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The Impact of Lighting on Office Workers' Well-being and Work Productivity

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Abstract

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This thesis investigates the impact of lighting on the health, well-being, and productivity of office workers, with a focus on natural daylight and various artificial lighting systems. It examines how various lighting conditions impact circadian rhythms, sleep patterns, mood stability, cognitive function, and overall employee satisfaction. Through a comprehensive literature review, the study addresses the primary research question: “Does lighting impact worker well-being and work productivity?” It identifies both the beneficial outcomes of effective lighting solutions and the negative effects of poor lighting setups. Existing reviews and studies are critically examined, addressing methodological challenges such as small sample sizes, limited study durations, and lack of standardised measurement approaches, along with individual differences based on age, chronotype, and visual sensitivity. The findings support the value of human-centric lighting strategies, highlighting the necessity of natural daylight exposure, dynamic lighting systems that adjust throughout the day, and personal control over lighting conditions. Finishing with practical recommendations for both future research and workplace design, emphasising the importance of lighting strategies that enhance not just comfort, but long-term productivity and well-being at both the individual and organisational level.

Keywords: Lighting, Well-being, Organisational Productivity, Work Performance, Health

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Contents

Glossary

CCT	Correlated Colour Temperature
CVS	Computer Vision Syndrome
HCL	Human-centric lighting
ipRGCs	Intrinsically photosensitive retinal ganglion cells
K	Kelvin
SAD	Seasonal Affective Disorder
SCN	Suprachiasmatic nucleus
SSL	Solid State Lighting

1 Introduction

This chapter and the following subchapters introduce the foundational context for the thesis by first outlining the importance of worker well-being and how it links to organisational performance. It then focuses specifically on lighting as a key environmental factor, exploring how light affects human physiology, psychology, and task performance in office settings. Finally, the scope and limitations of the study are discussed, clarifying the research boundaries, methodological challenges, and gaps in the existing literature. Together, these sections establish the basis for examining workplace lighting as a strategic tool for enhancing employee well-being and productivity.

1.1 The importance of Worker Well-being and Productivity

In today's global landscape post the Covid-19 pandemic, organisations are facing pressure to enhance productivity, and in light of this, the well-being of their employees has become an increasingly important focus. There is growing evidence that a productive workforce is more likely to thrive when its members experience a high level of well-being (Isham, Mair and Jackson 2020: 2). For instance, organisations with engaged employees who have high well-being have been found to have operating margins almost three times higher than those with low engagement (Haymes, 2013: 284).

Historically, this has not always been clear. In the early 20th century and before that, management mainly prioritised maximising output and efficiency, and employees' well-being was often overlooked. However, research and a shift in societal values, especially with the rise of a new generation of workers who are more aware of and interested in well-being, have highlighted the important role that well-being has in organisational success. This led to a shift, with modern organisations increasingly acknowledging the value of investing in their employees' physical, mental, and social well-being.

This shift is evident in the changing expectations of the modern workforce, with employees seeking supportive work environments that enhance comfort, flexibility, and overall quality of life. Companies must adapt to these evolving expectations to attract and retain top talent. Investing in employee health and well-being is no longer viewed as an optional expense, but rather as a strategic investment with substantial returns. Companies that prioritise employee well-being report higher employee retention, reduced absenteeism, and increased productivity, ultimately leading to greater profitability compared to those that neglect this crucial aspect.

Higher levels of well-being and high job satisfaction have been directly linked with higher individual and organisational productivity (Hafner et al., 2015). Experiences of positive emotions have also been linked to increased productivity across various task types, including creativity and analytical thinking tasks. On the other hand, neglecting well-being can have harmful consequences. For example, the experience of high work-related stress is directly linked to increased absenteeism and presenteeism (Isham et al., 2020).

1.2 Lighting as a Key Environmental Factor and Its Significance

This thesis specifically focuses on the critical role of lighting, one of the most significant yet often overlooked environmental factors impacting occupants' well-being and productivity in office spaces. The impact of lighting on human physiology and psychology has been a subject of increasing interest in recent years, particularly as organisations seek to draw their employees back to the office and optimise their work environments for better outcomes. While other factors in the office environment such as workspace design, air quality, temperature, and noise levels, all contribute to the overall quality, lighting stands out as a particularly influential element.

It is well established through various research studies that well-designed lighting systems, combined with daylight, can enhance cognitive function, boost productivity, and create a healthier and more comfortable work environment.

Poor lighting conditions, on the other hand, whether too dim or excessively bright, can lead to physical discomfort, eye strain, headaches and disruptions to circadian rhythms, which in turn affect sleep, stress levels, and overall mental health. (Clements-Croome, 2000 ; Králiková et al., 2021).

As mentioned previously, there is an increasing emphasis on employee well-being as a key factor in organisational success. The lighting industry has witnessed a trend shift from “energy and cost efficiency” to “well-being and health”. Now companies providing lighting solutions are incorporating human-centric lighting (HCL) technologies that mimic natural light patterns to promote health and well-being (Cupkova et. al, 2019), and are actively marketing these benefits to appeal to health-conscious consumers and businesses. This shift towards prioritising employee well-being through lighting systems like HCL is likely to have a significant impact on workplace design.

Modern workspaces today feature open-plan layouts, hot desking, and hybrid work models. These flexible and dynamic setups result in varying and sometimes unpredictable lighting conditions for employees. Optimising lighting for individual needs in these dynamic environments is essential for ensuring employee comfort, health, and productivity. Clements-Croome and Kaluarachchi's (2000) research results showed that employees preferred to have personal control over lighting and other environmental conditions to better adjust to their individual needs. The change from dedicated workspaces to hot-desking design, further highlights the need for adaptable and personalised lighting solutions.

As some organisations, such as Apple and Amazon, implement stricter office attendance requirements, the quality of the workplace environment, including lighting, becomes even more crucial in maintaining employee morale and preventing losses in productivity. When employees are expected to spend long hours in the office, providing them with a comfortable and supportive environment that adjusts to their needs is essential. Employees are more likely

to feel valued and perform well in an environment that prioritises their well-being, and lighting is a key component of this equation.

Workplace lighting is a strategic tool that can significantly impact employee well-being, productivity, and organisational success. By focusing on human-centered lighting design and using the latest lighting technologies, companies can create workspaces that not only look good but also boost employee health, comfort, and satisfaction. This approach aligns with the growing trend of prioritising employee well-being in office design, and this research aims to contribute to this understanding by exploring the different ways in which lighting interacts with the modern workplace and its workers.

1.3 Scope and Limitations of the Thesis

This thesis investigates the impact of lighting conditions on the well-being and productivity of office workers. Despite the recognised influence of lighting on human physiology and psychology, a clear understanding of how specific lighting parameters (intensity, color temperature and spectral composition) affect worker health (visual comfort, sleep quality, circadian rhythm, etc.) and productivity (task performance, error rates, and absenteeism) in office settings remains limited.

This study examines the relationship between diverse lighting conditions and their impact on worker well-being and performance in typical office settings. The aim is to synthesise the existing literature and draw general conclusions that can serve as a comprehensive review of the topic and inform evidence-based lighting solutions for optimal office environments.

Conflicting findings are also common in the literature, and it is essential to analyse and interpret these in a balanced and objective manner. Such differences are usually due to variations in experimental design, sample size, exposure duration, or the subjective nature of well-being assessment tools. Some of the research cited in this literature review has been funded by

stakeholders in the lighting industry, which may introduce potential conflicts of interest. For example, a study conducted by Mills et al. (2007) was funded by an unconditional educational grant from Philips Lighting, and research by Veitch et al. (2008) was supported by various stakeholders from the lighting and electrical industry.

The lack of standardised measures for assessing lighting quality, health impacts, and productivity presents a challenge when comparing and synthesising results across different studies. Much of the existing research assessing well-being relies on self-reported measures in the form of questionnaires, and individual biases and perceptions can influence the results. This makes it difficult to compare findings across studies. Many studies also use different definitions of well-being, and some only measure indirect aspects, such as mood or sleep, without utilising validated tools.

The majority of existing studies focus on the short-term effects of lighting, specifically how it impacts physiology and task performance. There is a lack of research on the long-term effects of lighting on health and performance, especially on the impact of new lighting technologies, such as solid-state lighting (SSL), including LED lights, and smart lighting, which needs to be taken into consideration. As these technologies become more common in the workplace, it is essential to conduct further research to understand their potential benefits and disadvantages.

2 Foundations of Employee Well-being and Performance

Productivity and well-being are terms that are closely related to each other, and support one another. Health, is a central aspect of well-being, and will be discussed separately, to emphasise its impact on employee outcomes. This section provides a solid conceptual foundation for understanding these terms and how they are measured in studies regarding the different impacts of light on

workers. A clear understanding of these principles is essential for effectively assessing, interpreting, and applying the findings discussed in later chapters.

2.1 Defining and Measuring Well-being

Although well-known, well-being remains challenging to define comprehensively (Dodge et al., 2012). Well-being is a broad concept that consists not only of physical, mental, and social well-being, but also emotional well-being, thereby providing a more complete picture of quality of life. It can be categorised into objective well-being, which refers to measurable external factors that contribute to quality of life, and subjective well-being, which is an individual's own assessment of their life based on cognitive judgement and emotional experience.

Employee well-being specifically refers to the physical, emotional, and psychological health within work settings, significantly impacting both personal outcomes and organisational performance. Workplace well-being is closely linked to productivity, performance, and organisational outcomes, suggesting that healthier and satisfied employees contribute positively to their organisations (Baptiste, 2008).

In the studies and reports related to lighting, well-being is measured through questionnaires such as the Positive and Negative Affect Schedule (PANAS), the Health-Related Quality of Life Survey (sf-36), the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS), and the World Health Organisation Subjective Psychological Wellbeing Index (WHO-WB5). Other less official questionnaires such as the Quality of Life Enjoyment and Satisfaction Questionnaire, measures of psychological well-being, quality of life, happiness, and life satisfaction are also used (Landvreugd et al., 2024).

2.2 Defining and Measuring Health

Health is defined as a "State of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (World Health Organization, 2025). In this thesis, health is conceptualised through various aspects, including physical capabilities, absence of illness, mental health dimensions such as emotional and cognitive functioning, and social interactions. Physical health specifically relates to the physiological aspects such as circadian rhythms, sleep quality and cognitive function. Mental health dimensions discussed in this work include emotional stability, cognitive performance, stress management, and overall psychological resilience.

In occupational settings, health measurements typically focus on identifying productivity loss associated with poor health, which is usually measured through absenteeism and presenteeism metrics. Absenteeism refers to periods when employees are unable to attend work due to illness, while presenteeism refers to situations where employees attend work but perform below their usual capacity due to health-related issues. Studies on the effect of light on health are typically assessed through self-report questionnaires, medical check-ups, and objective physiological measures.

2.3 Defining and Measuring Work Productivity

Productivity is a measure of economic performance that compares the amount of goods and services produced (output) with the amount of inputs used to produce them. In the context of this literature review, productivity refers specifically to employee productivity, which is the amount of work produced within a specific time frame. Good concentration, technical competence, effective organisation and management, a supportive environment and well-being are factors on which productivity relies (Clements-Croome, 2000: 129).

Measuring productivity involves both objective and subjective assessments, which are used when evaluating how lighting affects workers’ productivity.

Objective measurements quantify output through metrics such as the number of units produced, task completion rates, accuracy, errors, or quality ratings. Subjective assessments involve self-reported productivity, perceived efficiency, and overall job performance ratings, which reflect personal perceptions and satisfaction related to productivity.

2.4 Environmental Design for Health, Well-being, and Performance

In recent years, the architecture and design industry has experienced a significant shift from prioritising energy- and cost-effective structures, towards designing high-quality buildings that prioritise the well-being of occupants. Historically, it was believed that there could be either an energy-efficient building or a high-quality building that is comfortable and healthy, but not both. However, this has since been proved wrong as concluded by Roulet et al., (2006: 473) the existence of buildings that are healthy, comfortable and have good energy performance, as well as the better perceived comfort and health shown on average by low-energy buildings, shows that an apparent conflict between comfort and energy use does not exist.

Early office buildings were constructed and designed prioritising energy efficiency, often at the expense of the health and comfort of their future occupants. Sick Building Syndrome (SBS) is a term coined by the World Health Organisation (WHO) in 1986 to describe acute health symptoms or effects linked to the time individuals spend in certain buildings. A considerable number of buildings have been identified as having unhealthy indoor environments, leading to symptoms such as headaches, fatigue, dry or irritated eyes and throat, blocked, stuffy, or runny noses, skin irritation, sneezing, and breathing difficulties (Roulet et al., 2006: 468). High-quality buildings, however, which have been designed by taking occupants' well-being into consideration, have positive effects not only on physical and mental health, but also on productivity.

Lighting is one of the most important aspects in the design of high-quality office buildings. Natural light supports various physiological processes and promotes

a sense of well-being. Artificial lighting should match natural light as closely as possible, and office lighting systems should be dynamic, with intensity adjusting throughout the day. Modern office environments increasingly include features such as large windows for daylight access, dynamic lighting systems, and individual controls that allow employees to personalise lighting according to their needs (Tenner, 2003: 173).

While lighting is the central focus of this thesis, it functions as a part of a larger environmental system. Other factors such as temperature control, noise management, indoor air quality, and workspace layout also contribute to employee comfort and performance. Research suggests that productivity is often most effectively enhanced when lighting works in combination with other well-optimised environmental conditions (Lamb and Kwok, cited in Isham et al., 2020: 66). Therefore, lighting should not be considered in isolation but rather as a key component of a broader strategy aimed at supporting wellbeing and enhancing workplace outcomes.

3 The Science of Light

Understanding the scientific foundations of light is essential for examining how various lighting conditions impact human health, well-being, and performance. This chapter provides a foundational overview of the different types of light, the significance of spectral distribution, and key lighting metrics, including luminance, correlated colour temperature (CCT), and lux.

3.1 Types of Light and Their Characteristics

Natural light, or daylight, is electromagnetic radiation emitted by the sun. It has a full spectrum of light, containing all wavelengths of visible light, which we perceive as different colours. The early morning light contains shorter wavelengths, peaking around noon, after which the wavelengths throughout the rest of the day are longer (McKee and Hedge, 2022:336). In other words,

daylight is not a fixed quantity in terms of either illuminance or light spectrum; it varies in intensity and colour temperature throughout the day, depending on latitude and the time of year.

Artificial lighting or electric light, refers to human-made light sources. It has completely changed the human lifestyle by lengthening our days and shortening our nights (Králiková et al., 2021). There are three main types:

- Incandescent lighting, where light bulbs produce light by heating a filament until it glows.
- Fluorescent lighting uses electricity to excite gases within a tube, causing them to emit light.
- Light-Emitting Diodes (LEDS) are the newest and most popular lighting technology in office environments due to their energy efficiency and flexibility. Also, commonly used in electronic screens. They produce light by passing an electric current through a semiconductor diode.

Understanding the characteristics of different types of light is crucial for creating healthy and productive workplace environments. A well-designed lighting strategy often involves a combination of these light sources, balancing the benefits of natural light and carefully selected artificial lighting solutions.

3.2 Spectral Distribution and Its Importance

The spectral power distribution (SPD) is a quantitative measure of the amount of energy (or power) emitted at different wavelengths by a light source (E. Chen, 2024). The light source can be daylight, a luminaire, a reflective surface, or a combination of these. The SPD indicates which colours are present in the emitted light, thereby influencing both its colour appearance and overall quality. (T. Kruisselbrink et al., 2018). Below is an image showcasing the spectral power distribution of different light sources.

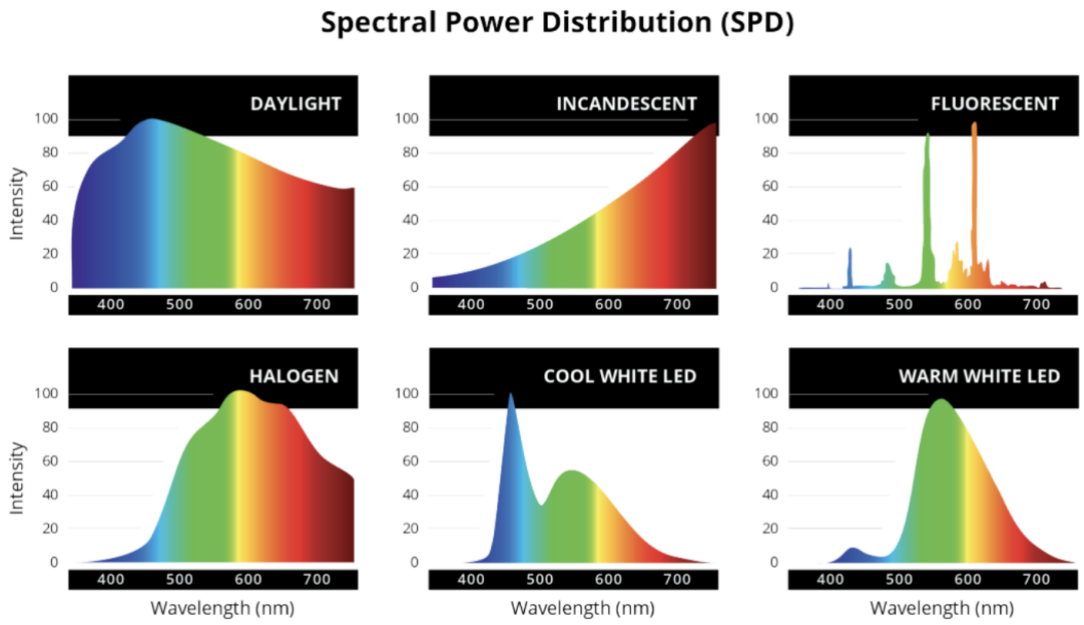

Figure 1. Spectral Distribution of different light sources (NVC Lighting, 2022)

Daylight possesses all colours of the spectrum, with a higher peak in blue light. Fluorescent and LED lights are the most commonly used artificial light sources. “Cool White LED” emits a bright blue light, as shown in the wavelength graph, with a blue peak as high as that of daylight, followed by a smaller peak in green and almost no intensity in the red colour. “Fluorescent” light displays two high peaks in the green and orange parts of the spectrum, with a noticeably smaller blue peak compared to the “Cool White LED”.

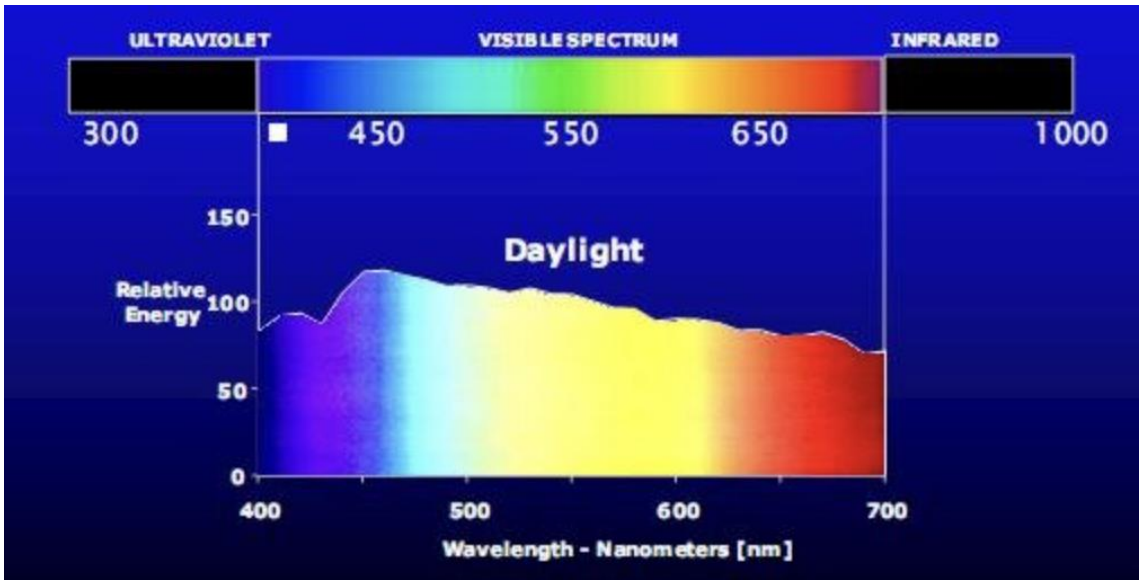

Figure 2. Spectral Distribution of Daylight (Tseghai, 2016)

As shown in the figure above, the spectrums include the visible light which ranges from violet to red (wavelength from 400 to 700); ultraviolet (UV) light (wavelength from 300 to 400) which is essential for Vitamin D production in the skin; and infrared light which is perceived as heat (wavelength from 700 to 1000).

3.3 Measurement of Light: Luminance, Colour Temperature, and Lux

Luminance represents the brightness of a surface as perceived by the human eye, measured in candelas per square metre (cd/m²). Colour Correlated Temperature (CCT), measured in Kelvins (K), defines how light appears and how it might make us feel. For example, a low CCT value, such as 2700K, indicates that the light contains a substantial proportion of red, orange and yellow wavelengths, often referred to as “warm” white. A higher CCT value, such as 5,000K, has fewer red and orange but more the blue wavelengths, giving it a “cool” white appearance. These variations in CCT significantly impact visual comfort (Aryani, Kusumawanto and Suryabrata, 2020).

Illuminance is a photometric measurement of the amount of light falling onto a surface, and it is measured in lux. For example, a lux level of 500 is recommended for workspaces where mainly paper-based tasks are carried out, while a lux level of 300 is considered sufficient for screen-based tasks. For perspective, during the day outdoor light levels can reach up to 100,000 lux in indirect sunlight and approximately 25,000 lux in full daylight (Blume, Garbazza and Spitschan, 2019).

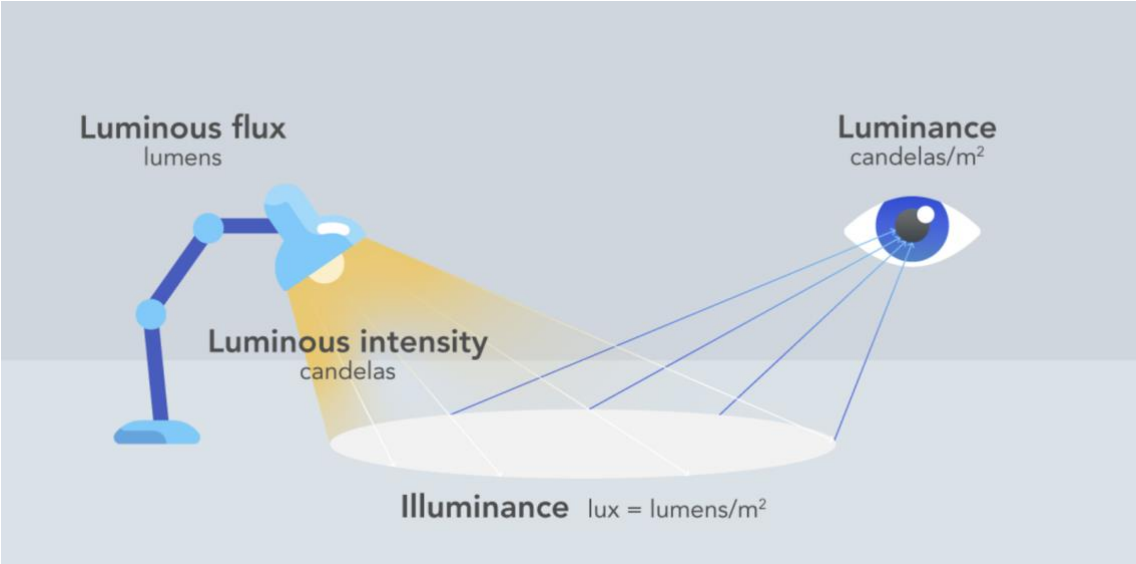

Figure 3. Luminance and Illuminance illustrated (Hunterlab, 2025)

Understanding the different photometric measurements of luminance, correlated colour temperature (CCT), and illuminance is crucial for designing effective and comfortable lighting environments.

4 Historical Context

The impact of lighting on human health and performance has been a subject of investigation for decades. The Hawthorne studies, led by Elton Mayo and colleagues in the 1920s and 1930s, were among the first to systematically explore the relationship between lighting and employee productivity. Although the Hawthorne studies' conclusions on lighting were later questioned, they sparked a growing interest in the topic and laid the foundation for future research on the impact of lighting in the workplace.

During the 1940s and 1950s, the Illuminating Engineering Society (IES) significantly increased recommended lighting levels for artificial lighting in industrial settings (McCowan, Birleanu and Hildt, 2003).

Between the 1960s and 1970s, fluorescent lighting became the dominant lighting technology in commercial and institutional settings. Early research focused on its energy efficiency and impact on worker productivity, although some employees reported issues such as headaches and eye strain. Due to environmental and health concerns, the European Union has recently implemented a ban on fluorescent lighting products.

In 1975, Richard J. Wurtman published *The effects of Light on the Human Body*. Wurtman was a pioneer in research on the effects of light on the human body, including its influence on circadian rhythms and melatonin production. His work had a huge impact on how light's effect is perceived. In the 1980s, Peter R. Boyce began extensive research on lighting quality and its impact on workplace performance, followed by Jennifer A. Veitch, who in the late 1990s and early 2000s found that workers who are satisfied with their lighting conditions are more likely to be productive (Veitch et al., 1995; 2008).

In the late 1990s and early 2000s, Igor Knez conducted several studies that examined the effects of light colour and intensity on mood, cognitive performance, and workplace appraisal. His research showed that the colour of light can influence workers' mood and cognitive performance (Knez, 1995; 2001).

From 2010 onwards, Mariana Figueiro focused on developing and applying light measurement tools to assess light exposure and its impact on human health. Her work has informed lighting design guidelines for various settings. Research by Hawes et al. (2012) found that LED lighting can improve worker alertness and cognitive performance compared to traditional fluorescent lighting.

More recent studies include that of Brown et al. (2022), published in *Current Biology*, which explored the effects of dynamic lighting systems designed to mimic natural daylight patterns. The study found that such systems can improve

workers' sleep quality, mood, and cognitive performance. A comprehensive review by Martinsons et al. (2024) examined the latest developments in LED lighting for workplace environments. This review highlighted the potential benefits of tunable LED to enhance both health and performance outcomes in the workplace.

5 Lighting and Human Physiology and Health

This chapter reviews the current literature on the profound impact of lighting on human physiology and health. It combines findings from scientific studies and comprehensive reviews, aiming to provide a solid understanding of how various lighting conditions affect biological processes and health outcomes. The chapter is structured into three subsections, each addressing a specific aspect of light's physiological effects. The role of the eye in regulating circadian rhythms and the clinical implications of disruptions to these rhythms will be discussed, followed by an examination of the direct and indirect pathways through which light affects cognitive function, mood, and alertness. Finally, the impact of light exposure on sleep duration and quality will be examined, highlighting both its beneficial and harmful effects.

5.1 The Eye, Circadian Rhythms, and Health Outcomes of Circadian Disruption

The circadian rhythm in humans is primarily synchronised by the cycle of day and night. The master circadian clock, also known as the suprachiasmatic nucleus (SCN), is a small region in the hypothalamus that receives photic input through the retinohypothalamic tract (RHT). The SCN is responsible for regulating various physiological processes on a 24-hour cycle, including signalling to the pineal gland, where the sleep hormone melatonin is produced. A fundamental environmental cue, or "zeitgeber" (German for "time-giver") (Blume et al., 2019: 147), is ambient light, which enables the suprachiasmatic

nucleus (SCN) to align the internal biological clock with the external environment.

Light enters the eye and reaches the retina, a thin layer of nerve tissue located at the back of the eye (Blume et al., 2019, p. 149). This stimulates different photoreceptors, including rods, cones, and light-sensitive ganglion cells (ipRGCs) (Aries, Beute and Fischl, 2020). Rods and cones are responsible for regulating the visual effects of light. “Cones allow us to see colour, spatial detail and motion at light levels typical for daytime” (Blume et al., 2019: 149), while rods enable vision in dimmer light conditions. The ipRGCs, which contain the photopigment melanopsin, are responsible for non-visual effects and are believed to mediate most effects of light on the circadian clock.

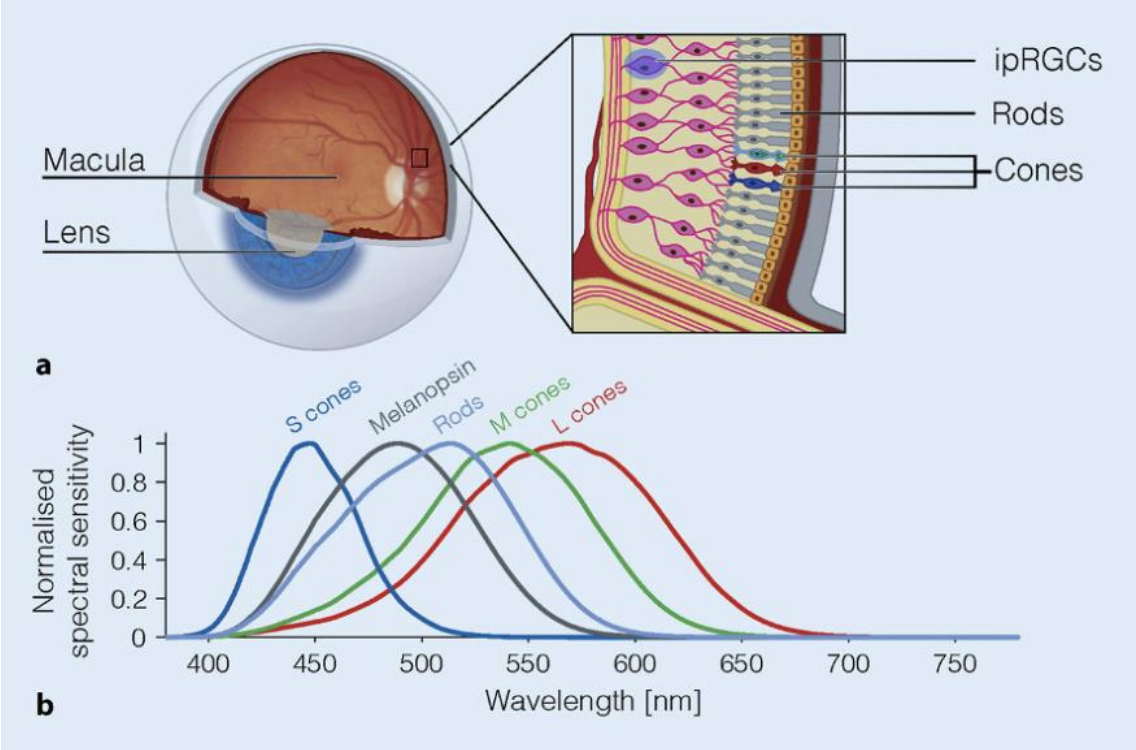

Figure 4. Overview of the retina photoreceptors (Blume, C., Garbazza, C., & Spitschan, M., 2019)

Two primary effects of light on the circadian rhythm have been studied: acute melanin suppression and phase shifting of the circadian rhythm. The photic history mediates both, that is, the amount of light exposure during the day. The system mediating melatonin suppression exhibits a spectral sensitivity similar to

that of melanopsin, the photopigment found in the ipRGCs, with a peak spectral sensitivity at approximately 480 nanometers, which corresponds to the wavelength of blue light. This is why exposure to blue light before sleep can disrupt our circadian rhythms and make it more difficult to fall asleep. Circadian phase shifting also shows maximal effect within this spectral range; exposure to light in the morning advances the clock, while evening light delays it. Even brief exposures or flashes of bright light can shift the circadian phase (Blume et al., 2019: 149; McKee and Hedge, 2022: 338).

Long-term circadian disruption is associated with imbalances in the metabolic and endocrine systems, increasing the risk of obesity, diabetes, cancer, cardiovascular disorders, and even mortality (Finger and Kramer, 2021, cited in Králiková et al., 2021). Psychiatric disorders and mental health conditions such as seasonal affective disorder (SAD), depression, and anxiety, are also frequently related to irregular lighting exposure patterns. Circadian misalignment negatively affects cognitive functioning and emotional regulation, leading to an increased vulnerability to mood disorders, higher stress levels, impaired memory, and reduced concentration and alertness (Králiková et al., 2021; LeGates et al., 2014: 443).

5.2 Effects of Light on Sleep

Building on the previous discussion of the circadian rhythm and its direct connection with sleep, this subchapter explores the specific effects of light on sleep duration and quality. As mentioned earlier, melatonin, a hormone produced by the pineal gland under the regulation of the SCN, is central to sleep regulation, promoting sleep onset and maintaining its continuation.

Exposure to high light levels, especially those containing a higher spectrum of blue wavelengths in the morning, can increase alertness and decrease sleepiness (Aries et. al, 2020). Exposure to natural daylight or artificial lighting designed to mimic daylight, particularly during the morning and daytime hours, supports healthy sleep patterns by reinforcing circadian rhythm entrainment.

Optimised exposure to appropriate lighting levels during the day enhances sleep quality and duration, including a healthier distribution of deep and REM sleep stages (Aryani et al., 2020; Blume et al., 2019: 151).

As noted in previous chapters, exposure to bright or blue-rich light in the evening or at night suppresses melatonin production, delaying sleep onset and disrupting overall sleep quality. Prolonged exposure to artificial lighting environments with high blue-wavelength content worsens these effects, resulting in persistent sleep disturbances, decreased sleep efficiency, and reduced slow-wave sleep, critical for restorative functions (Martinsons et al., 2023). To mitigate these effects, the general advice in today's digital age is to avoid technology in the bedroom, especially screens 1-2 hours before bed (McKee and Hedge, 2022).

Disrupted sleep due to inappropriate or misaligned light exposure has broader health implications, increasing the risk of cognitive dysfunction, mood disorders, and various chronic health conditions, including metabolic syndrome, cardiovascular disease, and compromised immune responses (Cajochen et al., 2022; Vetter et al., 2022 cited in Martinsons et al., 2023: 71). Therefore, exposure to appropriate light at the correct times of day is essential for maintaining good sleep patterns (Králiková et al., 2021; LeGates et al., 2014: 443).

5.3 Effects of Light on Cognition, Mood and Alertness

Several studies have shown that light can significantly influence cognitive function, mood, and alertness through both direct and indirect pathways, primarily mediated by the intrinsically photosensitive retinal ganglion cells (ipRGCs). These cells transmit photic information to brain regions involved in cognitive and emotional processing, including the suprachiasmatic nucleus (SCN), the lateral hypothalamus, the medial amygdala, and the lateral habenula (LeGates et al., 2014: 444).

Recent findings have shown that light can have a direct effect on mood and cognition. This is known as the direct pathway, referring to the immediate impact light has on cognitive and emotional brain regions through neural projections from ipRGCs, independent of any changes to circadian rhythms. The indirect pathway refers to how changes in the light environment alter circadian rhythms, which in turn affect sleep and contribute to alterations in mood and cognitive performance. Changes in the circadian rhythm due to external environmental factors affect the timing and intensity of physiological and behavioural processes, influencing mood stability, cognitive clarity, and alertness patterns over extended periods (LeGates et al., 2014: 443).

Light exposure, particularly to wavelengths in the blue spectrum, enhances alertness and cognitive performance, including attention, executive function, and working memory, by modulating neurotransmitter systems and cortical activation patterns. (LeGates et al., 2014: 449 ; Blume et al., 2019: 152). On the other hand, numerous studies have demonstrated that poorly timed light exposure can impair cognitive abilities, negatively impacting memory, decision-making, and attention (Aries et al., 2020).

Light has a well-established influence on mood regulation. It can influence mood by directly modulating the availability of neurotransmitters such as serotonin, which plays a key role in mood regulation. Additionally, stabilising circadian rhythm desynchronisation and sleep disorders, which are common in people suffering from mental health disorders (Blume et al., 2019: 152). Enhanced daytime illumination or exposure to dynamic lighting patterns that mimic natural daylight cycles has demonstrated efficacy in alleviating depressive symptoms, reducing anxiety, and elevating mood. Bright light therapy (BLT) for mood disorders was first introduced in 1984 for the treatment of Seasonal Affective Disorder (SAD), a condition characterised by depressive symptoms during winter months when daylight hours are reduced (Blume et al., 2019: 152).

The alertness-promoting effects of light are closely linked to its acute neurobehavioral impacts, primarily mediated through the suppression of

melatonin and the activation of cortical and subcortical areas responsible for vigilance and arousal. Exposures to light during the evening and night have a stronger effect on alertness than those during the day. Controlled exposure to appropriate lighting levels during daytime can substantially elevate alertness, reduce fatigue, and enhance productivity. While excessive exposure to bright or blue-rich light during evening hours can disrupt alertness regulation, contributing to sleep disturbances and subsequent daytime dysfunction (Martinsons et al. 2023).

6 Lighting and Worker Well-being

This chapter provides an overview of the literature on the relationship between lighting and worker well-being. By referencing comprehensive reviews and studies, it examines how both natural and artificial light impact employees' physical, psychological, and emotional well-being. The chapter is divided into three main sections, each focusing on different aspects of lighting in the workplace. Studies on the effects of natural light on overall well-being, as well as research into artificial lighting, such as static lighting environments, dynamic lighting systems, and the impact of blue light emitted from screens and digital devices, will be covered. The final chapter identifies gaps and contradictions in the current research, highlighting areas that require further investigation.

6.1 Impacts of Natural Light on Worker Well-being

Research consistently shows that natural light exposure has significant benefits for worker health and well-being, with its implementation into the workplace shown to enhance worker satisfaction and productivity. Natural light plays a crucial role in regulating the circadian rhythm, the internal biological clock that influences various bodily functions, including sleep, hormone secretion, and body temperature LeGates et al., 2014: 451). Boubekri et al. (2014) found that office workers with more daylight exposure experienced longer and higher-

quality sleep, engaged in more physical activity, and reported a higher overall quality of life.

Natural light also has profound effects on mood and psychological well-being. Knez (2014) found that exposure to natural light can improve cognitive performance and reduce stress levels. Similarly, Borisuit et al. (2015) found that office workers consistently report better moods and higher alertness in daylight conditions compared to conditions with only electric light. This psychological boost is linked to the biological effects of light on brain function. Also, access to daylight is generally perceived as more desirable for psychological comfort and environmental satisfaction. Employees with greater sunlight exposure reported higher job satisfaction, indicating a clear link between daylight and emotional well-being in occupational settings.

The link between natural light and mental health is further evidenced by it being an effective countermeasure to Seasonal Affective Disorder (SAD) and other forms of depression. Exposure to natural sunlight stimulates neural and hormonal responses that regulate mood-related brain chemistry (Borisuit et al., 2015: 193; McKee and Hedge, 2022: 339). Regular sun exposure is linked to lower incidences of depression and anxiety, partly because sunlight stimulates vitamin D production, which is essential for a strong immune response, mental health, regulating inflammation, and maintaining calcium homeostasis (McKee and Hedge, 2022).

Recent studies also confirm the importance of direct sunlight in workplace settings. A survey of 444 employees found that sunlight had a stronger positive effect on anxiety, depressed mood, job satisfaction, and occupational stressors than simply having a view of nature through a window (Mihyang et al., 2016 cited in McKee and Hedge, 2022: 340). A study also showed that just thirty minutes of exposure to bright daylight near windows (between 1000 lx and 4000 lx) was nearly as effective as a short nap in reducing post-lunch drowsiness in healthy individuals (Kaida et al., 2006 cited in Borisuit et al., 2015: 193).

Despite the many benefits, excessive daylight can sometimes cause visual discomfort. Belany et al. (2024) observed that overly bright spaces can become uncomfortable, affecting the visual experience and potentially sabotaging some of the positive effects on wellbeing. Office workers can suffer from glare, eye strain, or difficulty focusing due to natural light entering through poorly oriented windows, causing daylight to be too intense (McKee and Hedge, 2022: 340; Belany et al., 2024). Thermal discomfort is another aspect that can directly affect worker well-being. Roulet et al. (2007) note that this can negatively affect satisfaction and mood.

6.2 Impact of Artificial Light on Worker Well-being

Artificial lighting in workplaces plays a crucial role in enhancing employees' visual comfort, health, and psychological well-being. Historically, office lighting has been designed to be energy-efficient and sufficiently illuminate tasks while preventing visual discomfort, such as glare and excessive contrast. However, growing research over the years has demonstrated that office lighting has a profound impact on workers' health and well-being. Since modern employees spend a majority of their time indoors under artificial lighting, understanding and optimising these visual, psychological, and biological effects of light is essential for supporting worker well-being. This chapter examines the impacts of conventional static office lighting and advanced dynamic lighting systems, while also considering the particular issue of blue light exposure from screens and devices.

6.2.1 Static Artificial Lighting and Worker Well-being

Static lighting refers to the fixed lighting luminaires in the workplace that provide constant illumination and colour temperature throughout the workday. Traditional offices apply this type of lighting using LEDS or fluorescent lamps delivering around 500 lux, suitable for general tasks (Mills et al. 2007; Boyce et

al. 2006). However, although sufficient for most tasks, these systems fall short in terms of supporting human well-being. While they successfully prevent under-illumination or excessive glare under standard conditions, employees often describe them as “uninspiring” or “gloomy” due to the monotonous luminance levels and distributions (Boyce et al., 2006: 191).

A static system set at one level cannot accommodate individual preferences or the fluctuations in alertness that occur throughout the day. Consequently, some occupants may experience discomfort or fatigue even in a technically adequate lighting environment, especially if it is non-adjustable (Veitch et al., 2008: 134). Research in open-plan offices has shown that how pleasant or comfortable workers find the lighting is correlated with their mood and well-being at work (Veitch et al. 2008: 141). These psychological factors highlight the significance of design quality in promoting worker well-being.

Key static lighting design parameters include illuminance level and correlated colour temperature (CCT). Aryani et al. (2020) observed that increasing indoor office illuminance from 300 to 500 lux significantly improved subjective alertness and vitality, suggesting enhanced stimulation of the circadian system. This finding aligns with wider evidence indicating that both the intensity and spectral quality of ambient light can produce non-visual biological effects, influencing circadian regulation, mood, and alertness (Mills et al., 2007). This means that even with a static lighting system, a simple adjustment, such as increasing the CCT, can already make a significant impact.

A controlled study by Mills et al. (2007), conducted within a shift-working call centre, investigated the effects of a newly developed fluorescent lamp technology with a high CCT of 17,000K on worker wellbeing, functioning, and performance. After several weeks, individuals exposed to the new lighting conditions demonstrated significant improvements in self-reported alertness, concentration ability, daytime energy, and mental well-being compared to a control group working under standard warm-white lighting of 2,900 K. The high-CCT lighting (which mimics aspects of natural daylight) was particularly effective in reducing fatigue and sleepiness during the day, with improvements

of 30% or more observed in the intervention group in key areas such as concentration, light-headedness, fatigue, and sleepiness, consistent with laboratory findings that cooler light prompts higher levels of mental activity than warmer light (Mills et al., 2007).

6.2.2 Dynamic Lighting Systems and Individual Control

Dynamic lighting systems are advanced lighting setups that change illumination characteristics over time, rather than remaining constant. The goal of dynamic lighting in offices is to mimic natural light patterns or to deliver light stimulation optimised for human circadian rhythms and comfort throughout the day. One key term is human-centric lighting (HCL), which is lighting design focused on supporting human health, mood, and performance, often by accounting for non-visual effects of light. A dynamic HCL system usually delivers bright, blue-enriched light during morning and daytime hours, to promote alertness and alignment with the body's daytime phase, then gradually transitions to dimmer, warmer-toned light in the late afternoon and evening to stimulate relaxation and preparation for sleep.

Essentially, dynamic lighting extends the benefits of daylight to indoor settings. Research conducted by Králiková et al. (2021) suggests that properly timed lighting in offices can synchronise employees' biological clocks with their work schedules, positively affecting hormonal rhythms (such as melatonin and cortisol cycles) and even improving sleep quality and mood. A study conducted by Belany et al. (2024: 286) found a correlation between natural light and mood, and that a dynamic lighting system combined with natural light had a positive effect on satisfaction and concentration. Workers often preferred environments with abundant natural light, and any discomfort was usually related to glare or insufficient light in specific areas. The addition of an automatic system that adjusted electric light intensity based on daylight availability effectively mitigated these issues, creating a more uniform and comfortable visual environment that aligned with natural rhythms.

Providing employees with individual control over their lighting environment further boosts these benefits. The ability to adjust light intensity or direction allows workers to customise their environment to personal preferences, task requirements, or changes in mood and energy throughout the day. Boyce et al. (2006: 217) found that employees with access to personal lighting controls, such as dimmable task lights or adjustable overhead lighting modules, experienced higher levels of motivation and attention throughout the workday.

Veitch et al. (2008: 145) found that people who were more satisfied with their lighting, regardless of the specific configuration, reported the space as more attractive, felt more positive and comfortable, and were more satisfied with both their environment and their work performance. This study was the first to demonstrate the complete link from lighting conditions to perceived health and wellbeing, confirming the importance of lighting as a key design factor in shaping workplace experience.

6.2.3 Blue Light Exposure from Screens and Devices

Electronic screens have become a common part of everyday life. We spend a significant amount of time each day looking at them, whether it is our cellphones, tablets, computer monitors, or televisions. The light emitted by these screens is LED-based and rich in blue wavelengths, which presents both benefits and challenges. While it can support focus and alertness during working hours, uncontrolled exposure in the evening can interfere with sleep and contribute to long-term impacts on well-being. Green (2017, cited in McKee and Hedge 2022: 337) notes that exposure to blue-enriched screen light can directly harm ocular health and disrupt circadian rhythms, especially when used extensively in the evening. This, in turn, directly affects sleep quality and quantity due to the melatonin suppression caused by the screens.

In the office environment, it is important to consider not only overhead lights and natural light, but also the light exposure from digital screens, especially computer monitors that employees use throughout the day. While such light

exposure during daytime hours can support alertness and concentration, prolonged use can lead to eye fatigue and discomfort. Many office workers report symptoms of Computer Vision Syndrome (CVS), which includes eye strain, dryness, blurred or double vision, headaches, and general visual discomfort. Around 70% of computer users experience some form of these symptoms, and extended exposure has raised concerns about potential long-term impacts on ocular health, including risks related to retinal stress, macular degeneration, and cataract development (Hwang et al., 2021 cited in McKee and Hedge, 2022:336).

6.2.4 Gaps and Contradictions in the Existing Research

While research increasingly recognises the role of lighting in supporting employee well-being, several gaps and contradictions persist. In a recent comprehensive review, Martinsons et al. (2024: 85) observed that all reviews cited have highlighted the low quality of existing literature. Common methodological shortcomings include small sample sizes, brief exposure durations, insufficient monitoring of prior light exposure, poorly defined or selected lighting conditions, and reliance on self-reported data, all of which have limited the overall reliability and interpretability of many studies.

A systematic review and meta-analysis by Landveugd et al. (2024) concluded that, although there is a small to moderate positive effect of light on well-being, the supporting evidence is weakened by frequent methodological limitations. These include inconsistent definitions and measurements of well-being, inadequate reporting of light conditions (intensity, timing, spectral composition), and poor control of confounding variables. Some studies claiming to measure well-being were assesing related factors such as sleep or mood, without using standardised assessment tools. The review also raised concerns around statistical reliability and publication bias, which may lead to an overestimation of positive findings.

Conflicting results are particularly reported in studies on static lighting. For example, while blue-enriched lighting was found to improve alertness and mood by Mills et al. (2007), Borisuit et al. (2015) failed to produce the same effects in a similar experimental setting. However, this can be partly explained by the differences in study duration and sample size. The study by Borisuit et al. (2015) was conducted for two afternoons with a larger sample size, while Mills et al. (2007) experiment lasted three months but with a much smaller sample size. The long-term effects of lighting on well-being remain underexplored, and many field studies fail to control for confounding factors such as task type, work environment, or personal preferences.

The lack of standardised metrics for assessing lighting quality, health impacts, and productivity also makes it difficult to compare and synthesise findings across different studies, since assessing well-being relies on self-reported measures in the form of questionnaires. The results can be influenced by individual biases and perceptions. In the experiment conducted by Mills et al. (2007) in a real working environment, where two floors participated with only one having the lighting modified, results acknowledged that although participants did not know which floor they were assigned to, the lighting differed visually and hence there is the possibility of biased responses to questionnaires and cross contamination of information between groups (Mills et al., 2007).

Employee preferences for lighting conditions can also differ significantly, individual factors such as age, gender, visual sensitivity, and chronotype (morning-evening preference) affect how lighting influences wellbeing, yet most studies apply generalised solutions (Králiková et al., 2021; McKee and Hedge, 2022: 341). A study conducted by Knez and Kers (2000) highlighted age as an important variable that should be considered, older employees require more light for comfortable visibility compared to younger ones. These different factors present a challenge for designing lighting solutions that meet the diverse needs of employees, particularly affecting dynamic lighting systems that aim to support natural circadian rhythms. The effectiveness of these systems varies among individuals, with some users reporting discomfort or distraction (Belany et al., 2024: 227).

7 Lighting and Work Productivity

With organisations growing demand for efficiency and performance, more attention has been shifted towards environmental factors within office buildings that influence employee productivity. Among these, lighting has emerged as a key factor not only in supporting visual tasks but also because of its effects on cognitive function, alertness, and overall work productivity. Lighting affects task performance both directly, by improving visibility, and indirectly, through its impact on alertness and mood. This chapter reviews the existing literature on the relationship between lighting conditions and workplace productivity, examining how different types, qualities, and exposures of light influence performance outcomes. Special attention is given to studies linking lighting with cognitive tasks and decision-making, as well as the practical design implications within office environments. Finally, methodological considerations are discussed to evaluate the strength and reliability of current research in this field.

7.1 Studies Linking Lighting to Productivity

There is increasing research linking improved office lighting, especially when combined with natural light, to higher productivity and better work performance, while also showing that poor lighting can negatively impact performance. The study mentioned previously, conducted by Veitch et al. (2008), demonstrated that better quality lighting can support organisational productivity. Other researchers have also shown that satisfaction with lighting contributes to increased environmental satisfaction, which in turn leads to enhanced job satisfaction. As cited by Veitch et al. (2008: 146), these improvements are linked to greater organisational commitment, reduced employee turnover, and improved business unit performance.

Belany et al. (2024: 287) also concluded in their studies that modifying various aspects of lighting, such as illuminance levels, colour temperature, and glare, is possible to enhance overall work performance and improve the work environment. Approximately 70% of respondents in the study agreed that

lighting affected their mood, overall satisfaction and concentration at work, supporting the idea that better lighting leads to better productivity outcomes. Similarly, Konstantzos et al. (2020) observed that daylight-enhanced spaces were associated with improved work accuracy and reduced signs of fatigue. A meta-analysis by McKee and Hedge (2022: 339) further supports this, reporting that companies relocating to office buildings with higher daylight exposure experienced productivity increases ranging from 5% to 25%.

In the three-month field study conducted by Mills et al. (2007), employees exposed to bright 17,000K lighting reported a 19% improvement in self-rated work performance, as well as better concentration and lower fatigue, compared to a control group under normal lighting. Another study by Linhart and Scartezzini (2011: 986) compared two energy-efficient lighting scenarios in an office and observed that workers' performance on paper-based tasks was significantly better under the lighting setup providing higher illuminance, even though it had a slight risk of glare, than under the standard lighting scenario. However, overly high illuminance or poor glare control can lead to visual discomfort, which negatively impacts performance benefits (Boyce et al., 2006: 221).

In two one-time workday experiments conducted by Boyce et al. (2006: 216-217), no simple, direct effects of overall lighting quality variations on office worker performance were found across a range of administrative, cognitive, and visual tasks in field simulation settings. However, the research did reveal significant interaction effects, suggesting that the influence of lighting on performance is more subtle. Specifically, individual control over lighting appeared to have benefits for maintaining motivation and alertness over the working day. These findings suggest that while lighting design alone may not have a direct impact, its interaction with factors such as individual control and the surrounding environment can influence certain aspects of office worker performance.

Knez (1995: 40) found that while lighting influences task performance, mood may act as a mediating factor, with more pleasant lighting conditions indirectly

enhancing productivity by improving emotional states. This is further supported by the findings of Veitch et al. (2008: 141), which provide strong evidence for the appraisal pathway, meaning that when individuals perceive the lighting settings as pleasant, their emotional state improves, and therefore, productivity and performance outcomes are enhanced. In turn, if the lighting is perceived as unpleasant, it may negatively impact morale, which could indirectly lead to reduced productivity.

7.2 The Impact of Lighting on Cognitive Tasks and Decision-Making

Beyond basic task performance, lighting conditions have also been shown to affect cognitive processing, including attention, memory, and decision-making. Technical characteristics of lighting, such as illuminance levels, colour temperature, flicker frequency and their effects on task performance and cognitive functioning, have been studied for decades. Research by Zhu et al. (2017: 220) demonstrated that higher illuminance and cooler colour temperatures positively influenced daytime cognitive performance on several tasks involving reaction time and working memory. This supports the existing research that blue-enriched light has stimulating effects on the human nervous system (see section 5.1. on page 16)

The role of flicker in lighting has also received significant attention due to its influence on visual performance, particularly in tasks that require sustained attention or reading. Veitch and McColl (1995) conducted a study in which participants completed a visual acuity task under two different fluorescent lighting conditions: one using low-frequency magnetic ballasts, which produce flicker, and another using high-frequency electronic ballasts, which eliminate flicker. Participants working under the flicker-free lighting performed significantly better, reporting less visual strain and demonstrating higher task accuracy. This further confirms earlier work from Wilkins et al. (1989, cited in Clements-Croome 2000: 212), which found that users in offices with high-frequency ballasts reported fewer symptoms of eyestrain and headaches, even when they were unaware of the change in lighting condition.

As cited by Clements-Croome (2000: 210), “Mounting evidence suggests that low-frequency flicker interferes with visual processing, disrupting the eye movements in reading, causing visual fatigue, and hampering visual performance and computer-based task performance” (Veitch and McColl, 1995; Veitch and Newsham, 1998b; Wilkins, 1986). Modern high-frequency electronic ballasts, operating at frequencies above 20,000 Hz, eliminate this issue, as such rates exceed the capacity of human visual perception (Clements and Croome, 2000: 210).

Cognitive performance may also be affected by the indirect psychological effects of lighting, particularly through its influence on mood, as mentioned in earlier research conducted by Knez (1995). In two controlled experiments examining the impact of illuminance (300 lux vs. 1500 lux) and CCT (warm white at 3,000K vs. cool white at 4,000K) on cognitive tasks. He found that lighting conditions that improved mood also enhanced performance on problem-solving and memory tasks. Interestingly, the effects varied by gender, with females performing better under warm light conditions, while males showed enhanced performance under cool light.

7.3 Methodological Considerations in Productivity Research

Understanding the relationship between lighting and productivity requires careful consideration of research methodology. The Hawthorne experiments conducted in the 1920s are one of the first examples that taught researchers how human performance can be influenced by psychological factors, making it difficult to explain results through simple cause-and-effect relationships. In these studies, any change in lighting led to increased worker output, which was later explained by workers’ awareness of being observed and feeling valued, rather than the lighting itself. (Clements and Croome, 2000: 207). This is known as the Hawthorne effect, where cognitive and social factors often shape the impact of physical conditions. Modern lighting research is well aware of this, and typically addresses it by using control groups and ensuring that participants

are unaware of the lighting modifications to prevent expectations from influencing the results.

One significant methodological difficulty is the measurement of “productivity” itself. Productivity can be defined in numerous ways, such as speed or accuracy on specific tasks, overall work output, error rates, or indirect measures such as absenteeism. Studies in laboratory settings often use short-term cognitive or typing tasks as performance measures, which may not fully capture all aspects of workplace productivity. Field studies, on the other hand, may rely on self-reported productivity or organisational performance metrics, both of which can be influenced by numerous external variables.

A comprehensive review by Konstantzos et al. (2020) noted that variables such as illuminance, luminance contrast, and correlated colour temperature do impact task performance in many studies. However, the size and direction of these effects often vary, depending on the experimental design and setting. As a result, findings are sometimes not directly comparable, and no universal conclusions can be drawn due to differences in protocols, sample sizes, and performance tests.

Another challenge involves controlling for other environmental factors that might affect productivity. As mentioned previously, lighting is just one aspect of the indoor office environment; other elements, such as temperature, noise, air quality, and ergonomics, also affect employee performance. For example, in a field study by Lamb and Kwok (2016, cited in Isham et al., 2020: 66) combined effects of lighting and noise were found, highlighting the need to consider both factors to understand performance outcomes. Laboratory studies attempt to control these external factors, although this makes them less realistic. Basically, there is a trade-off between tightly controlled experiments and realistic field observations. This further complicates meta-analyses and comparative studies, highlighting the need for more standardised research methods to accumulate comparable data (Konstantzos et al. 2020).

Research to date also tends to focus on individual performance outcomes, rather than productivity in an organisational sense, such as teamwork,

innovation, or long-term productivity. This narrower focus limits our understanding of how lighting influences collective performance or strategic outcomes over time. Due to the lack of uniform reporting standards, some studies have failed to report essential details such as lighting intensity, spectral composition, or exposure duration, making comparisons across findings difficult. These methodological gaps, together with issues such as publication bias and different outcomes, result in conclusions with limited reliability and generalisability.

8 Analysis

The comprehensive review of the literature conducted in this thesis reveals a clear link between workplace lighting conditions and both employee well-being and work performance. Lighting is a crucial environmental factor with physiological, psychological and behavioural effects, being either directly or indirectly linked to well-being and productivity. Good lighting is not only about enabling visual tasks anymore, as numerous studies and experiments have shown that it has profound impacts on the circadian rhythm, mood, comfort, and cognitive function, all of which impact productivity. A key insight from this thesis is that optimal lighting supports workers' well-being, which in turn translates to improved job performance.

Daylight exposure in office environments proved to be as particularly important. Studies such as those conducted by Boubekri et al. (2014), Knez (2014), Borisuit et al. (2015), and McKee and Hedge (2022) have shown that employees who receive appropriate exposure to daylight in offices report higher levels of alertness, a better mood, and reduced fatigue. Office spaces with sunlight access contribute to healthy circadian rhythms, which in turn support better sleep at night and more stable energy levels throughout the workday. Analysis of research indicates that environments with access to daylight are associated with improved self-reported health and higher work satisfaction. However, the benefits of daylight must be balanced with potential challenges,

such as glare, visual discomfort, and thermal issues, which can undermine comfort and productivity if not properly managed.

Artificial lighting is equally important, especially in indoor spaces and during seasons when daylight is limited. Different lighting characteristics, such as intensity, correlated colour temperature, distribution, and the absence of glare or flicker, have been proven to impact well-being and influence work performance. Research by Mills et al. (2007), Aryani et al. (2020), and Veitch et al. (2008) concluded that well-distributed lighting at appropriate colour temperatures can enhance visual comfort and cognitive performance. Higher brightness levels and cooler, blue-enriched light during daytime hours can improve attention, reaction time, and short-term memory during mentally demanding tasks.

In practice, office lighting that mimics daylight helps workers stay alert, while poor lighting can lead to fatigue and discomfort. However, studies suggest that more light is not always better, since excessive brightness can cause glare or eye strain, which reduces comfort and productivity (McKee and Hedge, 2022: 340; Belany et al., 2024). This emphasises the importance of finding a balance in lighting design, where the conditions support performance without becoming overwhelming.

Another key finding is that dynamic lighting and personal lighting control can enhance well-being and improve work performance. Traditional static lighting fails to accommodate human biological rhythms. The literature review of this thesis highlights that lighting systems that adjust throughout the day to mimic sunlight can better support circadian rhythms and subjective well-being. Tracing back to research mentioned previously, studies by Boyce et al. (2006), Belany et al. (2024), and Králiková et al. (2021) have all had similar results, where workers under dynamic lighting report better mood, alertness, and satisfaction, which in turn gives a sense of empowerment, indirectly boosting morale and productivity. While not all studies report significant improvements, a consistent finding is that dynamic or personalised lighting tends to improve subjective well-

being, as workers feel better and more satisfied with their environment (Veitch et al. 2008; Belany et al. 2024).

Interestingly, the relationship between lighting, well-being and productivity is mediated by psychological factors, in other words, how employees perceive lighting. When workers find the lighting setting pleasant, they report a better mood, which in turn indirectly improves cognitive performance and motivation. If lighting is perceived as uncomfortable or harsh, it can decrease morale and lead to dissatisfaction, which may reduce work engagement and performance. These findings align with broader ergonomic research, which suggests that a supportive work environment can reduce stress and enhance productivity. This thesis notes that lighting influences productivity both directly, through improved visibility and alertness, and indirectly, by affecting mood.

Finally, this literature review acknowledges that lighting is one of the several environmental and organisational factors affecting workers. While factors such as air quality, noise levels, ergonomic design, and temperature are well known for their impact on employee wellbeing and productivity, this literature review aims to emphasise the role of lighting, which is often overlooked, as a distinct and influential contributor. By analysing and combining all relevant literature, this chapter confirms the main argument of the thesis that optimal lighting solutions and design in the office workplace have a meaningful positive impact on wellbeing and workplace performance.

The consistent positive findings between exposure to natural and dynamic artificial lighting and enhanced employee wellbeing and productivity support the integration of human-centric lighting solutions within office layouts. While not all studies report significant improvements, a consistent finding is that dynamic or personalised lighting tends to improve subjective well-being, as workers feel better and more satisfied with their environment (Veitch et al., 2008: 146; Belany et al., 2024).

9 Discussion

The findings of this thesis provide valuable implications for both theory and practical workplace applications, highlighting lighting as a key environmental factor in workplace well-being and productivity. Traditionally, lighting in offices was treated only by its visual utility. However, because of studies conducted over the last decades, lighting's broader role in human physiology and psychology is now widely recognised. This discussion examines the results within the wider context of health and performance in the workplace, addresses limitations in current research, proposes directions for future research, and improements to workplace design.

Organisations should prioritise access to natural daylight through architectural features, such as windows and skylights, and implement advanced dynamic artificial lighting systems that adjust intensity and spectral composition throughout the day. As discussed earlier, these systems mimic the beneficial impacts of daylight on circadian rhythms, alertness, mood, and sleep. This, in turn, supports employee well-being and performance

However, it is essential to acknowledge limitations and variability in research findings, which highlight the existing methodological challenges. Many studies on lighting and well-being or productivity have small sample sizes and short durations. While some experiments show immediate boosts in mood or performance over a few days or weeks, it is unclear whether these effects continue over months or years. Additionally, several studies highlight the difficulty in conducting lighting research in real-world office settings because of challenges in isolating its effects from other environmental factors. Accurately measuring individual experiences and maintaining adequate response rates also presents a challenge (Aryani et al., 2020; Veitch et al., 2007).

The absence of a common framework for measuring well-being is another critical issue. Many studies claim to measure well-being while measuring some aspects of well-being, such as sleep and mood. To improve consistency and reliability, future studies should use standardised and validated well-being

assessment tools, such as official questionnaires and psychometric scales. A meta-analysis on the effects of lighting on well-being reported small to moderate overall impacts. It cautioned that these findings may be inflated due to publication bias favouring successful outcomes. Researchers should therefore report lighting variables, including intensity, colour temperature, type of lighting system, exposure duration, season, and time of day. Baseline light levels should also be clearly stated to allow for accurate comparisons across studies.

Individual variability complicates lighting design. Factors such as age, personal preference, gender and chronotype influence how lighting is perceived. This variability means that there is not one lighting setting that will suit everyone. Dynamic lighting systems and personal controls can help address these differences, although the implementation of such flexibilities comes with its own challenges, such as cost and complexity. Essentially, the range goes from static lighting, which lacks stimulation and may reduce motivation, to highly individualised and tuned systems that are often too complex to manage. The solution lies in finding the middle ground, a balanced solution that maintains usability while accommodating individual needs.

Further research into dynamic lighting systems is needed. Current research on these systems is somewhat new, and they lack long-term evidence to support their effectiveness. Researchers, including Cupkova et al. (2019), Aryani et al. (2020) and Kruisselbrink et al. (2018) have addressed this gap in research and called for more extensive investigation. This is particularly important with the increasing use of LED and smart lighting systems in offices, whose long-term effects on circadian rhythms and other physiological processes remain insufficiently explored.

Although current studies suggest that lighting can positively impact well-being and performance, the evidence base is somewhat limited. Together, the limitations and gaps mentioned, highlight the need for well-designed, long-term studies that use consistent lighting conditions, reliable methods to assess well-being, and take individual needs into account to guide better workplace lighting strategies in the future.

10 Conclusion

This thesis investigated the impact of lighting on the health, well-being, and productivity of office workers. Through a comprehensive examination of existing research and theory, it confirms that lighting plays a far more profound role in workplace environments than traditionally acknowledged. Good lighting design, which aligns with natural daylight rhythms, supports physical comfort and mental alertness. In turn, these improvements in well-being are linked with benefits in concentration, accuracy, and overall productivity. On the other hand, poor lighting conditions can harm health by disrupting sleep patterns or causing eye strain, which can lead to performance issues through fatigue, low morale, and decreased focus.

Access to natural light has emerged as one of the primary beneficial environmental factors. Workers with greater daylight exposure experience better mood, energy levels and sleep quality, highlighting the importance of architectural designs that prioritise daylight access into indoor spaces. Additionally, the characteristics of artificial lighting (intensity, distribution and colour temperature) should be designed with human well-being in mind, rather than solely for task visibility. The psychological perception of lighting has a greater impact than one might expect, influencing both workers' overall satisfaction and productivity. This shows that beyond meeting quantitative standards, organisations must focus on qualitative aspects of lighting. Employees who feel comfortable and energised by their environment are more likely to be engaged, focused and productive in their roles.

By applying insights from research, such as providing adequate, glare-free illumination, incorporating daylight, enabling personal control, and considering circadian impacts, organisations can make evidence-based improvements to their lighting systems. Essentially, optimising workplace lighting benefits both employees and employers. Employees gain from a healthier, more comfortable workplace, and employers benefit from a workforce with higher performance and lower error rates. With modern and cost-effective lighting technologies such as solid-state lighting (SSL), primarily in the form of LEDS and smart systems,

these improvements are now more accessible than ever. This aligns with the shift toward more human-centred workplace design, where success is measured not only by financial outcomes, but also the long-term health and engagement of employees.

It is important to note that the science of workplace lighting is still evolving. While lighting improvements can significantly support well-being and performance, they should be part of a broader well-being strategy, rather than being treated as the only factor for enhancing productivity. However, the existing evidence is strong enough to act on; organisations should proactively implement the best practices in lighting discussed in this thesis. By doing so, they effectively apply current knowledge to real-world settings, benefiting workers now, while scientists and ergonomists continue to refine recommendations for the future.

This thesis has brought together evidence that illuminates the path for healthier, more productive office environments through optimised lighting design. Lighting should no longer be regarded as an afterthought in office planning or dismissed as a basic operational cost. Instead, it should be treated as a strategic asset and a core factor of workplace wellness strategies. The conclusion drawn from this literature review thesis is optimistic that with optimised design and proactive management of lighting conditions, it is possible to enhance employee well-being and achieve higher levels of performance, essentially improving both employee well-being and overall organisational success.

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