow range, approximately 500–600 nm, contribute to intermediate CCTs, such as 4000–5000 K, resulting in a "neutral" white light. This correlation arises from how human vision interprets the mixture of spectral energy, shaping the perceived colour tone of light sources.

Nonvisual effect of lighting

While this mechanism of colour detection and decoding has been understood since the 1850s, the broader impact of light on physiological functions in humans and animals was only discovered in 2002 (Berson *et al.*, 2002). This breakthrough came with the identification of a third type of photoreceptor in the retina, distinct from the visual system. Known as the intrinsically photosensitive retinal ganglion cell (ipRGC), this photoreceptor contains a photopigment called melanopsin, which is most sensitive to short wavelengths of visible light, peaking at approximately 480 nm in the blue region of the spectrum (Lucas *et al.*, 2014). Although ipRGCs account for just 1% to 5% of the total ganglion cells in the mammalian retina, it has been shown that they play a crucial role in regulating non-visual biological processes, including melatonin production, body temperature, cortisol secretion, and alertness (van Bommel, 2006).

The information captured by ipRGCs is sent to the Suprachiasmatic Nuclei, situated not in the visual cortex but in the centre of the brain. These signals are processed and transmitted to the pineal gland, which regulates various psychobiological functions by secreting hormones and controlling the sleep-wake cycle, which is commonly known as the circadian rhythm (Braun *et al.*, 2009). It is important to mention that ipRGCs can detect radiation of bluish 480 nm of light even when the eyes are closed, sending signals to the Suprachiasmatic Nuclei even during sleep hours.

In the late evening, when it becomes dark, and the proportion of bluish light is minimal or inexistent, Melatonin production rises promoting healthy sleep. Conversely, during the early morning, the proportion of 480 nm bluish light is high, and the detection of this light by the ipRGCs results in the suppression of melatonin to induce alertness (Boyce, 2003; Lucas, 2014).

On the other side of the cycle, the production of cortisol hormone is also regulated by the detection of bluish light through the ipRGCs. In the early morning, when the brain detects that daylight contains sufficient bluish light, it activates the mechanism to produce cortisol, which in turn increases blood sugar levels enhancing the immune system thus creating alertness and preparing the body for the day's activity. Because of this, cortisol is called the hormone of stress. After this peak, cortisol levels gradually decrease throughout the day, reaching their lowest levels in the evening and night, just before sleep.

Disruption of this circadian rhythm has been linked to various challenges in daily life. Research has extensively explored how inadequate light exposure schemes can contribute to disorders such as insomnia (Lack *et al.*, 2023, 2023; Walker *et al.*, 2020), depression (de Leeuw *et al.*, 2023; Samanta and Bagchi, 2024; Zhang *et al.*, 2024), and anxiety (Boiko *et al.*, 2022). For example, Lack *et al.*(2023) found that sleep onset insomnia is associated with later-timed circadian rhythms and can be treated with morning bright light therapy to shift rhythms to an earlier timing. A 2024 longitudinal study on 543 participants found significant associations between depression severity and circadian rhythm features, such as heart rate peak timing and sleep duration (Zhang *et al.* 2024). Similarly, Samanta and Bagchi (2024) reported that circadian rhythm disruption causes impaired neurotransmitter release, altered melatonin and cortisol rhythms, metabolic dysfunctions, and neuroinflammation, all of which contribute to the development of psychiatric disorders, including depression.

This is important for the analysis of prison design because, as we will see in the next section, conditions such as insomnia, depression, anxiety, and other mental health issues are disproportionately higher among incarcerated individuals.

These conditions can be produced or exacerbated by disruptions to their circadian rhythm, which, as mentioned earlier, can be the result of exposure to inadequate lighting schemes.

Psychological and Mental Health Issues in Prison Populations

Prison environments are characterised by harsh living conditions and social isolation and this has a profound impact on inmates' psychological well-being (Jewkes, 2015). The confinement, combined with the loss of autonomy, creates an atmosphere that fosters stress, anxiety, aggression, and hostility, undermining efforts at rehabilitation (Griffin and Hepburn, 2013). Several studies have highlighted the association between the physical conditions of prisons and the mental health of inmates. For instance, Morris *et al.* (2012) found that features of the prison environment contribute significantly to misconduct and psychological strain, with negative effects often outweighing the potential rehabilitative benefits.

The relationship between the built environment and inmate behaviour is complex, with certain design flaws exacerbating psychological distress. Deprived prison conditions such as lack of sufficient illumination in certain areas during dark hours or proliferation of shadow mould in areas where daylight doesn't reach, can also aggravate this distress. Research by Lahm (2008) indicates that aggression in inmates is often more pronounced in deprived prison conditions, with such aggression being a strong predictor of violent behaviour, including inmate-on-inmate assaults. The design of prison cells and common areas, therefore, plays a crucial role in either mitigating or amplifying mental health challenges.

In addition to social and environmental stressors, a lack of exposure to natural light and poor artificial lighting conditions are significant factors in prison-related psychological issues. Long-term exposure to inadequate lighting can disrupt circadian rhythms, leading to sleep disorders, anxiety, and depression, all of which are prevalent among prisoners (Bernhofer *et al.*, 2014; Joseph, A., 2006). The impact of light on psychological health is well-documented in other institutional settings, such as healthcare facilities, where it has been shown to affect mood, behaviour, and recovery times (Joarder and Price, 2013). In prison settings, the limited access to daylight and reliance on artificial lighting, particularly with high blue light proportions, can have a similar detrimental effect on inmates' mental well-being.

Additionally, studies on sleep disorders in prison populations suggest a strong connection between poor sleep quality and increased aggression, depression, and suicidal tendencies (Elger, 2003; Kamphuis *et al.*, 2012). For example, a study by Carli *et al.* suggests a significant link between sleep problems and suicidal behaviour in prisoners (Carli *et al.*, 2011). With mental health disorders, including major depression, being prevalent in prison populations (Fotiadou *et al.*, 2006), the design of prison environments, particularly in relation to lighting and sleep conditions, becomes an important factor in addressing these issues. This is essential not only for improving the psychological well-being of inmates but also for enhancing the overall rehabilitation process. However, while research into the impact of light on mental health continues to grow, it is clear that considerations of these findings in prison design, particularly in lighting and natural light access, could play a key role in mitigating these issues.

The Role of Light in Prison Design and Its Effects

In prison environments, light plays a critical role in shaping both the physical and psychological well-being of inmates. Proper lighting design in prisons is not only a matter of functionality but also affects the health, safety, and overall quality of life for prisoners. This section explores the significant effects of natural and artificial lighting in confinement institutions, with a focus on how they influence inmates' physical health, mental well-being, and behaviour.

Natural Light and Its Impact in Prison

Natural light should be an essential component of prison design, because it provides inmates with essential cues for the passage of time and contributes to their psychological well-being. As mentioned above, the lack of exposure to daylight in prison cells and communal areas can lead to various negative effects such as sleep disruption and mental health-related issues. A deficiency of natural light can disrupt sleep patterns, leading to sleep deprivation, irritability, and cognitive dysfunction (Figueiro and Rea, 2010). This is especially concerning in high-security facilities where daylight exposure may be limited due to the architectural design or security constraints. When light deprivation is chronic, as in the case of solitary confinement cells, this can lead to an increased risk of depression, anxiety, and stress (Bertani *et al.*, 2021). Studies in other institutional settings have shown that exposure to natural light helps reduce symptoms of mental health disorders, improving inmates' mood and reducing aggression (Aslanoğlu *et al.*, 2021; Kuchenbecker *et al.*, 2023; Madvari *et al.*, 2023) . In prisons, where the emotional stressors are already high, lack of natural light can exacerbate mental health issues.

Environments that maximise natural light can enhance inmates' mood, reduce aggression, and improve overall mental health outcomes (Figueiro *et al.*, 2023). Incorporating elements in prisons such as windows with views to the outdoors or skylights in common areas can have significant therapeutic effects, providing inmates with much-needed connections to the outside world (Dilani, 2008; Jimenez *et al.*, 2021; Ulrich, 1984).

Artificial Light and Its Effects in Prison

Artificial lighting, while necessary for nighttime visibility and security, can also play a crucial role in the psychological and physical environment of a prison. However, its design and quality can have both beneficial and detrimental effects. A growing body of evidence suggests that artificial light with high blue light content—often used in prison lighting—can significantly impact sleep patterns (Guyett *et al.*, 2024; Tsai *et al.*, 2024). As mentioned above, exposure to blue light during the evening can suppress the production of melatonin, the hormone responsible for regulating sleep, leading to difficulties falling asleep and maintaining restorative sleep cycles. This disruption is particularly concerning in prisons, where the confined nature of the environment means that sleep disturbances can have wide-ranging consequences on inmates' health.

Although artificial lighting in prisons is essential for security and daily operations, its selection often prioritises cost and visibility over inmate well-being (Urrutia-Moldes, 2022). Different light sources are used in prison settings, each with unique impacts on health and performance. The intensity and placement of artificial lighting can influence inmates' stress levels and behaviour (Soler and Voss, 2021). Harsh, overly bright lighting can lead to discomfort, irritability, and heightened aggression (Schlangen and Price, 2021). In contrast, a more nuanced approach to artificial lighting, with dimmable or adjustable systems, can help mitigate these negative effects by offering inmates control over their environment (Giggins *et al.*, 2019).

Halogen lighting, still used in security-sensitive areas in many developing regions, emits a spectrum rich in warm tones, which are less disruptive to circadian rhythms compared to other sources (Chao *et al.*, 2020). However, its application is usually limited to motion-activated devices and floodlights, where exposure is brief and intermittent. This minimises its direct circadian impact, though the harsh contrast of sudden brightness may cause momentary stress or agitation, particularly in environments where security responses are frequent (Soler and Voss, 2021).

Metal halide lamps, commonly used for outdoor perimeters and dormitory facades, emit bright, omnidirectional light with a significant proportion in the blue wavelength around 480 nm. This blue light strongly suppresses melatonin production, disrupting inmates' sleep-wake cycles when used for prolonged nighttime illumination (Chen *et al.*, 2021). In prisons, where these lamps often remain on through the night, inmates experience chronic circadian disruption. The resulting sleep deprivation contributes to heightened stress, irritability, and long-term mental health issues, including anxiety and depression (Schlangen and Price,2021).

High-pressure sodium (HPS) and low-pressure sodium (LPS) lamps, widely used in economically constrained settings for pathways and exterior areas, emit light spectra that have varying effects on biological rhythms. HPS lamps produce a pinkish-orange glow, while LPS lamps emit a monochromatic yellow light. While these spectra are less disruptive to melatonin suppression than blue-rich light sources, the poor light quality can indirectly affect mental health by creating dim, visually uncomfortable environments (Wieduwilt *et al.*, 2020). This low-quality illumination can amplify feelings of disorientation, unease, and stress in inmates (Samaan *et al.*, 2024).

Fluorescent lighting, the most common choice for interior spaces such as cells, corridors, and communal areas, poses significant risks to inmates' circadian health and mental well-being. Fluorescent lights often emit a limited spectral range and include intermittent spikes in blue wavelengths, which can suppress melatonin when inmates are exposed for long periods of time (Liu *et al.*, 2018). Prolonged exposure—common in cells where inmates spend up to 23 hours a day—can lead to circadian misalignment, sleep disorders, and hormonal imbalances (Guyett *et al.*, 2024). Combined with the flicker effect inherent in some fluorescent fixtures, this exposure contributes to headaches, visual discomfort, and heightened stress levels, potentially deteriorating mental health.

LED lighting, increasingly adopted in prison retrofits and new builds, offers the potential to reduce circadian disruption if designed and implemented with appropriate spectral considerations (Giggins *et al.*, 2019). LEDs are highly versatile and can be engineered to emit spectra that minimise blue light exposure during nighttime. However, the lack of standardisation across manufacturers means the specific effects on circadian rhythms and mental health can vary. In poorly designed systems, blue-rich LEDs can have similar disruptive effects on sleep cycles and hormonal regulation as metal halide lamps, compounding issues of insomnia, stress, and mood disorders.

The cumulative effect of detrimental environments such as inadequate lighting design in prisons extends beyond individual discomfort. Chronic circadian disruption and poor mental health could be contributing to increased aggression, and impaired cognitive function, potentially reducing chances for rehabilitation, although the relation between circadian function and aggression is not yet clear (Todd and Machado, 2019).

Having properly designed lighting systems in communal and residential areas can help to improve mood and reduce the feeling of confinement and stress. Therefore, providing inmates with the ability to regulate lighting to simulate natural light cycles, through dynamic lighting systems that adjust throughout the day, is vital. This approach can help maintain circadian rhythms and improve inmates' well-being, making artificial light a tool not just for visibility but for promoting better sleep patterns and psychological health (Harrison *et al.*, 2020).

Environmental Design and Psychological Health in Prison

The design of the prison environment—particularly the incorporation of light—can contribute to the reduction of violent behaviour and stress among inmates. Architectural strategies that emphasise well-lit spaces, access to daylight, and quality of artificial lighting can lead to a reduction in Aggressive Behaviour and promote Social Interaction and Rehabilitation (Wener, 2012). Studies suggest that prisons with better lighting conditions, including sufficient daylight exposure and the reduction of harsh, constant artificial lighting, experience less inmate violence (Wener, 2012, 2000). This may be due to improved mood regulation, reduced psychological stress, and better sleep. Similarly, environments with adequate lighting facilitate greater social interaction among inmates, which is essential for rehabilitation and reducing feelings of isolation. Well-lit communal areas can encourage social activities, improve mental well-being, and reduce the psychological burdens associated with incarceration.

The Importance of Holistic Design in Prison Lighting

Following the recommendations of design made by WELL Building Standards for buildings in general (WELL, no date), a comprehensive approach to prison lighting should consider not only the quantity of light but also its quality, colour temperature, and variability. The prison environment should be designed with consideration for:

- Daylight Availability: Maximising natural light through architectural features such as windows, courtyards, and skylights.
- Control over Artificial Lighting: Offering inmates some level of control over the lighting in their cells and common areas to create a sense of autonomy and reduce stress.
- Lighting Design for Safety and Well-being: While maintaining the safety and security of the prison, lighting should be designed to support the physical and psychological health of inmates, reducing the negative impacts of light deprivation and poor artificial lighting.

Recommendations for Integrating Light into Prison Design

The integration of light into prison design requires a careful balance between ensuring security, promoting rehabilitation, and safeguarding the mental and physical health of inmates. Evidence from various studies highlights the critical role light plays in regulating circadian rhythms, reducing stress, and improving overall well-being. Based on this evidence, this section outlines recommendations for incorporating light into prison design, emphasising strategies for maximising its therapeutic potential while meeting the operational needs of correctional facilities.

1. Enhancing Natural Light Exposure

Natural light is vital for circadian rhythm regulation and the psychological well-being of inmates. Studies like those by Joseph *et al.* (2006) and Bernhofer *et al.* (2014) demonstrate the benefits of increased daylight exposure in healthcare settings, such as improved recovery times and better circadian entrainment. Similar principles can be applied to prisons, where inmates often face limited access to daylight due to architectural constraints.

To address this, prison designs should include larger, unobstructed windows in cells and communal areas, allowing ample daylight to penetrate interior spaces. While bars and steel nets often block natural light, alternative security measures, such as shatterproof transparent materials, can maintain security without impeding light. Common areas, such as libraries, workshops, and recreational spaces, should be strategically positioned to maximise exposure to natural light, particularly during daylight hours.

Outdoor spaces should also be optimised for daylight access. Expanding the use of open courtyards or secure outdoor zones can allow inmates to experience sunlight directly. Establishing policies for regular outdoor activities, such as exercise or group programs, would further ensure inmates benefit from daylight exposure, supporting both their mental health and physical well-being.

2. Optimising Artificial Lighting for Health Benefits

Given that inmates often spend long hours indoors, artificial lighting becomes a critical aspect of prison design. Studies by Lucas *et al.* (2014) and Boyce (2003) highlight the effectiveness of well-designed artificial lighting in alleviating depression, improving mood, and promoting circadian entrainment.

To harness these benefits, prisons should adopt dynamic lighting systems that mimic natural daylight cycles. For instance, artificial lights with adjustable colour temperatures and intensities can simulate the gradual changes in daylight, supporting inmates' biological clocks. Morning lighting with cooler temperatures (e.g., 4000–5000 K) can promote alertness and productivity, while evening lighting with warmer tones (e.g., 2700–3000 K) can help inmates wind down and prepare for restful sleep. Additionally, care must be taken to provide adequate lighting in areas where inmates read, work, or engage in recreational activities, ensuring optimal visibility without creating glare or discomfort.

Artificial lighting should also avoid prolonged exposure to high levels of blue-enriched light at night, as studies by Gooley *et al.* (2010) indicate its potential to disrupt melatonin production, leading to poor sleep quality. Night lighting designs should focus on dim, warmer tones that are less likely to interfere with sleep patterns, especially in cell areas.

3. Designing for Psychological Comfort and Rehabilitation

Prison lighting designs must also consider the psychological effects of light. Findings by McCloughan *et al.* (1999) and Knes (1995) highlight how different light characteristics can influence mood and behaviour. Warmer lighting can create a calming environment, reducing hostility, while cooler tones can improve focus and productivity.

To incorporate these insights, lighting schemes in communal areas, such as dining halls or classrooms, should use neutral or cooler light to foster a sense of purpose and engagement. Conversely, relaxation areas could benefit from warmer tones to provide comfort and reduce stress. Additionally, lighting designs should account for individual differences, such as gender-specific preferences, ensuring that lighting contributes positively to all inmates' experiences.

Implementing a tiered lighting system that offers varying light levels and colours based on activity type and time of day can provide inmates with a sense of normalcy and control over their environment. Allowing inmates limited control over personal lighting, such as bedside lamps or dimmers, can further enhance their sense of autonomy, which is often lacking in confinement settings.

4. Balancing Security with Light Integration

While natural and artificial light can significantly improve health and well-being, prison designs must also prioritise safety and security. This often presents challenges, as traditional security measures can conflict with optimal lighting strategies.

To address this, architects and prison managers should adopt innovative security solutions that allow for light access without compromising control. For example, translucent materials like frosted or polycarbonate glass can maintain privacy and security while allowing daylight to enter. Skylights or clerestory windows positioned above reach level can also increase light penetration without creating security vulnerabilities.

Artificial lighting systems should include centralised controls to ensure lights can be adjusted quickly in emergencies, maintaining staff visibility and safety. Motion-sensor lights in hallways and outdoor areas can enhance security while reducing unnecessary energy consumption.

5. Monitoring and Adjusting Lighting Strategies

The success of lighting strategies in prisons depends on continuous monitoring and adaptation. Periodic assessments of lighting conditions and their impact on inmate's health and behaviour should inform necessary adjustments. For instance, if inmates report frequent sleep disturbances or heightened aggression, modifications to lighting schedules or designs may be required.

Additionally, staff training is essential to ensure proper implementation and maintenance of lighting systems. Correctional officers and facility managers should understand the importance of light for inmate well-being and know how to optimise lighting systems for therapeutic benefits.

6. Collaborative Design Approaches

Finally, designing effective lighting strategies for prisons requires collaboration between architects, lighting designers, and behavioural health experts. By involving multiple stakeholders, prisons can create environments that meet both security requirements and inmates' health needs. Evidence from studies like the Stanford prison experiment underscores the importance of creating humane living conditions that balance confinement with rehabilitation goals. Collaborative design efforts should prioritise evidence-based practices, integrating findings from existing research into practical, implementable solutions.

Conclusion

Since the discovery of intrinsically photosensitive retinal ganglion cells (ipRGCs), research has greatly expanded our understanding of how light influences human biological and psychological functions, particularly in regulating circadian rhythms and improving mood and overall psychological well-being. In the context of prisons, inadequate natural light exposure and the overreliance on artificial lighting can disrupt circadian rhythms, leading to sleep disorders, heightened anxiety, and increased aggression among inmates.

This paper has demonstrated the significant impact that lighting can have on the mental health and rehabilitation of prisoners. Despite considerable progress in understanding the psychological benefits of light, there remains a notable gap in its application within prison settings.

To address these challenges, we have proposed several key recommendations: enhancing natural light exposure, optimising artificial lighting for health benefits, designing for psychological comfort and rehabilitation, balancing security with light integration, monitoring and adjusting lighting strategies, and adopting collaborative design approaches.

In conclusion, integrating evidence-based lighting designs in prisons has the potential to improve the psychological well-being of inmates, reduce aggression, and enhance rehabilitation outcomes. By incorporating these recommendations, prison environments can shift towards supporting inmate health and rehabilitation, ultimately leading to better outcomes for both inmates and staff.

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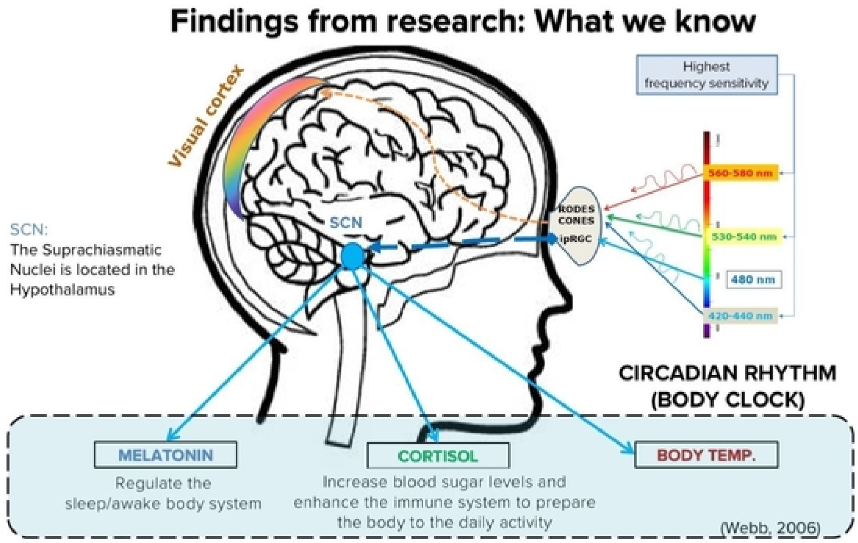
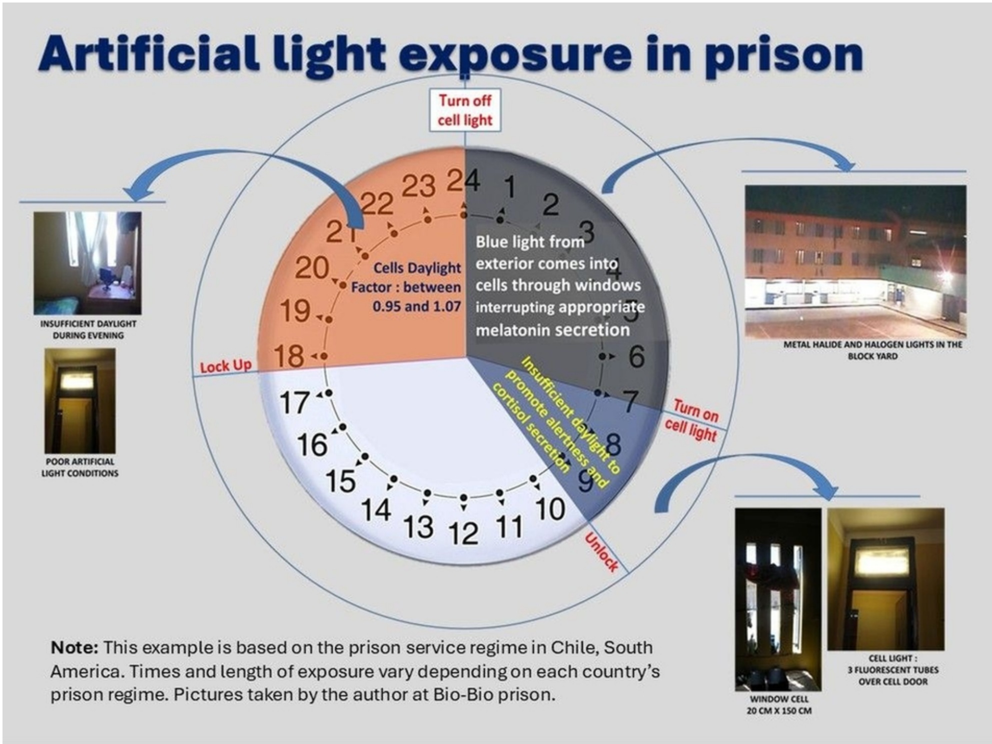


Light and its physiological links (Image by the author)

108x60mm (150 x 150 DPI)



Artificial light exposure (Image and pictures by the author)

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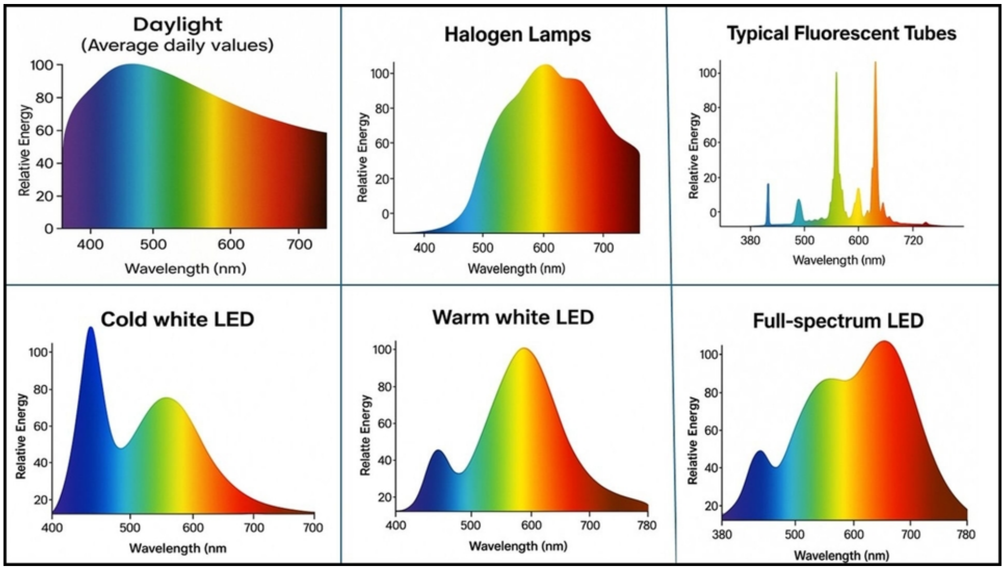

Relative energy spectrum of different sources of light (Image by the author)

162x91mm (150 x 150 DPI)