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Integrating Natural Light for Wellbeing, Performance, and Quality Care Delivery in Healthcare Environments

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UNIVERSITY OF
PLYMOUTH

INTEGRATING NATURAL LIGHT FOR WELLBEING, PERFORMANCE, AND QUALITY CARE DELIVERY IN HEALTHCARE ENVIRONMENTS.

by

ADEMOLA ADEBAYO AKINBAMI

A thesis submitted to the University of Plymouth
in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

School of Arts, Design, and Architecture

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questions, and insightful discussions were invaluable, particularly during the formative stages and in the face of the challenges posed by the pre-COVID and post-COVID eras.

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To my Lord and Saviour, Jesus Christ, I am eternally grateful. I owe you my life and my all.

Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

A programme of advanced study was undertaken, which included:

- MARE700 – Research in the Arts and Humanities
- Understanding and working with quantitative data, at the University of Plymouth
- Academic Writing Surgery at the University of Plymouth
- HIP2 university consultation events: Hospital Design – Achieving Net Zero Carbon, and improving well-being/productivity at the University of Plymouth
- NVivo users' workshop at the University of Plymouth

The following external institutions were visited for research and consultation purposes:

University Hospitals Plymouth NHS Trust, Plymouth, UK

Peninsula Allied Health Centre (PAHC), Plymouth, UK

Federal Medical Centre, Jabi, Abuja, Nigeria

Federal University of Technology, Minna, Nigeria

This research project was presented at the following conferences:

Akinbami A. 2021. Poster Presentation, at the University of Plymouth, Doctoral Conference, Faculty of Art, Humanities, and Business.

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Signed…… …………..

Date: 09/01/2024

Preface

In the complex tapestry of professional growth, there is a story woven together by intertwining threads. The fusion of design and a conscientious consideration of well-being acts as a unifying thread, guiding the narrative through chapters marked by adversity, redirection, and resilience. This research stands as a testament to a resolute dedication to enhancing well-being through deliberate and purposeful design choices, navigating the intersection with an unwavering belief in the transformative power of architecture.

Motivated by a deep concern for the impact of human ill-health on both healthcare professionals and patient care, this study examines the pivotal role of the built environment, specifically within the field of architecture. By examining firsthand experiences of users, this research not only acts as a catalyst for meaningful change but also acknowledges the immense pressures faced by caregivers in the face of the global challenge of human ill-health.

Despite advancements in technology, the design of healthcare facilities remains a critical factor influencing the well-being of patients and medical personnel. This research focuses on nuanced aspects, particularly the significance of lighting conditions, to analyse how healthcare facilities affect the well-being and performance of personnel. Human factors research emerges as a crucial tool in strengthening the well-being of those involved in patient care.

Further driving this research is a deeply personal experience—the loss of parents to cancer during formative years, leading to a redirection from medicine to a fervent pursuit of well-being through architecture. Recognising the profound impact that architecture has on human health, the researcher embarks on a transformative journey that began with the conceptualisation of a children's hospital in Abuja during the undergraduate years. This endeavour instils a strong belief in the power of intentional architectural choices to address holistic needs. The journey continues with a master's thesis focused on "His Throne," a grand auditorium seamlessly blending architectural brilliance with spiritual sanctity, utilising natural light to create a space that echoes the transformative power of faith.

The commitment to exploring the relationship between architecture and well-being remains strong in the doctoral research, specifically focusing on the role of natural light in healthcare environments. Given the COVID-19 global pandemic, the importance of optimal indoor healthcare environments becomes even more apparent, particularly for frontline professionals who work long hours. Thus, this research seeks to understand how daylight impacts the well-being and performance of healthcare personnel, considering the various climatic conditions in the United Kingdom and Nigeria.

However, conducting this research comes with challenges, primarily related to obtaining necessary approvals. Delays and obstacles in securing approvals from the Nigeria Health Authority and the NHS Plymouth in the UK require a change in approach. Time constraints, the busy nature of hospitals, and the complexities associated with COVID-19 make obtaining approvals even more difficult. Additionally, relying on NHS staff adds another layer of complexity, as the feasibility of the research within the current NHS climate is a concern.

While approval from the Nigeria Health Authority takes approximately twelve months, obtaining approval from the NHS Plymouth in the UK seems nearly impossible. Engaging with clinical and R&D staff at University Hospitals Plymouth NHS Trust (UHPHNT) reveals both enthusiasm and concerns about feasibility, prompting a careful evaluation of alternative options. As a result, contingency plans, designed with adaptability and foresight, shift the focus to alternative environments within the University of Plymouth health professions for one of the pilot studies.

Despite these complexities, this research is enriched by personal experiences, which are woven into the fabric of the study. This approach adds authenticity while acknowledging the need to critically examine potential biases. A thorough exploration of the theoretical and methodological frameworks that underpin the research establishes a strong foundation for understanding the significance of the study and its potential contributions to the field.

Abstract

Ademola Adebayo Akinbami

Integrating Natural Light for Wellbeing, Performance, and Quality Care Delivery in Healthcare Environments.

The global challenge of addressing human ill-health demands a re-evaluation of the multifaceted factors impacting health outcomes. Rising health issues in society impose significant burdens on healthcare professionals, affecting their comfort, overall well-being, and performance. While issues like inadequate funding and medical equipment shortages are frequently discussed, a growing recognition centres on the pivotal role that architecture and the built environment play in shaping health outcomes. Poorly designed healthcare facilities contribute to staff shortages and poor care outcomes. Consequently, architecture's transformative potential within the built environment becomes essential in advancing human health, well-being, and productivity.

Interestingly, the impact of a day-lit environment on human health, wellbeing, and performance has been acknowledged, but the statistical significance of these connections remains limited. This research aims to bridge this gap by highlighting the influence of the lighting conditions on personnel well-being, and their subjective performance within healthcare environments.

Conducted over a six-month period within a healthcare facility in Abuja, Nigeria, this study employs a mixed method approach, which include physical measurements, surveys, and semi-structure interviews. To assess personnel well-being and performance, a self-administered questionnaire comprising twenty items is employed. The study explores the correlations between personnel responses and various lighting conditions, with emphasis on daylight. The findings emphasise the influence of lighting conditions on personnel well-being and performance, with daylight emerging as the preferred daytime light source due to its positive impact both wellbeing and performance.

Furthermore, this research identifies intrinsic factors such as age, gender, job roles, and activities as modifiers of human perception and lighting preferences. By adopting an embedded mixed-method design, this study broadens the horizons of investigations into human performance across diverse buildings and climates. Importantly, it not only enriches the theoretical underpinnings of architectural and environmental psychology but also lays a solid foundation for future enquiries into the ways in which indoor lighting influences wellbeing and performance, serving as a crucial reference point for further advancements in healthcare architecture and design. Overall, this research underscores the indispensable role of daylit architectural design and environmental planning in fostering improved well-being and optimal performance among healthcare personnel.

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Glossary

The table below presents an alphabetically organised glossary of important terms and concepts used throughout the thesis. Certain definitions are precise and do not allow for interpretation, while other concepts are defined based on their specific usage within the thesis.

The compilation of this glossary assumes that the reader has no prior familiarity with the terms employed. It is designed as a tool for memory assistance and does not strive to provide an exhaustive or definitive account.

Alertness	Is a state of active attention characterised by high sensory awareness. Alertness is a psychological and physiological state.
Artificial Lighting	Is any light source that is not naturally occurring. It encompasses a wide range of sources, including electrically powered ones like lamps, fluorescent bulbs, and tubes, as well as non-electrical sources like candlelight.
Comfort	The term 'comfort' originated from Middle English and is commonly used in everyday language. For the purposes of this thesis, the term is understood in accordance with its general definition provided by the Oxford English Dictionary, as something that brings satisfaction or delight. This term is not exclusively used to refer to satisfaction with indoor lighting conditions. When discussing factors pertaining to the healthcare work environment, this thesis mostly refers to the occupants' 'comfort' with variables. In other instances where the term 'comfort' is used, it serves as a general synonym.
Daylight	Is the light received from the sun and the sky, which varies throughout the day, as modified by the seasons and the weather.
Facilities Design	Is the planning and design of the physical environment of an activity to best support the execution of this activity. It is a broader term that encompasses the planning and layout of spaces to accommodate specific functions or activities. In this thesis, architectural design is used as an integral part of facility design as architects play a crucial role in determining the overall layout, structure, and appearance of facilities.
Human Performance	It refers to an individual's capacity to consistently achieve optimal performance within their present operating environment. This concept encompasses both individual and collective performance, although it primarily emphasises the performance of individuals.
Human Physiology	Is the scientific study of the mechanical, physical, and biochemical functions of humans in a state of optimal health, including their organs and the cells that comprise them. It primarily concentrates on the functioning of organs and systems within the human body. Many aspects of human physiology exhibit close homology to their animal counterparts, and substantial physiological knowledge has been derived from animal

	experimentation. Anatomy and physiology are intricately interconnected fields of study, with anatomy focusing on the structure and physiology on the functioning, both of which are examined as integral components of medical education.
Mann Whitney U-Test	A non-parametric statistical test of non-normal data to determine the difference between two independent population samples. The U-test includes a t-test statistic which is used in the thesis.
Mood	Is a subjective feeling or emotional state that significantly influences various aspects of an individual's behaviour within a given environment. It is an integral component of the emotional rhythm, subject to fluctuations, disturbance, improvement, and often characterised as either positive or negative. In the thesis, the term “mood” is used as a trade-off between the mood of participants and the ambiance of a space since the contents of a room, including lighting, have the potential to either soothe or agitate individuals.
Natural light	Light generated naturally with the help of natural sources such as the sun or the stars. Throughout this thesis, the term 'Daylight' is largely used interchangeably or together with 'Natural daylight'.
Performance	This relates to the optimal use of resources (such as time, materials, and personnel) to achieve the desired health outcomes. It involves minimising waste and unnecessary steps while maximising the value of services provided. In this thesis, effective collaboration, and communication among healthcare personnel and with patients are regarded as essential for delivering quality care. This includes interdisciplinary teamwork, clear information exchange, and coordination of care. Moreover, the evaluation of this aspect throughout the thesis involves a combination of self-assessment, peer review, and analysis of observations as outputs.
Physiology	Is the study of the mechanical, physical, and biochemical functions of living organisms.
Productivity	It involves being focused, efficient, and effective in achieving specific goals or outcomes. It entails the optimal utilisation of individual's time, skills, and resources, aiming to maximise productivity while minimising distractions, interruptions, and inefficiencies.
Psychology	Is the study of the mind.
Response rate	In the thesis, the term "response rate" is defined as the percentage of respondents present in a study area on the day of a survey who have completed the questionnaire. The use of the daily ward log facilitates the monitoring of response rates and daily staff utilisation. An acceptable response rate is above 60%, as it is believed to guarantee coverage of all areas in a building or tenancy.
Satisfaction	In this survey, the term used to indicate the level of satisfaction expressed by the permanent or semi-permanent population of a building (excluding transient individuals) is 'satisfaction'. Throughout this thesis, the term 'comfort' is largely used interchangeably with 'satisfaction'.
Seasonal variables	Seasonal variables are defined as comfort or satisfaction variables which can change with the seasons. This includes levels of daylight and glare from daylight.
Skylight	Is the light received from the whole vault of the sky as modified by the weather and time of day, ignoring sunlight.
Soft Landings	A term for a set of generic principles whereby a construction project team performs graduated handover and delivers professional aftercare for up to three years post-

	completion. Soft Landings needs to be client-led and should involve all members of a project team working in a spirit of collaboration.
Sunlight	Is the light received directly from the sun, as opposed to that derived from the sky.
Wellbeing	Is not just the absence of disease or illness. It's a complex combination of a person's physical, mental, emotional, and social health factors. It is having the tools, support and environments needed for a productive life.

Chapter I: Introduction

"God heals, and the doctor takes the fees."
— *Benjamin Franklin*

1.1 Introduction

The burden of human ill health is a global challenge that places immense pressure on caregivers who strive to provide quality care (World Health Organisation (WHO, 2017a). Despite the integration of cutting-edge technology for diagnostics and treatment in healthcare facilities, the design of hospitals unfortunately contributes to stress, depression, and anxiety, impacting the health of both patients and staff (Malkin, 1991; Schweitzer et al., 2004). In healthcare, just like any modern work environment, the presence of physical and emotional stress can profoundly affect the well-being and performance of employees. Recognising the critical relationship between individuals and the spaces they work in is vital for promoting comfort, productivity, and safety (Parsons, 2000).

To address these issues, researchers have highlighted the need to understand the dynamic interaction between people and their work environments. A promising approach to mitigating the negative effects of such pressures is the strategic use of natural lighting to enhance visual performance, as demonstrated by review of studies conducted by Tavares et al. (2021), Day et al. (2020), and the Institute of Medicine (2001) report. However, while there has been extensive research on how building design influences performance, there has been a notable lack of attention given to how buildings impact human health, wellbeing, and performance (Heschong et al. 2002).

One area that has received insufficient attention is indoor daylighting, which has gained increased interest due to the growing number of people working remotely indoors. Researchers such as Mardaljevic (2021), Králiková et al. (2021), Xiao et al. (2021), and Awada et al. (2021)

have highlighted the importance of indoor daylighting, outlining its limited exploration in studies. Consequently, understanding the role of indoor lighting during the day in workspaces, especially in healthcare environments, is crucial for designing healthy and productive settings for employees.

This thesis aims to investigate the impact of lighting conditions during the day on the well-being and performance of healthcare professionals. By focusing on healthcare environments, where the well-being of both patients and medical staff is paramount, this research seeks to examine the significance of lighting during the day in promoting the well-being, and performance of employees. Exploring how natural light affects individuals in healthcare environments, this study aims to provide valuable user's feedback for architects, designers, and policymakers, enabling them to create better workspaces that prioritise the well-being and productivity of healthcare professionals.

Daylight has long been recognised as a crucial factor shaping the ambience and visual appeal of indoor environments, as noted by Poon (2018) and Knoop et al. (2020). It is the preferred light source among building users, as supported by studies conducted by Ando (1991), Kahn (2003), Holl (2006), and Zumthor (2006). Researchers have extensively studied the impact of daylighting on users' perception of spaces and the overall quality of the environment. However, in the context of healthcare environments, its significance extends beyond aesthetics and has potential implications for patients' recovery, medical staff's well-being, and overall operational efficiency.

Despite the potential benefits of use of daylight in healthcare environments, prevailing standards and guidelines have primarily focused on energy efficiency and carbon footprint reduction, often neglecting the influence of lighting on occupant wellbeing, performance, and productivity (Awada et al. 2021; Altomonte et al. 2020; Gou et al. 2014; Deuble and de Dear, 2012). Consequently, this research aims to address this imbalance by emphasising the importance of considering wellbeing and performance when designing healthcare environments. The findings of this study have the potential to inform new guidelines and best practices that prioritise both energy efficiency and the well-being of healthcare professionals, leading to the creation of healthier and more productive workspaces for the healthcare workforce of the future.

1.2 Thesis Structure

Chapter 1 Introduction

This chapter serves as an introduction to the research study including the structure of the thesis, highlighting the key chapters and sections presented in the subsequent chapters. This provides readers with an overview of what to expect from the rest of the thesis and how the various components of the study combine. The background of the study problems highlights the issues that have led to the research study being conducted. The research aims and objectives are also introduced, outlining what the study seeks to achieve and the specific objectives that will guide the research process.

To guide the research process, the chapter outlines the research questions that will be addressed throughout the study. These questions provide a framework for the research study and help to focus the investigation on specific areas of interest. This chapter also presents the research design and outlines the plan, emphasising the methodology for data collection, the research tools used, and the data analysis methods that assess the findings.

Overall, this chapter serves as an important foundation for the research study, providing readers with a clear understanding of the study's objectives, design, and structure.

Chapter 2 Literature

This chapter presents the findings of a literature review conducted to review studies on the impact of lighting conditions on healthcare staff. The review aims to investigate literature relevant to the research aim, objectives, and research questions.

The literature review focuses on examining the benefits of both visual and non-visual effects of daylight on healthcare staff within healthcare environments. Through this review, the study aims to uncover evidence of the psychological, physical, and physiological advantages that daylight can offer to healthcare personnel. This chapter examines relevant literature which highlights the impact of daylight exposure on staff performance and overall well-being, promoting improved mood, reduced stress, enhanced cognitive function, and increased alertness, among other positive effects. It investigates the current literature on healthcare personnel performance in relation to the characteristics of their physical environment, and how daylight is likely to exist in their wards. It also explores the relationship between human performance and the presence of daylight, as well as the relationship between the physical environment and performance in healthcare environments. The chapter concluded by identifying relevant gaps or areas of further research to enhance better understanding of the relationship between daylight and healthcare staff outcomes.

Overall, the literature review suggests that daylight in healthcare environments is beneficial for visual comfort, well-being, and performance. It highlights the importance of adequate light levels to benefit healthcare personnel. It also points out the need for more research to comprehend these effects and the potential effect of excessive daylight. This chapter lays the groundwork for the study's research questions and objectives, setting the stage for the subsequent chapters.

Chapter 3 Methodology

This chapter explore the various approaches and philosophies that are applicable to the aim and objectives of the current study. Through a critical analysis of different methodological perspectives, the chapter identifies the most suitable methodology for this study and provides a justification for this choice.

The chapter considers both qualitative and quantitative methodologies, weighing their respective strengths and weaknesses. After careful consideration, the chosen methodology is triangulation, which involves using multiple methods of data collection to increase the reliability and validity of the findings.

The chapter discusses the specifics of the chosen methodology, including the different methods of data collection used. The chapter also highlights the benefits of triangulation, including the ability to collect data from multiple sources and perspectives, which can provide a better understanding of the research problem.

Overall, this chapter provides a detailed account of the methodology chosen for the current study, demonstrating the careful consideration given to the selection process. The use of triangulation is justified, and the specific methods of data collection are outlined, setting the stage for the subsequent chapters where the methodology will be put into practice.

Chapter 4 Quantitative: Results and Findings

This chapter focuses on presenting the findings obtained from the questionnaires administered in the study, as well as the results obtained from lighting measurements conducted as part of the research. The chapter analyses the responses received from the study participants in relation to their profiles, providing a detailed examination of the data collected in relation to the study's aim and objectives.

The lighting measurements obtained during the research are compared with the questionnaire responses to determine the degree of correlation between the two sets of data. This analysis helps to identify any patterns or trends within the data and provides a more complete understanding of the research problem.

The chapter also examines any discrepancies that arose during the analysis, explaining the reasons behind these inconsistencies and offering insights into how they may impact the overall research findings.

By combining the results from the questionnaires and lighting measurements, this chapter provides an overview of the data collected in the study. It offers insights into the respondents' profiles and their perspectives on the lighting conditions, as well as a detailed analysis of the lighting measurements obtained during the research.

Overall, this chapter provides a well-rounded analysis of the data collected, examining both the physical measurements and personnel’s responses to provide a more complete understanding of the research problem.

Chapter 5: Qualitative: Results and Findings

This chapter is dedicated to the analysis of the findings obtained from interviews with relevant stakeholders in the healthcare industry. The goal is to provide a real-world perspective on the research questions and leading to practical recommendations for the effective use of daylight in healthcare environments and to illuminate the findings in relations to aim and objectives.

To accomplish this goal, thematic analysis approach analysed the data collected from the interviews. The approach aims to identify key themes and patterns that emerge from the interview data. The themes' identified serves as proposed guidelines for the effective use of daylight in healthcare environments.

Additionally, this chapter discusses the features of the identified themes in detail. The features of the analysis of the interview data serves as recommendations for healthcare professionals and facility managers. These recommendations would address the challenges and barriers to the effective use of daylight in healthcare environments improve the overall quality of care for patients and staff.

Chapter 6 and 7: Discussions, Recommendations and Conclusion

Chapter six discusses the research findings, their contextual implications, and propose recommendations based on the results. It presents implications for architectural design strategies in relation to the use of daylight in hospital wards, with a primary focus on improving staff psychological, physical, and physiological well-being to enhance task performance.

The limitations of the research provide valuable insights for guiding future research endeavours in this field. The evaluation of the research outcomes included consideration of their potential applications in broader healthcare environments, indicating the relevance of the findings beyond the immediate study context. The implications for design strategies put forward in chapter seven aimed at enhancing the physical environment of hospital wards, with the goal of creating spaces that better support staff performance and well-being.

It is essential to acknowledge that the recommendations presented in this chapter are rooted in the findings of this research and may not be universally applicable in all healthcare environments. As such, these recommendations should be adapted to suit the specific needs and requirements of individual healthcare facilities. This approach recognises the uniqueness of each setting and the importance of tailoring design interventions accordingly.

Chapter seven concluded with suggestions for future research, drawing from the limitations and gaps identified in this study. By identifying areas for further investigation, the research opens opportunities for advancing the understanding of the impact of indoor lighting on personnel performance and well-being in healthcare facilities.

Overall, chapters six and seven achieved their aims of presenting the research findings, discussing their implications, and proposing practical design strategies to enhance the hospital ward environment for staff performance and well-being. The consideration of limitations and future research prospects ensures that this study's contributions can serve as a foundation for ongoing investigations in this vital area of healthcare facility design.

1.3 Background of the Study

In recent years, there has been growing evidence that architecture and the built environment play a significant role in determining human health, wellbeing, and performance. Researchers such as Rice (2019), Shishegar and Boubekri (2016), and Heschong et al. (2002) have suggested that the design of the built environment is related to the rise in sedentary lifestyles as people spend more time indoors than ever before. The impact of the indoor environment on human health and performance is multifaceted, involving key elements. These include air quality, thermal comfort, visual comfort, acoustic levels, and the layout of spaces, as pointed out by Alfa and Ozturk (2019), and Aries et al. (2015), and Nimlyat et al. (2015).

In healthcare environments, studies have explored the impact of hospital design on patient outcomes, such as patient safety, satisfaction, and experience. The American Institute of Architects (AIA) (2001) guidelines stressed the essential role of facility design in shaping human performance, health, and safety. In line with this perspective, Reiling et al. (2008) emphasised that the design of facilities and structures, including both fixed and moveable components, significantly impacts human performance, regarding the health and safety of employees, patients, and their families.

Study by Ulrich et al. (2004) found that the physical environment of hospitals, like the design of single-bed or multiple-bed patient rooms, can impact patient and staff outcomes. The study demonstrated that the design of a hospital significantly improves patient safety by decreasing health care-associated infections and medical errors. Also, Joseph (2006a, 2006b) and Joseph and Ulrich (2007) reviewed the impact of hospital design on patient safety and found that single-bed room design can enhance patient safety and create healthier environments for patients, families, and staff. This is achieved through the prevention of injury from falls, infections, and medical errors; minimising environmental pressure associated with noise and inefficient room and unit layout; and using nature, colour, light, and sound to control potential stressors. Ulrich et al. (2004) also found that facility design can have a direct impact on patient and staff satisfaction, patient's stress experience, and organisational performance metrics.

Moreover, research by Reason (1997) and Leape (1994) highlighted the value of practices based on principles designed to compensate for human cognitive failings (Reiling, 2006; Leape et al. 2002). When applied to the healthcare field, human factors research, which includes human performance, technology design, and human-computer interaction, can be used to improve healthcare outcomes by emphasising the need for standardisation, simplification, and the use of protocols and checklists (NHS, 2019; Wahr et al. 2013).

The built environment significantly influences human health and performance, making it imperative to acknowledge its lasting impact (Dianat et al. 2013). A well-designed environment has the potential to enhance healing, provide comfort, and improve efficiency, benefiting both patients and medical staff. On the other hand, poorly designed spaces can contribute to increased stress, reduced productivity, and compromised health outcomes. Therefore, the critical role of the built environment cannot be ignored, as it plays a crucial part in shaping overall well-being and performance.

Research consistently supports the notion that well-designed healthcare facilities directly contribute to better patient outcomes, shorter recovery times, and fewer medical errors (Joarder, 2011). Additionally, adopting a thoughtful ergonomic design can significantly enhance the work experience for medical professionals, leading to increased productivity, job satisfaction, and overall performance (Dianat et al. 2013).

However, to fully harness these advantages, human factors research must be prioritised, and healthcare practices standardised. Integrating principles of human-centred design and evidence-based approaches into healthcare facilities can optimise layouts, equipment placement, and workflows, supporting the well-being of both patients and staff. Ultimately, transforming healthcare environments into spaces that promote healing, efficiency, and well-being (Dianat et al. 2013).

Literature have also acknowledged the negative impact of modern hospitals on patient and staff well-being. It has been noted that despite incorporating state-of-the-art technology for diagnostics and treatment, hospitals’ design has inadvertently contributed to stress, depression, and anxiety, which adversely affect the health of patients and staff (Malkin, 1991; Schweitzer et al. 2004). One crucial aspect of healthcare facility design that often go unnoticed is the indoor lighting. While modern hospital focuses on advanced technological features, the importance of adequate lighting levels for quality care has not been sufficiently addressed (Joarder et al. 2009). Research by Taguchi et al. (2007) revealed that worldwide, light levels in standard patient rooms remain extremely low, ranging from 50-300 lux.

In their 2008 study, Rea et al. underscored the crucial role of light-dark cycles in the regulation of the sleep-wake cycle and the profound impact they have on various physiological and behavioural processes in living organisms (Rea et al. 2008). These natural patterns of light and darkness are of utmost significance, particularly in healthcare environments where prioritising patient comfort and care is paramount, encompassing physical, social, and symbolic elements. Among the many factors contributing to this objective, one key element is the implementation of a well-designed and well-lit environment within the healthcare environments. The careful implementation of lighting solutions plays a vital role in promoting patient well-being, supporting the healing process, and enhancing overall healthcare experiences.

By aligning the lighting design with natural light-dark cycles, healthcare providers can help regulate patients' circadian rhythms, optimising their sleep patterns and promoting faster recovery (Figueiro et al. 2018; Joarder, 2011). Adequate exposure to natural light during the day can positively influence mood and reduce stress levels, thereby creating a more comfortable and healing-oriented atmosphere for patients (Boubekri et al. 2014). Furthermore, a well-lit environment in healthcare facilities can contribute to better staff performance and alertness, resulting in improved patient care and safety (Figueiro et al. 2018). Adequately lit spaces also facilitate communication and interaction between patients and healthcare providers, fostering a supportive and caring atmosphere (Zadeh et al. 2018).

Mardaljevic (2021) further emphasises the traditional notions that well-being enhances human performance, as content and happy individuals tend to be more productive. Therefore, to create a healthy environment that promotes human health, wellbeing, and improves performance, integrating natural daylight is essential (Heschong et al. 2002). Incorporating ample daylight into different areas of hospital buildings is a critical consideration for optimising the overall work environment and ensuring a positive impact on both patients and staff.

In healthcare facility wards for example, proper window design would allow the potential benefit of daylight to be experienced by patients and staff. Their physical attributes are intertwined in the healing environment of hospital wards, as noted by Markus (1967) and Todd (2007). Studies conducted by Benedetti et al. (2001) over two decades measured lighting and daylight and how it affects the physical and psychological health of inpatients. Patients exposed to natural sunlight in the morning experienced shorter hospital stays compared to those exposed in the evening. Ulrich et al. (2004) and Boyce (2004) in their studies documented the importance of light in reducing depression, decreasing fatigue, improving alertness, modulating circadian rhythms, and treating conditions such as hyperbilirubinemia among infants. Eyestrain can result from inadequate lighting, uncomfortable glare, and flicker, which can irritate the eyes (Boyce, 2004).

Studies have shown that daylight has significant effects on the well-being of humans, both physically and psychologically (Shishegar, & Boubekri, 2016; Aripin, 2007). As noted by Commission for Architecture and the Built Environment (CABE) (2004) access to natural light is one of the crucial factors affecting patients' recovery. Light has a significant effect on the circadian rhythm, as recognised for years (CABE, 2004). The presence of visible light in an indoor environment influences physiological responses, mood, and visual needs (Schweitzer et al. 2004). In addition, the use of natural lighting in buildings has been a topic of interest and debate among researchers for decades (Mardaljevic, 2021; Aries et al. 2015; Aripin, 2007). While maximising natural light is always beneficial, excessive light can cause discomfort and glare (Boyce et al. 2003).

Parsons (2000) highlighted the detrimental effects of inadequate lighting on vision, which could lead to headaches, indigestion, and even elation. Meanwhile, Hedge (2000) suggested a solution: the combination of direct task lighting and indirect ambient lighting, offering a holistic approach that could enhance comfort, health, and productivity. Carayon et al. (2006) emphasised the significance of specific physical settings in optimising performance, further underlining the importance of well-designed spaces. Building on these insights, buildings have traditionally been evaluated based on research-driven studies focusing on functionality, efficiency, and performance, as noted by Poon (2018).

However, the conventional approach to assessing daylight in buildings has been quantitative, like criteria used for other environmental aspects such as air quality, energy usage, and thermal comfort. Yet, daylight's impact extends beyond quantifiable factors like task performance and visual discomfort. It encompasses a broader experiential aspect that cannot be fully grasped through traditional metrics.

In the historical context before the 1940s, natural daylight was the primary source of illumination within buildings, while artificial lighting played a supplementary role (Shishegar & Boubekri, 2016). The advent of fluorescent lighting and the availability of cheap energy in the mid-20th century led to the construction of deep-planned, fully air-conditioned, and mechanically ventilated buildings in crowded and polluted urban areas. Consequently, external walls often had fewer or no windows, except for glass curtain walls.

The energy crisis of the 1970s and concerns about greenhouse gas emissions (ERG, 1994) encouraged renewed interest in designing buildings with ample daylight. Research also revealed the non-visual effects of daylight on human circadian rhythms, sleep-wake cycles, and overall health (Cajochen et al., 2010). Additionally, daylight was found to have positive effects on mood and alertness (Boubekri et al., 2014), emphasising its role in enhancing the well-being of building occupants. This shift in perspective highlighted the multifaceted importance of daylight in built environments.

Despite this renewed interest, a consensus on how to best incorporate daylight into building design remains elusive (Wirz-Justice et al., 2021). Some suggest dynamic daylighting systems, which adapt to changing environmental conditions (Reinhart & Wienold, 2011; Altomonte, 2008), to provide the right amount of natural light while minimising discomforts like glare. Initially, the primary aim was energy conservation and environmental benefits (Joarder, 2011), but by the late 1970s, the focus shifted to human health and performance, given the high cost of reduced productivity (Bernstein and Russo, 2011).

In the 1990s, research on indoor lighting began to explore daylight's health and performance benefits (Mardaljevic, 2021; Joarder et al., 2009). Daylight was recognised as crucial for healing environments (Baker & Steemers, 2014), also in healthcare facilities where it affected staff performance and patient well-being (Akpan et al., 2017; Salonen et al., 2013; Huisman et al., 2012). However, compared to schools and offices, research on daylight in healthcare facilities remained limited. Studies in other fields demonstrated the positive impact of adequate daylight and dynamic lighting on workers' performance and quality of life (Knoop et al., 2020; Kompier et al., 2020; De Kort & Smolders, 2010; Izsó et al., 2009), emphasising the importance of lighting quality for well-being and performance.

Existing research largely overlooked the significance of indoor daylight quality on hospital user satisfaction (Münch et al. 2020), highlighting the critical need for functional lighting in hospitals for efficiency, safety, and well-being during various activities. To address this gap, this study promotes the incorporation of daylight in design as a fundamental aspect of healthcare facility indoor environments to promote sustainable facility design.

To advance this understanding, it would be interesting to investigate how objective lighting measurements can be effectively combined with subjective assessments to develop design recommendations that optimise daylight access in healthcare facilities, enhancing occupants' perceived well-being and performance. Thus, this study aims to explore the relationship between lighting conditions and human factors that promote human health, well-being, and performance in healthcare environments.

By integrating both quantitative and qualitative data, this research seeks to provide practical guide that not only promotes objective lighting standards but also consider the subjective preferences and needs of the people using these spaces. This approach aims to improve the indoor environment of healthcare facilities and contribute to the overall well-being and satisfaction of patients, staff, and visitors.

1.4 Statement of the Problem

In the context of healthcare facilities, much like any other workplace, the physical environment holds a profound influence over the well-being, morale, performance, and productivity of employees. It is a topic well-documented in academic literature, with research highlighting how the design and management of a workplace can significantly affect its occupants (Zhenjing et al.

2022; Kaushik et al., 2021; Dianat et al. 2013). When a workspace is poorly designed and/or poorly managed, it can result in low morale, poor performance, and lead to diminished employee productivity. Furthermore, poorly design healthcare facilities can result in medical errors and inefficiencies, impacting the well-being of patients. Hence, the creation of an efficient workplace is key to achieving desired health outcomes (Mike, 2010; Shikdar, 2002).

Numerous studies underscore the crucial role of the physical environment in safety and human performance (Carayon, 2016; Reiling et al., 2008; Reason & Bradbury, 2001; Leape, 1994). This saying applies equally to the healthcare sector, where the design of facilities and equipment can significantly influence the performance of healthcare workers (Reiling et al., 2008). Reiling et al. (2008) explains how the interplay between humans, the tools they employ, and the environment they work in are crucial determinants of performance. For instance, patient rooms, whether equipped with fixed devices like oxygen and suction ports on walls or mobile equipment such as patient beds, must be thoughtfully designed to accommodate the needs of both healthcare workers and patients. A well-thought-out ergonomic design ensures that healthcare professionals can carry out their responsibilities efficiently and comfortably, ultimately resulting in improved patient care and outcomes. Incorporating ergonomic considerations, efficient layout planning, placement of tools and resources, healthcare facilities can work in spaces that facilitate seamless workflow and, consequently, better patient care (Reiling et al., 2008).

Moreover, Nelson et al. (2003) emphasises the importance of addressing elements that can reduce a patient's length of stay in healthcare facility design. This entails designing facilities while keeping in mind the needs of healthcare workers as well as patients. In Nigeria, anecdotal evidence suggests significant issues with the physical working environment in many hospitals, including unfavourable conditions for healthcare professionals. Among the most significant workplace variables that influence the performance of health workers are physical and environmental elements (Chandraseker, 2011). Elements like ventilation, inadequate illumination, and excessive noise have been shown to have a detrimental impact on employee performance and productivity (Chandraseker, 2011).

In Nigerian hospitals, the practice of maintaining low levels of lighting, based on the belief that darkness and quietness aid patients' rest, has been noted (Adeolu & Fajemisin, 2010). However, research indicates that such low light levels can disrupt the body's normal chronobiological rhythms, particularly the sleep/wake cycle and various circadian rhythms (Pechacek et al., 2008). Additionally, patients often struggle to adapt to the clinical environment within the hospital, with lighting playing a significant role in this adaptation (Dijkstra et al., 2006).

Furthermore, healthcare personnel are exposed to potential risks from medical equipment, such as high-intensity surgical light sources that could cause retinal damage in surgical staff (Fox & Henson, 1996). Thus, it is crucial to create a comfortable physical environment for healthcare personnel to perform their duties efficiently. As stated by Boles et al. (2004), considering both the physical and emotional needs of the workplace can improve employee performance outcomes.

A positive working environment, as observed by a survey conducted by Huges (2007), has a constructive impact on employees' attitudes and performance. Conversely, poor and unhealthy conditions like inadequate ventilation, poor lighting, and excessive noise have been shown to negatively affect well-being and performance (Chandraseker, 2011). Studies have indicated that specific workspace elements, including lighting, ventilation, access to natural light, and acoustics, significantly influence employees' productivity and satisfaction (Veitch et al., 2004; Karasek, 1990). Therefore, providing an adequate and comfortable environment for healthcare workers and patients is essential for improving their performance and well-being within hospitals.

The impact of the physical environment on productivity, well-being, and overall performance is not limited to healthcare environments. In office environments, factors like lighting, temperature, air circulation, and the presence of windows have been found to influence employee attitudes, behaviours, satisfaction, and performance, as shown by studies conducted by Veitch (1996) and Kaushik (2021). Other research by Dianat et al. (2013), Vahedi and Dianat (2013), and Veitch and Newsham (2000) highlights the positive effects of ergonomic furniture and lighting on employee health and performance.

In healthcare facilities, inadequate lighting can lead to patient and healthcare personnel falls, as well as medication errors (Chaudhury et al., 2009). Previous studies by Bernhofer et al. (2014) and BaHammam (2006) have revealed that frequent interruptions, bright light exposure, and noise are common environmental challenges faced by healthcare workers. Fanning (2005) discovered that lighting and illumination in operating rooms significantly impact surgery outcomes. Elements like lighting, daylighting, and visual distractions are all key factors that must be considered when designing healthcare facilities, as shown in studies conducted by Dalke et al. (2004).

The quality of the working environment, including lighting, ventilation, noise levels, and other features, is critical in influencing employee attitudes, behaviours, satisfaction, and performance, according to studies by Huges (2007) and Chandraseker (2011). Becker (1981), Becker and Smith (2001), Humphries (2005), Karasek (1990), and Veitch et al. (2004) emphasised the significant impact of specific workspace elements such as lighting, ventilation rates, access to natural light, and acoustics on employees' productivity and satisfaction with their workspace.

Furthermore, other studies have explored the impact of lighting on healthcare workers' well-being and efficiency. Salonen et al. (2013), Huisman et al. (2012), and Choi et al. (2012) have examined the influence of building-related factors like lighting, thermal environment, acoustic environment, and space layout on the productivity and well-being of hospital staff. There is compelling evidence linking daylight to health indicators that affect well-being, productivity, and task performance.

In addition to lighting-related influences, ergonomic design, as Hedge (2000) explains, is the scientific study of how ambient environmental conditions affect human comfort, performance, and health. Poor ergonomic design of patient beds and nurses' stations has been known to lead to back stress, fatigue, and other injuries among healthcare workers. In a study by Garg and Owen (1992), the evaluation of manual tasks considered stressful by healthcare workers resulted in a reduction in back injuries of almost 50 percent, from 83 per 200,000 work hours to 47 per 200,000 work hours, after interventions such as selecting patient-transferring devices and modifying toilets and shower rooms.

Moreover, gaining a better understanding of the relationships between environmental stimuli and individual responses within Nigerian healthcare facilities is imperative, as many design-related issues remain unresolved. While several studies have focused on workplace environments, these studies often do not encompass healthcare environments specifically. The limited existing studies in healthcare environments often around user preferences and perceptions of daylighting, with a limited focus on the methodology for quantitatively and qualitatively measuring healthcare professionals' experiences with daylighting and their lighting situation at work (Andersen & Guillemin, 2013; Shafavi et al. 2020; Jakubiec et al. 2021; Moscoso et al. 2021).

In the context of Nigeria, the standardisation of lighting parameters remains largely overlooked, with little attention directed towards the impact of lighting quality on the work environment and its effects on the health, safety, and performance of healthcare professionals. As noted by Ibhadode et al. (2019), empirical research data and publications concerning indoor illumination levels are scarce or seemingly unavailable in Nigeria and many other developing African countries. Consequently, unfavourable lighting conditions have been demonstrated to not only discomfort hospital patients but also reduce the visual acuity of healthcare personnel (Fanning, 2005). Additionally, prolonged exposure to inadequately lit indoor spaces without sufficient natural light exposure throughout the 24-hour diurnal cycle can result in physiological and psychological stress among healthcare workers.

Addressing these challenges and promoting a restorative atmosphere beneficial for both staff and patients necessitates the establishment of well-defined design and planning principles for interiors illuminated by natural daylight. These guidelines should include considerations for appropriate lighting levels, effective use of daylight, and the minimisation of visual distractions (Dalke et al., 2004). Regrettably, prior investigations have revealed that these pivotal aspects of lighting often receive inadequate attention in the architectural design of healthcare facilities, resulting in poor visual environments that detrimentally impact the health, well-being, and performance of healthcare professionals (Dalke et al., 2004).

This lack of research on incorporating various aspects of lighting into healthcare facility design is particularly evident in Nigeria, resulting in inadequately lit healthcare environments that fall short in promoting health, well-being, and optimal performance among healthcare professionals. Conversely, a well-designed and well-lit interior can have a substantial positive impact on both employees and patient outcomes, creating a healing environment that ensures good health and enhances personnel's performance at work. An assessment of empirical studies conducted within hospital settings has revealed that, in comparison to patients, staff members generally express lower levels of contentment regarding comfort and well-being (Eijkelenboom & Bluyssen, 2022). Considering the mounting pressures on hospital personnel due to shortages and increased intricacy duties, the appreciation of staff well-being and satisfaction has gained increasing significance (Eijkelenboom et al., 2020).

The objective of this current study is to bridge the existing research gap by examining the correlation between lighting conditions, the well-being, and performance of personnel. The hypothesis posits that the lighting conditions within indoor spaces during daylight hours have a significant influence on the overall well-being and performance of personnel. Furthermore, this research aims to identify design recommendations that can optimise daylight access within healthcare facilities, thereby enhancing occupants' perceived well-being and performance.

Through the development of a framework in this study, architects can access invaluable insights into how hospital design and implementation impact the quality of available daylight. The integration of these recommendations into healthcare facility design will pave the way for the establishment of environments that promote wellbeing, increased job satisfaction, and improved performance for healthcare workers, all the while positively affecting patient outcomes.

1.5 Research Questions

1. What is the relationship between the current lighting conditions in healthcare environments and personnel wellbeing, considering circadian rhythm, mood, alertness, and subjective performance?
2. What is the correlation between healthcare personnel's subjective perceptions of illuminance levels and objective measurements, and how do these findings align with established standards for workstation activities?
3. What are the preferences of healthcare professionals regarding the use of natural light, and how do they perceive its impact on wellbeing and job performance?
4. What are the potential implications of these preferences for the design of healthcare facilities?

1.6 Aim and Objectives

The aim of this research is to investigate the impact of lighting conditions on healthcare work environments, with a focus on advocating for the integration of natural light. The study intends to provide evidence supporting the advocacy for the integration of natural light into healthcare facility designs, aiming to enhance the wellbeing and performance of healthcare personnel and improve the overall quality of care delivery.

The objectives of this research are as follows:

1. To evaluate the current lighting conditions in healthcare environments and their effects on personnel wellbeing, considering factors such as circadian rhythm, mood, alertness, and subjective performance.
2. To establish a correlation between subjective perceptions of illuminance levels among healthcare personnel and objective measurements and assess the alignment of these findings with established standards for workstation activities.
3. To explore and analyse healthcare professionals' preferences regarding the use of natural light, their perceived impact on wellbeing and job performance.
4. To examine potential implications for the design of healthcare facilities.

1.7 Scope of the Study

The significance of lighting on staff performance within hospital buildings has emerged as a key part of research investigation. In pursuit of a better understanding, this study aimed to examine the non-visual of daylight on staff performance, within the constraints of limited time and resources.

To assess the non-visual impact of daylighting, the research assesses various variables, including lighting conditions (e.g., light source, light levels, use of daylight, glare, and unwanted shadow), demographics (such as gender, age, job roles, and work hours), and environmental factors (e.g., room type, room temperature, proximity to windows, and weather conditions). Additionally, considerations extend to the provision of outdoor views, potential discomfort, and protection against ultraviolet radiation (UVR), with recommendations made for architectural design enhancements.

Beyond its direct impact on staff performance, daylighting in hospital settings is connected to aesthetics, energy consumption, thermal management, glare mitigation, ventilation, acoustics, costs, safety, security, and subjective considerations like privacy and views. Due to constraints related to data access and availability, certain human factors like individual daylight preferences and physiological conditions were omitted from the study. Furthermore, the research did not investigate broader aspects such as energy conservation, heating, ventilation, cost-benefit analysis, and other parameters associated with daylight implementation.

Despite this study's limitations, it lays the groundwork for future research for examining the implications of daylight integration within hospital wards, including aspects like temperature regulation and comfort levels alongside performance enhancement. Nevertheless, it underscores the necessity of considering diverse factors, including human aspects and the effects of daylight inclusion, in future investigations to gain a better understanding of its impact on hospital staff and their working environment.

1.8 Research Assumptions

The study assumes that adequate office illumination should provide optimal working conditions, even when workers are looking away from the task at hand. To ensure adequate lighting of the working environment or workstation, the study refers to the international standard EN 12464-1 (2021), which outlines essential criteria that should be met. These criteria include visual performance (workers should be able to perceive objects of vision unequivocally with speed and accuracy), visual comfort (the environment should meet physiological, psychological, and well-being needs, helping to significantly increase productivity), and safety.

To evaluate whether these fundamental requirements are being met, the study cites numerous previous studies (Leccese et al. 2012; EN 6385, 2004; Aghemo and Piccoli, 2004) that have advocated for the use of specific operating parameters, where both quantitative and qualitative data can be collected and interpreted as performance indicators. EN 12464-1 (2021) specifies several criteria that enable an accurate evaluation of a specific work environment's lighting, including illuminance level, illuminance uniformity, luminance distribution, daylight availability, glare prevention, colour rendering, and colour temperature.

The study also recognises that different activities and needs exist in a hospital setting, including those of patients, visitors, medical professionals, and support staff, and that these diverse needs must be considered when designing the lighting system. Dalke et al. (2006) and Lo Verso et al. (2016) have emphasised that functional hospital lighting is necessary to ensure the effectiveness, safety, hygiene, and well-being of users and operators when their operations are being developed. However, meeting these standards requires a thorough evaluation of the current lighting systems through measurements to determine and fully describe the lighting risk assessment (Leccese et al. 2012; Tziaferi et al. 2011).

As such, the study aims to provide practical implications for planners and architects for optimising daylight access for occupants' wellbeing and performance, based on evaluation of the essential criteria for indoor lighting in the working environment and an understanding of the diverse needs in a hospital environment.

1.9 Research Methodology Approach

A literature review was conducted to explore the relationship between the physical environmental factor of indoor lighting and the performance of healthcare personnel. Specifically, the review focused on three key areas of interest: the lighting conditions and their impact on performance, the relationship between human performance and the presence of daylight, and the relationship between the physical environmental factor of lighting and performance in healthcare environments. Studies have found that exposure to natural light can have a range of positive effects on healthcare personnel, including improved mood, reduced stress levels, and increased job satisfaction.

A two-phase embedded mixed method approach was employed in the collection of quantitative and qualitative data for this current research study. Although, the research design gives equal priority to both quantitative and qualitative aspects of the research study; however, the methodology for this research study was more qualitatively dominated. In the research design, the researcher used qualitative perspective to assist in explaining and interpreting findings from the quantitative phase. Following the data collection, findings from the two phases were integrated for a complete interpretation. The strategies used for data collection include:

1.9.1 **Quantitative Method**

- A field study was conducted to investigate the relationship between indoor light levels and personnel responses. In contrast to many previous studies that have primarily focused on the physical environment in a variety of occupational settings, this field work sought to achieve a better understanding of the lighting parameters at play. To accomplish this, physical measurements were supplemented by subjective assessments, allowing for a more comprehensive and nuanced analysis of the lighting conditions.

- A survey was conducted to gather information about the lighting conditions in the workplace, including lighting characteristics and disturbances. This survey was carried out using paper questionnaires. The purpose of this survey was to determine the impact of lighting conditions on subjective assessments of employee satisfaction, job performance, and wellbeing. Data was collected regarding how these factors were influenced by the lighting conditions present in the working environment.
- The physical measurements taken during the experiment included data on various indoor light levels. These measurements were then used to supplement the subjective assessments, which involved gathering personnel responses to the lighting conditions. By combining these two types of data, the study was able to provide a proper analysis of the relationship between lighting and personnel responses.

1.9.2 Qualitative Method

- To understand the impact of daylight on healthcare personnel's performance, interviews were conducted with a variety of professionals in the healthcare industry, including doctors, nurses, pharmacist, midwives, and physiotherapist. During the interviews, participants were asked about their experiences working in spaces with natural light, and how it affected their performance. The responses were varied but largely positive, with many participants noting that natural light had a significant impact on their overall well-being and performance at work.

- Development of achievable recommendations for planners and architects to improve indoor environmental lighting conditions, based on a review of existing literature and primary data collection. These would be actionable recommendations for professionals in the field to promote better outcomes for healthcare personnel.

1.10 Unit of Analysis

The relationship between indoor lighting and its impact on the wellbeing and performance of healthcare personnel is a critical area of research in healthcare facility planning and design. This study aims to investigate this relationship in a healthcare facility in Abuja. In research, defining the unit of analysis is useful, as it describes the boundaries of enquiry (Trochim, 2006). According to Trochim (2006), the unit of analysis can take various forms depending on the study's nature and characteristics.

The unit of analysis for this research is the healthcare facility, while personnel performance serves as the fundamental unit of examination. A longitudinal mixed-methods approach will be employed for data collection and analysis. Data will be collected through surveys and interviews with healthcare personnel across various wards in the selected healthcare facility in Abuja. The surveys will use a five-level Likert scale, ranging from very low to very high, as the fundamental unit of measurement to assess personnel performance. The analysis will be performed at the group level, where performance data of individuals from different wards in the healthcare facility will be aggregated to determine correlations between indoor lighting conditions and overall personnel performance. This approach will provide a broader perspective on the impact of indoor lighting on healthcare personnel across various departments within the facilities.

While the study focuses on the physical environment of indoor lighting and its effects on personnel wellbeing and performance, it does not encompass the behavioural environment and its influence on performance. Additionally, the study considers the regional level of Abuja, acknowledging that external weather conditions may affect how personnel perceive and respond to the indoor lighting environment.

By understanding the impact of indoor lighting on healthcare personnel in a healthcare facility in Abuja, this research study aims to provide valuable insights for healthcare facility planning and design. The unit of analysis being the healthcare facility and personnel performance, the longitudinal mixed-methods approach will allow for a comprehensive examination of the relationship between indoor lighting and personnel wellbeing and performance in the selected healthcare facility.

1.11 Significance of the Study

The built environment is an essential factor in promoting physical and emotional well-being, especially in healthcare facilities. It plays a key role in shaping both physical and emotional well-being, with implications for patient care and staff performance. This understanding is supported by a body of research that underscores how the design of healthcare facilities influence on comfort, wellbeing, performance, and health outcomes (Dianat, 2013; Parsons, 2000).

The interplay between individuals and their surroundings can exert physiological and psychological stress on healthcare personnel, leading to adverse consequences such as eye strain, medical errors, and falls. As such, the need to design healthcare facilities with a user-centred approach is clear. While studies by Ulrich et al. (1984; 1991; 1993) have examined the concept of the healing environment, questions have arisen regarding their methodology for measuring anxiety levels (Devlin & Arneill, 2003). Nonetheless, these debates have underscored the complexity of the relationship between environmental stimuli and individual responses, showing that numerous enquiries regarding environmental design remain unanswered.

One area for further investigation is the role of lighting within healthcare environments. Optimal performance depends upon a conducive physical work environment (Carayon et al. 2006). Establishing fundamental design guidelines for lighting is essential to create functional, comfortable, and healing healthcare spaces for patients and other users. The guiding principles of lighting design his connected to satisfying three fundamental human needs: visual comfort, safety, and productivity (EN 12464-1, 2021). Key determinants of the luminous environment include illuminance, daylight exposure, light colour, glare, and flicker.

Hospital wards provide a valuable research focus, as several lessons about natural light, human health, and performance have originated from the hospital ward. Throughout history, natural light has been recognised as a promoter for human well-being. Exposure to daylight has been shown to improve mood, mitigate fatigue, enhance sleep quality, promote healing, reduce hospitalisation durations, and boost staff productivity (Boubekri et al. 2014; Heschong & Mahone, 2003).

The impact of the built environment on human health and performance in healthcare facilities extends beyond patient outcomes. Clinicians and nurses can also benefit from a well-designed healthcare environment. Encouraging their involvement in studies investigating the interplay between the built environment and overall well-being and performance could yield valuable insights into this complex relationship.

Recognising the dual role of hospitals as instruments of healing and platforms for well-being, modern healthcare facility design has moved towards an evidence-based approach. This approach prioritises the creation of healthcare environments that facilitate effective care delivery while promoting psychological and physiological well-being among personnel. In this context, lighting assumes a key role, necessitating thoughtful design guidance to ensure optimal, functional spaces. This current research within hospital wards hold promise for informing the design of future healthcare facilities.

To address the complexity of the relationships between the built environment and individual responses, this study proposes adopting a mixed-methods approach. By combining quantitative measurements of lighting parameters like illuminance, daylight levels, and glare with qualitative data from healthcare personnel's experiences and perceptions, a more comprehensive understanding of the impact of lighting on well-being and performance can be achieved. This mixed-methods approach will not only provide valuable insights but also contribute to evidence-based design recommendations for healthcare facilities that prioritise the health and well-being of both patients and staff members.

1.12 Contributions of the Study

This research study seeks to address the limited research investigating the lighting conditions in hospital indoor environments that affect healthcare workers' performance. Its contributions are twofold, benefiting both the industry and academia.

In the industry, this study serves as a resource for architects, planners, and building professionals, emphasising the crucial role of lighting in healthcare facility design. By providing the link between personnel performance and lighting conditions, it provides invaluable insights to inform design decisions, promoting wellbeing and productivity among healthcare professionals.

The study's mixed-method approach, combining physical measurements, questionnaires, and interviews, offers a framework for collecting essential data to design healthcare spaces that prioritise wellbeing and enhance personnel performance. This approach has the potential to become a standard in healthcare facilities across the African region.

Furthermore, the study highlights critical lighting conditions within healthcare facilities, potentially influencing changes in building codes and healthcare facility design guidelines. By advocating for improved lighting standards, it ensures that future healthcare environments prioritise personnel wellbeing and performance. This research fills a critical gap by focusing on the impact of indoor lighting on occupant performance and productivity in healthcare environments, an aspect often overlooked in existing standards and guidelines. It encourages the development of new criteria for lighting standards and the revision of existing guidelines for healthcare buildings.

Additionally, the study contributes to the existing knowledge base by identifying and buttressing five key physical lighting conditions that influence wellbeing and performance. It also uncovers various inter-dependencies and indirect effects among occupant comfort, wellbeing, and performance, providing essential tool for future research in the field of indoor lighting.

The research enhances a better understanding of the metrics and methodologies necessary to analyse indoor lighting's impact on occupant comfort and wellbeing within healthcare facilities. Leveraging advanced measuring instruments, the data analysis process combines statistical and thematic approaches, contributing valuable insights to the field.

Notably, this study sets a precedent by being one of its kind in its specific context and encourages similar research in diverse building types and climates, with the goal of improving comfort, wellbeing, and performance on a broader scale and contributing to more sustainable building practices.

1.13 Chapter Summary

The introductory chapter of this thesis is designed to lay the foundation for the entire work, providing an overview on its background, significance, objectives, research questions, methodology, scope, limitations, and contribution.

This is presented as the research's aim and objectives, with a clear understanding of the study's aspirations. The research questions, serve as guiding principles for the chosen research methodology and subsequent data analysis.

The chapter then discuss the research methodology, explaining the approach taken to realise the established aim and objectives. Thereafter, define the research's scope, setting clear boundaries for the study. Additionally, it acknowledges the study's limitations, highlighting potential factors that may have influenced the validity or reliability of the study’s findings.

This chapter conclude by summarising the research's contribution to the field and underlining its relevance for future investigations. In essence, this introductory chapter offers an overview of the thesis, effectively setting the stage for the ensuing chapters.

Chapter II: Review of Literature

"Of the elements of a room, the window is the most marvelous. The great American poet Wallace Stevens prodded the architect, asking "What slice of the sun does your building have?" To paraphrase: What slice of sun enters your room? What range of mood does the light offer from morning to night, from day to day, from season to season and all through the years?
- Louis I. Kahn

2.1 Introduction

This literature review aims to assess the impact of lighting conditions during the day on the well-being and performance of healthcare personnel. It begins by highlighting the varied priorities in the design and planning of healthcare environments, where different stakeholders emphasise distinct aspects of knowledge related to lighting. These perspectives range from empirical sciences and policymaking to design professionals and the daily experiences of healthcare occupants.

Through an examination of existing literature, the review emphasises the need to recognise the diverse influences shaping the perception of lighting within healthcare environments. The research problem discussed in section 1. 4, underscores the challenges faced by personnel in such environments, often marginalised in the design process, leading to a disconnect between their first-hand experiences and the expert-driven design decisions. This disconnect highlights the necessity to understand and address the dynamics of knowledge creation, interpretation, and application in healthcare environment design.

The primary objective of this review is to establish a knowledge framework that aligns with the research problem, guiding the development of an integrated approach discussed in subsequent chapters. Drawing upon transdisciplinary principles, the review situates the research within a broader spectrum, incorporating insights from architecture, engineering, medicine, sociology, and philosophy. This approach aims to provide a holistic understanding of the intricate relationship between lighting conditions, well-being, and performance of healthcare personnel, ultimately contributing to a more nuanced and effective design of healthcare environments.

The aim of this research is to investigate the relationship between indoor lighting conditions and the wellbeing and performance of healthcare personnel. The hypothesis posits that exposure to daylight during the day significantly impacts overall wellbeing and performance among healthcare staff. Additionally, the study seeks to identify design recommendations that optimise daylight access within healthcare facilities, thereby enhancing occupants' perceived wellbeing and performance.

Thus, drawing from a review of relevant literature, this chapter assesses the influence of indoor lighting on personnel's wellbeing and personnel in healthcare environments. Specifically, it examines how indoor lighting in hospitals and healthcare facilities, affects individuals, exploring both its positive and negative effects on their wellbeing and performance. The analysis considers various factors, including environmental, physiological, and psychological elements, to assess lighting preferences and their influence on performance. The chapter also details the lighting metrics employed to evaluate performance, the fieldwork methodologies used, and the research approaches taken in similar studies.

The chapter is structured into two main sections. The first section presents evidence on the influence of incident light on the eye and its non-visual effects on performance, such as improving concentration, increasing alertness, and reducing fatigue in response to daylight. It also explores the biological effects of daylight on the body, including its impact on circadian rhythms and the metabolism of Vitamin D. It also examines the intricacies involved in crafting and defining mood, emphasising a pivotal trade-off between the mood of participants and that of a given space.

An inherent dichotomy arises when considering mood, which is manifested as a critical trade-off between the mood of participants and the ambiance of a space. The creation of the interior atmosphere is intricately linked to the infusion of psychological elements, such as light and shadow, colour, scale, composition, and special effects, which collectively influence human perception of a space. Notably, light stands out as a primary environmental stimulus capable of shaping individuals' mood and perception in both indoor and outdoor settings, as noted by Abboushi et al. (2019).

Building on this perspective, Bille (2015) emphasises that light serves a greater purpose than simply providing illumination. It operates at the crossroads of individual perception, spatial appearance, and symbolic associations. Its influence goes beyond visual aesthetics, impacting the human body on a physiological level by affecting vitamin D levels, serotonin, and dopamine. As a result, light becomes a dynamic force that is consistently used to establish physical orientation within a room and mentally connect individuals with their environment. Consequently, it plays a vital role in shaping the overall ambiance of a space. The symbiotic relationship between architecture and the mind becomes apparent, as architects intuitively acknowledge that the spaces, we inhabit have profound effects on our thoughts, emotions, and behaviours, as noted by Anthes (2009). The contents of a room, including lighting, have the potential to either soothe or agitate individuals. The first section concludes by highlighting the need to address the knowledge gap before hospital ward design strategies can fully consider the beneficial effects of natural light.

In the second section, the chapter focuses on the adverse effects of daylight exposure on individuals' wellbeing and performance. It examines factors that can lead to negative outcomes, such as glare and unwanted shadow, and their impact on performance. Finally, it emphasises the importance of proper planning, designing, and conducting fieldwork using appropriate assessment tools and surveys to effectively evaluate the impact of workplace lighting on individuals' performance and wellbeing.

Overall, this chapter provides evidence that workplace lighting significantly influences individuals in healthcare environments and underscores the importance of thoughtful consideration when designing lighting solutions. The review underscores the necessity for healthcare facilities to incorporate the use of daylight in the design strategies for hospital wards. Improved indoor lighting during the day can serve as a vital tool in enhancing the safety and performance of healthcare facilities, creating better places to work. Moreover, the emphasis on evidence-based healthcare facility design can contribute to reducing stress and hazards, ultimately elevating the overall quality of healthcare (Konstantzos et al. 2020).

2.1.1 **Background**

The background to this literature review recognised that healthcare facilities are complex and demanding environments where healthcare professionals provide a wide range of services to patients. These facilities operate round-the-clock with various services, including healthcare, therapy, food services, hospitality, and extensive use of materials and equipment. The stress and discomfort experienced by staff in these settings attributed to the high-intensity nature of their work, has far-reaching implications for their well-being and performance.

This is further exacerbated by the many environmental factors that impact on individuals' health, well-being, performance, and productivity, with lighting being a key factor. Research demonstrates that lighting conditions have significant effects on well-being with attendant impact on performance (Konstantzos et al. 2020; Heschong et al. 2002). Adequate lighting, whether natural or artificial, not only enhances visual performance but also provides non-visual benefits that facilitate optimal work performance (Alzubaidi et al. 2013; Konstantzos et al. 2020).

The significance of lighting in healthcare environments has been well-documented since the early 2000s (Amorim et al. 2022). The interaction between natural and artificial light sources in creating aesthetically pleasing patterns and shadows, which contribute to human well-being, has been explored (Rockcastle et al. 2013; van den Wymelenberg et al. 2010). Moreover, the non-visual effects of light and daylight have been recognised and studied in the field of built environment research (Wirz-Justice et al. 2021; Fontoynont, 2014; Guzowski, 2000). For instance, Knoop et al. (2020) examined the impact of natural daylight on various aspects of human responses, ranging from visual performance and eyesight to circadian entrainment and non-image-forming effects. The findings showed multiple benefits, including enhanced visual appeal, comfort, outdoor views, reduced energy consumption, and increased savings. However, not all research findings align, as evidenced by a study by Aries et al. (2015), which found limited statistical correlation between exposure to natural light and adverse health outcomes.

The influence of the lighting environment extends to task performance, encompassing the illumination of tasks, safe movement through space, and the aesthetic appreciation of surroundings (Boyce, 2014; Veitch et al. 2013; Boyce et al. 2000). Studies have shown that lighting impacts various aspects of human function, including melatonin suppression, alertness, and cognitive abilities in the workplace (Cajochen et al. 2019; Boyce et al. 2000). Adequate illuminance level improve vision, while light exposure at night can have arousing effects, enhancing concentration levels and influencing social behaviour due to correlated colour temperature (CTT) (Barkmann et al. 2012). This extends beyond healthcare facilities, as research indicates that natural light can enhance student performance in classrooms, which may have implications for employee performance in office and healthcare environments (Heschong et al. 2002).

Improving employee comfort and well-being in the workplace is instrumental in boosting overall performance and productivity. Many studies have highlighted the role of the spectral quality of daylight in promoting vitamin D production in human skin, a unique attribute of sunlight that cannot be replicated by artificial light (Aries et al. 2015; Figueiro et al. 2017; Shishegar & Boubekri, 2016; Zhang et al. 2017).

Despite the growing awareness of how physical environments, particularly lighting, affect patient and staff outcomes, a lack of sufficient data on the attributes of daylight that promote health, performance, and productivity persists (Huisman et al. 2012). This knowledge gap exists, in part, because the implications of natural light transcend disciplinary boundaries (Münch et al. 2020). Thus, collaboration in various fields useful for evidence-based healthcare facility design is necessary to gain a better understanding of how the physical environment, including lighting, affects the occupants' performance, much like the principles of evidence-based medicine that inform clinical decisions (Hamilton, 2003).

Besides, the healthcare delivery system faces multiple of challenges, including the prevalence of hospital-acquired infections and medical errors that rank high among leading causes of death

(Institute of Medicine, 2000; 2001; Ulrich et al. 2010; Adeolu et al. 2010). These challenges are not confined to patients but also include issues such as staff shortages (Ulrich et al. 2004). Inadequate healthcare facility design and conditions further exacerbate these problems, alongside insufficient funding and medical equipment, particularly in developing countries (Welcome, 2011; Ulrich et al. 2004).

Ulrich et al. (2008) argue that, given the long lifespan of hospitals and clinics, the construction of healthcare facilities presents a unique opportunity to rethink their design and mitigate the stress and fatigue experienced by medical professionals. This shift towards evidence-based facility design mirrors the evolution of medicine toward "evidence-based medicine" (Hamilton, 2003).

Considering this context, this literature review aims to scrutinise the impact of indoor lighting on personnel's outcomes in healthcare facilities, including aspects such as staff satisfaction, wellbeing, and performance. Three key questions guide the review in assessing the influence of indoor lighting on personnel’s wellbeing and personnel in healthcare environments:

- What is the impact of indoor lighting on personnel's well-being and performance in healthcare environments?
- How do measured illuminance levels at workstations correlate with subjective perception compared to established standard requirements for different workstation activities?
- What are the preferences of healthcare personnel regarding daylight usage, and how might these preferences influence healthcare facility design?

Through examination of scholarly articles, the review provides evidence that various lighting conditions, including light level, light source, light colour, use of daylight, flickering lights, glare, and unwanted shadows, significantly influence error rates, stress levels, and performance in healthcare facilities (Dianat et al. 2013). Furthermore, it emphasises that historical healthcare facility design can inadvertently increase risks and stresses, which can be mitigated through improved lighting and other indoor environmental factors, such as outdoor views, ergonomics, and safety.

The literature review underscores the positive effects of exposure to natural light during the day, such as risk reduction, increased staff satisfaction, and improved performance in healthcare facilities. The review provides evidence that the design of indoor lighting within healthcare facilities plays a pivotal role in shaping staff outcomes. It advocates for a reimagining of healthcare facility design to enhance employee satisfaction and performance, reduce risks, for improved health outcomes.

2.1.2 **Search Description**

The literature review is a key component of this PhD research project, centred on the built environment discipline, with a specific focus on understanding how indoor lighting impacts the well-being and performance of personnel in healthcare environments. Its significance lies in its role as the foundation for advancing knowledge in this field. This is achieved by examining existing research and identifying potential areas for future study, as discussed by Dawson et al. (2015).

To ensure a comprehensive examination of the existing body of work, the literature review employs a distinct search methodology. It commences by articulating the research study's objectives and its goal of assessing the influence of indoor lighting in healthcare environments. This clarity sets the stage for identifying pertinent topics. Subsequently, the review examines specific themes and issues related to the research question, as noted by Fillary et al. (2015). These topics includes the historical development of healthcare facilities, various sources and forms of lighting, interactions between humans and lighting, and the assessment of lighting perception. Each of these areas is scrutinised to gather substantial evidence and insights that contribute to the overall research objectives.

Furthermore, the review uses appropriate search phrases and keywords for each chosen topical area. It adopts both backward and forward sourcing techniques to identify relevant literature. This entails examining the reference lists of published articles (reverse sourcing) and investigating articles that have cited the original material (forward sourcing) through platforms such as Web of Science, as noted by Fillary et al. (2015). This combined approach maximises the retrieval of pertinent literature and broadens the scope of the evaluation.

The selection of literature sources is conducted with care. Decisions are made regarding which databases, journals, books, websites, and major authors to consult, aiming to ensure sufficient coverage without overwhelming the study with excessive search results or overlooking vital information. Depending on the specificity of the research questions, both electronic and hard copy resources are used to collect relevant data. The incorporation of both journal articles and books ensures a better understanding of the topic, facilitating cross-referencing and information verification from multiple sources, as suggested by Fillary et al. (2015).

The literature review places a significant emphasis on the use of current materials while establishing a timeframe for the period under consideration. Publications after January 1, 1990 are given priority to incorporate recent and up-to-date research findings. However, seminal works and historical perspectives are also included if they make substantial contributions to the knowledge base in the field. This approach strikes a balance between contemporary insights and essential historical context, as suggested by Fillary et al. (2015).

Language considerations play a crucial role in the literature review, with a focus solely on English-language publications. This decision is made to avoid potential resource constraints and translation challenges that could hinder the progress of the research project, as noted by Fillary et al. (2015).

This literature review within the built environment discipline adopts a purposeful search technique, well-defined objectives, and strategic use of sources to gather relevant and current evidence. By incorporating backward and forward sourcing techniques and being mindful of language limitations, the review aims to provide a robust foundation for the subsequent phases of the research project and contribute significantly to the advancement of knowledge in this specific area of study.

2.2 The Healthcare Facilities

As the healthcare industry continue to evolve, the design and functionality of healthcare facilities have become increasingly vital. It is no longer sufficient for these spaces to meet the medical requirements of patients; they must also prioritise the wellbeing and comfort of the personnel who work within them. Among the various factors that influence the overall design of healthcare facilities, lighting stands out as a critical element. Its impact extends to patients, staff, and visitors, affecting their comfort and performance within these spaces. Thus, this section examines the historical development of healthcare facilities, focusing on understanding the evolving demands of users and identifying appropriate lighting solutions that can enhance comfort, satisfaction, and performance.

The origins of healthcare facilities can be traced back to ancient Greece, where hospitals were first established to adapt to environmental and technological changes (Ahmed et al. 2015). These early facilities laid the foundation for the evolution of healthcare infrastructure. The 19th century saw the emergence of modern technologies and designs, which brought about significant advancements in user comfort and performance. Through historical studies of healthcare facilities, designers gained valuable insights into user preferences and behaviours. These insights proved instrumental in providing lighting systems to cater to the specific needs of patients, staff, and visitors.

Today, healthcare environments can make a significant difference in people's lives who require help, comfort, and care. Hence, there is a need to create conducive atmospheres for all users, particularly for those working there. A better understanding of the parameters that contribute to comfort is essential, as it holds the key to enhancing performance in future healthcare facilities. However, highlighting the unique needs and preferences of different users necessitates a proper assessment of the diverse typologies of healthcare facilities.

Therefore, this section examines existing literature to review and analyse the various lighting types employed across different healthcare facility typologies. By exploring the relationship between lighting and user performance in healthcare environments, this research aims to provide implications for improving indoor lighting for comfort and performance. In an era where healthcare is at the forefront of societal concerns, the significance of well-designed healthcare facilities and their impact on users cannot be underestimated. The goal is to contribute to healthcare facilities that not only function with optimal efficiency but also actively promote the overall well-being of all individuals who interact with these spaces.

2.2.1 **Definitions: Healthcare Facility Types and Classifications**

Healthcare facilities include a diverse array of building types, each providing distinct health services to patients (Ahmed et al., 2015). In its broadest sense, a healthcare facility is defined as a structure designed for the provision of health services, with its characteristics derived from the nature and quality of care offered (Sheth, 2011). At the apex of this complexity are hospitals, the most intricate and multifaceted of healthcare facilities, whose etymology, rooted in the Latin "hospitium," originally meant providing shelter for the poor. Hospitals primarily function as providers of diagnostic, medical, and professional healthcare services, extending their role to include preventive care, rehabilitation, long-term and intensive care, end-of-life support, and specialised services.

Global healthcare systems classify facilities differently based on services offered, client demographics, and length of stay. In the United States, the classifications are based on the services rendered, the client demographics served, and the expected duration of stay (Ahmed et al., 2015). This results in various facility types, including general hospitals, community hospitals, district hospitals, teaching hospitals, special hospitals, and tertiary care hospitals. Furthermore, the US healthcare system includes long-stay and short-stay hospitals, nursing homes, skilled nursing homes, hostels, and hospices. Acute care facilities provide brief, intensive treatments, while long-stay hospitals cater to patients requiring extended, continuous care due to physical disabilities, chronic ailments, or other conditions. Community and teaching hospitals typically affiliate with medical schools, research centres, or universities, while nursing homes offer extended care, encompassing short-term rehabilitation, long-term care, skilled nursing, and specialised services.

The United Kingdom adopts a dual-tiered approach to healthcare. The National Health Service (NHS) serves as the primary provider, separating healthcare into primary care and secondary care (Department of Health, 2013). Primary care, administered by general practitioners, nurses, and pharmacists, is commonly dispensed from GP surgeries and health centres. Secondary care offers more intricate treatments, overseen by hospital-based specialists. Notwithstanding the NHS's availability, some individuals may use nursing home care, due to personal needs and preferences. NHS nursing homes, regulated by the Care Quality Commission, adhere to specific care standards. These nursing homes play a key role within the UK healthcare system, offering essential services to individuals requiring long-term care or specialised medical attention. Qualified medical personnel such as nurses and doctors usually provide medical and specialised care while providing social support and companionship.

In contrast, Nigeria employs a decentralised healthcare system, with local governments managing primary healthcare, state ministries of health overseeing secondary healthcare, and federal ministries of health responsible for tertiary healthcare. However, this system has fallen short of meeting the healthcare needs of many Nigerians, leading to inadequate modern medical facilities and a poorly developed healthcare system. As a result, private providers often deliver primary healthcare services, resulting in restricted access for many and financial barriers to essential services. This situation has led to a two-tiered healthcare system, wherein the privileged enjoy superior facilities and advanced treatments. Nigeria's healthcare indicators rank among the world's lowest, where medical personnel are in limited supply (Fullman et al., 2018). This inadequacy in the healthcare system not only affects the health of the nation but also its economic growth, as those without access to necessary treatments and medications are unable to work or even take part fully in their daily lives. A critical need exists for governmental reforms and investments in the healthcare system to enhance access to essential treatments and medications.

Given the variations among healthcare systems globally, a universal description applicable to all facilities remains difficult. Nevertheless, this research seeks to offer a framework adaptable to diverse settings, bridging the gaps between healthcare facilities globally. The aim is to examine the commonalities shared by healthcare facilities while accommodating each setting's distinct characteristics, thus offering a unified set of standards to uplift global healthcare facilities.

2.2.2 **History and Developments**

The history and developments in the field of hospitals and healthcare infrastructure have undergone an interesting evolution over centuries, shaped by societal needs, medical advancements, and changing philosophies. The history of hospitals can be traced back to approximately 500 B.C. during the time of Mesopotamia. These early hospitals served as places where individuals could seek medical assistance and were integral parts of their respective communities. As time advanced, ancient civilisations like Rome and Greece developed more sophisticated medical infrastructures, constructing hospitals within temples and barracks for diagnosing and treating patients (Retief & Cilliers, 2001).

In Ancient Rome, the city boasted an advanced medical infrastructure, complete with aqueducts, sewers, and numerous public baths. Meanwhile, in Ancient Greece, temples were built not only for worship but also to provide medical care and diagnosis (Ahmed et al., 2015). During the Middle Ages, hospitals evolved from the concept of hospices that initially offered lodging for travellers and messengers. Over time, these early Christian hospices transformed into institutions providing medical treatment, leading to the usage of the modern term "hospital" (Retief & Cilliers, 2001, 2006). In addition to these changes, military hospitals emerged during the Middle Ages and the Renaissance period, with a specific focus on caring for soldiers during extended campaigns. This era marked a crucial transition in healthcare, leading to more professional medical staff and formalised physician training. Hospitals now featured advanced medical equipment, preventative medicine, and enhanced care for the public. However, civilian hospitals of this era still emphasised spiritual healing over medical treatment.

As the 19th century progressed, civilian hospitals began shifting away from spiritual treatments and towards more scientific healing methods. Research and education in medicine gained prominence, resulting in more effective treatments and improved patient outcomes. Physician training became more rigorous and evidence-based, leading to a better understanding of human anatomy and functions. This transformation in medical thinking laid the foundation for significant advances in healthcare.

Hospital design also underwent significant evolution. By the mid-19th century, the UK adopted the concept of wards organised in rectangular blocks connected by corridors, primarily due to Florence Nightingale's advocacy. These design principles emphasised better ventilation and illumination and became standards in hospital ward design (Nimlyat & Kandra, 2016; Prasad, 2012). Hospital design, once provider-centred, gradually shifted towards being more patient-centred by the 1970s, acknowledging the importance of patient preferences in influencing design (Ahmed et al., 2015). In the 1980s, research aimed at improving the sensory experience in healthcare environments led to more aesthetically pleasing building designs. Factors such as acoustics, lighting, space, and stress reduction became focal points in architectural considerations, with the goal of improving patient outcomes and overall experiences (Nimlyat & Kandra, 2016).

A significant milestone in hospital typology emerged with the modern movement in architecture, with the evidence-based design (EBD). In the 1980s, Ulrich conducted scientific studies investigating architectural decision-making in hospital design based on medical facts (Joarder, 2011). By the 1990s, design solutions in healthcare were rooted in research on healing environments, where interactions between patients and staff positively impacted health outcomes. EBD examined various aspects of hospital design, from floor plans to signage, and revolutionised hospital typology in the late 20th and early 21st centuries. Healing settings created through EBD were seen as cost-effective investments, improving staff productivity and reducing patient hospital stays (Huisman et al., 2012).

The importance of integrating evidence-based design principles into healthcare facilities became evident, leading architects and designers to focus on the healing process alongside functionality and aesthetics. Incorporating EBD had the potential to improve patient outcomes, enhance care quality, and create more pleasant environments for both patients and healthcare workers. However, some factors like noise, lighting, and outside views were not given equal attention (Joarder, 2011).

While the debate on the effectiveness of healing-built environments in improving patient outcomes continues, Ulrich's research significantly impacted healthcare architecture. A study conducted by Ulrich and his team demonstrated a positive correlation between access to natural light and patient recovery (Ulrich et al., 2008). In addition to patient outcomes, the impact of daylight on healthcare workers' performance has also been studied. Exposure to natural light is essential for human health, providing mental and physical benefits such as improved mood, better sleep patterns, better concentration, and improved performance (Dianat, 2013; Joarder, 2011). However, studies have shown that inadequate or poor lighting is one of the contributing factors to healthcare worker falls and prescription mistakes, but the connection is not fully understood (Dianat, 2013). This may be due to the variable nature of daylight and its effects on comfort and well-being (Galasiu & Reinhart, 2008). There is not enough evidence-based research on the direct impact of daylight on healthcare workers' performance in the built environment (Dianat, 2013; Joarder, 2011).

Despite its importance, there has been limited research in this area, as highlighted by Dianat in 2013. Moreover, Information on how to plan and design the visual environment within healthcare facilities is scattered across numerous sources in various fields, including architecture, medicine, ergonomics, psychology, and lighting design (Joarder, 2011; Dalke et al. 2006). To address this gap, there is a need to adopt a multidisciplinary approach that combines insights from different scientific perspectives. By combining insights from various scientific perspectives, such as architecture, engineering, sociology, and psychology, there would be better understanding of the effects of daylight on the well-being and performance of healthcare personnel.

Thus, this literature review aims to explore the evidence of indoor lighting conditions that not only support staff performance functionally but also emotionally. It investigates the impact of both natural and artificial light on the well-being and performance of healthcare professionals, examining their beliefs and attitudes toward daylighting. Furthermore, it will assess how various environmental factors, including natural light, ventilation, noise levels, and temperature, interact to enhance the emotional and physical well-being of healthcare professionals in their workplace.

It is crucial to recognise that healthcare facilities have unique indoor environmental needs, as underscored by Ulrich in 2004. These needs set them apart from other building typologies, emphasising the importance of understanding how various environmental factors collectively contribute to the overall health and performance of healthcare professionals. This is useful in analysing the impact of daylight conditions and the indoor environment in healthcare facilities, to create a healthier and more productive workplace for those dedicated to the well-being of others.

2.3 Environmental Factors and Health Outcomes

Healthcare facilities are designed with the goal of disease prevention and diagnosis, using various spatial arrangements (Ahmed et al. 2015). However, the design of these facilities is often not explicitly developed to improve the safety, comfort, and satisfaction of occupants (Reiling et al. 2004). This lack of focus on environmental factors in healthcare design can have adverse effects on both healthcare workers and patients.

The physical environment of healthcare facilities can contribute to stress and unpleasantness for both patients and staff, leading to decreased effectiveness in care provision, errors in diagnosis, and inadequate management of chronic diseases (Ulrich, 2004; Reiling et al. 2004). This has led to healthcare environments being identified as one of the factors that affect staff performance (Boubekri et al. 2014; Huisman et al. 2012).

Studies have shown that environmental factors have a direct impact on the well-being and performance of medical staff (Gawande, 2014; Dianat et al. 2013). Medical staff working in unsupportive environment can become stressed, leading to mental health issues such as burnout, depression, and fatigue (Koinis et al. 2015). Poor environmental conditions can also lead to a decrease in staff performance (Dianat et al. 2013). There is a clear link between the design of hospital spaces and the well-being of medical personnel. Therefore, it is essential for architects and planners to examine the environmental factors that influence the well-being and performance of medical personnel. These factors include adequate lighting and temperature control, ergonomics, and access to natural light (Dianat et al. 2013).

One significant factor that affects both patients and staff in healthcare facilities is access to natural light. The absence of natural light in healthcare facilities can lead to longer hospital stays, delayed recovery, and increased need for pain medication (Walch et al. 2005). On the other hand, providing adequate natural light can improve the healing process, increase patients' satisfaction, reduced medication needs, and reduce their stress levels (Ulrich et al. 2008; Walch et al. 2005). Additionally, natural light can improve the circadian rhythm of both patients and medical staff, leading to better sleep patterns and better mental health (Münch et al. 2020; Vietch et al. 2009).

Another environmental factor that impacts the well-being and performance of medical staff is noise. High levels of noise in healthcare facilities can lead to annoyance, stress, and decreased performance (Topf & Dillon, 1988). It can also impact patient outcomes, leading to sleep deprivation and increased use of pain medication (Ulrich et al. 2014). Therefore, it is crucial to design healthcare facilities with adequate acoustic control measures to create a peaceful environment for both patients and staff.

Temperature control is another important environmental factor that affects the well-being of patients and staff in healthcare facilities. Inadequate temperature control can lead to discomfort, stress, and decreased productivity (Zhao et al. 2015). Additionally, high temperatures can increase the risk of heat-related illnesses, which can be especially dangerous for elderly patients and those with pre-existing conditions (yoon Yi et al. 2022). Proper temperature control can create a comfortable environment that contributes to positive outcomes for patients and staff.

Ergonomics is another critical factor to consider in healthcare facility design. Healthcare workers are at risk of developing musculoskeletal disorders due to the physically demanding nature of their work (National Institute for Occupational Safety and Health, 2019). Proper ergonomic design can reduce the risk of injury and improve staff comfort and performance. For example, adjustable workstations can help healthcare workers maintain proper posture and reduce the risk of musculoskeletal injuries (Hignett et al. 2013).

Providing a pleasant and productive workspace for medical staff not only boosts morale and productivity but also reduces stress levels, resulting in fewer mental health issues (Gawande, 2014). Ultimately, creating a safe and comfortable work environment for medical staff can significantly improve their overall well-being and quality of life.

Thus, healthcare facilities are critical environments that require careful consideration of environmental factors to ensure that the physical environment supports optimal medical care for both patients and medical staff. Environmental factors such as lighting, temperature control, ergonomics, and natural light can have a direct impact on the well-being and performance of medical staff. Creating a pleasant and productive workspace for medical staff can not only improve staff morale and productivity but also reduce stress levels, resulting in fewer mental health issues. As a result, it is crucial for architects and planners to prioritise the well-being and safety of medical staff when designing healthcare facilities.

2.3.1 **Comfort and Health Outcomes**

Occupant comfort and satisfaction with the physical environment are critical factors in creating a conducive work environment for medical staff (Frontczak et al. 2012; Choi et al. 2009). Studies have shown that the level of comfort experienced impacts not only health but also well-being, productivity, and performance (Dianat, 2013). Conducive environmental conditions are shown to lead to a reduction in absenteeism and employee complaints and increase employee productivity (Kaushik, 2019; Zhai et al. 2015). Even when the predictions of environmental comfort and building usability are different from the experience of the finished product, the level of comfort experienced is related to occupant comfort and satisfaction with the physical environment (Frontczak et al. 2012; Choi et al. 2009). The design of healthcare facilities also plays a significant role in reducing the risk of healthcare-associated infections (HAIs). Studies have shown that environmental factors such as ventilation, surfaces, and room layouts are crucial in preventing the spread of HAIs (Dancer, 2014; Boyce, 2007). Therefore, the physical environment plays a significant role in the success of staff, and there is an essential need for it to be tailored to the comfort and needs of the occupants to improve well-being and promote performance (Public Health England, 2015; Huisman et al. 2012; Leaman & Bordass, 2006).

Comfort is a subjective state that is influenced by a wide range of factors such as physical, psychological, and social aspects. In the literature, it is defined as the condition in which an individual experiences no undesirable experiences or feelings (Freire et al. 2008). This definition is supported by many physical variables, including temperature, air quality, humidity, acoustics, lighting, and visual comfort (Rupp et al. 2015; Freire et al. 2008). Additionally, comfort can be influenced by psychological and social factors, including functional comfort, physical comfort, and psychological comfort, as well as social aspects such as interaction, privacy, and collaboration (Feige et al. 2013; Haynes, 2008).

A comfortable environment provides the users with a feeling of safety, security, control, and self-expression, which is essential in healthcare environments where patients require comfort and support. Oseland (1999) further emphasised that comfort is the result of a combination of physiological, psychological, and environmental variables. Leaman and Bordass (1999) and Clements-Croome (2006) considered comfort as the outcome of the interactions between functional, environmental, and individual health aspects. These various definitions suggest that comfort is a complex mix of subjective perceptions, physiological responses, and environmental factors.

Despite the variety of definitions, all acknowledge that comfort is a measure of satisfaction with a given environment and an individual's well-being. It is a subjective experience that can be influenced by individual needs and perceptions of an environment. The concept of comfort is important in different fields, including architecture, design, and healthcare, as it can have significant impacts on individuals' productivity, performance, and well-being.

This research specifically focuses on the physical environmental factor of lighting conditions and its quality in healthcare work environments. Lighting is a crucial aspect of healthcare environments, as it can impact both the physiological and psychological well-being of individuals. Adequate lighting is necessary for visual accuracy and task recognition in healthcare environments. Poor lighting conditions can negatively affect healthcare workers' performance, through discomfort, fatigue, and headaches leading to reduce productivity.

Research suggests that appropriate lighting can improve healthcare workers' satisfaction and performance levels by providing good visibility, increasing alertness, and reducing fatigue. Adequate lighting can also create a safer and more comfortable work environment for healthcare workers and patients.

In essence, comfort is a complex mix of physiological, psychological, and environmental variables that can be influenced by various physical and social factors. In healthcare environments, lighting conditions play a crucial role in the comfort, satisfaction, and performance levels of healthcare workers. Adequate lighting can positively impact the well-being of healthcare workers and improve their productivity, which can lead to better patient outcomes. Therefore, it is essential to consider lighting and its impact on health outcomes when designing healthcare work environments.

2.3.2 **Lighting Conditions and Health Outcomes**

Healthcare facilities have complex lighting requirements to meet a wide range of demands for perfect conditions. The visual tasks with unique lighting demands include the needs of doctors and nursing staff for different lighting situations to perform tasks requiring high levels of concentration. In addition, adequate lighting is crucial for professionals to perform meticulous tasks that may mean life or death for patients. Healthcare facilities also aim to create a healing environment for patients, who often stay in hospitals for extended periods due to poor ward lighting. Therefore, lighting solutions must cater to the needs and preferences of different user groups in various situations for efficiency, safety, and wellbeing (Sholanke et al. 2021).

The planning and designing of indoor lighting for a healthcare environment must consider the importance of task performance, visual accuracy, and patient comfort to reconcile the disparate requirements and interests necessary for quality care delivery. Innovative and user-centred approaches to lighting design can help create a healthier healing environment for patients, clinicians, and other stakeholders. To ensure adequate lighting in healthcare environments, it is important to consider not only the technical details of lighting but also user behaviour (Sholanke et al. 2021).

Achieving the right level of lighting is essential, as excessive brightness can lead to glare and eye strain, while insufficient illumination may affect visibility. To address this, EN12464 specifies luminance levels for various activities in healthcare environments. Additionally, factors such as colour temperature and hue should be carefully considered to create a comfortable and stimulating environment for occupants. Natural light also plays a crucial role and should be integrated into the lighting design. It has numerous beneficial health effects and can contribute to the well-being of patients and staff alike.

While some research has examined the impact of lighting on healthcare workers, there is a shortage of studies addressing lighting and its effect on the wellbeing and performance of these professionals. The primary function of lighting is to enhance vision, ensuring that the space, location, or object is visible to the human eye (Sholanke et al. 2021). Adequate lighting in healthcare facilities facilitates high visual performance, enabling workers to carry out their tasks quickly and accurately. It should promote the psychological and physiological well-being of both staff and patients, ensuring high safety standards and aiding in the identification of potential hazards within the environment.

Lighting has functional and emotional components that produce both visual and non-visual/biological effects on humans. For example, light provides a valuable time base for circadian sleep-wake rhythms. Lighting could help to change the mood of a space or the perceived size of an enclosed area. Light can also affect the quality of the air and reduce the number of bacteria in an area, making it much safer for patients and staff. However, to better understand the relationship between lighting and performance, it is important to examine how different types of lighting may impact different types of healthcare tasks.

Lighting can be in artificial or natural form. Intensity, colour, direction, and movement are qualities associated with light. These qualities can be manipulated to achieve the desired end in mood, focus, modelling, and visibility. Architectural design of a space often takes advantage of these qualities in artificial lighting to enhance the ambience, promote execution of tasks, and highlight features or objects. When carefully planned as an essential part of aesthetics, a pleasing and supportive environment is achieved (Sholanke et al. 2021).

Thus, healthcare facilities associated with complex lighting requirements should cater to the needs and preferences of different user groups (Boyce et al. 2003), in various situations for efficiency, safety, and wellbeing. Both functional and emotional components of lighting produce both visual and non-visual/biological effects on humans. Reconciling the disparate requirements and interests through innovative and user-centred approaches to lighting design will ensure quality care delivery. Moreover, understanding the relationship between lighting and performance can be enhanced by examining how different types of lighting may impact different types of healthcare tasks as adequate and adequate lighting in healthcare facilities will provides high visual performance and ensures the psychological and physical comfort of all users.

2.3.2.1 ***Artificial Form of Lighting***

Artificial lighting has become an integral aspect of modern life, even as it strives to mimic natural daylight spectrums. Its importance lies in providing illumination that differs from the natural sunlight or moonlight. It encompasses a wide range of sources, including electrically powered ones like lamps, fluorescent bulbs, and tubes, as well as non-electrical sources like candlelight. The use of artificial lighting has increased significantly in recent years, and it serves many functions such as extending daylight hours, providing light for reading or writing in dark spaces, illuminating workspaces, creating ambiance, and facilitating precision tasks.

In the built environment, artificial lighting can be used strategically to create environments that are visually appealing and conducive to productivity. For example, using a combination of direct and indirect lighting can help users achieve the desired level of brightness while avoiding glare. The intensity, colour temperature, and hue of artificial lighting can be adjusted to create a range of ambiances that can evoke emotion and affect people psychologically.

Studies have demonstrated a significant correlation between the luminance levels of spaces and their effect on the visual comfort of users of such spaces (Sholanke et al. 2021). By adjusting the luminance levels of a room to create visual balance, artificial lighting can have a positive impact on the user's visual comfort. However, it is crucial to consider the effect of glare on visual comfort, as it can create visual discomfort for the user and even lead to impaired task performance (Leccese et al. in 2020; Konstantzos, 2020). Therefore, it is necessary to consider the role of glare in the use of artificial lighting.

Artificial lighting is an essential tool for communication and navigation in the built environment, affecting human psychology and impulse (Schielke, 2019). Research shows that artificial lighting can be useful for psychological aspects of building and space design, particularly in public spaces, where it can create a sense of security and safety for people. Artificial light can also be used to influence human behaviour and promote learning in educational buildings. In general, artificial lighting can improve the visual comfort of occupants in various environments, and it is essential to consider the factors that influence visual comfort when designing lighting systems.

One of the primary benefits of artificial lighting in healthcare environments is that it can help create a calming and relaxing atmosphere for patients. Studies have shown that lighting has a significant impact on patients' mood and well-being and can help reduce their anxiety and stress levels (Ulrich et al. 2008). By providing warm and inviting lighting in patient rooms, healthcare facilities can create a comfortable and soothing environment that promotes healing and recovery.

In addition, artificial lighting is important in providing adequate illumination for medical procedures. Bright, focused lighting is essential in operating rooms and emergency departments to ensure that medical professionals can see clearly and perform procedures safely and effectively (Golvani et al. 2021). LED lighting is increasingly being used in healthcare facilities due to its energy efficiency and ability to produce bright, clear illumination (Joseph, 2006).

Moreover, artificial lighting plays a crucial role in reducing the spread of infectious diseases in healthcare facilities. Studies have found that ultraviolet (UV) light can kill microorganisms such as bacteria, viruses, and fungi (Yin et al. 2013). UV light can be used in disinfection processes, including disinfecting equipment and surfaces in healthcare facilities (Boyce, 2016; Rutala & Weber, 2008). However, it is important to note that direct exposure to UV light can be harmful to humans, and appropriate safety measures should be taken when using UV light for disinfection.

Moreover, the use of smart lighting technology has revolutionised the way artificial lighting is used in various environments. Smart lighting systems use sensors to detect occupancy and adjust lighting levels, accordingly, ensuring energy efficiency and reducing operating costs (Ikuzwe et al. 2020). This technology can also enhance user experience by creating personalised lighting settings that suit individual preferences.

Artificial lighting in healthcare environments impacts not only patient experience but also healthcare worker productivity and efficiency. Artificial lighting can also be used to promote staff productivity and well-being. For instance, a study found that the bright output of LED lighting in operating rooms improved the accuracy of clinical diagnoses and decreased the risk of surgical complications (Yun & Kwok, 2017). Similarly, appropriate lighting levels and colour temperature in nurses' workstations improved their performance and mood, leading to improved patient outcomes (Jin et al. 2023; Blume et al. 2019). Adequate lighting levels can reduce eyestrain and headaches, and improve alertness and focus, leading to higher job satisfaction and productivity (Münch et al. 2017). By providing comfortable and functional lighting in staff areas, healthcare facilities can create a positive work environment that fosters employee satisfaction and retention.

However, excessive or poorly designed lighting can have negative effects on healthcare environments. Studies have shown that overly bright or harsh lighting can lead to increased stress levels and agitation among patients (Graves et al. 2021). Inadequate lighting levels can also compromise patient safety and increase the risk of medical errors (Institute of Medicine, 2001). Therefore, it is important to carefully design and control artificial lighting in healthcare environments to ensure that it promotes patient and staff well-being and safety.

Research into the impact of artificial lighting on occupant comfort in an office building revealed that natural lighting was preferred by workers over artificial lighting (Jin et al. 2023). This finding supports the notion that artificial lighting should be used in addition to natural lighting, as it will create a more comfortable and productive working environment. Additionally, natural lighting positively impacts the health and well-being of workers, improving cognitive performance and reducing fatigue, thus leading to increased productivity (Boubekri et al. 2014).

In addition, the use of artificial lighting as a supplement to natural lighting can help reduce energy costs and improve user wellbeing. For example, a study conducted on how to reduce energy costs on a Nigerian university campus concluded that planned energy efficiency policy measures could result in an estimated annual savings in electricity consumption of about 16% (Oyedepo et al. 2015). This evidence suggests that artificial lighting should be used as a supplement to natural lighting when feasible to increase energy efficiency and reduce energy costs.

While advancements in artificial lighting and air conditioning have allowed architects and planners to design large, deep buildings with enclosed spaces requiring minimal access to natural light for illumination, such buildings often lack efficiency and have a negative impact on well-being, performance, and productivity. Thus, using artificial lighting only when needed is essential for achieving building maintenance and life cycle costs in the built environment (Sholanke et al. 2021).

2.3.2.2 ***Natural Form of Lighting***

Natural daylight is a fundamental element in the design and operation of buildings, playing a pivotal role in creating a conducive indoor environment that significantly influences the health, well-being, and overall performance of occupants. This importance is crucial in healthcare facilities, where the benefits of natural daylight extend to patients, staff, and visitors, making it an integral component of architectural considerations.

Research underscores the critical impact of daylight on individual outcomes and well-being. Notably, exposure to natural daylight not only reduces the dependency on artificial lighting, thus contributing to energy savings, but also has profound effects on physical and psychological health (Oyedepo et al. 2015). Studies have demonstrated that natural daylight exposure can improve concentration, alertness, and overall productivity while also promoting healthier living habits (Awada et al. 2021; Shishegar & Boubekri, 2016).

Beyond its functional aspects, natural daylight in the built environment provides health and well-being benefits (Altomonte et al. 2020). These benefits include improved sleep patterns, reduced eyestrain, improved moods, and an overall sense of well-being. In essence, the presence of natural daylight is beyond visual comfort and aesthetics, influencing the overall experience of indoor spaces.

The significance of daylight finds its roots in human evolution, where the natural rhythms of light and dark were crucial for regulating biological clocks and overall well-being (Aries et al. 2015). This historical connection is evident in architectural history, from the earliest rudimentary openings in caves to the grandeur of medieval cathedrals illuminated by stained glass windows (Kleiner, 2020; Gagg, 2011). Daylight has long been a means for introducing heat, sound, and fresh air into buildings (Ahmed et al. 2015), and its interplay with light and shadows has become an integral part of architectural expression (Schielke, 2019). The dynamic qualities of daylight, including variations in intensity, colour, and direction, uniquely shape the nature and appearance of indoor spaces within buildings (Dalton, 2014).

However, the advent of electricity and the widespread use of artificial lighting disrupted this natural cycle, leading to a gradual diminishment in the appreciation of daylight's intrinsic beauty. Despite the convenience and popularity of artificial lighting since the 1940s, daylight has persisted as an essential and irreplaceable tool for architects (Aries et al. 2015; Bluyssen, 2010).

Daylight's influence on well-being is multipurpose. It has been associated with improved indoor air quality, stress reduction, and increased physical activity (Aries et al. 2015; Salonen et al. 2013). The dynamic qualities of natural light, with its variations in intensity, colour, and direction, have a pronounced positive impact on individuals' experience and mood (Aries et al. 2015; Joseph, 2006).

Moreover, daylight plays a crucial role in human health, stimulating the release of nitric oxide, enhancing mood, and improving overall performance (Abboud et al. 2017; Razzaque & Eldabi, 2018). Scientific research has established that adequate exposure to daylight is a necessary for optimal human functioning and can have a positive influence on overall health and wellbeing (Aripin, 2007; Ulrich et al. 2004). Conversely, insufficient exposure to daylight has been linked to an increased risk of depression and anxiety (Boyce, 2022).

The consequences of inadequate daylight exposure due to seasonal variations can manifest as symptoms of seasonal affective disorder (SAD), such as depression, fatigue, and irritability (Bower, 2005; Evans, 2003; Morris, 2001). Beyond these psychological aspects, daylight facilitates the performance of visual tasks and stimulates essential physiological processes, positively affecting human physiology and psychology (Schweitzer et al. 2004).

Access to daylight also plays a pivotal role in workplace satisfaction and productivity, with evidence suggesting that employees with access to natural light tend to be more productive and experience a better sense of well-being (Shepley et al. 2012; Ulrich, 1984). In contrast, individuals lacking access to natural light are more likely to endure high stress levels, eyestrain, fatigue, depression, and a desire to leave their jobs (Zadeh et al. 2014).

In healthcare environments, the presence of natural light can be transformative for the well-being of patients, staff, and visitors. Numerous studies have established a strong correlation between the quantity and quality of daylight exposure and various patient and staff outcomes (Ulrich et al. 2008). Patients benefit from better recovery rate, improved sleep patterns, and reduced stress levels in healthcare facilities that prioritise natural light (Shepley et al. 2012). Access to daylight has been shown to improve patient satisfaction, mood, and openness, while reducing levels of agitation and rates of depression (Alzubaidi et al. 2013; Husein & Salim, 2020). Moreover, daylight can positively impact the vitamin D metabolism of patients, further supporting their health and recovery (Husein & Salim, 2020). Thus, exposure to natural light contributes to shorter hospital stays and improved recovery rates among patients (Shepley et al. 2012; Choi et al. 2012). Therefore, the availability of natural light in healthcare facilities is seen as a key factor for the health and well-being of both staff and patients.

Studies also underline the positive effects of natural light on staff performance and health, ranging from stress reduction and improved sleep quality to enhanced cognitive performance and fewer work-related musculoskeletal disorders (Aripin, 2007; Caspari et al. 2006; Salonen et al. 2013; Ulrich et al. 2004). Daylight's presence has been found to increase job satisfaction, concentration, and overall well-being among staff members (Shepley et al. 2012; Zimring & Turner, 2011). It is essential to emphasise that the quality and quantity of daylight exposure significantly contribute to the well-being of staff, patients, and visitors alike.

Furthermore, studies have indicated that poor performance resulting from inadequate lighting levels in healthcare environments may lead to medical errors, underlining the pressing need for appropriate access to natural light in these facilities (Ulrich et al. 2008). Thus, access to natural light is crucial for promoting human health and well-being, necessitating careful consideration in the design and operation of healthcare facilities.

Regrettably, despite the various benefits associated with natural light, many healthcare facilities, including critical areas like nurse stations in hospitals, often lack adequate access to this vital resource (Vleugels, 2018). This shortfall highlights the urgent need to ensure that healthcare facilities, particularly in wards and nursing stations, provide adequate access to natural light, especially considering the physically and mentally demanding work conditions faced by medical personnel who often work extended hours and irregular shifts.

Achieving adequate daylight in healthcare facilities requires a holistic approach, starting with site planning and building orientation. The correct placement of buildings can optimise the penetration of natural light into all parts of the facility, even during the winter months when daylight intensity tends to be lower. Additionally, light control measures, such as blinds and shades, as well as reflective surfaces, can be strategically employed to maximise the entry of natural light. Innovative solutions like skylights and light tubes can effectively channel natural light into deeper areas of the facility. Incorporating larger windows in wards not only improves natural light but also offers occupants a visual connection to the outdoors. The importance of aligning light levels and timing with the tasks performed within healthcare environments cannot be overstated; bright lighting is essential in locations where staff members carry out critical tasks, such as medication dispensing.

Recognising the pivotal role of natural daylight in healthcare facilities, it becomes evident that its multiple positive effects on the health, well-being, and overall satisfaction of staff, patients, and visitors requires commitment to integrating it into healthcare facility design and operation. This approach will not only serve as a commitment to the facility's dedication to the occupants' health and well-being but also facilitate improved outcomes and experiences for all users.

2.3.2.3 ***Use of Daylight***

Research, such as the study conducted by Mardaljevic et al. (2012), highlights the profound impact of light intensity on biological processes. Their findings revealed that effective suppression of melatonin, a hormone crucial for regulating sleep, can be achieved with illuminance levels around 1,000 lux, depending on the light spectrum. This research underscores the key role that natural light plays in human lives and supports the need to incorporate it into healthcare environments.

In a study carried out in San Diego, researchers found that the average person spent only 4% of each 24 hours in illumination greater than 1,000 lx, and individuals with the shortest daily exposure time to high light levels reported the lowest mood (Wirz-Justice et al. 2011). This pattern has been observed in other studies, where exposure to daylight has been shown to produce much higher illuminance levels than artificial lighting (Figueiro et al. 2011).

It is worth noting that while the visual system can react to and process light impulses in a fraction of a second, the human biological clock requires minutes or even hours to respond. This means that both the illuminance at the eye and the duration of exposure are important factors in the effect of light on our circadian system (Cajochen et al. 2019).

Furthermore, the light that is important for the circadian rhythm is different from the light that is important for the visual system, due to the spectral difference in the light sensitivity of individual photoreceptors. The timing of light exposure is also a critical factor, as the time of day at which light is registered on the retina has a distinctly different effect on both the visual system and the circadian rhythm (Gooley et al. 2011).

Daylight provides the ideal conditions for visual and biological activities in the human body, including the highest levels of light needed for biological functions compared to typical artificial light sources (Figueiro et al. 2011). Therefore, healthcare facilities would benefit from exposure to natural daylight in maintaining good health and wellbeing of both the patients and the staff.

In fact, studies have shown that exposure to natural daylight can lead to a significant reduction in hospital stays, medication intake, and pain levels, and an improvement in sleep quality, mood, and cognitive function (Zadeh et al. 2018; Park et al. 2018). Moreover, natural daylight has also been found to be an effective way to reduce stress in the workplace, improve productivity, and enhance job satisfaction among employees (Heschong & Mahone, 2003).

Natural daylight is an essential source of light that plays a crucial role in the biological processes, including the circadian rhythm, visual system, and overall health and wellbeing. Exposure to natural daylight can have a positive impact on the mood, cognitive function, sleep quality, and physical health, making it an important consideration in designing healthcare facilities and workplaces. Therefore, it is important to prioritise access to natural daylight in our daily lives for optimal health and wellbeing.

2.3.2.3.1 **Daylight Availability and Spectral Qualities**

In healthcare facilities, adequate lighting is critical for staff to perform optimally, as it can help reduce eyestrain, fatigue, and discomfort for the staff. The ability of individuals to perceive, quickly, safely, and comfortably carry out a visual task depends on the light levels, their distribution on the task area, and their immediate surroundings (BS EN 12464-1-2021). Furthermore, the spectral qualities of the light are also a factor, as some medical procedures require light to be at certain wavelengths to provide an optimal environment for care (Boyce, 2003).

Adequate lighting conditions are necessary and play a critical role in providing optimal care. These conditions include the necessary light levels, distribution, and spectral qualities to meet the requirements of the BS EN Standard. The European standard, BS EN 12464-1-2021, recommends specific light levels for different areas in healthcare facilities. For instance, the general lighting in the wards should be 100 lux, while the reading lighting in the wards should be 300 lux. For simple examinations in the wards, the recommended light level is 300 lux, and for staff rooms, it is also 300 lux. Additionally, the European Standard prescribes a minimum colour rendering index (CRI) of 80 for general lighting and 85 for reading light to ensure the accurate representation of colours.

While the requirements for daylighting have not yet been specified in terms of specific illuminance levels, there is enough evidence in the literature to suggest that illuminances between 100 and 3000 lux are likely to result in a significant decrease in the amount of electricity used for lighting (Andersen, 2014; Mardaljevic, 2008). This range of daylight illuminance levels is also likely to lead to improved occupant comfort, with increased daylighting associated with greater physical and mental wellbeing. Furthermore, daylight has been suggested to have a range of spectrums that impact staff well-being and performance (Golvani et al. 2021; Alzubaidi et al. 2013).

Considering the minimum CRI and illuminance levels, occupants are better placed to benefit from a space illuminated by natural light due to its spectrum and quality (Alzubaidi et al. 2013; Mardaljevic, 2008). This has led to an increased recognition of the potential for daylight to reduce energy consumption and create a healthier environment for building occupants. In addition to this, the benefits of daylighting also extend beyond energy savings and can contribute to patient outcomes in healthcare environments. For instance, a study conducted by Ulrich et al. (2008) found that patients with access to natural light had lower pain medication requirements and shorter hospital stays compared to those without access to natural light.

2.3.2.3.2 **Daylight Access Evaluation**

Daylight access is a crucial factor in designing and creating comfortable and productive indoor environments for building occupants. It has been recognised that daylight has a positive impact on the health, wellbeing, and productivity of building occupants (Heschong & Mahone, 2003). However, the amount of daylight reaching indoor spaces is influenced by several factors, including the location, climate, orientation, building façade, and occupation (Chraibi et al. 2016).

Designers must consider these factors when designing windows to ensure optimal daylight levels. For example, in sunny climates, designers must consider the angle of incidence of sunlight when designing window dimensions to optimise daylight access while minimising heat gain (Zhang et al. 2017; Mangkuto et al. 2016).

In modern buildings, reduced daylight access can negatively impact occupant visual comfort and productivity (Reinhart et al. 2006). Therefore, evaluating daylight access is crucial to ensure adequate visual comfort and task performance. Comprehensive evaluation methods that incorporate factors such as wall surface reflectance, glare control, and shading devices must be used (Shafavi et al. 2020).

To provide sufficient light levels for occupants, it is essential to understand the factors that influence daylight quality and quantity (Despenic et al. 2017; Chraibi et al. 2016). Daylight not only enhances health, awareness, productivity, and comfort but also reduces energy use (Shafavi et al. 2020; Boubekri et al. 2016). There are several metrics available to assess daylighting performance (Mardaljevic et al. 2012; Reinhart et al. 2006). However, little is known about how they are used (Zhang et al. 2017; Galasiu, & Reinhart, 2008). Daylight availability metrics consider the variability of daylight across seasons, time of day, and weather conditions. They are expressed as relative terms and describe the relationship between light available inside and outside. The most used metric is the daylight factor (DF), which is expressed as a percentage (%) and represents the amount of daylight available inside compared to outside. However, this approach is limited in sensitivity to climate and orientation (Reinhart et al. 2006).

There are several limitations to using the DF metric to evaluate daylight access. For instance, it does not consider the colour rendering of daylight, which can have an impact on visual comfort and colour appearance (Carlucci et al. 2015). Additionally, the DF metric assumes that the indoor light distribution is uniform, which is not always the case (Reinhart et al. 2006).

To address these limitations, other metrics, such as the Spatial Daylight Autonomy (sDA) and the Annual Sunlight Exposure (ASE), have been developed to evaluate daylighting performance (Marzouk et al. 2022; Shafavi et al. 2020). These metrics consider factors such as colour rendering, luminance, and illuminance distribution in the indoor space, providing a more comprehensive evaluation of daylight access.

One other commonly used metrics is the Daylight Autonomy (DA) Index, which measures the percentage of hours per year when daylight illuminance levels exceed a certain threshold for the task (Reinhart et al. 2006). Other metrics include the spatial daylight autonomy (sDA), the continuous daylight autonomy (DAcon), and the useful daylight illuminance (UDI). These metrics are based on hourly calculations of direct and diffuse radiance horizontal illuminance from a weather data file, as well as shading devices and occupants acting in accordance with a predefined plan (Boyce, 2014; Mardaljevic et al. 2009; Reinhart et al. 2006).

These metrics are designed to assess many factors of visual comfort such as light intensity, light uniformity, light quality, and glare (Marzouk et al. 2022; Bellia et al. 2017). They differ from one another in terms of accuracy, simplicity, space, and time discretisation (Carlucci et al. 2015). The incorporation of these metrics into standards and grading systems suggests simplified procedures and values for evaluating building sunshine and glare performance (European Committee for Standardisation, 2019; Konis and Selkowitz, 2017).

Simulation application tools such as Radiance, Daysim, Relux, IES-VE, and DIALux have also been developed to assess the availability of daylight in buildings (Reinhart and Walkenhorst, 2011; Reinhart and Fitz, 2004). These tools use computer algorithms to compute the direct and diffuse illuminance from a variety of sources, such as sunlight, electric lighting, and shading devices. However, significant levels of discrepancies have been observed for certain conditions in some studies (Rucinska and Trzaski, 2020; Merghani and Bahloul, 2016).

While these simulation tools provide useful information about the potential for daylight availability, they tell little about human responses to well-being and productivity in each space (Boyce, 2014). According to Boyce (2014), most of the measures tell little about human response. As a result, there is still a need for more accurate simulation methods to assess the potential daylight performance of buildings accurately.

It is important to note that these metrics should be used in conjunction with other factors, such as building orientation, fenestration design, and interior layout, to accurately assess daylight performance. Proper daylight optimisation in buildings can lead to energy savings, increased comfort, and improved productivity. Therefore, it is crucial to continue developing and refining methods to evaluate and optimise daylight performance in buildings.

2.3.2.3.3 **Daylight for Health and Well-being**

Recent research suggests that the lighting environments of the future must consider health and wellbeing issues (Aarts & Vleugels, 2019). The impact of lighting on human health and wellbeing has long been recognised, with considerable research devoted to understanding the effects of the spectrum and exposure to daylight on behaviour and physiology (van Bommel, 2006). However, it is still unclear how to incorporate this knowledge into lighting design in a practical and effective manner. Nevertheless, it is certain that the lighting environment has a direct effect on the health and wellbeing of users of such environments.

To accurately assess the potential impact of daylight on health, well-being, and performance in buildings, a comprehensive and reliable approach is essential. This requires close collaboration among diverse disciplines, including physiology, psychology, medicine, physics, and architecture (Münch et al. 2020; van Bommel, 2006; Brainard & Veitch, 2007). By integrating the knowledge from these various fields, this research endeavour can generate informed recommendations and evidence-based design strategies that effectively combine energy efficiency, lighting quality, and health considerations. Through this interdisciplinary approach, buildings can be designed not only to be visually appealing and functional but also to foster the well-being and productivity of their occupants.

One essential factor to consider is the interplay between various lighting conditions, including lighting intensity, colour spectrum, and duration of exposure. Two concepts that are commonly used to quantify the spectral quality of light are the correlated colour temperature (CCT) and the colour rendering index (CRI) (Shishegar & Boubekri, 2016). CCT measures how closely a light source mimics natural sunlight, while CRI measures how accurately a light source can reproduce colours.

While both CCT and CRI measure the intensity of a given light source, they are distinct factors that provide valuable insight into how people perceive different types of light and how it impacts health, wellbeing, and performance. For instance, an object's colour will typically appear to be close to its natural colour observed in daylight or from an incandescent light source with the same colour temperature when the light source's CRI is high. In contrast, natural light emits a broad spectrum of light with enough wavelengths for everyone to recognise and distinguish between colours. The sun's light spectrum is unique, having a CRI of 100, the highest value that a light source can achieve (Shishegar & Boubekri, 2016). Consequently, exposure to natural light can benefit human health in ways that are not possible with artificial lighting.

Numerous studies have highlighted the advantages of daylight in terms of its spectrum characteristics, including the production of vitamin D through human skin. Vitamin D has been associated with improving energy levels, reducing stress, and helping maintain a healthy body weight (Boyce, 2014). Additionally, daylight has been found to improve cognitive performance and concentration by providing the eyes with a break from staring at computer screens and offering a psychological connection to the natural environment through the visibility of outside views (Boyce, 2014). These findings underscore the importance of incorporating daylight into buildings as a means of enhancing overall health and wellbeing.

Thus, the importance of lighting environments in promoting human health and wellbeing cannot be overstated. Designing healthcare buildings that incorporate the benefits of natural daylight and the latest research on lighting quality can provide numerous advantages, from reducing stress and improving cognitive performance to enhancing overall wellbeing. To achieve these goals, collaboration among various disciplines is essential, and measuring factors such as CCT and CRI can provide valuable insight into how different lighting conditions impact human health and wellbeing. By integrating these insights into lighting design, healthcare facilities can be healthier and more productive for the personnel and all user groups.

2.3.2.4 ***Windows and View of Outside***

Natural daylighting is an essential aspect of building design, particularly in healthcare facilities, where it has been linked to positive outcomes such as patient comfort, recovery rates, and staff productivity (Huisman et al. 2012; Sadler et al. 2011; Clancy, 2008). Incorporating daylight into buildings can be done in several ways, including windows, skylights, reflective surfaces, and tubular daylighting devices (TDDs). Windows have a significant impact on the user's experience by providing not only access to natural light but also views of the surrounding environment. The provision of natural daylight alone may not satisfy user needs, but access to daylight and the presence of windows have been found to improve user satisfaction and productivity in the workplace (Boyce et al. 2003).

Strategically placed windows offer visual contact with the outside environment, providing views of the sky, cityscape, or landscape, which can alleviate feelings of monotony and confinement. This can have a positive impact on user comfort and experience, creating a stimulating and calming environment that promotes productivity. Access to natural daylight, large windows, and outdoor views has been shown to be beneficial to health outcomes in healthcare design, according to evidence-based design (Huisman et al. 2012; Sadler et al. 2011; Clancy, 2008).

Windows can enhance the user's experience by providing orientation, weather information, and a connection to the outdoors (Boyce et al. 2003). Views from windows can counteract monotony and alleviate the feeling of being closed in, leading to increased satisfaction and productivity in the workplace. In healthcare environments, views of nature have been found to reduce stress, anxiety, and the need for pain medication (Ulrich, 1984). Moreover, the standard ISO 7730 highlights six parameters that significantly influence thermal comfort, of which four are influenced by windows and their accessories. The amount of light available to users can affect air temperature and mean radiant temperature, both of which are critical to thermal comfort. Windows can also impact thermal insulation and shading, which affect air temperature and relative humidity (CEN, 2005). These findings emphasise the importance of natural daylighting and views from windows in architectural design, particularly in healthcare facilities, to enhance user comfort and experience.

Numerous studies have demonstrated the positive effects of natural light and windows on the well-being and performance of healthcare staff (Zadeh et al. 2014; Dianat et al. 2013). Research has demonstrated that exposure to natural light and outdoor views can significantly reduce stress and fatigue, enhance well-being and satisfaction, and improve performance quality and task completion times for healthcare staff (Dianat et al. 2013). Furthermore, studies have found that access to daylight and outdoor views can improve the perceived quality of the work environment for medical staff, reducing stress and improving performance, concentration, alertness, and job satisfaction (Zadeh et al. 2014). For example, nurses working near windows have reported improved perceived alertness and reduced acute stress, whereas those working near blank walls reported the opposite (Zadeh et al. 2014).

However, designing windows for optimal daylighting presents several challenges that must be considered to create a comfortable and efficient work environment. Direct sunlight can create discomfort and inefficiency, while glare can cause eyestrain and fatigue, reducing productivity (Aries, 2005). Therefore, achieving a balance between optimising daylight harvesting and controlling associated discomfort risks is crucial (Bellia et al. 2017).

It is crucial to avoid glare, which is caused by high or non-uniform brightness distributions, high contrasts between light sources (i.e., windows) and the surrounding environment, and the position and size of the source in the field of view (Schlangen, 2019). Therefore, designing windows that manage daylighting and avoid glare is essential to create an optimum daylit environment that is comfortable, efficient, and effective for healthcare staff.

Additionally, factors such as the size, position, and orientation of windows in relation to the eye level of the building occupants, as well as insulation and/or sound attenuation to control temperature and reduce outside noise, must be considered to create an optimal daylit environment for workers (Reinhart et al. 2006; Boyce, 2003). Windows should strategically place considering the orientation of the building, the user's needs, and the local climate. In addition, designers should consider the use of window accessories, such as light shelves and wall washers, to reflect and diffuse light, reducing glare and increasing the distribution of natural light (Karlen et al. 2017; Baker & Steemers 2014). TDDs, which capture daylight from the roof and redirect it into interior spaces, can also be used to provide natural light to areas without direct access to windows. The goal is to create a comfortable, efficient, and effective work environment that maximises the benefits of natural daylight and outdoor views.

In general, access to natural light and windows has been shown to have positive effects on the well-being and performance of healthcare staff. However, designing windows and managing daylighting in healthcare environments can be challenging. Balancing daylight harvesting and the management of associated discomfort risks, such as glare, is crucial. The size, position, and orientation of windows in relation to the eye level of building occupants, insulation, and/or sound attenuation must also be considered. By considering all these factors, an optimum daylit environment that is comfortable, efficient, and effective can be created for healthcare staff.

2.4 Daylight and Health Outcomes

Daylight includes all the direct and indirect sunlight received from the sun during the day, and its significance extends to the survival of numerous plants, animals, and humans (Baker & Steemers 2014; Kreitzman & Foster 2011). A primary function of daylight lies in photosynthesis, the process through which plants produce oxygen, making it indispensable for sustaining life on the planet (Talaei, 2020). Moreover, daylight plays a key role in regulating human circadian rhythms, influencing our internal body clock and overall health (Gooley et al. 2011).

In building design, daylight has significant benefits. It reduces the need for artificial lighting during the day, contributing to energy savings as natural light enters through windows and other openings, encompassing direct sunlight, diffuse skylights, and reflected light (Andersen, 2014; IES, 2013). Daylight also impacts heating and cooling loads, allowing for more energy-efficient building designs (Reinhart, 2014). Over centuries, daylight has been a fundamental aspect of building elements, shaping architectural design (Knoop et al. 2020).

Human health also greatly benefits from exposure to daylight. It enables human bodies to produce essential Vitamin D, necessary for strong bones and healthy muscles (Aries et al. 2015; Figueiro et al. 2017; Laird et al. 2010). Moreover, daylight helps regulate human activities and contributes to creating a visually appealing environment that facilitates visual tasks and supports non-visual human biological needs. Recent research has demonstrated the various health and comfort benefits of daylight, highlighting its importance in building design (Knoop et al. 2020; Boyce, 2014; Baker et al. 2013).

Daylight plays a key role in sustaining life on Earth, providing energy to plants and animals, affecting circadian rhythms, and enabling the production of Vitamin D (Heschong, 2021; Boubekri, 2008). In the context of building design, daylight serves as a crucial element, offering illumination, influencing energy usage, and contributing to health and comfort benefits (Knoop et al. 2020; Aries et al. 2015). Its impact on both the natural world and human well-being makes daylight an indispensable and integral part of human lives.

2.4.1 **Visual Effects of Light**

Lighting as an essential aspect of the built environment serves the primary goal of providing adequate light levels for visually demanding tasks that require contrast and colour rendition (Knoop et al. 2020; Cuttle, 2015). The proper spectrum of daylight is crucial to achieve this goal. Achieving this requires the right spectrum of light, with natural daylight being the ideal source. In the early centuries, daylight was introduced into buildings through windows and skylights. Today, artificial lighting has become the preferred option due to its flexibility and control over the light output. The peripheral vision is influenced by several factors, including the size and shape of the space, the atmosphere, the materials, and the distribution of light.

Artificial lighting has its advantages, but it cannot replicate the beneficial effects of natural daylight on the human body and mind. Natural daylight enhances psychological well-being, provides more accurate colour perception, and creates a more energising visual environment that enhances concentration and leads to improved performance. However, the use of natural daylight in the built environment requires the proper placement and sizing of windows to achieve the right balance between the light, its position, and its direction.

According to a study by Edwards and Torcellini (2002), natural daylight has been proven to improve visual performance by creating a naturally lit environment. It also provides other non-visual effects such as improved well-being, comfort, and health benefits. This is because natural daylight is constantly changing, with various levels of illumination at different times of the day and year. This variability of natural daylight helps to regulate the body's circadian rhythms, which are responsible for regulating sleep and wake cycles, hormonal balance, and other physiological processes.

Natural daylight presents numerous advantages over artificial lighting, creating a unique ambiance, offering time-of-day cues, and contributing to a better sense of well-being (Golvani et al. 2021). The COVID-19 pandemic has highlighted the significance of natural light, with many individuals experiencing the effects of its absence in buildings lacking windows or having poor natural lighting, often hindered by blinds or curtains. This is because natural daylight is not just a static source of illumination; rather, it is a dynamic, ever-changing element that profoundly influences perception of the built environment.

Boyce (2003) points out that the impact of natural daylight on the built environment depends on various factors, including the space's size, shape, atmospheric conditions, materials used, and light distribution. These factors collectively influence human peripheral vision, illuminating surroundings and shaping perception of the space. Consequently, this interplay between natural daylight and the built environment creates a distinctive atmosphere and ambiance, contributing to an enhanced overall sense of well-being for occupants.

While artificial lighting serves a key role in providing stable and controlled illumination, it cannot replicate the full range of benefits offered by natural daylight. Research has shown that natural daylight improves visual performance, enhances psychological well-being, and provides additional non-visual effects, such as increased comfort and health benefits. However, integrating natural daylight into the built environment requires thoughtful consideration of window placement and sizing to strike the right balance between light, its position, and its direction (Ching, 2020; Baker & Steemers, 2014). Understanding the dynamic relationship between natural daylight and the built environment is pivotal in designing visually appealing, functional, and healthy spaces for occupants. By harnessing the advantages of natural daylight, architects and designers can create environments that promote health, productivity, and an overall better experience for those who inhabit them.

2.4.1.1 ***Visual Comfort***

Visual comfort is a critical component of building design that has become increasingly important in recent times. Architects and planners now recognise that visual comfort has a significant impact on the health and well-being of building occupants (Boyce et al. 2003; Heschong, 2002). This has led to the emergence of a new field in architecture and planning known as "human comfort," which considers visual comfort along with other factors that impact the comfort and well-being of building occupants (Heschong, 2002).

While the absence of discomfort during visual perception is not enough to measure the success of a space, visual comfort is essential for building occupants to carry out their activities efficiently and effectively (Aries et al. 2010). Visual comfort includes both subjective and objective factors, such as lighting levels, the nature of the light, and the spatial distribution of light within an indoor environment (Frontczak and Wargocki, 2011; Kaushik, 2019). Achieving visual comfort in indoor environments is vital, as it can significantly impact occupants' satisfaction, productivity, and overall well-being (Boyce et al. 2003).

However, there is currently no universally agreed-upon metric for accurately predicting visual comfort (Zanon et al. 2019; Chraibi et al. 2016; Xue et al. 2016). Individual differences in visual comfort perception, preferences, and acceptance further complicate the matter, with factors such as age, gender, and professions influencing these variations (Golvani et al. 2021; Gharaveis et al. 2020; Hadi et al. 2016; Dianat et al. 2013). Additionally, the existing metrics for predicting visual comfort have their limitations, as highlighted by Dogan and Park (2018) in their criticism of current CBDM metrics in residential buildings and their proposal for a better analysis procedure.

To overcome these limitations and better assess perceived glare and light-induced physiological responses, researchers have proposed new analysis procedures and metrics. Hamedani et al. (2019) reviewed literature on methods measuring light-induced physiological responses and suggested the use of objective physiological measurements to evaluate visual comfort accurately. Likewise, Wasilewski et al. (2019) examined spatio-temporal glare simulation, highlighting the shortcomings of existing methods and evaluating their potential for empirical studies. These research findings emphasise the importance of accounting for individual differences in visual comfort perception, preferences, and acceptance among occupants.

Given the significance of providing lighting that caters to diverse individual preferences while considering both temporal and spatial glare effects, further research is essential. Developing new metrics and analysis procedures to accurately predict visual comfort and create an optimal visual environment for various tasks will require a multidisciplinary approach. Integrating knowledge from fields such as psychology, engineering, and lighting design will be crucial in comprehensively understanding human visual perception and its impact on well-being and productivity, as demonstrated by previous works (Aries et al. 2010; Nastaran et al. 2020).

2.4.1.2 ***Lighting and Visual Perception***

Individual differences in preferences, perception, and acceptance play a crucial role in how visual perception is impacted, and these are influenced by individual demographics such as age, gender, cultural background, and level of education. However, there are universal aspects of visual perception that span different demographics. One of the most important factors that affect visual perception is lighting, which has a significant influence on performance, health, and personal well-being.

Inadequate or poor lighting indoors can result in eye strain, irritation, fatigue, and headaches. These symptoms can be caused by poor brightness and contrast, high luminance differences, and flickering, among other lighting issues. Good lighting indoors should provide substantial amounts of glare-free light, while poor lighting provides inadequate amounts of light, making it difficult to carry out tasks effectively (Boyce et al. 2003). To achieve good lighting indoors, it is essential to have representations of colour, low reflection, and uniform distribution of light (Boyce et al. 2003). Also, clear views to the outside are fundamental to perfecting the quantity and location of the openings in the building envelope to control natural light intensity.

Natural lighting is the most significant element to consider for the visual comfort of indoor spaces. Under daylight conditions, human vision is better than under artificial lighting because of the higher quantity that enables better visual performance (Joseph, 2006). Beyond vision, daylight influences the human biological clock based on the sun’s movement (sunrise and sunset) and controls human physiology and productivity (Aries, 2005). Daylight is recommended as the best source of light related to human health and comfort because of its spectacular colour spectrum, which has a positive influence on the occupant's mood, performance, and mental attitude (Kaushik, 2019).

Natural light has always been the most comfortable and preferred for human beings (Aries, 2005) because it is the source of illumination to which human eyes naturally adapt. Furthermore, the variability and spectrum of daylight (Galasiu and Reinhart, 2008) are well suited for changing visual tasks, with similarly changing demands on the lighting. Besides the proven impact on health and well-being, it also generates enormous energy savings.

The human eye serves two essential purposes, which are vision and input into the circadian rhythm of the body. Therefore, there is a need to assess how non-visual light effects can impact human performance, health, and well-being. It is important to consider individual demographics such as age, gender, cultural background, and level of education, as these can also affect how we process visual information. However, ensuring good lighting, especially natural lighting, can have a significant positive impact on visual perception, human health, and well-being, regardless of individual demographics.

2.4.2 **Non-visual Effects of Light**

The human eye is a complex system that detects visual signals and relays them to the brain for interpretation. Visual processing and interpretation of the images detected by the eye are essential for vision and other non-visual functions. Light entering the eye and causing signals to be conveyed via the primary optic tract causes none of those activities to be possible without visual processing (Xiao et al. 2021). However, light also affects human physiology, behaviour, and mood through non-visual effects. These effects are mediated by specialised photoreceptor cells located in the retina that are involved in non-image-forming functions, such as regulating the circadian rhythm, which is the body's internal clock (Chellappa et al. 2011).

Recent research is now focused on the non-visual effects of light on human physiology, behaviour, and mood, which are produced when visual information leaves the retina and travels along the optic nerve to the primary visual cortex located in the occipital lobe (CIE, 2019). Though importance of light on human health, especially daylight, has been the subject of research for several years. Empirical studies have shown the link between daylight and health (Chellappa et al. 2011). Studies have also shown that photoreception in the eye leads to vision and affects human physiology, behaviour, and mood. Photoreceptors in the human eyes contribute to several non-image-forming functions, such as alertness, mood, and cognition (CIE, 2019). The discovery of these cells has opened new research in the non-visual effects of light. These non-visual light signals have revolutionised lighting research, lighting technologies, and lighting applications. Research has focused on the physiological impact of light on the human body and mind. This research has demonstrated that light exposure affects not only sleep and alertness but also mood, memory, and cognitive performance (Chellappa et al. 2011).

Photoreceptors in the suprachiasmatic nuclear (SCN) of the hypothalamus are part of the brain that holds the human body clock. This circadian clock regulates many physiological activities that respond to a circadian rhythm, such as hormone levels, timing and structure of sleep, body core temperature, and cardiovascular functions, among others. Incident light on the cells synchronizes the body clock, and thus influences not only sleep and alertness but also mood, memory, and cognitive performance (Gooley et al, 2003).

2.4.2.1 ***Circadian regulations***

Recent advancements in research have led to the discovery of a new type of light-sensitive ganglia cells that have transformed the way architects and planners approach daylight and artificial lighting in buildings (Berson et al. 2002; Volf 2013). This discovery has highlighted the critical role that light plays in promoting human health, and new building requirements, such as BR2006, have been implemented based on this research (CIE, 2019).

Overall, research on photoreceptors in the human eye has shown that light is essential to human health, affecting not only visual function but also non-image-forming functions. The regulation of the human body clock by photoreceptors in the SCN has significant implications for sleep, alertness, mood, memory, and cognitive performance. The discovery of new light-sensitive ganglia cells has led to a new approach to designing lighting in buildings and has highlighted the importance of considering the non-visual effects of light. The implementation of new building requirements based on this research is just one example of the many ways that photoreceptor research is transforming the understanding of human health and shaping the built environment.

Understanding the intricate relationship between light and health is essential, as human evolution has been influenced by the natural light-dark cycle, which has a direct impact on mood, cognitive performance, and sleep-wake patterns (Aries et al. 2015). However, exposure to light at inappropriate times of the day can increase the risk of various diseases, including cancer. Research has shown that darkness stimulates the production of melatonin, a hormone that plays a vital role in reducing the risk of cancer. In contrast, exposure to light promotes the production of serotonin, which increases the levels of melatonin in the body, leading to a more refreshed and active feeling upon waking up after a restful night's sleep in complete darkness.

The regulation of the circadian rhythm, which controls human physiological functions, including sleep-wake patterns, is influenced by light signals from ganglion cells (Lucas et al. 2014). These light-sensitive cells are in the retina and transmit signals to the suprachiasmatic nucleus (SCN) of the brain. The SCN acts as the master clock for the body and regulates the circadian rhythm (Joarder, 2011).

The hormone melatonin, which is responsible for regulating sleep and lowering core body temperature, is secreted by numerous cells in the human body, but the most significant source of its circulation is during the night and in darkness. Light is the primary regulator of melatonin, although social cues and dietary preferences can also affect its secretion (Veitch & Galasiu, 2012). The timing, intensity, duration, pattern, and spectrum of light exposure can all affect circadian regulation through light, which is measured by changes in melatonin secretion.

Exposure to bright light at night can disrupt the body's natural production of melatonin, and the hormone's highest secretion level for a healthy daytime worker is in the middle of the night, with core body temperature reaching its lowest point immediately after (Walker et al. 2020; Blume et al. 2019). The SCN is particularly sensitive to light exposure during this time, and the darker the period, the more amplified the subsequent light exposure becomes. Exposure to light later in the biological night can speed up the cycle, causing melatonin secretion and other processes to start earlier the following day (Blume et al. 2019). However, prolonged exposure to bright light can lessen the effect of melatonin suppression. The detection of light at the retina serves as the trigger for this reaction (Aries et al. 2015; Veitch & Galasiu, 2012).

However, the assumption that the physiological responses of the ipRGC system are additive across wavelengths, necessary for establishing a new metric, may not be valid (CIE, 2004/2009). Evidence suggests that increased exposure to short-wavelength light leads to a stronger response, but two studies examining melatonin suppression following night-time exposure to commercial light sources did not observe the expected results (Chang et al. 2015; Vartanian et al. 2015). These results raise questions about the validity of the current action spectrum and highlight the need for further research in this area.

In 2002, a significant discovery was made in the field of ocular physiology: the intrinsically photoreceptive retinal ganglion cell (ipRGC) was found in photobiology, revolutionising the field. This discovery confirmed the previously suspected notion that the light signals responsible for regulating circadian rhythms are functionally separate from those that signal the retina to the pineal gland (Lucas et al. 2014; Hattar et al. 2002). This process is highly sensitive to short-wavelength visual radiation and has a different spectral response curve than the photoreceptors, rods, and cones. The action spectrum for this process has been studied in various mammalian species, including rats, mice, and humans, and for various responses, such as pupillary light responses and melatonin suppression (Brainard et al. 2008).

The action spectrum is not merely academic but has important practical consequences. Several authors have argued that the existence of a separate system for irradiance information via the Retinohypothalamic tract (RHT) should lead to the development of a new metric for expressing the quantity of light (CIE, 2004/2009; Brainard et al. 2001). The current metric for measuring light, illuminance, is a measure of the strength of the light signal to the photopic visual system, which is not the same as the ipRGC-mediated response. Illuminance, which is a measure of the strength of the light signal to the photopic visual system, is not sufficient for characterising the effects of light on the circadian system (CIE, 2018). The current metric used to measure the effects of light on the circadian system, known as the action spectrum, has been called into question by recent studies. Moreover, a new metric in this way assumes that the physiological responses of this system are additive across wavelengths, which may not be the case (CIE, 2004/2009).

Two studies, conducted by Chang et al. (2015) and Vartanian et al. (2015), have found that exposure to commercial light sources at night did not result in the expected suppression of melatonin, a hormone associated with sleep. These findings cast doubt on the validity of the current action spectrum and suggest a need for new metrics that accurately measure the effects of light on the circadian system.

2.4.2.2 ***Lighting and Mood***

Beyond the circadian system, lighting conditions have also been found to influence human mood and behaviour. A 2003 study by Boyce et al. found that people's moods can be affected by different types of lighting conditions. Mood changes can in turn impact behaviour and performance at work. However, individual factors such as preferences, expectations, discomfort, and gender can cause mood changes to differ even under the same lighting conditions. Glare and thermal discomfort are two factors that can negatively impact mood and task performance.

Interestingly, studies have shown that people prefer sitting near windows and having access to natural daylight as opposed to artificial light for work (Joseph, 2006). Aries et al. (2015) suggests this preference may be due to factors such as the view outside, the amount of daylight, and the presence of the full continuous spectrum. Furthermore, Heerwagen and Heerwagen (1986) identified several factors that can influence people's preferences for daylight in offices, including psychological comfort, office appearance, general health, visual health, colour appearance of people and furnishings, work performance, and jobs requiring fine observation. It is worth noting that exposure to daylight has also been linked to higher job satisfaction.

While the presence of windows in the workplace is generally associated with improved mood and work performance, it has been challenging to prove this conclusively. Studies have yielded mixed results, with some confirming that access to a window can reduce negative mood in occupants, while others do not support this assertion (Boyce et al. 2003). Boyce et al. (2003) suggest that individual preferences and expectations can affect how people respond to different lighting conditions, and factors such as glare and thermal discomfort may have a negative impact on mood and task performance. Thus, providing access to daylight with controlled glare and lighting levels is crucial and should be encouraged for improved mood and task performance (Boyce et al. 2003).

In addition, lighting plays a significant role in human alertness, with light intensity and spectral composition being crucial factors that affect it. Alertness is an essential aspect of psychology related to environmental awareness, wakefulness, low levels of fatigue, and high mental ability. It is influenced by light exposure and the timing of the circadian system.

During night-time hours, there is an increased level of melatonin and low core body temperature, which causes a decrease in alertness levels. However, the exact mechanism underlying this effect, particularly for exposure during the day, is still largely unknown. Understanding the impact of light on alertness is vital, as it has far-reaching implications, including performance and productivity in the workplace.

2.4.2.3 ***Mood and Staff Performance***

In healthcare facilities, where a range of professionals work tirelessly to provide essential services, such as healthcare, medication, therapy, food, hospitality, and equipment handling, lighting conditions are particularly critical (Alzubaidi et al. 2013). Healthcare professionals are often under high levels of stress, requiring effective communication with patients and colleagues while performing their duties efficiently, often under extreme pressure and at any time of day or night.

Therefore, optimising lighting conditions in healthcare facilities to promote alertness and mitigate fatigue is paramount. This can significantly benefit both healthcare professionals and patients by ensuring that staff members are alert and mentally sharp, providing better care and improving patient outcomes. By creating a work environment that promotes alertness, improve mood, and reduces fatigue, healthcare facilities can enhance the well-being of their staff and the quality of care they provide. It is essential to provide well-managed workspaces that consider both the physical and mental well-being. According to Choi et al. (2012), providing suitable visual and spatial environments that are easy to manage can go a long way in promoting staff productivity and reducing stress levels.

Lighting is a crucial factor in creating a supportive environment for healthcare workers, as it has a significant impact on both visual and non-visual biological functions. Inappropriate lighting can negatively affect healthcare professionals and increase the risk of errors when carrying out tasks (Shepley et al. 2012; Anjali, 2006). On the other hand, adequate lighting can improve staff performance, reduce the risk of errors, and enhance their overall well-being.

Studies have shown that many factors of lighting, including natural daylight can have a range of positive effects on both patient and staff well-being (Alzubaidi et al. 2013). For instance, the dynamic nature of daylight can help caregivers like physicians, nurses, and other staff feel connected to the outside world, which can enhance their task performance (Alzubaidi et al. 2013; Golvani et al. 2021). Daylight can also provide information about the time of day, support human circadian rhythm, and contribute to a better sense of well-being (Golvani et al. 2021).

One of the key tasks of medical staff is the rapid and correct evaluation of a patient's health status. The ability to quickly and accurately evaluate a patient's health status is a crucial task for medical staff. Visual inspection of the patient's skin, eyes, and tissues can provide important clues to their condition, but this requires appropriate lighting conditions (Dijk et al. 1997; Anderson, 1991). Medical professionals rely heavily on their visual assessments to make critical decisions promptly and accurately (McPhillips et al. 2021). Adequate lighting is imperative for them to effectively carry out their evaluations. For example, the yellowing of a patient's skin may indicate a liver problem, while blue skin colour may indicate breathing difficulties. The interplay between light and the human body can profoundly influence a patient's appearance, enabling medical practitioners to discern subtle indications of various health conditions. However, research on the impact of daylight on mood or specific task performance in hospitals is limited (Anjali, 2006), indicating the need for further research in this area (Alzubaidi et al.

2013). Accounting for individual differences in perception and preferences can lead to the design of patient-centred lighting solutions that enhance comfort and recovery.

One survey conducted at a healthcare facility in Turkey found that hospital staff who had access to sunlight during the day reported feeling less stressed and more comfortable (Anjali, 2006). Another study carried out at a healthcare centre explored the impact of natural light on hospital staff comfort and found that over 40% of surveyed staff perceived natural light as having a positive impact on their work (Anjali, 2006). Furthermore, a study on staff lighting needs and satisfaction found that 79% of participants named daylight in wards as a factor that helped them do their work more easily (Alzubaidi et al. 2013).

Additionally, a significant percentage of nurses and doctors (78%) believe that exposure to daylight has many benefits, including faster patient recovery, reduced length of hospital stay, and improved staff performance (Alzubaidi et al. 2013). By providing adequate access to appropriate lighting and natural light, healthcare facilities can create a more supportive and conducive environment for staff, to enhance their performance and well-being, leading to improved patient outcomes.

Unfortunately, many nurses' stations in hospitals lack adequate exposure to natural light, highlighting the need for further research to better understand the impact of daylight on staff mood and performance (Alzubaidi et al. 2013). While the importance of adequate lighting in hospitals for patient care is well established, the impact of lighting on staff mood and performance is less well understood. Further research in this area is needed to help optimise hospital lighting conditions for the benefit of both patients and staff.

2.4.3 **Vitamin D: The Sunshine Vitamin**

The human body requires vitamin D to maintain optimal health. While it can be obtained through dietary sources, such as fatty fish and fortified foods, exposure to sunlight remains the primary source of vitamin D for most people. In fact, most of the vitamin D in the blood can only be obtained through exposure to daylight (Shishegar & Boubekri, 2016; Wurtman, 1975).

The importance of vitamin D for overall health was first recognised in the 17th century, when a lack of vitamin D caused by underexposure to sunlight was linked to rickets, a bone disease affecting children (Shishegar & Boubekri, 2016). Since then, research has shown that vitamin D plays a vital role in the proper functioning of the immune system, with a deficiency potentially resulting in physiological disorders such as osteoporosis, diabetes, and cancer (Holick, 2017).

In the late 19th century years, Niels Ryberg Finsen, a Danish physician, made significant discoveries regarding the benefits of light on the immune system. Finsen suggested that ultraviolet (UV) light could directly benefit health, a notion that has been supported by contemporary scientific research (Volf, 2013). Additionally, natural light interacts with human skin through photosynthesis, resulting in the production of vitamin D (Shishegar & Boubekri, 2016). Today, new studies continue to confirm the critical role of vitamin D in promoting general well-being and overall health. A deficiency in vitamin D can result in physiological disorders, such as rickets, which were first attributed to a lack of vitamin D caused by underexposure to sunlight in the 17th century (Shishegar & Boubekri, 2016).

Recent research has also demonstrated that vitamin D plays a vital role in the proper functioning of the immune system (Boubekri, 2008). Vitamin D is essential to produce antimicrobial peptides, which help the body fight off infections (Boubekri, 2008).

While sunlight is necessary for vitamin D production, it is essential to find the right balance. Overexposure to sunlight can lead to sunburn and increase the risk of skin cancer. On the other hand, a lack of sunlight exposure can result in a vitamin D deficiency. To maintain optimal vitamin D levels, a British study suggests that a minimum of 30 minutes of daily sun exposure on the arms and face during the summer months, from April to October, is necessary (Hobday, 1999). However, it is important to consider factors such as skin type, geographic location, time of day, and season when determining an appropriate level of sun exposure (Holick, 2017). For example, people with darker skin require longer exposure to sunlight to produce the same amount of vitamin D as those with lighter skin. People living in northern latitudes or areas with significant air pollution may also require more sun exposure to produce adequate vitamin D (Holick, 2017).

Niels Finsen's discovery and subsequent research have highlighted the critical role of light and vitamin D in human health. Exposure to daylight is crucial for maintaining optimal levels of vitamin D, but overexposure can lead to skin damage. To harness the positive benefits of daylight while minimising the risks associated with excessive UV exposure, it is essential to find the right balance in design.

2.5 Lighting and Personnel Performance Assessment

In healthcare facilities, the physical environment within spaces such as hospital wards holds a pivotal role in shaping health outcomes. This PhD study examines the significance of lighting in hospital wards and its impact on task performance. One area of interest is the functional fit of the physical attributes of the built environment with the specific purpose for which hospital wards are designed. Such alignment would provide an environment conducive for best health outcomes.

In this context, ensuring the provision of indoor lighting during the day, access to vitamin D, and connection to the outdoors all contribute to enhancing well-being and performance. However, there is need for a proper assessment of lighting requirements to strike the right balance—adequate lighting during the day without exposing individuals to undue risks associated with excessive UV exposure. Achieving this balance calls for an approach that considers multiple factors, including building orientation, the selection of glazing materials, shading strategies, and interior layout.

2.5.1 **Healthcare Lighting Environment**

Another crucial consideration is the perspectives of both patients and healthcare workers when evaluating the healthcare facilities-built environment. By gathering insights into how users, including medical staff and patients, perceive the environment, researchers can explore potential links between environmental factors and user satisfaction with the facility they interact. Of interest is the impact of natural daylighting and access to outside views on both patients and healthcare workers. Daylighting is undeniably a key element in designing healthcare environments that contribute to positive health outcomes for both patients and the productivity of healthcare workers (Mardaljevic, 2013; Chinazzo, 2019). While numerous studies have explored the influence of daylighting on patients, fewer have examined its effects on healthcare workers (Vleugels, 2018; Applebaum et al. 2010).

One approach to investigating human perception of daylighting is through laboratory testing, where participants are exposed to specific lighting conditions under controlled settings (Karami et al., 2016; Izmir et al. 2022; Figueiro et al., 2011). However, it is worth noting that laboratory settings have their limitations, as participants may behave differently due to the awareness that they are being observed. In contrast, real-world settings offer opportunities for research in dynamic social contexts but may lack the precise control necessary for data analysis (Izmir et al., 2022).

One advantage of studying daylight perception in real-world settings is the ability to capture the full spectrum of daylight variations that occur throughout a day or year (Mardaljevic, 2013). However, laboratory studies offer better control over environmental conditions, which can help isolate specific variables to better understand their impact on daylight perception (Chinazzo, 2019). To gain a better understanding of how human perception of daylighting is consistent with lighting conditions in healthcare environments, a combination of laboratory testing and real-world settings is necessary (Chinazzo, 2019; Yasukouchi et al., 2019). This approach can offer invaluable insights into the impact of daylighting on both patients and healthcare workers, thereby informing design considerations. Regardless of the setting, studies of daylight perception typically combine subjective and objective measurements, which are evaluated based on current lighting conditions obtained by either spot measurements or daylighting simulations. These methods allow for the evaluation of daylight perception in various ways supported by factors associated with circadian rhythm (Chinazzo, 2019).

One critical factor to consider in evaluating daylight perception is the ability to see and perform visual tasks. According to Boyce et al. (2003), the type of task, quantity, spectrum, and distribution of light all affect performance levels. The authors stated that increased light levels improve visual task performance, which is crucial in healthcare environments where accurate and timely completion of tasks is essential. For tasks involving fine colour discrimination like setting of lines, daylight without any glare or unwanted shadows is preferable (Boyce, 2003). Additionally, age is another factor that influences how well visual tasks are carried out, as the need for light increases due to the declining transmittance of aging eye lenses (Edwards & Torcellini, 2002).

Moreover, it is essential to evaluate the lighting options for various tasks carried out by doctors, nurses, and other staff members in healthcare environments. This assessment should focus on analysing the lighting conditions for the visual task and its immediate surroundings, as well as calculating how uniform the lighting is in those locations. Understanding these factors and their effects on daylight perception can inform the design of healthcare environments that promote positive health outcomes for all users of the built environment in healthcare environments.

Research shows that light can influence human behaviour, health, well-being, and visual comfort. Therefore, it is essential to evaluate lighting options for various tasks carried out by nurses and other staff members in healthcare environments. One effective approach to evaluating lighting conditions is by examining the light levels required for specific visual tasks and their immediate surroundings. Understanding the lighting requirements for different activities can help ensure that the right amount and quality of light are available where needed. For instance, surgical procedures may require precise and focused lighting, while patient care areas might benefit from a softer and more ambient lighting approach to promote relaxation and comfort.

Furthermore, assessing the uniformity of lighting in various locations within the healthcare facility is crucial. Uneven lighting can lead to areas with insufficient light or unwanted glare, potentially hindering staff's ability to carry out their duties effectively. Identifying such areas can inform targeted improvements, ensuring that lighting conditions are consistent and appropriate throughout the healthcare environment. By leveraging the knowledge gained from these assessments, healthcare environments can be thoughtfully designed to support the well-being and efficiency of their users.

2.5.1.1 ***Lighting and Visual Discomfort***

As the quality of the lighting in the built environments can have a significant impact on health, productivity, and overall wellbeing. Lighting research aims to better understand human vision and perception and develop standards and guidelines for various lighting applications to improve these factors.

Boyce and Wilkins (2018) argue that such standards and guidelines can improve work performance, enhance safety, and alleviate visual discomfort. Healthcare environments, for example, can be designed to meet the necessary standards and guidelines for visual tasks, work performance, safety, and visual comfort by understanding the effects of daylight perception.

Adequate lighting can reduce the risk of falls, support the circadian rhythms of patients and staff members, and help reduce stress and anxiety.

However, research shows that the visual system has limitations with respect to wavelengths, luminance, detail size and contrast, colour discrimination, and temporal variations. Prolonged exposure to these limits may cause eyes to become red, itchy, or teary (Boyce & Wilkins, 2018). Complaints of visual discomfort are classified based on individual differences in responses to the same stimulus and variation in the acceptability of discomfort. The general underlying causes of visual discomfort are rooted in visibility problems, overstimulation, and distraction. Visibility problems can result from inadequate lighting or poor distribution that cause shadows, while overstimulation could result from temporal fluctuations in light output and distraction could be in the form of glare. Poor visibility strains visual processing, and prolonged working under overstimulation can result in eyestrain, headaches, and fatigue (Boyce & Wilkins, 2018; Boyce, 2014). Both environmental design and lighting contribute to visual discomfort, as task characteristics, surface colours, and reflectance also play a part.

Despite the possibility that the immediate cause may be unknown, earlier attempts to reduce visual discomfort due to lighting have proven that individuals are typically aware of their condition. They may shield their eyes from a source of glare to determine what is causing it and how to prevent its occurrence. In recent years, growing concern about the use of electric lighting in buildings and awareness of public health have led to the publication of standards and general guidance on lighting. These two factors combined have resulted in an increase in the number of lighting guides and standards available (BS EN 12464-1:2021; CIBSE, 2012; IESNA, 2011).

2.5.1.2 ***Illuminance Levels***

Adequate lighting is essential for good visibility and visual comfort, and poor visibility is the most common lighting condition that can cause discomfort. According to Boyce and Wilkins (2018), in most countries, the minimum illuminance recommendations exceed what is needed for good visibility. Lighting standards in most nations exhibit variations predicted by the consensus process used to establish the illuminances adopted as minimum standards.

For instance, the European standard, BS EN 12464-1-2021, recommends light levels in healthcare ward environments of 100 lux for general lighting, 300 lux for reading lighting, 300 lux for simple examinations, and 300 lux for staff rooms. Additionally, a minimum colour rendering index (CRI) of 80 for general lighting and 85 for reading light is recommended to ensure the accurate representation of colours.

While the requirements for daylighting have not yet been specified in terms of specific illuminance levels, evidence in the literature suggests that illuminances between 100 and 3000 lux are likely to result in a significant decrease in the amount of electricity used for lighting (Andersen, 2014; Mardaljevic, 2008). However, indoor discomfort is linked to light levels over 1000 lux, and separate evidence suggests discomfort at 2500 lux (Rea, 1982). It is important to note that the model of the effect of illuminance on visual performance is rarely used (Boyce & Wilkins, 2019).

Illuminance is the luminous power that comes from all directions and reaches a given point where a specific task is performed. The levels of illuminance that fall below or above the specified ranges of measurement on the work surfaces can generate discomfort. For example, a much higher level of illuminance could lead to glare with a resultant discomfort effect, while a lower illuminance level would lead to melatonin secretion, which affects alertness and performance.

Maintaining proper illuminance levels is healthy and productive, as even visual discomfort leads to lower productivity and general wellbeing (Kaushik, 2019; Boyce & Wilkins, 2018). However, the desired level of illuminance can vary depending on the individual. For instance, while high light levels are desirable for older adults for proper visual performance, those who suffer from migraine or have autism may prefer lower levels of lighting (Aries et al. 2015).

The illuminance (lx) is measured by a Lux meter, which determines the amount of luminous flux that falls on a surface per unit area. Adequate lighting can enhance visibility, performance, and overall wellbeing, while inadequate lighting can lead to discomfort and lower productivity. It is essential to adhere to recommended lighting standards to ensure adequate illumination and visual comfort.

2.5.1.3 ***Shadows***

In addition to maintaining appropriate lighting as specified in of standards, shadows also play a significant role in visual perception and aesthetics. shadows are captivating phenomena that arise when an object obstructs light from a specific direction, resulting from a complex interplay of factors such as object size, shape, texture, light source intensity, and angle. The research by Zhang et al. (2017) highlights how the distance between an object and the light source influences the size and shape of the shadow. Shadows serve a crucial purpose in revealing the form and texture of three-dimensional objects, introducing depth and contrast to create visually appealing images. In photography, shadows are skilfully employed to add interest and dimension to photos, while in architecture, they can produce captivating and dramatic effects on structures.

Nevertheless, shadows can also lead to visual discomfort in certain situations. For example, in display lighting, they may distort the perception of the showcased object, diminishing its visual impact. When shadows obscure details, accurate examination and interpretation of objects become challenging, potentially causing confusion or difficulty in discerning essential information. In situations where ample illumination is necessary across a work surface, shadows can reduce the spread of light, making it difficult to observe intricate details in objects. This limitation poses problems in environments where precise observation and precision are vital.

Overall, shadows play a multifaceted role in human perception and appreciation of the surrounding environment. Through thoughtful lighting design and awareness of shadow-related issues, healthcare facility design can harness the potential of shadows to enhance visual experiences while mitigating any potential drawbacks they may present.

2.5.1.4 ***Visual Discomfort and Glare***

One of the drawbacks that careful design can address is visual discomfort, a widespread problem with both psychological and physiological impacts. Visual discomfort can cause eye fatigue, headaches, as well as neck and shoulder pain, and has been linked to decreased employee performance, moods, and motivation, and increased sick leave (Boyce, 2014). Several factors can contribute to visual discomfort, including inadequate or excessive illumination, flickering or stroboscopic effects, and glare.

Glare is defined as an obstruction to vision caused by an excessive amount of light, and it is a frequent cause of visual discomfort in the workplace. Glare can occur because of high-luminance reflections from polished or glossy surfaces in the field of view (Vos, 2003). Disability glare refers to glare that impairs vision, while discomfort glare causes discomfort without necessarily impairing vision (CIE, 1987). Vos identified eight types of glares, with discomfort glare being the only one that is commonly experienced indoors (Vos, 2003).

Discomfort glare occurs when an individual can distinguish all objects in their field of view, but the overall brightness of the scene causes eye strain, resulting in premature tiredness and watering of the eyes (Reinhart, 2018; Iwata et al. 2008). This type of glare has been linked to adverse health outcomes and decreased productivity (Reinhart, 2018). However, good long-term visual perception can be achieved if there is a balance between uncomfortable moments and the benefits of daylighting, such as a view and visual interest (Boyce, 2018).

Fortunately, adaptive measures such as shading devices can be used to mitigate visual discomfort. Shading devices can reduce the amount of light entering a workspace and prevent reflections that cause glare (Xiong, 2019; Osterhaus, 2005). Other potential solutions include changing the position of the workstation or adjusting the angle of the computer monitor to avoid direct glare.

To identify potential sources of discomfort, it is essential to evaluate personnel's response to visual comfort and discomfort in the workplace. This can be done through subjective assessment using questionnaires and objective assessment using physiological measures such as pupillometry (Aries et al. 2015). By identifying and addressing the sources of visual discomfort, healthcare facilities can improve the health, performance, and productivity of personnel.

2.5.2 **Healthcare Worker and Performance**

The impact of lighting conditions on healthcare workers' task performance is a significant concern in healthcare facilities. Multiple studies have emphasised the importance of lighting in healthcare facilities, indicating that it can impact patients' and healthcare workers' physical and emotional wellbeing, as well as their cognitive performance and job satisfaction (Ulrich et al. 2008). Hadi (2014) also reviewed the literature on lighting design in hospitals and concluded that lighting can affect patients' and healthcare workers' physical and emotional wellbeing, performance, and job satisfaction, as well as their ability to perform visual tasks accurately and efficiently.

Moreover, daylighting, the practice of incorporating natural light into buildings, has been shown to have positive effects on healthcare workers' wellbeing and performance. Choi et al. (2015) conducted a study that showed how natural light exposure can improve sleep, mood, and daytime alertness in patients with bipolar depression. Similarly, Boyce et al. (2017) highlighted the benefits of daylight through windows, which can help regulate the circadian rhythms of healthcare workers, reduce stress, and improve overall wellbeing. These findings support the importance of addressing lighting conditions in healthcare facilities to enhance the well-being and performance of both patients and healthcare personnel.

2.5.2.1 ***Personnel and the Ward Environment***

In addition to the physical environment, healthcare professionals, including nurses and doctors, play a critical role in delivering quality patient care and ensuring the efficient functioning of hospital wards. These professions work together to diagnose, treat, and prevent illnesses, injuries, and disabilities, with the goal of improving the health and well-being of individuals, families, and communities. This section, provides an overview of the job tasks of nurses and doctors in a hospital ward setting, drawing upon recent literature and best practices.

Medical professionals, such as physicians, surgeons, dentists, and chiropractors, are licensed healthcare providers who diagnose, treat, and prevent illnesses and injuries (American Medical Association, 2021). They are trained in various specialties and subspecialties and use their medical knowledge and skills to evaluate patients and determine the best course of treatment (American Medical Association, 2021). Medical professionals play a critical role in the diagnosis and treatment of illnesses, injuries, and disabilities.

Nursing professionals are responsible for providing care and support to individuals, families, and communities. They work in a variety of settings, including hospitals, clinics, nursing homes, and home health agencies. Nurses provide medical care, administer medications, monitor patients' conditions, and educate patients and families about healthcare. They also collaborate with other healthcare professionals to develop and implement patient care plans. The nursing profession is a critical component of the healthcare industry, with registered nurses (RNs) serving as the largest group of healthcare professionals in the United States. The scope of practice for RNs includes a wide range of responsibilities, including assessment and monitoring of patient health, administration of medications, and education of patients and families about health and wellness (American Nurses Association, 2021). RNs also collaborate with other healthcare professionals to develop and implement patient care plans and may specialise in areas such as paediatrics, critical care, or oncology (American Association of Colleges of Nursing, 2021).

Nursing care plays a critical role in patient outcomes, as RNs are often the primary healthcare providers with whom patients interact. RNs use their knowledge and skills to assess and monitor patient health, identify and address health concerns, and provide education and support to patients and families. Research has shown that higher levels of RN staffing in healthcare facilities are associated with lower rates of patient mortality and infections, as well as improved patient satisfaction (Aiken et al. 2002; Aiken et al. 2012).

However, meeting the demands of nursing and medical job roles has both individual and societal consequences, and it calls for a more holistic approach to understanding the characteristics of the medical practice environment and how they may be objectively measured against predetermined criteria. The enquiry by Robert Francis QC into the case of Mid Staffordshire NHS Foundation Trust (Francis, 2013) concluded that patients were failed by a system that ignored warning signs of poor care and put corporate self-interest and cost control ahead of patients and their safety. Despite current trends, there is still a dearth of tools developed to assess the characteristics of hospital ward environments, which constitutes a workplace for medical personnel.

2.5.2.2 ***Nurses and Physicians***

Nurses are essential healthcare professionals who play a critical role in patient care in hospital settings. According to the World Health Organisation (2020), nurses are the largest group of healthcare professionals, providing care to patients around the clock. They are responsible for monitoring and documenting vital signs, such as blood pressure, heart rate, temperature, and oxygen saturation, as well as administering medications, injections, and treatments as prescribed by the physician.

In addition to clinical tasks, nurses assist patients with activities of daily living, such as bathing, dressing, and grooming. They also provide emotional support and comfort to patients and their families, collaborate with the physician and other healthcare professionals to develop and implement a comprehensive care plan for each patient, and maintain a clean and safe environment for patients, including regular cleaning and disinfecting of patient rooms and equipment (Buchan & Aiken, 2011).

Moreover, nurses play a significant role in the detection of adverse reactions or changes in patient condition. They observe and assess patient symptoms, alert physicians to changes in a patient's condition, and initiate appropriate interventions, such as oxygen therapy or administering medication to manage pain. Nurses' vigilance and attention to detail are crucial in ensuring the safety and well-being of their patients (World Health Organization, 2020).

Physicians, on the other hand, are responsible for diagnosing and treating medical conditions in hospital settings. They examine and diagnose patients, perform physical exams, interpret diagnostic test results, and develop and implement treatment plans, which may include ordering and interpreting diagnostic tests, prescribing medications, and collaborating with other healthcare professionals to ensure the delivery of high-quality patient care. Physicians must also stay up to date with the latest medical advancements and technology to provide the best possible care to patients and participate in ongoing medical education and training to maintain and improve their skills and knowledge (Buchan & Aiken, 2011).

Communication with patients and their families is another crucial aspect of physicians' work in a hospital ward setting. Physicians must be able to explain complex medical information to patients and their families in a way that is easily understandable, and they must be able to answer any questions or concerns that may arise. Effective communication is essential in building trust and confidence in patients and their families and in ensuring that they are actively involved in their treatment plans (Buchan & Aiken, 2011).

Both nurses and physicians are essential to the delivery of high-quality patient care in hospital settings. They work collaboratively, with nurses providing support and assistance to physicians, and physicians relying on the expertise and assistance of nurses. The job tasks of nurses and physicians are complementary, and both play a critical role in ensuring the effective functioning of the hospital ward and the well-being of patients.

2.5.2.3 ***Ward Environment and Staff Duties***

In today's fast-paced world, amidst people constantly on the go, health and wellbeing can sometimes be overlooked. Fortunately, hospitals are always prepared to offer medical care to those in need. However, the environment of a hospital ward plays a critical role in facilitating the healing and recovery process for patients. Osmond (1957) emphasised that a hospital ward's primary function is to provide a safe and conducive environment that supports patient recovery. Schweitzer et al. (2004) further stressed that a well-designed environment is significantly linked to patient recovery, as patients tend to behave better toward staff in such wards. Colley and Zeeman (2020) highlighted the importance of healthcare environments that prioritise safety and support, including well-designed ward environments, to ensure the safe management of patients and staff.

While the impact of the physical environment on patients has received considerable attention through research, relatively little focus has been placed on understanding its impact on healthcare professionals. Nursing and medical professions are demanding and can be physically, emotionally, and mentally exhausting careers. Healthcare workers often face numerous environmental demands in the workplace, including long working hours, physically strenuous tasks, and exposure to hazardous materials, all of which can negatively affect their health and well-being. These impacts may, in turn, influence the quality of care provided to patients.

Recognising the crucial role healthcare professionals play in patient care, it becomes imperative to address the challenges they face due to their work environment. A supportive and well-designed healthcare ward environment can significantly contribute to the overall well-being of healthcare workers, reducing burnout, stress, and related health issues. Enhancing the hospital environment to cater to the needs of both patients and staff can foster a positive work atmosphere and ultimately improve patient outcomes.

Therefore, it is necessary to understand the tasks performed by healthcare professionals. Research has shown that nurses spend 31% of their time in patients' rooms, with 91% of that time spent on nursing care tasks (Chappel et al. 2017; Hendrich et al. 2008). Many of these tasks involve documentation, direct patient care, and administering medications. However, a significant amount of time is also wasted on paperwork, rework, duplicate work, or inappropriate tasks (Chappel et al. 2017; Hollingsworth et al. 1998).

To optimise healthcare delivery and ensure that healthcare professionals can provide high-quality care to patients, the physical features of the ward environment play a crucial role. Abbas and Ghazali (2012) noted that the physical environment of the ward, including factors such as lighting, noise, temperature, and air quality, can influence the healing process. For example, studies have shown that natural light can have a positive impact on patients' well-being, and temperature can affect recovery time (Ulrich et al. 2008).

A well-designed and well-laid-out outward environment also contributes to staff performance, leading to increased efficiencies and output. Research has shown that a well-designed physical environment can improve staff morale, job satisfaction, and reduce staff turnover rates (Mourshed & Zhao, 2012). A time-and-motion study conducted by Hollingsworth et al. (1998) in emergency medicine revealed that healthcare workers spend their time on three activities: direct patient care, indirect patient care, and non-patient care. Therefore, creating a conducive working environment that supports both patient welfare and staff performance is essential.

Efficiency in healthcare delivery is not only dependent on the physical environment but also on the well-being and job satisfaction of healthcare staff. Studies have shown that staff satisfaction is an indicator of the health of hospital patients (McHugh et al. 2011). Therefore, it is crucial to prioritise the well-being and job satisfaction of healthcare professionals. By creating a supportive work environment that considers the demands and challenges faced by healthcare workers, hospitals can improve healthcare outcomes and increase efficiencies in healthcare delivery.

Several studies have shown that addressing environmental demands in healthcare workplaces is essential for improving the health and well-being of healthcare workers and reducing the risk of stress, burnout, and job dissatisfaction (Shanafelt and Noseworthy, 2017; Shanafelt et al. 2015; Aiken et al. 2012; Laschinger et al. 2009).

One environmental factor that has been found to influence the physiological and psychological aspects of individuals in healthcare environments is daylight. Despite the long shifts of healthcare workers, most of the research and design considerations regarding the impact of daylight and views of outside have focused on patients (Gharaveis et al. 2020). However, recent studies have shown that access to natural light and outside views can have a significant impact on the well-being of healthcare workers.

Gharaveis et al. (2016) found that natural light had a positive impact on the mood and job satisfaction of nurses. Similarly, Andersen and Guillemin (2013) reported that exposure to natural light improved the sleep quality and circadian rhythm of nurses, reducing their risk of developing sleep disorders. In addition, Boubekri and Wang (2012) found that access to natural light improved the cognitive performance of healthcare workers, resulting in better decision-making and reduced medical errors.

On the other hand, inadequate lighting has been consistently linked to negative consequences on the performance of healthcare workers, contributing to medical errors (Chaudhury & Mahmood, 2009; Ulrich et al. 2008). Salonen et al. (2013) highlighted a range of effects associated with improved lighting conditions, including reduced stress, fewer errors, decreased absenteeism, lowered rates of depression and fatigue, as well as enhanced performance, attitudes, mood, and job satisfaction among healthcare workers. Additionally, Ulrich et al. (2008) conducted a systematic review that specifically explored the impact of natural light on staff mood, shedding light on the significance of lighting in healthcare environments. The findings from these studies underscore the vital role lighting plays in healthcare environments and its direct influence on the well-being and effectiveness of healthcare professionals. Adequate lighting design, particularly the incorporation of natural light, has the potential to create a more conducive and supportive atmosphere for medical staff, positively impacting their mental and emotional state, and subsequently, their job performance.

Access to outside views has also been found to influence the clinical outcomes of patients. Ulrich (1984) found that patients with views of nature had shorter postoperative hospital stays and required less pain medication than patients with views of a brick wall. Zadeh et al. (2014) further showed that access to outside views improved the recovery time of patients and reduced their risk of developing postoperative complications.

In addition to the impact of natural light and outside views, research has shown that the quality of the built environment in healthcare environments is closely related to the behaviour of its users (Bowie and Mountain, 1997). Studies have emphasised the need for a better understanding of the characteristics of the care environment, especially in an institutional setting, to ensure that it promotes better health outcomes for patients and service users (Douglas and Douglas, 2005).

However, the majority of the available environmental assessment tools in healthcare environments only assess the adequacy of the physical environment for patients and service users, with little or no attention paid to the medical staff responsible for the effective use of these healthcare facilities for the treatment or support of the patients and/or service users. This has resulted in a lack of understanding of how healthcare workers perceive the built environment, despite working long shifts within it (Gharaveis et al. 2020).

2.5.3 **Measuring the Impact of Lighting on Healthcare Workers**

The physical environment of the workplace has a significant impact on employee productivity and well-being, and this holds true even in healthcare environments where employee satisfaction is crucial to the delivery of quality care. Research has shown that satisfied employees tend to perform better on the job, and dissatisfaction with the physical environment can worsen already stressful working conditions (Ulrich et al. 2008). Factors such as temperature, noise, air quality, and lighting can all affect concentration and productivity in the workplace.

Studies have shown that lighting levels can impact staff effectiveness when performing critical tasks such as dispensing medical prescriptions, and distractions during surgery can slow down procedures and reduce staff productivity. In addition, productivity is a crucial factor in the success of any workplace, and it depends on several factors, including employee competence, organisation and management, environment, and well-being (Schreyer & Pilat, 2001; Clements-Croome & Kaluarachchi, 1999).

To measure productivity, employers often use specific performance measures that ensure validity, reliability, freedom from bias, and practicality. Validity and reliability are concerned with ensuring the accuracy of the standards used, while bias is mostly due to Rater bias. Practicality refers to the ease of use of the performance measurement methods. Healthcare consultant Michael O’Donnell (2004; 1998) suggests that optimal health for employees involves balancing physical, emotional, intellectual, spiritual, and social health.

However, measuring the impact of lighting conditions on healthcare workers is an important but challenging issue. One study conducted by Davis et al. in 2020 took a mixed-methods approach to measure the impact of lighting conditions on healthcare workers' well-being and performance in a hospital setting (Davis et al. 2020). The study surveyed 138 healthcare workers and conducted in medical–surgical units in four hospitals. The study found that lighting conditions significantly affected healthcare workers' work-related stress and job satisfaction. Poor lighting conditions were associated with higher levels of work-related stress and lower job satisfaction (Davis et al. 2020).

These findings are consistent with previous research that has linked poor lighting conditions to negative effects on healthcare workers' well-being and performance. A study conducted by Applebaum et al. in 2010 found that poor lighting conditions were associated with increased stress levels, lower job satisfaction, and higher risk of errors among healthcare workers (Applebaum et al. 2010). Therefore, it is essential for healthcare facilities to implement strategies to improve lighting conditions to promote a more positive work environment for staff.

When evaluating productivity and performance, it is crucial to use valid, reliable, unbiased, and practical measures. Performance measurement methods can be classified as physiological, objective, and subjective (Ilgen & Schneider, 1991). Physiological measures, which assume that increased activity of the nervous system equates with an increase in the stress level, can be intrusive and/or impractical due to task demands and safety considerations (Clements-Croome & Kaluarachchi, 1999). On the other hand, objective measures assume that variations in performance reflect changes in workload or performance when compared across different tasks. Finally, subjective measures rely on respondents' opinions and assume that people are aware of and capable of evaluating changes in their experiences.

In the context of healthcare workers, subjective measures, such as questionnaires and semi-structured interviews, are non-intrusive, easy to implement, low-cost, valid, and have a wide range of techniques (O'Donnell, 1988). Although subjective measures may not always reflect objective reality, they can provide valuable information about how people experience their work environment and the factors that influence their work (Antikainen & Lonngvist, 2006; Clements-Croome & Kaluarachchi, 1999). Therefore, the selection of measures for assessing the impact of environmental factors on work life is critical for valid outcomes.

Research shows that using subjective measures, the effect of the environment on both emotional and behavioural responses can be easily assessed (Clements-Croome & Kaluarachchi, 1999). In manufacturing, for example, Juslen et al. (2007) found that higher lighting levels improve production speed. However, there are no specific studies related to healthcare environments or tasks. Studies have looked at the effect of bright light (2,500 lux) and set sleep schedules on night shift workers, and the most significant positive effect is seen when these factors are combined (Driver & Taylor 2000).

Mrockzek et al. (2005) exploratory analysis of employee satisfaction survey given at a medical centre found that natural light, followed by live music in the atrium, had the most positive environmental impact on work life. Alimoglu and Donmez (2005) discovered that employees who had more than 3 hours of daylight exposure during their shift were more satisfied with their jobs than employees who had less daylight exposure. However, the findings are complicated by the different types of nursing activities performed by each group. Access to daylight contributes to higher employee satisfaction, and adequate natural light is associated with higher staff satisfaction. Therefore, natural light is required in employee work areas, especially in critical areas such as medication dispensing, where bright lighting is preferred.

Medication dispensing errors are a significant concern in healthcare facilities, as they can negatively impact patient outcomes. However, research indicates that the level of worksurface lighting can play a crucial role in reducing such errors. A study by Reijula et al. (2014) found that medication dispensing errors were lower in workstations with high levels of lighting than in those with lower levels of lighting.

While the study focused specifically on worksurface lighting, it is reasonable to assume that bright lighting would be beneficial in other areas of the hospital where precision is required. Distractions during critical tasks, such as medication preparation, can lead to errors that affect patients. Fortunately, evidence suggests that reducing noise with sound-absorbing materials and providing bright lighting at workstations can help minimise distractions, reduce medical errors, and improve work efficiency (Joseph, 2006).

One other critical aspect that should be carefully considered in healthcare facility site planning and orientation is the provision of adequate daylight. Natural light not only enhances the physical environment but also promotes healing and reduces stress, which is critical for both patients and staff (Ulrich et al. 2008). To achieve this, it is essential to avoid building structures that block light from other buildings. Additionally, larger windows in wards can provide not only natural light but also views of nature, which has been shown to reduce stress and promote healing (Ulrich et al. 2008).

Lighting conditions in healthcare environments also play a crucial role in patient and staff performance. Different areas within the facility require varying levels of light. For instance, operating rooms and intensive care units require bright light, while dimmer light is appropriate in-patient rooms to promote rest and relaxation (Golvani, et al. 2021). Adequate lighting not only enhances performance but also reduces errors and improves staff and patient wellbeing.

2.5.3.1 ***Objective Assessment***

To assess the impact of lighting conditions on occupant work performance, research has focussed on alertness (Konstantzos et al. 2020). These studies have used biomarker measurements to measure the effects of lighting conditions on alertness. Brain-wave patterns have been used for comparison, with studies conducted during both the day and night (Souman et al. 2018; Motamedzadeh et al. 2017; Borisuit et al. 2016; Sahin et al. 2014, 2013).

Visual environment research often focuses on tasks with three components: visual, cognitive, and motor (Konstantzos et al. 2020). Some studies have focused on memory-related performance, while others have examined cognitive and reaction skills. Test batteries have been used in other studies to cover a variety of performance-related aspects. For example, Smith et al. (2009) used a comprehensive test battery that evaluated simple reaction time, procedural reaction time, mathematical processing, delayed matching to sample, and code substitution. Sahin et al. (2013, 2014) used a Multi-Attribute Task (MAT) battery.

Previous studies have focused on the objective evaluation of the visual environment on occupant work performance, with an emphasis on alertness (Konstantzos et al. 2020). To measure the effects of lighting conditions on alertness, biomarker measurements have been used in studies conducted during both the day and night, with brain-wave patterns being used for comparison (Souman et al. 2018; Borisuit et al. 2016; Sahin et al. 2013, 2014).

Many tasks that are studied in visual environment research have three components: visual, cognitive, and motor (Konstantzos et al. 2020). Some studies have focused on thinking and memory-related performance, while others have examined cognitive and reaction skills. To cover a variety of performance-related aspects, other studies have used test batteries. For instance, Smith et al. (2009) used a comprehensive test battery that evaluated simple reaction time, procedural reaction time, mathematical processing, delayed matching to sample, and code substitution. Sahin et al. (2013, 2014) used a Multi-Attribute Task (MAT) battery.

Visual environment research involves various tests to evaluate task performance in workstations. However, the absence of clear guidelines for reliable task performance tests in workstations with respect to the visual environment is a major challenge (Smolders & de Kort, 2014). To overcome this challenge, it is essential to consider various neurobehavioural functions that constitute performance and limit the selection of tests based on the type of work and the associated performance aspects. Moreover, the different effects of the visual environment on different tests suggest that different performance-related factors should be investigated separately.

2.5.3.2 ***Subjective Assessment***

In addition to objective measures, subjective assessments of task performance are also important in visual environment research. Surveys and questionnaires are commonly used to obtain subjective assessments of task performance (Konstantzos et al. 2020; de Kort, 2015). While subjective self-sleepiness assessments are considered less reliable than subjective assessments of comfort and performance, some studies have employed the Karolinska Sleepiness Scale (KSS) or simple scale rating and description feedback to assess sleepiness subjectively (Smolders & de Kort, 2014).

In a study conducted by Sadeghi et al. (2016), respondents were asked about their preferences for lighting with electric lighting and shading operation, and a subjective productivity assessment was included in addition to sleepiness assessments. However, the effectiveness of subjective assessments in replacing objective measures of performance or productivity remains unclear (Konstantzos et al. 2020).

The evaluation of subjective assessments is essential for determining their reliability and validity. A range of factors such as cognitive biases, mood, and lack of understanding of task requirements can influence the accuracy of subjective assessments (de Kort, 2015). Therefore, it is necessary to use multiple measures, including objective performance measures, to ensure the accuracy of the findings.

When assessing task performance in workstations concerning the visual environment, a comprehensive approach is required. This approach should consider various neurobehavioural functions and investigate different performance-related factors separately. Furthermore, subjective assessments of task performance through surveys and questionnaires can provide valuable insights in visual environment research.

2.5.3.3 ***Reliability of Subjective Assessments***

While there have been some studies that compared subjective and objective evaluations of performance in experimental setups (Smolders & de Kort, 2014; Veitch & Galasiu, 1998), no comparison was made between the two evaluation methods. To obtain conclusive results, research on task performance and productivity in relation to lighting conditions should compare both subjective and objective evaluations.

Objective tests are the most reliable method for assessing human performance and productivity in relation to lighting and other indoor environmental conditions. However, clear guidelines for dependable task performance evaluations of the visual environment at workstations are lacking. Depending on the tasks at hand, subjective tests may be more time- and cost-efficient, although there is insufficient evidence regarding their relative accuracy. (Konstantzos et al. 2020).

In general, a comprehensive approach that combines subjective and objective assessments is crucial for evaluating task performance in workstations concerning the visual environment. While objective tests are the most reliable method for assessing human performance and productivity in relation to lighting and other indoor environmental conditions, subjective tests may be more time- and cost-efficient depending on the tasks at hand. Further research is needed to establish clear guidelines for dependable task performance evaluations of the visual environment at workstations.

2.5.4 **Ward Environment Overview**

This section focuses on the correlation between hospital ward-built environments and job performance. Beginning with the core principle of assessing these environments, research highlights that well-designed spaces positively influence both patients and staff well-being (Shepley et al. 2012; Ulrich et al. 2008). Hospital ward layouts play a vital role in patients' healing and recovery, with elements like indoor lighting significantly impacting this process (Ulrich et al. 1984). Beyond this, the ward's atmosphere can significantly affect individuals with cognitive limitations, potentially leading to complication.

Addressing such issue involves creating a comfortable, conducive, and permissive ward environment (Gesler, 2003). Various data collection methods have been employed in studies focusing on indoor environmental quality to map occupant discomfort and its effect on productivity, as well as the physical parameters of the indoor environment. One such method is post-occupancy evaluation (POE), which compares occupant feedback with physical parameter measurements to identify performance shortcomings in the building's operation (Kaushik et al. 2019; Preiser, 2015). POE encompasses the collection of occupant responses through surveys or questionnaires, as well as measurements of indoor environmental parameters like lighting, allowing research to examine the relationship between environmental conditions and occupant performance and productivity (Ozturk et al. 2012).

Furthermore, personal variables related to health, well-being, and performance demand a deeper assessment than just physical dimensions and spatial configurations. Merely achieving high quantitative ratings for a building's design features does not necessarily guarantee occupants' complete comfort and satisfaction, as argued by Preiser (2001). This highlights the importance of carefully examining qualitative variables, such as how occupants interact with and feel within a space, during the design assessment.

Post-occupancy evaluation (POE) serves as an invaluable tool with architects and building construction professionals for assessing both a built environment and the behaviour of its occupants. While its primary aim is user satisfaction, it also strives to explain the cause-and-effect relationships between technical aspects and the physical and psychosocial needs of users. Bridging the gap between user expectations, architectural principles, and insights from social scientists on environmental behaviour is one of the key roles of POE (Turpin-Brooks and Viccars, 2006).

Nicola and Roaf (2005) emphasise the utility of POEs in determining users' actual spatial usage and subjective comfort, which may not always align with a building's technical performance. Becker (1989) agrees, highlighting the design profession's occasional failure to fully grasp and accommodate user requirements, often relying too heavily on intuition rather than empirical data.

Interestingly, POE has been in practice for decades, initially gaining traction in the United States during the 1970s economic crisis and simultaneous concerns about global warming. This period of evaluation allowed decision-makers to compare individual buildings against similar ones, facilitating evidence-based decisions. It also played a crucial role in establishing criteria, standards, measurements, benchmarks, and recommendations for enhancing energy efficiency, user comfort, productivity, health, and overall building quality in new construction projects.

In the United Kingdom, the Royal Institute of British Architects (RIBA) introduced stage M, "feedback," as the final phase of its work plan in 1965. This mandated architects to revisit their designs two to three years after construction and occupancy. The Plan of Work, Stage 7 (POE), introduced by RIBA in 1972, aimed to elevate building quality and customer satisfaction. However, its adoption in the UK construction industry was slow, partly due to a lack of incentives for design professionals to be concerned with a building's performance after commissioning. Cooper (2001) suggests that this reluctance might have been linked to architects' compensation structures and perceived conflicts among stakeholders. Additionally, a lack of agreed-upon indicators for assessing building performance and limited technical expertise among building owners may have hindered POE adoption.

The European Union's sustainability agenda, Directive 2002/91/EC, acted as a catalyst for the integration of POE into the UK building procurement industry. This directive mandated minimum energy standards for new and majorly renovated buildings, aiming to increase the number of net-zero-energy buildings. These initiatives were essential steps toward the EU's goal of reducing energy consumption in buildings by 60% by 2050.

However, concerns persisted regarding the limited application of POE in the UK construction sector. In response, the UK government issued policy documents outlining measures to encourage greater POE utilisation. This policy intervention had a positive impact, doubling the number of projects involving POE between 2007 and 2010. Government action served as an indirect approach to building performance assessment.

Furthermore, Stevenson and Lehmann (2010) suggested that providing feedback on energy use efficiency could influence occupant behaviour positively. Their research illuminated that understanding occupant behaviour is integral to a better understanding of building functionality.

In 2005, Way and Bordass advocated for a "forward-feeding POE" approach to building design and evaluation (Way & Bordass, 2009). This approach prioritises occupant behaviour and offers feedback to clients and designers for enhanced building performance. Way further developed "Soft Landings" as an alternative assessment approach, focusing on long-term maintenance and usage. This method has proven to bring measurable value to building projects by reducing costs and improving long-term outcomes.

Nonetheless, Way (2006) later proposed "Soft Landings" as an alternative method to assess building functionality. It concentrates on how a building is maintained over time and its usage, offering a more accurate indicator of building performance. This approach was tested in a project where Mark Way served as the lead architect, and it demonstrated measurable value by reducing rework and associated costs while facilitating better tuning (Bordass et al. 2014).

Despite the merits of Soft Landings, sceptics questioned its actual value and whether the additional time and resources were justified for better long-term results. Further research and documentation on the initiative's outcomes are needed to provide a more comprehensive understanding of its effectiveness (Bunn, 2018; Durosaiye, 2017).

POE employs both quantitative and qualitative methods to evaluate building performance. Quantitative methods involve the analysis of structured numerical data, including measurements and monitoring of the indoor environment. In contrast, qualitative methods focus on subjective information collection through interviews, surveys, observations, and questionnaires.

Baird (1996) identified various evaluation tools, such as observations, surveys, questionnaires, walkthroughs, focus groups, energy surveys, structured and semi-structured interviews, physical measurements, computer software, and plan analysis. However, not all these methods are precise or relevant, and some may be excessively labour-intensive or time-consuming. Therefore, the selection of appropriate POE methods is vital when evaluating and monitoring hospital ward lighting conditions.

Diverse types of POE exist, including indicative, investigative, and diagnostic POE. Investigative POE assesses how a building aligns with predefined criteria or performance standards. Indicative POE involves interviews with users who are most familiar with the space. On the other hand, diagnostic POE aims to establish a link between occupant perception of building performance and objective measurements of the physical environment. Its primary objective is to assess how building performance impacts occupant well-being, health, and productivity.

In healthcare facilities, where the environment can directly affect patient outcomes, diagnostic POE is particularly valuable. Gathering user perceptions about the healthcare environment helps identify which features may require improvement to enhance overall patient satisfaction. Common methods for information gathering in diagnostic POE include measuring and observing indoor environmental conditions, conducting interviews, and employing questionnaires. This approach provides an unbiased assessment of the ward's indoor lighting, providing useful information on the relationship between various lighting conditions and their impact on worker performance and productivity.

A diagnostic POE is a valuable assessment tool that shows direct connections between the physical environment and its occupants. This approach is particularly relevant in healthcare facilities, where the environment directly influences patient outcomes. By collecting user perceptions about the healthcare environment, researcher can highlight areas for improvement to enhance overall patient satisfaction. Thus, providing appropriate guidance for future healthcare facility design and renovation, ultimately contributing to improved patient care quality.

2.6 Existing Knowledge Gap

This research focuses on exploring the relationship between lighting conditions and the wellbeing and performance of healthcare personnel. The hypothesis posits that exposure to daylight significantly impacts staff wellbeing and performance. The study also aims to provide design implications for healthcare facilities to optimise daylight access, leading to enhanced wellbeing and performance among the personnel. This chapter conducts a literature review to examine the effects of natural light on healthcare environments. It analyses previous studies on indoor lighting in healthcare environments, considering both positive and negative effects on individuals' wellbeing and performance. Factors such as environment, physiology, and psychology are evaluated for their influence on lighting preferences and performance.

By analysing research conducted over the past ten years, the study identifies significant findings related to light and human performance, classifying assessments of light's impact on staff into three groups: objective measurement, subjective assessment, and objective measurement with subjective assessment. Table 1, shows that the relationship between light and the psychological benefit of staff, such as improving mood and stabilising circadian rhythms, as well as the impact of light on cognitive performance, are well established and supported by robust research. However, research on the impact of daylight on medical staff performance is limited, with only three out of 22 articles listed in Table 1. Furthermore, only six out of 15 empirical studies on the psychological impact of light on staff identified the impact under artificial light sources.

The table also highlights at least five pieces of evidence confirming that exposure to daylight intensities improves staff performance. These studies examined performance related to staff with psychological problems, such as mood, alertness, and perceived stress, as well as performance related to staff output, such as absenteeism and job performance. However, the methodologies of two research studies on task performance are questionable, as later discussed.

Previous studies related to healthcare environment, have identified defined knowledge about the impact of daylight on staff performance as weak and controversial, and the results are still

Table 1: Significant Findings in Research on Light and Its Impact on Staff

Assessment Method	**Study/Source**	**Variables**	**Design/ Method**	**Country**	**Setting**	**Sample population**	**Analysis**	**Findings**
Subjective assessments	Adamsson et al, 18	Light sources, mood, sleep activities	Questionnaire, Logs	Sweden	Office	20 women and 10 men	ANOVA Repeated Measures	A seasonal variation in mood and sleep activity pattern was observed.
	Izmir et al, 22	Daylight conditions, Illuminance level, satisfaction, mood, lighting preference	Experiment, subjective ratings, questionnaire	UK	School	50 students	Univariate descriptive statistics	Individual **daylight** perception in the context of cultural background can be assessed using the subjective rating and seat preference methods. When selecting the best seats, the leading reason for participants was daylight
	Keis et al. 2014	Cognitive performance	Experiment: controlled trial with pre/post measurements and four different lighting conditions	Germany		58 students 8–16 years old	Two-way ANOVA with the within-subjects factor Time (pre vs. post) and the between-subjects factor Lighting Condition	Light not only has an acute visual effect, but also an important non-visual biological effect on the human body, positively influencing alertness.
	Sleegers et al, 12	Test of concentration of pupils, lighting conditions	Lighting settings, illuminance level, CCT	Netherlands		181 elementary school students Grades 4–6	ANOVA Repeated measures	There is a positive influence of classroom lighting conditions on concentration
	Hawes et al. 2011	Mood, visual acuity, cognitive performance	Experiment, questionnaire	USA	Military shelter	24 subjects: 20 male, 4 females	ANOVA with paired *t-test*	**Performance** on a visual perception task involving colour recognition showed faster performance with lighting of higher colour temperatures.
	Alzubaidi et al, 13	Types of work, ALOS, daylight	Questionnaire	Qatar	**Hospital/ Healthcare facility**	134 staff	Descriptive statistics	Hospital staff perceive daylight to have a strong health, comfort and diagnostic benefit for staff and patients in hospital wards.
	Davis et al. 2020	Job performance, satisfactions,	Questionnaires	USA		138 med-surg staff (128	Content analysis	Innovative lighting approaches and technologies in hospital

		overall perception				females, 10 males)		improve perceptions of the patient room environment
	Gharaveis et al, 20	Mood, alertness, stress, and comfort	Cross-sectional study used a mixed methods approach	Iran		15 nurses (3 male and 12 females	Descriptive, inferential statistics, content analysis	Among all the investigated factors impacted by daylighting—mood, stress, satisfaction, and comfort—surveys and interviews indicated that daylighting highly promotes resident moods in inpatient units.
	Golvani, 21	Daylight, experiences,	Explorative design with focus group interviews	Sweden		15 operating room nurses	Qualitative content analysis	Operating room nurses experienced positive emotions, energy, and wellbeing because of daylight exposure. Daylight is important for the wellbeing of the staff in the healthcare context
	Hadi et al, 16	Lighting control, lighting satisfaction	Online survey, focus group	USA		393 surveys, 8 focus group participants	Kolmogorov–Smirnov, Shapiro–Wilk tests, nonparametric Mann–Whitney test	A significant relationship between nurses' access to lighting controls and satisfaction about the lighting environment was found
	McCunn et al, 21		Questionnaires	Canada		138 med-surg staff (128 females, 10 males	Systematic content analysis	The ability to control overhead and task lighting in patient rooms is important to nurse. **Daylighting** was among the best attributes.
	Vleugel, 18	Stress, seasonal symptoms, tiredness, sleep quality	Cross-sectional survey; a within-subjects repeated measures	Netherlands		97 females, 22 males	ANOVA, Shapiro-Wilk test	Perceived stress is found to be significantly lower in an environment with access to daylight and an exterior view
Objective measurements and subjective assessments	Bellia, et al, 17	Luminance and illuminance measurements, users' opinion	Measurement, survey	Italy	Office	Three offices	Statistical analysis	Despite the great variation in indoor environment characteristics, each of the offices is considered daylit, **underlining the capability of the human visual system to adapt to very different luminous conditions.**

	Figueiro et al, 17	Sleep and mood.	Questionnaires and objective measurement	USA	Office	81 participants:54 females, 27 males	Mixed-model linear regressions using IBM SPSS Statistics software	High levels circadian-effective light in the morning are associated with reduced sleep onset latency
	Lim et al, 16	Mood, light level	In-situ illuminance measurements, POE	Malaysia		90 sets questionnaire	Mann-Whitney U test via IPSS software. Spearman's rho correlation.	Lighting environment with the provision of task light elevates peoples' mood of pleasure and arousal.
	Smolders et al, 13	Light exposure, mood, vitality	Experience sampling, continuous light measurement, sleep diary	Netherlands	Office/ School		Hierarchical linear model (HLM) analyses	The relation between diurnal light exposure and feelings of vitality illustrates the **relevance of light exposure throughout the day in everyday situations.**
	Choi, et al, 19	Alertness, mood, and visual comfort	Experiment, questionnaire	Korea	School	Fifteen university students: eight men and seven women	T-test; Wilcoxon signed-rank test	Blue-enriched LED light seems effective potential countermeasure for morning drowsiness and dozing off in class, in schools with insufficient daylight
	Vahedi & Dianat, 13	Light level, light source, use of daylight, demography	Illuminance measurement, questionnaire	Iran	Manufacturing plant	130 male employees	Descriptive statistics, contingency coefficient test, Spearman's correlation analysis and non-parametric Friedman tests.	The employees' satisfaction with lighting was also highly correlated with the employees' subjective assessments of the light level. It is suggested that quantitative lighting measurements should be supplemented by qualitative subjective assessments
	Dianat et al, 13	Lighting conditions, demography, job factors	Questionnaire, Physical measurements	Iran	**Hospital/ Healthcare facility**	208 employees (81 males, 127 females)	Descriptive statistics, non-parametric tests with SPSS	Evidence that improving lighting in the working environment can increase job performance.

	Sen, 18	Perception of health, perception of lighting conditions	Light measurements, Questionnaire	Denmark		Medical staff: 71 women, 28 men	Fisher's exact test, **Light measurement data were analysed using an online Mann-Whitney U test**	LED virtual **windows** improved lighting experience, impression of the space, retinal illuminance and the CCT at the desk and at the retina in the windowless rooms.
	Shepley et al, 12	Staff attrition, staff absenteeism, medical errors, patient length of stay, and perceived pain	Pre-test/post-test quasi-experimental Light level measurements,	USA		58 patient (40 men & 18 women). Regular medical staff (Oct. 2006 to Sept. 2007; Mar. 2008 – Feb. 2009	Independent means t-tests compare the differences in patient age, perceived pain, length of stay, medical errors rates, & annual absenteeism and vacancy rates regression models	High levels of **natural light** and **window views** may positively affect staff absenteeism and staff vacancies. Pain levels perceived as lower in rooms with more **daylight** and better **window views.**
	Zadeh et al, 14	Physiological assessment, behavioural mapping, and records analysis	Quasi-experimental, illuminance measurements	USA		10 Females and 2 Males	Non-parametric paired test	Reduction in sleepiness and increase in alertness provided by windows and daylight is significant in the morning and the effect of the treatment is reduced over time.

debated (Van Hoof et al. 2015; Dianat et al. 2013; Joarder, 2011). Therefore, it is suggested that since individuals are physically and psychologically influenced by daylight, objective measurements should be complemented with subjective evaluations.

Other studies have evaluated lighting from the standpoint of how much light is needed for specific performance criteria, such as the minimum intensity needed to ensure accuracy in medication administration. However, limited research has been done on staff's preferences in the healthcare environment. The particular interest of this PhD research is to quantify the impact of daylight intensity on personnel's subjective performance and to explore the opinions and preferences of personnel working in ward units about lighting in areas where they provide care to patients and perform other tasks.

This review's findings highlight the need for further research on the impact of daylight on medical staff performance and the importance of complementing objective measurements with subjective evaluations. The review also emphasises the need to consider staff preferences when designing lighting systems in healthcare environments. The findings presented in this literature review could provide insights for healthcare facility managers, designers, and policymakers to improve healthcare environments' lighting and enhance staff performance, ultimately improving patient outcomes.

2.7 Chapter Summary

Indoor lighting is a crucial in creating a comfortable visual environment for occupants within buildings. An understanding of the factors influencing visual comfort can aid in designing lighting environments that enhance occupants' well-being and productivity. The body of research on visual comfort extends over more than half a century (Jakubiec, 2023), and the concept divided into two components: observable and implicit. Observable components pertain to the physical lighting conditions, including both natural and artificial light, effective glare control, and access to outdoor views. Implicit components refer to the subjective human factors like perception, preference, and acceptance of the visual environment. These factors are influenced by individual characteristics such as age, gender, occupation, and the specific activities undertaken.

The review indicated that numerous studies have shown that adequate levels of daylight can have positive effects on individuals' well-being and performance (Applebaum et al. 2010; Edwards & Torcellini, 2002). However, excess daylight can have adverse effects on human health and must be considered while designing lighting environments (Reinhart et al. 2006; Boyce et al. 2003). In regions such as Nigeria, where the sunlight is intense, UVB protection should be considered when designing with daylighting and windows. The review underscores the effectiveness of using occupant surveys and physical measurements to evaluate a building's performance concerning occupant comfort and productivity (Al Horr et al. 2016; Heschong et al. 2003). Various independent variables, including age, gender, job role, and activity type, have been identified as influential factors in shaping visual comfort (Reinhart et al. 2006).

The effectiveness of using occupant surveys and physical measurements to evaluate a building's performance in terms of occupant comfort and productivity has been demonstrated in the review (Al Horr et al. 2016; Heschong et al. 2003). Several independent variables, such as age, gender, job role, and activity type, have also been identified as influencing visual comfort (Reinhart et al. 2006).

To address the existing knowledge gap, the study described in Chapter 3 investigates the impact of incident daylight on the task performance of clinicians and nurses based on real-world data collected from the field. The study aims to evaluate the lighting conditions and occupants' perceptions of these conditions in healthcare environments, considering both observable and implicit components. The study will use existing visual comfort standards and guidelines to design the lighting environment, considering a range of factors, including climate conditions, building layout, materials, and occupants' behaviour. The research collects occupant responses through surveys and illuminance levels using sensors to investigate the impact of incident daylight on the task performance of clinicians and nurses based on real-world data collected from field studies. The outcomes are presented in Chapters 4 and 5.

In essence, this review emphasises the crucial role of comprehending the factors that influence visual comfort in designing lighting environments that promote well-being and productivity among healthcare facility occupants. The existing literature emphasises the significance of occupant surveys and physical measurements to assess a building's performance in terms of occupant comfort and productivity. Additionally, the studies reviewed in Chapter 2 contributes to expanding the knowledge of the impact of incident daylight on task performance in healthcare environments. However, designers must also be mindful of potential harms of excess daylight and provide UVB protection when incorporating daylighting and windows.

The review has provided an overview of existing research and identified gaps in knowledge that this study aims to address. The impact of healthcare lighting on staff has been shown in the literature to have various physiological and psychological effects, positively influencing well-being and alertness. Different methodologies such as surveys, interviews, experiments, and lighting measurements have been used in studies to understand the impact of healthcare lighting on staff. Each of these methods has been examined to better understand the relationship between lighting and staff performance, productivity, satisfaction, and well-being, aiming to fill gaps in the literature.

Survey data offer insights into the attitudes and preferences of healthcare staff, while interviews provide qualitative information about staff perceptions regarding lighting quality in healthcare environments. Experiments help understand how various lighting conditions affect staff performance and productivity, and lighting measurements provide quantitative data to assess the impact of different light levels on staff well-being. Utilising a combination of these methods is beneficial, as they each have their strengths and weaknesses. Therefore, a mixed approach using both quantitative and qualitative methods can effectively examine the impact of lighting on healthcare staff, leading to a comprehensive understanding of their well-being and productivity in relation to lighting environments.

Chapter III: Research Methodology

"The human body when kept in an indoor environment of low lux light will not realise that it is daytime, as it cannot sense the increasing levels of daylight that the genetics are accustomed to. As such, by late morning your body may start sending a signal for you to sleep!"
— Steven Magee, Electrical Forensics

"We're burnin' daylight."
— John Wayne

3.1 Introduction

The chapter is concerned with design and execution of fieldwork interactions with participants. Building upon the findings presented in the previous chapter, healthcare lighting has been found to exert diverse physiological and psychological effects, positively influencing staff well-being and alertness. To explore this subject comprehensively, various methodologies, including surveys, interviews, experiments, and lighting measurements, have been employed in past studies.

The critical examination of six selected studies (Golvani et al. 2021; Gharaveis et al. 2020; Davis et al. 2020; Hadi et al. 2016; Zadeh et al. 2014; Dianat et al. 2013) was undertaken to assess the state of research design methodology in this area. As shown in Table 2, the primary objective was to establish an evidence-based methodology for data collection and analysis. Each of these studies employed a combination of surveys, interviews, experiments, and lighting measurements to better comprehend the impact of healthcare lighting on staff.

In past studies, researchers have utilised a range of methodologies, such as surveys, interviews, experiments, and lighting measurements, to investigate the influence of healthcare lighting on staff. To assess the state of research design methodology in this area, this study critically examines six selected studies (Golvani et al. 2021; Gharaveis et al. 2020; Davis et al. 2020; Hadi et al. 2016; Zadeh et al. 2014; Dianat et al. 2013). The primary objective is to establish an evidence-based methodology for data collection and analysis.

Table 2: Overview of Six Key Research Studies Relevant to the Methods Employed in this Investigation.

	Dianat et al, 13	**Zadeh et al, 14**	**Hadi et al, 16**	**Davis et al, 20**	**Gharaveis et al, 20**	**Golvani, 21**
Period						
Country	Iran	USA	USA	USA	Iran	Sweden
Setting (Hospital)	Hospital	Hospital	Hospital	Hospital	Hospital	Hospital
Environmental Variables	Light intensity, window view	Physiological assessment, behavioural mapping, and records analysis	Perception about lighting	Lighting characteristics	Daylighting, view of outside	Light, daylight, view of outside
Demographic Variables	Age and gender, education level, job details, daily working hours	Age and gender	Age, gender, eye conditions, working shifts, years of experience	Age, work shift	Age, gender, job experience, working department;	Age, gender, working experience
Sample population	208 employees (81 males and 127 females) volunteers	12 nurses in two clusters of nurses' stations	393 nurses	138 (128 females, 10 males	156 nurses	15 operating room nurses
Design/Method	Pre-test/post-test quasi-experimental Light level measurement	Quasi-experimental, illuminance measurements (i.e., biological measurements, behavioural mapping, and analysis of archival data	Survey, focus groups	A mixed methods approach	A mixed-methods approach: qualitative explorations (structured interviews) and a validated survey, was applied and the results were compared and triangulated.	Qualitative design with four semi-structured focus groups.
Instrument/tools	Questionnaire developed by the authors; calibrated Digital Lux Meter DX-200	Digital light meter, model 401025	Questionnaire	Questionnaire	Notes taking, paper questionnaire	Recordings, notes regarding facial expressions, body language, sighs, and tone of voice.
Analysis	Descriptive and inferential analysis of staff and patient behaviours	Mixed model analysis; non-parametric paired test	Kolmogorov–Smirnov, Shapiro–Wilk tests, Mann–Whitney test, and Wilcoxon signed-ranks test	Content analysis, Friedman's test	Content analysis, regression analysis.	Content analysis with an inductive approach.

The chapter begins by presenting the philosophical assumptions that shape the research approach. In this context, this chapter expound upon the fundamental concepts of pragmatism, which justifies adopting a mixed-method approach as the scaffold for the research methodological design. This approach ensures a solid knowledge base to comprehend the subsequent intricacies of the applied embedded mixed methods during fieldwork.

The concluding section of this chapter entails discussions on the implications and limitations of the research methods utilised. It is essential to recognise that the field is predominantly defined by the perceptual context of well-being and performance in healthcare rather than being limited to a specific healthcare environment, as exemplified by the study conducted in a healthcare facility in Abuja. Consequently, the analysis and comparison of data sometimes necessitated exploring alternative locational contexts to address conceptual gaps, which are expounded upon in the subsequent sections detailing the different methodological applications as required.

3.2 Research Philosophical Assumptions

Research methodology is a systematic and structured process of discovering new knowledge in a particular field of study (Babbie, 2016; Creswell, 2014). It involves a set of principles, procedures, and techniques that guide researchers in collecting and analysing data to answer research questions or test hypotheses (Saunders et al. 2019). These beliefs and assumptions are examined from the perspectives of ontology, epistemology, and axiology. The goal of research methodology is to provide valid and reliable answers to research questions and increase the understanding of a particular phenomenon (Bryman, 2012).

In the field of research, understanding the fundamental approaches to knowledge is essential for researchers to conduct sound studies. Creswell et al. (2003) identified five primary approaches to studying knowledge: ontology, epistemology, axiology, rhetoric, and methodology.

Ontology, according to Easterby-Smith et al. (2008), is the study of "what exists" and refers to the nature of reality. This approach raises the question of whether reality is external or constructed by social actors. Bryman (2004) highlights that ontology can be approached from two perspectives: externalism, which posits that social entities have an objective reality, and constructionism, which views social entities as social constructions.

Epistemology, on the other hand, concerns the types of knowledge that are possible and how researchers can ensure that they are legitimate and adequate. Maynard (1994) argues that epistemology is concerned with the relationship between the researcher and reality, while Crotty (1998) explains that epistemology is the study of how knowledge is acquired and justified.

Axiology, according to Saunders et al. (2012), focuses on the values that researchers bring to their studies and how these values affect the validity of research findings. Heron and Reason (1997) emphasise that all research projects must articulate their values as a foundation for making judgments, as values are the driving force behind all human action. Axiology can be divided into two continuums: value-free and value-laden studies. A value-free study is conducted independently, impartially, and objectively, while a value-laden study is not.

Rhetoric refers to how knowledge is reported and communicated. It is the process of sharing research findings with the wider community. Researchers must ensure that their findings are communicated effectively and accurately. Methodology, according to Creswell et al. (2003), is the process of studying knowledge. It involves choosing the appropriate methods to collect and analyse data.

The philosophical stance of a research project is determined by its ontological, epistemological, and axiological assumptions. Easterby-Smith et al. (2008) refer to this stance as research philosophies, while Sarantakos (2005) calls it perceptions of reality. According to Creswell et al. (2003), different theoretical perspectives reflect different philosophical stances, and the fundamental difference between these perspectives is their assumption about the nature of reality.

So, based on general debates about worldviews, the ideas of positivism and interpretivism are seen as foundational. They are looked at in this study to explain and better understand the philosophical position of this study. Positivism, according to Bryman (2012), assumes that reality is objective and can be studied using scientific methods. Interpretivism, on the other hand, assumes that reality is socially constructed and that subjective interpretations are necessary to understand it.

3.3 Underpinning Research Philosophies for the Study

The study of how indoor lighting during the day impacts healthcare personnel's performance is a complex endeavour that necessitates careful consideration of various philosophical perspectives. This section aims to highlight the relevance of three key perspectives - positivism, interpretivism, and pragmatism - in understanding the research process.

Positivism, as a philosophical perspective, prioritises empirical data collection and objective investigation to formulate generalisations and laws in social phenomena. It seeks to identify correlations and causal relationships through systematic testing, relying on empirical evidence and maintaining objectivity. However, positivism has limitations, such as its failure to be value-neutral and its neglect of ethical considerations. To address these shortcomings, researchers are encouraged to supplement positivism with other research methods to gain a more comprehensive understanding of social phenomena. Combining positivism with interpretivism, for example, can help researchers consider subjective experiences and meanings, providing a more nuanced perspective.

Interpretivism, on the other hand, recognises the subjective nature of reality and emphasises individual interpretations. It is well-suited for studies investigating subjective meanings and individual interpretations of events in natural settings. By adopting an interpretivist approach, researchers can gain insights into the perspectives of healthcare professionals and explore subjective meanings in their experiences. This perspective could contribute to a more holistic understanding of the effects of environmental factors like daylight on personnel's performance by acknowledging the importance of individual perceptions and interpretations.

Pragmatism, as a philosophical perspective, emphasises the practical application of ideas and an iterative process of data collection and interpretation. It is ideal for studying complex phenomena, such as the effects of environmental factors like daylight on personnel's well-being and performance, due to its focus on understanding contextual factors. Pragmatic researchers recognise that truth is relative and ever-changing, which aligns well with studying dynamic environments like healthcare environments. Pragmatism highlights the importance of understanding context, making it relevant when considering factors like the number and type of personnel present in a healthcare environment.

For this study, the researcher examined various philosophical worldviews and selected the pragmatic research philosophy as the most suitable approach to explore the perceptions and experiences of individuals within a healthcare context. The decision is based on specific assumptions and justifications that align perfectly with the research objectives and the nature of the problem being addressed. Pragmatism is deemed highly appropriate for research in healthcare environments due to its emphasis on real-world relevance, where decisions have immediate implications for patient care and outcomes.

The pragmatic approach to research ensures collaboration with relevant stakeholders, such as healthcare personnel and policymakers. For example, management of healthcare facilities in both Plymouth and Abuja were actively involved in designing the research protocol used for the study. This collaborative approach fostered a sense of ownership and relevance, as the perspectives and insights of these stakeholders directly influenced the study's direction and outcomes. This research believes that such collaboration would lead to more meaningful and impactful research in addressing real-world challenges.

Pragmatism offers flexibility, particularly in dealing with complex healthcare environments that involve diverse stakeholders and variables. By adopting a pragmatic approach, this research would select and adapt research methods to fit the specific needs and constraints of the healthcare context, ensuring that the research design would be both practical and feasible.

An intriguing aspect of pragmatism is its promotion of a holistic understanding through mixed methods. Recognising that the experiences of healthcare personnel are multifaceted and rich with nuances, the study planned to use qualitative methods such as interviews and observations to capture these intricacies, while also employing quantitative methods like surveys and physical measurements to provide broader statistical data. The combination of these approaches would lead to a comprehensive understanding of the healthcare landscape under investigation.

Furthermore, to enhance the credibility and robustness of the research, the study would utilise triangulation, a key tool of pragmatism involving the use of multiple data sources and methods to cross-validate findings. This method is particularly valuable in a study focused on understanding perceptions and experiences, as it allows the research to combine data from different sources, thereby verifying and validating the results.

Ethical considerations in healthcare are integral to this research as detailed in section 3.8. Pragmatism recognises the importance of adhering to ethical principles such as informed consent and confidentiality, and this research is committed to navigating these complexities responsibly, ensuring the well-being of the study participants while conducting valuable research.

By adopting pragmatism, this research aimed to unveil the hidden depths of the healthcare indoor lighting environment and bring about positive change for the benefit of all. The findings were expected to provide valuable insights into the positive experiences of personnel in healthcare environments, contributing to the improvement of healthcare practices and policies.

3.4 Research Approach

In the context of pragmatic research philosophy, the choice of research approach is closely tied to the researcher's perspective on knowledge construction. Pragmatism highlights the practical implications of research and the need to select the most appropriate methods to address a research problem. The research approach refers to the method used to work through the research problem and generate theories. According to Saunders et al. (2012), there are two main categories of research approach: deductive and inductive. The deductive approach is based on testing a hypothesis derived from a pre-existing theory. It is quantitative in nature and relies on measurements, observations, and predetermined instruments to gather data and produce statistical results. This approach is based on a set of tentative hypotheses, and its knowledge claims are positivist. (Dubois & Gadde, 2002)

On the other hand, the inductive approach involves developing a theory from the collected data and analysing it. This approach provides insights into the context of a problem and generates ideas, propositions, and hypotheses that can later be evaluated using quantitative research to determine the underlying motivations, connections, and elements that affect decisions and opinions (Dubois & Gadde, 2002). It employs strategies that are subjective which are centred on values, attitudes, and opinions by the gathering and analysis of non-numeric data to interpret and construct meanings.

However, the abductive approach emerged as a response to the limitations of the deductive and inductive approaches in examining, exploring, or explaining relationships among variables in a specific situation (Saunders et al. 2012). The abductive approach combines elements of both deductive and inductive approaches, creating a middle-ground continuum to increase the credibility of the results. It involves the transition between theory and data (deductive) and data and theory (inductive) (Saunders et al. 2012). According to Collis and Hussey (2014), this approach is concerned with developing new theories or modifying existing ones by considering both existing data and theoretical constructs. It employs strategies that are subjective and centred on values, attitudes, and opinions by gathering and analysing non-numeric data to interpret and construct meanings.

The abductive approach offers several benefits over other research approaches. The abductive approach allows for the incorporation of both qualitative and quantitative methods into a single study, thereby countering any potential drawbacks of a single approach (Denzin, 1970, cited in Collis & Hussey, 2009). This enables expansion and triangulation in research to obtain a more comprehensive understanding of the phenomenon being studied (Collis & Hussey, 2014). As a result, the abductive approach is concerned with understanding the phenomenon being studied to develop a contextual theory and discovering new variables and relationships using various concepts found in existing theories. Another benefit of the abductive approach is its flexibility. It allows for the exploration of current ideas and the discovery of new variables and relationships. This is because it involves a back-and-forth movement between theory and data, allowing for constant modification and revision of the research question (Saunders et al. 2012).

Furthermore, the abductive approach aligns well with the pragmatic research philosophy as it enables researchers to combine qualitative and quantitative methods in a single study. This approach counters the limitations of a single approach and enables expansion and triangulation of research findings to gain a more comprehensive understanding of the phenomenon under investigation (Collis & Hussey, 2014).

Mixed methods complement the abductive approach by integrating both qualitative and quantitative data within a single study. This involves collecting and analysing both non-numeric data (such as interviews, observations, and open-ended survey responses) and numeric data (such as surveys, experiments, and statistical data). By incorporating mixed methods, researchers can enrich their findings by leveraging the strengths of both qualitative and quantitative data, leading to a deeper and more nuanced understanding of the research problem.

3.5 Research Design

The foundation of any research lies in its methodology, which involves a structured approach used by researchers to address specific research questions. By carefully selecting appropriate research strategies and methodologies, researchers can navigate the complexities of their study and gain valuable insights. The design of the research plays a crucial role in shaping the study's path, determining the validity and reliability of the findings, and enabling exploration of research questions from multiple perspectives. In this context, providing a conducive and supportive work environment for healthcare professionals is of utmost significance.

Daylight exposure has long been recognised as a crucial aspect of the built environment, exerting a significant influence on various facets of human well-being and performance. Numerous studies have highlighted the positive impact of daylight exposure on individuals, leading to increased cognitive function, improved mood, and enhanced productivity. Such effects are particularly relevant in healthcare environments, where the well-being of both patients and staff is of utmost importance. In this context, the role of natural lighting during the day becomes even more significant.

Despite the recognised benefits of daylight exposure, limited research has been dedicated to investigating the specific relationship between daylight exposure and healthcare workers' performance and satisfaction. Addressing this research gap is essential to shed light on how indoor lighting conditions can influence the well-being and effectiveness of healthcare workers. By undertaking this study, it aims to provide practical implications for designing healthier and more efficient healthcare environments, thus promoting the provision of a conducive and supportive work environment for healthcare professionals. Ultimately, this research will offer valuable insights into the subject effect of daylight exposure, helping to determine its significance and scope in healthcare environments.

The study's focus on daylight and its multidisciplinary nature, encompassing cognitive science, architecture, and engineering, adds to its significance. By considering a range of factors that may influence healthcare workers' experiences, it is essential to employ a research design that transcends traditional disciplinary boundaries and embraces the integration of diverse methods to gain a comprehensive understanding of the phenomenon. The use of both qualitative and quantitative data in this study aims to complement the strengths of each method and address their respective limitations. The concurrent collection and analysis of both types of data enhance the validity and reliability of the results. Figure 1 provides an overview of the research design.

The research design will integrate quantitative and qualitative data from both the observable, the physical environment and implicit, human factors components as described in section 2.8 of the study.

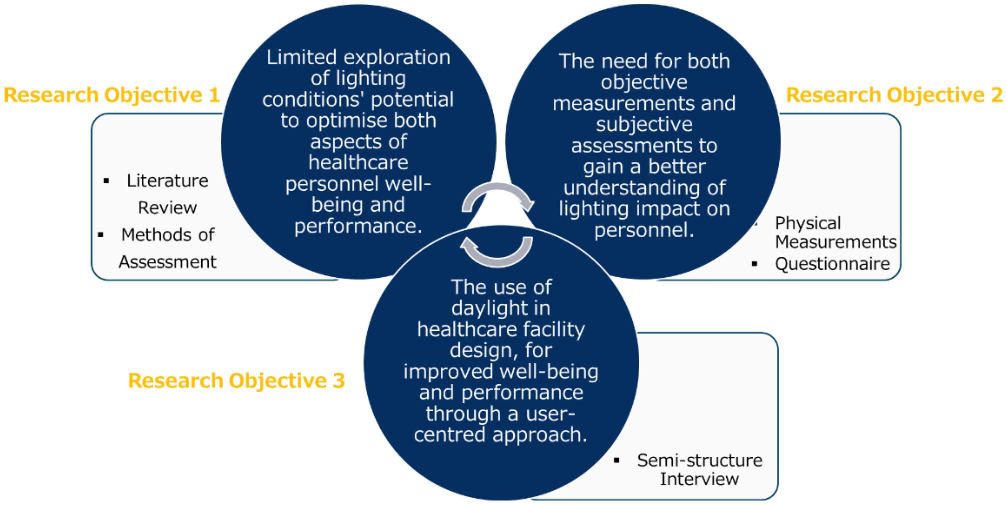


Figure 1: Research Design- Gaps, Objectives, and Methods.

By examining variables related to the physical environment (such as artificial light, daylight, light levels, view of outside, glare, and shadow) and human factors (such as perception, preference, and acceptance of the visual state), the study aims to investigate the complex relationship between daylighting and healthcare workers' experiences. These human factors are subjective and may vary based on individual characteristics such as age, gender, occupation, and activity. To capture a holistic representation of the healthcare workforce and minimise potential biases in the findings, participants from various job roles, genders, and age groups will be engaged in the study.

In the subsequent sections, the research design, methodologies, data collection procedures, and data analysis techniques employed in this study will be outlined. By combining both quantitative and qualitative perspectives, the study strives to shed light on the intricate relationship between daylighting and healthcare workers' experiences, ultimately paving the way for evidence-based recommendations and transformative advancements in healthcare facility design and policy.

3.5.1 **Mixed Methods**

This study investigates the experience of daylighting, which is a multidisciplinary phenomenon that encompasses fields such as cognitive science, architecture, and engineering. To address the complex nature of this research question, the researcher adopted a mixed-methods approach that combines different key research strategies. Fellows and Liu (2021) suggests that each research question usually requires a single research strategy. However, when multiple strategies are used, it is important to consider the specific research question that each strategy addresses. The researcher acknowledges that this approach may lead to a potential lack of depth in the results. Nonetheless, the combination of different research methods can also be a strength, as it enhances the validity of the findings.

The researcher believes that using a quantitative research design coupled with a phenomenology strategy will yield results that could not have been achieved using either method alone. As stated in section 3.3 an intriguing aspect of pragmatism is its promotion of a holistic understanding through mixed methods. It allows research select and adapt research methods to fit the specific needs and constraints of the healthcare context, ensuring that the research design would be both practical and feasible. In this study, the phenomenology strategy involves studying a phenomenon from the perspective of the individuals who experience it, and it involves involving study subjects in the research process. Additionally, the researcher will deploy and evaluate developed solutions in a real-world setting, which will provide richer and more valid results than a purely quantitative research strategy.

One key strength of this research approach is triangulation, a method that involves using multiple data acquisition techniques. As Denzin (2012) highlighted, triangulation facilitates the validation and corroboration of research results obtained through different methods. By employing various approaches such as interviews, observations, or surveys researchers can obtain a more holistic view of the subject under investigation. For example, combining interviews and observations may yield deeper insights and nuances that could be missed when using just one of these methods in isolation.

This integrative approach of using multiple methods is increasingly embraced across diverse fields, including architecture, where Groat and Wang (2002) advocate for its implementation. Researchers have come to appreciate the benefits of employing triangulation as it complements the limitations of each method, ultimately reducing errors and enhancing the accuracy of the research outcomes.

Triangulation's effectiveness lies in its ability to cross-check information from diverse sources and perspectives. It safeguards against biases inherent in any single data collection method and ensures a more reliable and credible analysis. The convergence of results from multiple angles enhances the validity of the findings, increasing confidence in the research outcomes.

Moreover, triangulation enables researchers to capture various dimensions of complexity within the phenomenon of interest. Different methods may uncover diverse aspects, shedding light on the intricate relationships and interactions within the subject matter. This multifaceted approach allows for a more nuanced understanding and enriches the overall comprehension of the research topic.

Additionally, the combination of qualitative and quantitative methods through triangulation fosters a deeper exploration of the research question. Quantitative data provides statistical rigor and generalisability, while qualitative data offers rich contextual insights and detailed narratives. By harmonising these diverse forms of data, researchers can attain a comprehensive analysis that transcends the limitations of either approach in isolation. Enabling the research to establish a quantitative relationship between indoor lighting during the day and subjective performance of personnel, based on real-world subjective ratings.

In this study, the primary objective is to investigate the impact of indoor lighting on the perceived performance of medical staff during the day. The research gap identified in Chapter 2 emphasises the need for a quantitative relationship between indoor lighting and subjective performance, backed by real-world subjective ratings. To achieve this, data collection was carried out in an existing hospital building, measuring indoor lighting levels and obtaining occupant ratings of performance.

The research question guiding this study is, "How do (quantitative) illuminance measurements at workstations correlate with (qualitative) perceptions of performance, in comparison to established standard requirements for different workstation activities?" To address this question, the study adopted a mixed-methods approach following Creswell and Plano Clark's (2011) guidelines.

Mixed-methods research designs offer diverse options, such as mixed convergent, explanatory sequential, exploratory sequential, and embedded designs. However, the choice of design depends on the research goals, timing of data collection, and the significance of each data type. In this study, an embedded design is considered appropriate, which involved gathering both quantitative and qualitative data simultaneously and then integrating the two datasets during the analysis phase (Creswell & Plano Clark, 2017). This approach allows for a comprehensive understanding of the relationship between indoor lighting and perceived performance by medical staff, combining objective illuminance measurements with subjective perceptions from the medical personnel.

3.5.1.1 ***Mixed Convergence Methods***

Mixed convergence methods refer to the use of multiple data sources and research methods to gain a comprehensive understanding of a phenomenon (Tashakkori et al. 2020). This approach is particularly useful when studying complex issues that require a more holistic understanding, such as social problems or health-related concerns.

The method involves collecting both qualitative and quantitative data and analysing them together to gain a more complete picture of the phenomenon under investigation (Tashakkori et al. 2020). Qualitative data collection methods, such as interviews and focus groups, can provide in-depth insights into individual perspectives and experiences, while quantitative methods, such as surveys and experiments, allow for the measurement of variables and the exploration of statistical relationships.

Mixed convergence methods also facilitate the integration of different types of data to gain a more comprehensive understanding of the phenomenon under investigation (Creswell & Plano Clark, 2017). By combining qualitative and quantitative data, researchers can enhance the validity and reliability of their findings and gain a more complete understanding of the complexity of the phenomenon under investigation.

Moreover, mixed convergence methods enable the researcher to consider both the social context in which the phenomenon occurs and the specific individual characteristics that may influence it (Creswell & Plano Clark, 2017). This approach allows for a more nuanced understanding of the relationships between variables and can provide insights into the underlying mechanisms that drive the phenomenon.

3.5.1.2 ***Explanatory Sequential Mixed Methods***

Explanatory sequential mixed methods are an approach to research that involves collecting quantitative data first to explain a phenomenon, followed by collecting qualitative data to further explore the phenomenon (Johnson & Onwuegbuzie, 2004). This approach is commonly used in social science research to gain a comprehensive understanding of a complex phenomenon.

The use of quantitative data in the first phase of the research process allows researchers to develop an initial understanding of the phenomenon under investigation. The quantitative data can provide a general overview of the phenomenon and identify potential patterns and relationships. The qualitative data collected in the second phase of the research process can then be used to explore these patterns and relationships in greater depth and detail.

One of the key advantages of the explanatory sequential mixed methods approach is that it allows researchers to build upon their initial quantitative results, gaining a deeper understanding of the phenomenon through the qualitative data collected (Creswell, 2014). By collecting both types of data, researchers can triangulate their findings and provide a more robust and comprehensive account of the phenomenon.

Moreover, this approach enables researchers to form an initial hypothesis about a phenomenon, which can then be explored and validated by collecting qualitative data. This helps to increase the reliability and validity of the research findings (Teddlie & Tashakkori, 2009).

However, it is important to note that the use of explanatory sequential mixed methods may not always be suitable for every research question or investigation. Due to the nature of the investigation with which this study is concerned, explanatory sequential mixed methods are not considered suitable for this study.

3.5.1.3 ***Exploratory Sequential Mixed Methods***

Exploratory sequential mixed methods are an approach that involves the collection of qualitative data first, followed by quantitative data to develop a more informed understanding of a phenomenon. This approach combines the strengths of both qualitative and quantitative methods, allowing researchers to explore a phenomenon in-depth while also rigorously analysing the data.

Qualitative data collection allows researchers to explore a phenomenon in detail, providing rich and descriptive information. This approach is useful for developing theories and hypotheses, and for identifying potential variables to be explored in quantitative research. Quantitative data collection, on the other hand, provides a more structured and objective approach, allowing researchers to test hypotheses and generalise based on the data.

By using an exploratory sequential mixed methods approach, researchers can develop a more comprehensive understanding of a phenomenon. The qualitative data collected can be used as a tool for exploration, while the quantitative data can provide evidence to support the findings of the qualitative analysis. This approach is particularly useful when exploring complex phenomena that cannot be fully understood through one method alone.

However, while the exploratory sequential mixed methods approach is a powerful tool for gaining a comprehensive understanding of a phenomenon, it may not be suitable for all studies as it is case for this study.

3.5.1.4 ***Embedded Designs***

Embedded designs are a mixed methods research methodology that combines both quantitative and qualitative methods to gain a more comprehensive understanding of a phenomenon (Creswell et al. 2003). In embedded designs, both types of data are gathered and analysed simultaneously, allowing researchers to benefit from the advantages of qualitative research, such as in-depth understanding and interpretation, while also gaining the benefits of quantitative data analysis, such as its objectivity (Creswell & Plano Clark, 2011). The essence of the embedded design lies in incorporating one dominant method (either qualitative or quantitative) with the other method embedded within it. While one type of data is given priority, the secondary data type supplements the primary data by providing additional depth, context, or complementary insights. For example, a researcher might primarily use a quantitative survey and include qualitative open-ended questions within it to capture additional information enriching the quantitative findings.

One of the main advantages of the embedded design is that it allows for the collection of both types of data during a single study, making it more efficient and cost-effective (Creswell & Plano Clark, 2017). This approach also enables researchers to build on the information gathered and analysed during each step to provide a more complete understanding of the phenomenon under investigation (Johnson et al. 2007). This approach is particularly useful for research that requires a deeper understanding of complex phenomena that cannot be fully captured by either quantitative or qualitative methods alone (Tashakkori & Teddlie, 2010).

After a thorough examination of the four major types of mixed methods designs, the embedded design was deemed the best fit for this research project. This study aimed to investigate the correlation between light levels in workstations and personnel's subjective performance. In this design, quantitative data was given priority, and qualitative data was used to add depth and context. As part of this quantitative study, a series of qualitative, semi-structured interviews with purposively sampled personnel were embedded to further strengthen the argument (Creswell, 2014). The interviews aimed to provide deeper insight into potential links between daylight levels and task performance (Morgan, 1998).

The semi-structured interview is designed to explore the participant's perception and preferences for light levels and their relationship with job performance, adding a qualitative dimension to the research that could not be measured using quantitative methods (Creswell & Plano Clark, 2017). This method is employed to develop the research design for this study, illustrating how certain factors, such as light levels and daylight use, may have an impact on performance.

3.5.2 **Quantitative and Qualitative Design**

When researching complex social phenomena, like the environmental factors in building performance, researchers often grapple with the decision of selecting between quantitative and qualitative research methods. Each approach has its strengths and limitations, but an integrated approach that combines both methods can lead to a more comprehensive understanding of the research question.

Quantitative research is valuable for its ability to provide precise and generalisable data. It involves collecting numerical data through techniques such as physical measurements, surveys, and experiments. In the context of evaluating building performance, quantitative information can offer specific assessments of a building's performance and identify cause-and-effect relationships between variables. Similarly, in healthcare facilities, quantitative methods can be used to gather physical measurements and standardised data from respondents, enabling comparisons and statistical analysis.

However, a limitation of quantitative research is its tendency to oversimplify human experiences. Human interactions and perceptions are often complex and nuanced, and quantitative data may not fully capture these aspects. This is where qualitative research becomes crucial.

Qualitative research encompasses various techniques, such as case studies, phenomenology, and ethnographic studies, to explore and understand human experiences from the participants' perspectives. For instance, phenomenology can be employed to delve into participants' experiences and perceptions of "real living" in buildings. This approach allows researchers to gain a deeper understanding of the lived experiences and subjective interpretations of participants.

The integration of both quantitative and qualitative methods offers several benefits. By combining the strengths of each approach, researchers can achieve a more holistic and well-rounded understanding of the research problem. Quantitative data provide a broader overview and statistical insights, while qualitative data offer in-depth insights and capture the richness of human experiences.

For instance, when evaluating the effect of indoor lighting on performance in healthcare facilities, using both methods can help identify specific lighting characteristics that affect well-being and performance (quantitative), while also understanding the emotional and psychological impact of lighting on individuals (qualitative). The integrated approach aims to guide policymakers and designers in creating healthcare spaces that optimise both objective and subjective aspects of user experience.

Furthermore, the integration of quantitative and qualitative methods helps triangulate findings, enhancing the overall validity and reliability of the research outcomes. The complementary nature of both methods helps overcome the limitations of each approach, resulting in a more robust and comprehensive research study. Researchers can use the strengths of both methods to corroborate findings and gain a more nuanced understanding of the complex social phenomenon under investigation.

3.6 Quantitative Data Collection Method

The main objective of this study is to examine the perceptions of healthcare workers regarding the impact of indoor lighting on their wellbeing and performance. As previously mentioned in section 1.9.1, the quantitative aspect of the research focused on both physical measurements and subjective ratings of performance to assess the influence of daylight on healthcare personnel. The physical measurements of indoor lighting are detailed in subsequent sections.

To gather the subjective ratings of the participants, a survey was deemed appropriate, given the large size of the population under study. This approach was supported by Rea and Parker (1997) and Field (2009) as suitable for large sample sizes. The survey was conducted using a well-structured questionnaire, which, according to De Vaus and de Vaus (2013), can yield significant data suitable for interpretation in quantitative research. The questionnaire was carefully designed to align with the study's objectives and to produce reliable data. Ensuring the validity of the questionnaire was crucial, as it directly affects the accuracy and credibility of the information obtained (Saunders et al. 2009).

Sampling is an important consideration in research, particularly when dealing with a large population. However, it is impossible to determine the exact size of the population, as outlined by Saunders et al. (2009), Creswell (2012), and Yin (2014). Therefore, the researcher chose a sampling technique that would measure a representative subset of the population. This technique is less expensive, requires less work, and takes less time than studying the entire population (Bryman, 2008; Cochran, 1963).

Two primary sampling techniques are available for researchers: probabilistic sampling and non-probabilistic sampling. Both techniques can be used in social science research (Saunders et al. 2009; Creswell & Plano Clark, 2011). A probabilistic sample is used when the researcher is aware of the complete population being studied. If the researcher is not aware of an exact representation of the total population, a non-probabilistic sample is employed (Oates et al. 2022; Trochim, 2006).

In this study, a database of healthcare workers was available at the hospitals, providing a general category of responses for the researcher to draw from. Sets of questions were created to collect the necessary data, and a self-administered questionnaire was distributed to participants to provide their responses (Berdie, 1986).

To accurately explain the subject and produce mathematical or statistical predispositions, the information obtained from the survey was analysed (Totten et al. 1999). This comprehensive approach to sampling and data collection provides a robust foundation for this research.

3.6.1 **Survey Design**

In conducting this study, the methodology took into consideration the procedures for survey research, as recommended by Creative Research Systems (2003) and detailed in Table 3.

Table 3: Individual Steps for the Survey (Source: Creative Research Systems, 2003).

S/No	Steps taken for the survey
i	Establishing the goals of the project
ii	Determining the sample
iii	Selecting survey methodology
iv	Develop the instrument (questionnaire)
v	Piloting the questionnaire
vi	Conduct the interviews and data entry
vii	Carryout data analyses
viii	Develop the report

The survey protocol utilised in this study, as identified by Akande (2015), involved identifying the range of respondents to be included in the survey. To ensure that the survey findings would accurately represent healthcare workers with varying backgrounds and experiences, the following steps were taken:

Firstly, the sample size calculation and choice of the sampling frame were carefully considered. The sample size was determined based on the population of healthcare workers in the target area and the level of precision required to draw valid conclusions from the data. The sampling frame was selected to include a diverse range of healthcare workers from different facilities and sectors within the healthcare industry.

Secondly, the development of questionnaires was approached with the intention of eliciting comprehensive and informative responses from the survey participants. The questions were designed to cover a wide range of topics related to the research objectives, with particular attention paid to gathering information on the respondents' experiences, opinions, and perceptions.

Thirdly, the selection of data gathering techniques was critical to ensuring the reliability and validity of the survey results. The survey was conducted using a paper-based questionnaires, with appropriate measures taken to ensure the privacy and confidentiality of the respondents.

3.6.2 **Population of the Study**

Research is an essential part of any field that seeks to gain new knowledge or solve existing problems. However, before embarking on any research project, it is crucial to have a clear understanding of the population being studied. Burns and Grove (2010) define population as any process, person, thing, or circumstance that is relevant for inclusion in a study.

To ensure accurate and effective research, it is vital to establish clear population guidelines (Mouton, 1996; Polit and Hungler, 1997). These guidelines help researchers identify the most suitable research tools to use for the intended sample size of the population being studied.

In the healthcare industry, understanding the population is especially critical, as it can impact patient care and outcomes. For example, in a hospital setting, healthcare workers are an essential population to study. They are responsible for providing care and support to patients and play a crucial role in maintaining the overall functioning of the hospital.

To conduct research on healthcare workers in a hospital setting, it is crucial to identify the appropriate population size accurately. The healthcare workers in the hospital where the survey was carried out made up the population size and include doctors, nurses, midwives, and other healthcare professionals who work in the hospital. By identifying the population size accurately, this research ensure that findings are representative of the entire population.

3.6.3 **Sampling**

Sampling is a fundamental procedure in research that involves selecting participants, determining their number, and devising a plan for recruitment. To ensure the adequacy and representativeness of the sample in this study, the sampling method was developed following the guidelines proposed by Creswell et al. (2014) and Saunders et al. (2012). These scholars highlighted the importance of sampling in gathering both quantitative and qualitative data.

Saunders et al. (2012) emphasised that sampling is essential because it may not be feasible or practical to survey or interview the entire population. In this study, the population under investigation comprised healthcare workers at a hospital. Given the constraints of time, cost, and accessibility, it was not feasible to approach the entire population to obtain the required data (Cohen, 2013).

The sampling method used in this study was designed to ensure that the selected sample was representative of the population and provided sufficient data to address the research questions. To achieve this, the researcher used a combination of stratified and random sampling techniques. Firstly, the researcher stratified the population into relevant categories, such as doctors, nurses, and other healthcare professionals, to ensure that the sample included representatives from each group. Secondly, they randomly selected participants from each stratum to avoid any bias in the selection process.

3.6.3.1 ***Sampling Technique***

Sampling techniques are crucial in research as they determine the representativeness and generalisability of the study findings. In this study, the researcher aimed to obtain a comprehensive sample population of healthcare workers to collect quantitative data.

To achieve this, the researcher first outlined the structure of the target population. According to Bernard (2013), a thorough understanding of the population's components is essential in selecting an appropriate sampling technique.

In this study, purposive sampling was employed. This non-random sampling strategy involves selecting participants based on specific criteria or characteristics deemed relevant to the research question (Palinkas et al. 2015). Purposive sampling allowed the researcher to collect data from various categories of healthcare workers, including doctors and nurses.

Overall, the use of purposive sampling in this study enabled the researcher to obtain a comprehensive sample population of healthcare workers, which can increase the generalisability of the study findings to the larger population of healthcare workers.

3.6.3.2 ***Sampling Frame***

Sampling is a crucial aspect of research, and one of the essential components of a successful sampling process is the sampling frame. A sampling frame is a collection of components that closely resembles the defined population under investigation (Czaja & Blair 1996: p. 116). It is a list of accessible populations from which a sample can be drawn. In practice, it is often challenging to obtain an exhaustive list or database of the entire theoretical population under study (Trochim, 2006).

In this study, the research aimed to investigate the perceptions of healthcare workers in a selected hospital in Abuja, Nigeria. However, due to the lack of an exhaustive list or database, it was impossible to compile a list of all the healthcare workers in the hospital. Therefore, the sampling frame was based on the populations that were accessible and from which a sample could be drawn.

To ensure that the sample was representative of the population, the participants received an invitation to take part in the study. The invitation included information about the study's purpose, the inclusion criteria, and the confidentiality of the responses. Participants were selected based on their availability and willingness to participate in the study.

3.6.3.3 ***Sample Size***

Determining the appropriate sample size is a critical step in any research study. As stated by Krejcie and Morgan (1970), sample size determination is a compromise between the level of accuracy required and the available resources. According to Martínez-Mesa et al. (2016), the size of the sample is a question of convenience and a compromise among numerous elements, the size of the sample for a study depends specifically on the resources that are available and the method's accuracy (De Vaus & de Vaus, 2013). However, the sample size must be large enough to produce reliable and accurate results while also considering available resources (Fink, 1995). Furthermore, determining the sample size for a study, will requires considering the research question, the population being studied, and the statistical method to be employed. In this study, the sample size determination method adopted from Akande (2015), which was based on Czaja and Blair's (1996) method and Creative Research Systems' (2003) sample size calculator, was used.

$$ss = \frac{Z2*(p)*(1-p)}{C2}$$

Where:

Z = Z value (e.g., 1.96 for 95% confidence level)

P = percentage picking a choice, expressed as decimal

(.5 used for sample size needed)

C = confidence interval, expressed as decimal

In surveys, it is common to aim for a 95% confidence level or 5% accuracy levels (Creative Research Systems, 2003). To achieve this confidence level, a significance level of 0.05, z = 1.96 for a 95% confidence interval, was assumed (Creative Research Systems, 2003). A 95% confidence level and a 5% accuracy level were set as standard (Creative Research Systems, 2003). The confidence interval was chosen to be ±10%, which strikes a balance between the level of accuracy, resources available, and utility of the research findings (De Vaus, 1996). The worst-case proportion (p) was set to 50% (0.5) when choosing an option, following Czaja and Blair's recommendation (1996). Using the above assumptions, the sample size was determined using the following formula:

$$ss = \frac{1.962 \times 0.5 (1 - 0.5)}{0.12}$$

$$ss = 96.04$$

The calculated response shown above demonstrates that 96 respondents should make up the required sample size for the questionnaire. For finite populations, the computed figure requires an additional modification. As a result, the following formula was taken from Czaja and Blair (1996) to calculate for limited populations:

$$\text{new ss} = \frac{\text{ss}}{1 + \dfrac{\text{ss} - 1}{\text{pop}}}$$

Where:

Pop = population

$$\text{new ss} = \frac{96.04}{1 + \dfrac{96.04 - 1}{10{,}342}}$$

$$\text{new ss} = 95.16$$

Based on these assumptions, the sample size was calculated using the formula suggested by Akande (2015). The formula produced a range between 95 and 96 participants for the limited population. Therefore, a minimum of 95 healthcare workers were required for the survey. To provide a buffer for non-response, a random selection of 108 healthcare workers was made using a system-based random number generator.

3.6.4 **Data Collection**

The proposed research study aimed to measure the physical parameters of indoor lighting while simultaneously collecting the responses from the occupants. To ensure a comprehensive and robust approach, the research conducted an extensive review of literature from various sources, including books, journals, periodicals, newspapers, and the internet. This helped in gaining a thorough understanding of the research subject and identifying the most appropriate method for data collection.

Based on the literature review, the research concluded that post-occupancy evaluation (POE) would be the most suitable method for data collection. POE involves collecting data from occupants after they have occupied the space for a certain period. This method is known to provide a more accurate understanding of the user experience, as compared to pre-occupancy evaluations.

To ensure ethical considerations were considered, the study received ethical approval for data collection. This is a crucial step to ensure that the study is conducted in an ethical and responsible manner. The details of the ethical approval process are detailed in section 3.8 and attached in the Appendix.

Both quantitative and qualitative data were collected for this research project. Physical measurements were taken to determine the lighting parameters of the indoor space. Questionnaires were administered to the occupants to collect their responses on their experience with the lighting. Interviews were also conducted to gain a more in-depth understanding of the occupants' experiences and to gather any additional information that may be relevant to the study.

3.6.4.1 ***The Pilot Studies***

The two pilot studies described in this field investigation aimed to observe staff tasks and behaviours in actual health profession settings. During the observation, the researchers identified several issues, including glare, visual discomfort, and blinds, which later influenced the research question and analysis.

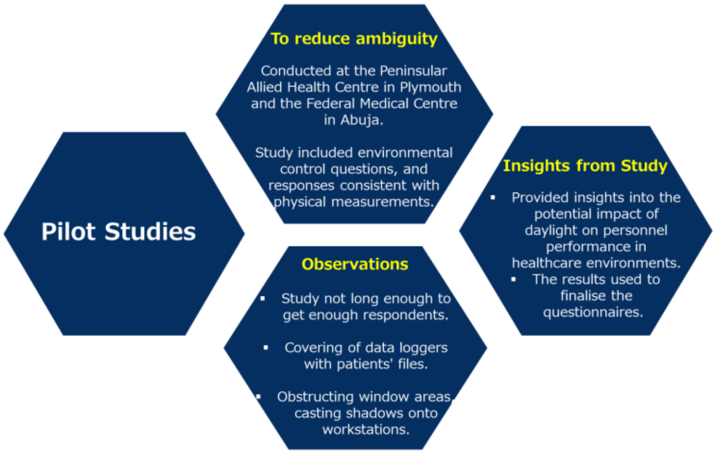
One issue that arose from the observation was visual discomfort. This occurs when participants feel visually uncomfortable and begin to change their behaviour, such as drawing curtains or blinds, changing positions, adjusting computer monitors, or complaining. The use of curtains and blinds was included in the analysis to gain a better understanding of their impact on visual discomfort.

Interestingly, some occupants reported experiencing a visual sensation other than normal but were still comfortable with the use of natural light and the outside view. This observation prompted a discussion about the adverse effects of daylight and its impact on health.

To gather data on participants' immediate perceptions of their performance and satisfaction, two questionnaires were created - the general questionnaire and the instant questionnaire. The latter was followed by simultaneous environmental measurements, which will be explained later.

The Health and Work Performance Questionnaire (HPQ) by the World Health Organisation (Kessler et al. 2003) served as the foundation for the survey. This questionnaire has been well validated and is known to provide reliable and valid data. The answers were based on five Likert scales.

To reduce ambiguity, a pilot study was conducted at the Peninsular Allied Health Centre in Plymouth and the Federal Medical Centre in Abuja, Nigeria as illustrated by figure 2. The results of these pilot studies were used to finalise the questionnaires.



Conducted at the Peninsular Allied Health Centre in Plymouth and the Federal Medical Centre in Abuja.

Study included environmental control questions, and responses consistent with physical measurements.

- Provided insights into the potential impact of daylight on personnel performance in healthcare environments.
- The results used to finalise the questionnaires.

- Study not long enough to get enough respondents.
- Covering of data loggers with patients' files.
- Obstructing window areas casting shadows onto workstations.

Figure 2: The Pilot Studies.

The pilot study also included environmental control questions, and the participants' answers were consistent with their physical measurements. However, one significant limitation of the pilot study was the duration, which was not long enough to get enough respondents. Only 33 questionnaires were administered, which limited the scope of the study. To address this limitation, the duration of the principal study was extended to four months to generate more responses and questionnaires from the respondents and to substantiate the impact of daylight on staff performance statistically.

Another limitation of the pilot study was the condition of the staff's workstations. The nurse station is typically busy, especially during the morning shift, resulting in the covering of data loggers with patients' files and obstructing window areas, casting shadows onto workstations. It was difficult to get their attention to respond to questionnaires as they have a busy work schedule throughout their working shift. Efforts were made to persuade them to pause their work and respond to questionnaires and interviews.

Despite these limitations, the pilot study provided valuable insights into the potential impact of daylight on staff performance in healthcare environments. The results of the principal study, which addressed these limitations by extending the duration and making efforts to persuade staff to participate in the study, will provide a more comprehensive understanding of this issue.

3.6.4.2 ***Research Questionnaire***

Questionnaires are widely used instruments in survey research, allowing researchers to gather data that is essential to achieving study objectives. These instruments capture all relevant information identified in the literature review and practical issues observed during the study (Bryman 2016). As a low-tech and cost-effective tool, questionnaires have become a popular choice for data collection (Bryman 2016; Siedlecki et al. 2015).

In this study, questionnaires were distributed to all participants over a period of 6 months. The study included participants from various categories, and all were given questionnaires to complete. The questions were designed to obtain information related to the study's objectives and to capture relevant data from all participant categories.

The use of questionnaires as a data collection tool has been shown to be reliable and efficient in many research settings (Dillman et al. 2014). The data collected through questionnaires can provide valuable insights that may be used to inform decision-making processes.

3.6.4.3 ***Pre-testing of the Questionnaire***

Designing a questionnaire is a crucial step in any research project, as it directly impacts the quality and reliability of the data collected. Once the questionnaire is finalised, it is recommended to pre-test it in the field to ensure its comprehensibility and accuracy. This step is particularly important as it helps to identify and correct any potential errors or ambiguities in the questionnaire (Bryman 2016; Collins, 2003; Mugenda & Mugenda, 2003).

To ensure the comprehensibility and accuracy of the questionnaire used in this study, a pre-testing was conducted on a convenience sample of 10 healthcare workers in Abuja, Nigeria. This pilot survey aimed to evaluate the clarity and ease of understanding of the questionnaire items and to identify any potential problems that might arise during the actual data collection process.

The pre-testing process involved administering the questionnaire to the participants and collecting their feedback on the questions, response options, and overall layout of the questionnaire. The feedback collected was then used to make necessary modifications to the questionnaire to improve its clarity and accuracy.

The use of a convenience sample in the pre-testing process may limit the generalisability of the results, as the sample may not be representative of the population of interest. However, it is important to note that the focus of the pre-testing process is on the evaluation of the questionnaire and not on the generalisability of the results (Bryman 2016).

3.6.4.4 ***Scale of Measurement***

The Likert scale is a five-point scale where respondents rate their agreement or disagreement with statements using numerical values ranging from 1.00 (Very Low) to 5.00 (Very High). This scale has been widely adopted in various fields, including psychology, education, and business, as it provides a simple and effective way to measure attitudes and opinions.

In this study, the Likert scale was used to collect data from a sample of 108 participants on their perceptions of indoor lighting. The study employed a five-point Likert scale, as shown in Table 4, to measure respondents' rating of the given proposition.

Table 4: Illustration of Scale Applied to Data Collection.

Range of value	Interpretation
0.00-1.49	Very Low
1.50-2.49	Low
2.50-3.49	Moderate
3.50-4.49	High
4.50-5.00	Very High

The Likert scale used in this study allows for a range of responses, including moderate opinions, enabling research to obtain a more comprehensive understanding of respondents' attitudes towards the indoor lighting. The use of the Likert scale also ensures that the data collected is reliable and valid, as it provides a standardised approach to measuring respondents' opinions.

3.6.4.5 ***Questionnaire Survey Validity and Reliability Test***

Questionnaire surveys are widely used in social science research to gather data from large groups of people. However, the reliability and validity of the survey instrument are crucial to ensure accurate and consistent results. The present study aimed to evaluate the validity and reliability of the questionnaire survey instrument used in this research.

To assess the validity of the survey instrument, the study uses content validity, construct validity, and criterion validity tests. Content validity was ensured by verifying that the survey questions were relevant to the research topic and covered all relevant aspects. Construct validity was tested by examining whether the survey questions accurately measured the intended constructs. Criterion validity was assessed by comparing the survey results with established measures or external criteria.

To evaluate the reliability of the survey instrument, the study employed internal consistency and test-retest reliability tests. Internal consistency measures the extent to which the questions in the survey are related to one another and measure the same construct. Test-retest reliability measures the consistency of the results obtained from the survey over time.

The results of the validity and reliability tests demonstrated that the questionnaire survey instrument used in this research was both valid and reliable for data collection. Content validity was confirmed by verifying that the survey questions were relevant and comprehensive. Construct validity was demonstrated by ensuring that the survey questions accurately measured the intended constructs. Criterion validity was established by comparing the survey results with established measures as discussed in chapter four. The internal consistency and test-retest reliability tests also showed that the survey instrument was reliable.

3.6.4.5.1 **Validity Test**

This study examined the validity of a research measure using both content and construct validity tests. Content validity refers to the extent to which a measure has captured the intended universe or domain of content. In this study, the research utilised purposive sampling techniques to select a defined group of respondents who were best suited to respond to the research issues

(Maina, 2012; Ibrahim, 2015; Mugenda & Mugenda, 2003). The adequacy of the sampling technique ensured that the research sampled from the intended universe of content.

Moreover, the study employed a construct validity test to evaluate the extent to which the measurement instrument specifically measured what it was designed to measure. The questionnaire used in the research was able to measure all the variables it was intended to measure, thus meeting the condition of construct validity.

According to Maina (2012), purposive sampling is an effective sampling technique that allows researchers to select a specific group of participants who are best suited to provide relevant data. Furthermore, Mugenda and Mugenda (2003) suggest that the validity of a research instrument can be enhanced by ensuring that it accurately measures the intended variables. Therefore, the current study used these best practices in research to ensure both content and construct validity were met.

3.6.4.5.2 **Reliability Test**

In this study, the reliability of the questionnaire was assessed using the internal consistency test. To measure the reliability index of the questionnaire, Cronbach’s alpha was used, which is a coefficient of reliability or consistency (Field, 2009). This coefficient measures the consistency of a questionnaire’s construct and indicates the extent to which a scale is free from random error (Pallant, 2020; Ibrahim, 2015).

The use of Cronbach's alpha allowed for the detection of negative constructs and the acceptance of positive constructs, with a range of values from 0 to 1.0 (Ogwueleka, 2011). The minimum acceptable value for Cronbach’s alpha is typically between 0.5 to 0.6 (Ogwueleka, 2015; Olatunji, 2010). For this study, a cut-off value of 0.70 was used, meaning that items needed to be above this value to be used together as a scale.

The questionnaires were designed to capture two broad constructs, demographic profiles and study objectives. Using the Cronbach’s alpha scale as a measure, this study found that the reliability of the questionnaire's constructs was very high, with all values exceeding the cut-off score of 0.7. Therefore, the questionnaires used in this study were highly reliable, consistent, and free from random error.

Overall, the use of Cronbach’s alpha as a measure of reliability allowed for a comprehensive and robust assessment of the questionnaire's consistency, with appropriately chosen cut-off values and a clear explanation of the study's objectives and constructs. The study's findings suggest that the questionnaire can be considered a reliable tool for future research in similar areas.

3.6.5 **Level of Significance and Statistical Techniques**

Level of significance is an important statistical concept used to determine whether a research finding is meaningful or simply due to chance. It refers to the probability threshold set for accepting or rejecting research outcomes in various settings. In other words, it is a measure of how confident researchers can be that their results are not just the result of random variation.

One way to set the level of significance is to use a p-value, which represents the probability of obtaining a result as extreme or more extreme than the observed result, assuming that there is no real difference between the groups being compared. The commonly used level of significance in social research is 0.05, which means that there is a 5% chance of rejecting a true null hypothesis, and researchers can be 95% confident in their results.

Several statistical techniques can be used to analyse data and determine the level of significance of research outcomes. Some of these techniques include Kendall Tau and Kruskal-Wallis correlations, the median test, crosstabs, and multivariate analysis. These techniques allow researchers to examine relationships between variables, compare groups, and identify significant differences between variables.

For example, Kendall Tau and Kruskal-Wallis correlations can be used to examine the strength and direction of relationships between variables that are not normally distributed. The median test is useful when comparing the central tendency of two or more groups that have non-normal distributions. Crosstabs can be used to analyse the association between two categorical variables, while multivariate analysis can be used to examine the relationship between multiple variables.

Overall, setting the level of significance and using appropriate statistical techniques are essential steps in conducting valid and reliable research. By carefully considering the significance level and using appropriate statistical techniques, researchers can draw meaningful conclusions and contribute to the advancement of knowledge in their respective fields.

3.7 Qualitative Data Collection Method

The use of qualitative methodology in research has proven to be valuable in obtaining detailed explanations that cannot be obtained solely through physical measurements and surveys. The use of this methodology allows for the identification of perspectives, meanings, and interpretations of respondents that would have been missed by other methods.

While numerical data collection is supported by the quantitative approach, it cannot capture the richness and complexity of human experiences that qualitative research can. Therefore, a mixed methodology, where qualitative research is preferred, is a suitable approach to analyse research problems that involve both numbers and human experiences.

As noted by Hancock et al. (2001), qualitative research can help answer "how" and "why" questions and can be particularly useful in developing or novel areas where there has been little prior research. This study is an example of such a case.

The use of qualitative methodology in this study demonstrates its robustness in analysing complex and multivariate real-world phenomena. As Moser and Korstjens (2018) noted, this approach is particularly useful in gaining a deeper understanding of the experiences and perceptions of healthcare workers in a specific context. The qualitative methodology employed in this study enabled the researchers to use open-ended questions and flexible interviewing techniques, allowing the participants to express themselves in their own words, and providing rich and detailed data.

3.7.1 **Phenomenology Aspect of the Research Strategy**

The present study builds upon a robust approach and adopts a phenomenology to explore the influence of daylighting on human experiences within architectural settings. Phenomenology is chosen as the research strategy due to its systematic data collection and analysis methods, which focus on comprehending the significance of a phenomenon as it is perceived and experienced by individuals. This strategy involves examining the phenomenon from the viewpoint of those who directly experience it and actively includes the study participants in the research process. Using phenomenology, this study probes into participants' experiences and perceptions of "real living" regarding the lighting levels in the facility. Both textual data, gathered through interviews, and visual data, captured through photographs, are utilised to construct a comprehensive profile of this phenomenon.

According to Kemmis (1980) and Myers (2000), the real value of non-experimental research lies in its ability to define participants' actions in their social and historical contexts and to logically critique these descriptions. This study affirms the value of qualitative research in exploring the subject in its natural setting and developing a comprehensive profile for any study, which can reinforce the quantitative study's capacity to provide extensive data on the subject while considering slight variations in the respondents' responses.

The use of multiple data sources and methods of data collection and analysis is a strength of phenomenological research. As noted by Creswell and Poth (2016), this approach "helps to ensure that the findings are reliable, valid, and credible, as well as richer and more complex than they might be using a single method." By combining both textual and visual data, this study was able to provide a comprehensive understanding of the phenomenon of daylighting and its impact on human experience in architectural settings.

Phenomenology is often seen as a philosophy of research, but in cognitive and social sciences, it is used as an empirical approach to study human experience (Gallagher, 2012). Phenomenological architecture differs significantly from positivist and socioeconomic disciplines, as it is based on human experiences and behaviours, analysed through sensory influences that augment the atmosphere of the place. The emphasis of phenomenological architecture is largely on the role of light, as light is known to have a strong effect on the experience of space.

The study argues that one possibility for why daylighting studies are struggling to find a consensus on metrics to analyse the quality of daylighting is that there is a lack of focus on the human cognitive and perceptual aspects of it and on the methodology to investigate experience. Therefore, a shift from evaluating performance to researching experience in the analysis of people’s interactions with space and daylight is necessary (van den Wymelenberg & Inanici, 2014).

This study used phenomenological methodology to investigate the phenomenon (experience) of daylighting and combined it with quantitative measurement and description of daylight. Merleau-Ponty (2010) emphasises the need to first understand the experience of space, which differs from its physical description. While there is much written on the theory of phenomenological architecture, fewer studies have been done on concrete phenomena. Experiences of situations that typically go unnoticed in everyday life can be studied with an open mind through phenomenology.

Phenomenologists study experience through collecting descriptions of that first-person experience. Unlike quantitative science, phenomenology seeks rich descriptions of lived experiences rather than empirical generalisations. Even though the descriptions of singular lived experiences are the starting point for most phenomenological studies, researchers have repeatedly been able to discover generic structures of experience from the collection of descriptions of singular experiences for a given study.

To gain a comprehensive understanding of participants' experiences in this study, the micro-phenomenological interview technique developed by Petitmengin et al. (2019) and Petitmengin (2006), which is a methodologically controlled guideline designed to capture the subjective experience of individuals in a particular situation.

3.7.1.1 ***The Micro-Phenomenological Interview***

When studying people's experiences, it is important to plan data collection carefully to gain an understanding of their perceptions and the micro-phenomenological interview technique provided rich descriptions of participants' experiences. Moreover, as the experience of feeling at home in a particular space often goes unnoticed (Petitmengin, 2006; Natvik et al. 2019), it can be challenging to capture this experience and to explain the perception of such spaces (Vikberg et al. 2022). Thus, simple unstructured interviews may not be sufficient to capture the full experience, and phenomenological interviews should be used instead, employing a methodologically controlled guideline (Gallagher, 2012; Zahavi, 2020).

Phenomenological interviews aim to shift the focus from what we experience to how we experience it, enabling access to real experiences (Gallagher, 2015; Gallagher, 2012). This requires interviewees to suspend preconceived opinions and theories about daylighting (Vikberg et al. 2022). It is important to note that epoché, the suspension of preconceived notions, is of primary importance for a phenomenological interview. This is because false conceptions can lead to inaccurate results (Gallagher, 2022).

Furthermore, it is important to understand that this applies not only to the interviewee but also to the researcher (Gallagher, 2022). Researchers must also suspend earlier theories about daylighting (Gallagher, 2003; Gallagher & Zahavi, 2008) to avoid influencing the interviewee's responses. Therefore, the interviewer should not prompt the interviewee to describe their experience through categories typically used in daylight studies, such as glare, views, or amount of light (Vikberg et al. 2022). The interviewer should use non-inductive but directive questions, which do not induce any content but are "content empty" (Vikberg et al. 2022).

One important consideration in conducting interviews is the use of language. As Gallagher (2022) notes, interviewers should avoid using professional or specialised language and words, instead allowing interviewees to find their own words. This approach can help to ensure that the focus of the interview is on the interviewee's experiential matters, rather than their attitudes, beliefs, or theories about the experience.

3.7.2 **Qualitative Sample Size**

This study employed a phenomenological approach to investigate the experience of daylighting in the workplace. In contrast to quantitative studies, the number of interviewees in qualitative research is less important (Parks, 2021). In fact, some phenomenological studies have found that having too many participants can lead to essential themes being overlooked in the vast amount of data collected (Parks, 2021). Therefore, the sample size in phenomenological studies is often determined by categorical saturation, where new interviews only produce the same categories as previous ones (Petitmengin et al. 2019).

To reduce the burden on the interviewees and ensure consistency in the interview process, this study adopted the method of "frontloading phenomenology" (Gallagher, 2003; Gallagher and Zahavi, 2008). This involved having a trained interviewer guide the participants through the process, eliminating the need for them to learn to bracket their experiences. The data collected through interviews was transcribed and analysed using the micro-phenomenological analysis method. This involved identifying structures in the descriptions of the participants' experiences and comparing them with each other to identify generic structures that could describe the experience of daylighting in the workplace.

The iterative process of micro-phenomenological analysis allowed the identified structures to be used as hypotheses for subsequent interviews. These subsequent interviews could confirm, refine, or invalidate the initial hypotheses, allowing for a more comprehensive understanding of the experience of daylighting in the workplace (Petitmengin et al. 2019).

3.7.3 **Interview Questions Guide Development**

In qualitative research, interviews are considered a valuable data collection method as they enable researchers to obtain a retrospective and prospective account of individuals' experiences, thoughts, and emotions (Seale, 2004). To obtain essential information from healthcare workers, the appropriate data collection method for the qualitative portion of this study was a semi-structured interview, where unstructured interview questions were developed, and interview procedures were followed.

As suggested by Gummesson (2000), Denzin and Lincoln (2011), and other authors, a qualitative research method must be flexible and adaptable to the interview format. In this study, interviews were seen as a beneficial approach as they provided a platform for one-on-one interactions between the researcher and respondents, allowing for a more in-depth exploration of their perspectives. This approach was considered advantageous as it offered an opportunity for interview subjects to express their ideas freely.

Moreover, interviews are not just another way to gather survey data but rather a unique method for collecting valuable information (Walliman, 2021). According to Marshall and Rossman (2014), if conducted correctly, interviews can provide insights into interviewees' perspectives and help identify trends in their responses. This further justifies the use of interviews as a data collection method in this study.

For the semi-structured interviews, the recommended sample size ranges from 5 to 25 participants, as suggested by Creswell and Poth (2016) and Saunders (2012). In this case, 16 healthcare workers were selected as interviewees based on their responses to the questionnaire survey. The study employed a combination of quantitative and qualitative data collection methods to gain a comprehensive understanding of the research topic. By integrating these approaches, the researchers aimed to achieve a more robust and nuanced analysis.

3.7.3.1 ***Interview Procedure***

All participants in the study were visited at their respective wards. To change the mental focus of the subjects from their actual working task to the evaluation of their perception, the procedure started with a short interview. The interview contained a set of standardised questions designed to evaluate the subjects' perception of their environment and their wellbeing.

The aim of the interview was to obtain reliable data on the impact of natural light on the wellbeing and performance of healthcare personnel. The questions were carefully designed to elicit specific information on the subjects' perception of natural light and its impact on their mood, stress levels, cognitive function, and overall wellbeing.

Numerous studies have demonstrated the importance of natural light exposure for healthcare personnel. Boubekri et al. (2013) found that nurses who were exposed to natural light had significantly lower levels of stress and higher levels of job satisfaction compared to those who worked in areas with little natural light. Similarly, Choi et al. (2012) found that healthcare workers who were exposed to natural light had improved cognitive function and alertness compared to those who worked in areas with artificial lighting. Schweitzer et al. (2004) also found that healthcare workers who were exposed to natural light had significantly lower levels of depression and anxiety, as well as improved sleep quality.

3.7.4 **Generalisations of Results**

The phenomenological approach is often criticised for its limitations in generalising from the results (Vasileiou et al. 2018). In this thesis, the findings presented are derived from a study that involved only a limited number of participants from various healthcare professions. It should be noted that healthcare workers may be organised in diverse ways, which could impact the results (Åmo, 2006). Additionally, the research was conducted in a single healthcare area, which may also influence the outcomes.

It is important to acknowledge that the phenomenological approach, which emphasises subjective experiences and perceptions, is not intended to produce generalisable results (Creswell, 2013). Rather, the purpose of this approach is to provide a rich and detailed understanding of the lived experiences of individuals within a specific context. Therefore, the focus of this study was to gain insight into the experiences of healthcare workers in a particular setting, rather than to draw conclusions that can be generalised to other contexts.

To address the limitations of the sample size and setting, future research could involve a larger and more diverse group of participants from various healthcare environments. This would allow for a more comprehensive understanding of the experiences of healthcare workers across different contexts. Furthermore, utilising multiple methods of data collection, such as interviews, surveys, and observations, could also provide a more thorough understanding of the phenomenon under investigation (Creswell, 2013).

3.8 Ethical Consideration

As research involving human subjects becomes increasingly prevalent, it is essential to ensure that ethical considerations are carried out to prevent physical or psychological harm to participants. In this research project, ethical aspects were identified and addressed in accordance with the University of Plymouth ethics policies. An ethical protocol was devised, which included principles such as informed consent, openness and honesty, right to withdraw, debriefing, confidentiality, and protection from harm.

To obtain informed consent, an information sheet was produced that outlined the scope and purpose of the research project, as well as the uses of the data collected. A consent form was provided to each participant, and during the recorded semi-structured interviews, participants were given the opportunity to state their consent to participate in the research.

The principle of openness and honesty underpinned the use of the information sheet and the formal consent, ensuring that participants were fully aware of how information would be collected, treated, and stored. Channels of communication were established through phone and email to provide participants with the ability to ask questions or provide feedback.

Participants were informed of their right to withdraw from the research at any time up to a set deadline, without providing any reason or explanation. They were also informed that they could request the destruction of the data collected without any negative consequences.

Confidentiality was maintained throughout the research project. Personal data were associated with an arbitrary reference number, and only in the validation process of the focus group was confidentiality and anonymity not maintained. In this instance, all participants were informed and provided with a specific consent form and invitation letter.

Data collected for the research project will be stored in accordance with the University of Plymouth's research ethics policy, which states that data should be securely held for a minimum of ten years after the completion of the research project.

Finally, it was acknowledged that none of the methods or procedures applied in this research would cause any physical or psychological harm to the participants. Health and safety risks were not identified during the semi-structured interviews, as they were administered in the participants' place of work, where health and safety procedures were already in place.

This research project demonstrated a commitment to ethical conduct when researching human subjects. All documents described in this section are available in the Appendix A.

3.9 Data Collection and Analysis

This section highlights key elements related to the data collection and analysis in the research study. The proposed methodology for the research study involves assessing the physical parameters of indoor lighting while also gathering responses from the occupants. As discussed earlier, the data collection and analysis processes utilise a mixed methods research design, as detailed in the preceding section.

In April 2021, a field investigation was conducted to study the indoor environment of hospitals in Abuja city. The study surveyed 20 hospitals in the city and identified three hospitals suitable for conducting the survey: the Federal Medical Center in Jabi, Garki Hospital in Garki, and the National Hospital in the Central Business District. The research obtained approvals (see appendix) from the Federal Medical Center in Jabi and the Garki Hospital in Garki to conduct pilot and principal surveys that spanned six months.

The indoor environment's conditions and occupants' responses to the environment are the main subjects of environmental measurement. Temperature, humidity, CO2, radiant temperature, light, and noise levels are among the readings taken in an indoor environment. Researchers use various tools, including sensors and a lux meter, to conduct studies on lighting and visual comfort. In this study, the indoor and outdoor environmental data was collected by installing data loggers and a handheld digital lux meter. Measurements are taken at various levels, including the floor, desks, and the building's roof. During the survey, subjective ratings of task performance were collected from the staff of the case hospitals. This research empirically studied the building's performance by measuring the lighting environment, and personnel's perception of their visual environment was captured through a questionnaire.

3.9.1 **Research Location**

Healthcare personnel play a crucial role in society by providing essential medical services to the public. However, the conditions of their work environment, which are greatly influenced by climate, can have a significant impact on their well-being and performance. This is particularly evident in Abuja, Nigeria's federal capital, where the climate includes a hot and humid rainy season from April to October, a dry season from October to April, and a brief cold and dusty harmattan period in December and January.

In the quest to establish a comfortable and healthy indoor environment for healthcare professionals, it is important to consider the unique outdoor conditions shaped by diverse climatic regions. A range of factors, such as the age and gender of occupants, along with regional weather patterns, play a critical role in determining the ideal comfort range (Kaushik, 2019; Quang et al., 2014).

Acknowledging the variation in daylight patterns across different regions (Volf, 2013), the initial research plan involved fieldwork in both the United Kingdom and Nigeria. The UK, characterised by day-to-night transitions and significant seasonal changes, stands in contrast to Nigeria, which is located closer to the equator, where transitions are shorter and seasonal variations are minor. Initial studies were conducted in both locations.

However, unforeseen circumstances, particularly the consequences of the COVID-19 pandemic and the strain on the UK's National Health Service (NHS), led to a strategic shift in the research focus. As a result, Abuja, Nigeria, emerged as the primary location for the main study. Abuja, with its distinct character based on unity and national identity, serves as a symbolic home for all Nigerians (Ahmadu, 2021). Established with a clear vision and master plan, Abuja has become Nigeria's administrative and political capital, gaining significance in African geopolitics (The Nigeria Capital City, 2022; Ahmadu, 2021). Furthermore, it has become a prominent conference centre, hosting major events such as the 2003 Commonwealth Heads of Government meeting and the 2014 World Economic Forum (Africa) meetings.

The remarkable growth of Abuja since 1991, fuelled by increased development and investments from multinational companies, has led to extensive real estate development, including the construction of office spaces and healthcare infrastructure. This dynamic urban landscape provides an engaging backdrop for the comprehensive exploration of the interaction between environmental factors, especially light, and the creation of optimal indoor living conditions.

3.9.1.1 ***Microclimate of Abuja***

The impact of microclimatic conditions on human performance has become a significant concern in recent years. In Abuja, the Federal capital of Nigeria, this concern is no different. With a population of over 3 million people, the microclimate in Abuja has an impact on various aspects of daily life, including personnel performance in hospitals. This section examines the microclimate of Abuja, with a focus on the impact of daylight on personnel performance in a hospital setting.

3.9.1.1.1 **Geographical location**

Abuja, Nigeria, is in the West Africa Time zone (WAT), which is GMT+1 as shown in Figure 3. Abuja is located at a coordinate of 9 4'20.1504" N and 7 29' 28.6872" E and sits at an altitude of 1,180 feet (360 meters) above sea level (Worldatlas, 2022). The city is situated in the central region of Nigeria and is surrounded by hills and valleys. Its location has an impact on its microclimate, which is characterised by two main seasons: a hot and humid rainy season from April to October, and a dry season from October to April, with a brief period of cold and windy weather known as harmattan (World Weather Online, 2022). The city is near the equator, so the length of daylight and night-time is relatively constant throughout the year, with only minor variations.

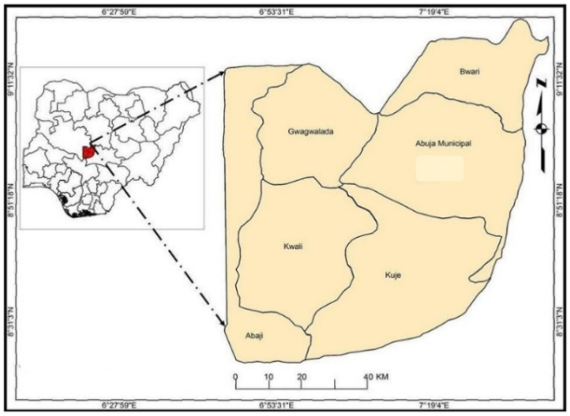


Figure 3: Map of Nigeria Showing Abuja.

The rainy season has the highest amount of rainfall in the months of June, July, August, and September. During this season, the average temperature is 28.3°C (World Weather Online, 2022). In contrast, the dry season, which starts in October and ends in March, is characterised by intense heat, with March being the hottest month. Daily temperatures can reach as high as 36°C (World Weather Online, 2022). The harmattan period is experienced mainly in December and January, when cold, dry, and dusty winds blow from the Sahara into West Africa and the Gulf of Guinea. During this period, temperatures in Abuja are cold in the evenings and early morning but can become hot in the afternoon (World Weather Online, 2022).

3.9.1.1.2 **Climate**

During the dry season, Abuja experiences sunny and dry weather conditions, with little or no rainfall. The city experiences a high-pressure system known as the Harmattan, which brings dry and dusty air from the Sahara Desert across West Africa. This period is also characterised by low humidity, high solar radiation levels, and low cloud cover (Adegun et al. 2020; Ikechukwu & Nnabuchi, 2018). As expected, the cloud cover is higher during the rainy season, from April to October, with peak values in June and July, when the city experiences the highest amount of rainfall. Consequently, the city experiences overcast weather conditions more frequently, characterised by a sky covered with clouds and limited to no direct sunlight. The CIE (2004) defines the standard overcast sky as having a steep luminance gradation towards the zenith and azimuthal uniformity. During the dry season, from December to March, the cloud cover is lower. The solar radiation levels are higher during the dry season, from December to March, with peak values in February and March, when the city experiences the highest amount of sunshine. During the rainy season, from April to October, the solar radiation levels are lower, with the lowest values in June and July, when the city experiences the highest amount of cloud cover and rainfall.

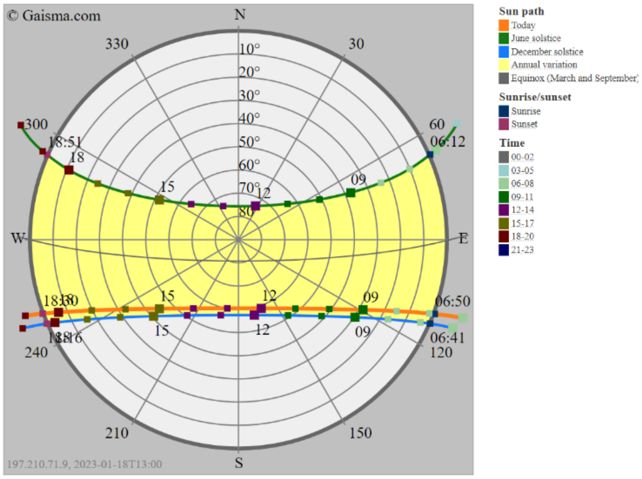


Figure 4: Sun Path Diagram - Abuja, Nigeria (source: https://www.gaisma.com/en/location/abuja.html)

The sun path (figure 4) during this period is generally high, and the hourly horizontal exterior illuminance can be intense, reaching up to 100,000 lux at midday (Adegun et al. 2020; Ikechukwu & Nnabuchi, 2018).

In December, the sunrise in Abuja typically occurs around 6:45 am, while sunset occurs around 6:15 pm. As the months progress towards May, the sunrise gradually gets earlier, and the sunset gets later. By May, the sunrise in Abuja occurs around 6:10 am, while sunset occurs around 6:45 pm. Figure 5 shows the sunrise and sunset times in Abuja by month of study.

Month	**Sunrise**	**Sunset**	**Hours of daylight**
December	6:45 am	6:15 pm	11:30 h
January	6:50 am	6:15 pm	11:25 h
February	6:45 am	6:25 pm	11:40 h
March	6:35 am	6:30 pm	11:55 h
April	6:20 am	6:40 pm	12:20 h
May	6:10 am	6:45 pm	12:35 h

Figure 5: Sun & Moon Times, Abuja, Nigeria. Source: https://www.timeanddate.com/sun/nigeria/abuja.

In contrast, the rainy season is characterised by increased cloud cover and reduced solar radiation levels due to frequent cloud cover and rainfall. Abuja experiences high levels of cloud cover, which can range from partly cloudy to mostly cloudy or overcast. This is due to the increased amount of moisture in the air, which can lead to the formation of clouds and rain. According to historical weather data, the average cloud cover in Abuja during the rainy season ranges from 60% to 90%. Abuja receives much of its annual rainfall during the rainy season, with peak rainfall occurring in June and July. The average rainfall during the rainy season ranges from 120mm to 250mm per month, with occasional heavy downpours and thunderstorms.

The sun path is lower during this period, and the hourly horizontal exterior illuminance is lower, ranging from 3,000 to 10,000 lux. The lower illuminance levels during the rainy season can have various impacts on human health and well-being. For instance, lower illuminance levels can lead to Vitamin D deficiency, which can result in several health issues such as bone deformities and rickets. Additionally, lower illuminance levels can affect mood, productivity, and cognitive function.

However, during the dry season, illuminance levels can be relatively high due to high solar radiation levels. The hourly horizontal exterior illuminance during this period can range from 10,000 to 120,000 lux (figure 6). These high illuminance levels can provide an abundance of natural light in healthcare facilities, but can also lead to increased heat and discomfort, which can negatively impact the wellbeing and performance of healthcare workers.

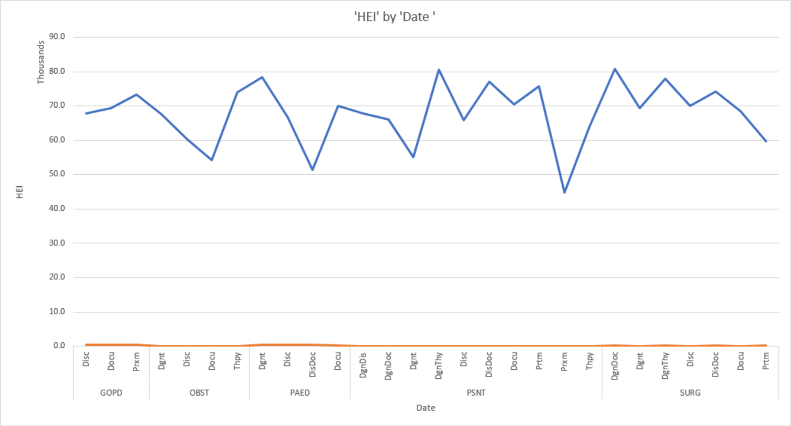


Figure 6: Akinbami A. (2022) Fieldnote: Snapshot of Horizontal External Illuminance (HEI) by Dates for Different Activities (recorded from site).

The hottest months are typically March and April, with average temperatures ranging from 30°C to 36°C (86°F to 96°F). The coolest months are December and January, with average temperatures ranging from 25°C to 28°C (77°F to 82°F). During the rainy season, the temperature in Abuja is generally cooler than during the dry season, with average temperatures ranging from 22°C to 27°C. However, the humidity can make the temperature feel warmer, particularly during periods of high cloud cover. Moreover, the rainy season in Abuja is characterised by occasional high winds and gusts, particularly during thunderstorms.

3.9.1.2 ***Hospital Building - Federal Medical Centre, Jabi, Abuja, Nigeria***

The Federal Medical Centre (FMC) Abuja is a tertiary health institution located in the Jabi district of Nigeria's capital city. The hospital is situated in a prime location, making it easily accessible from the city centre and surrounding districts. The centre's primary objective is to provide quality healthcare services to its patients in a safe and comfortable environment.

The FMC Abuja consists of six major buildings, three of which are linked together and have three floors. These buildings house various essential units such as the General Outpatient

Department (GOPD), Accident and Emergency Unit, Surgical Theatres, Major Departments, Administrative Offices, and Major Wards with a capacity of 150 beds. The other buildings on the premises include the Private Wing, Children's Department, and Physiotherapy Department. The hospital's buildings are oriented to maximise natural light penetration, with large windows, creating a more pleasant and comfortable environment for patients and staff alike (figure 7 and 8).

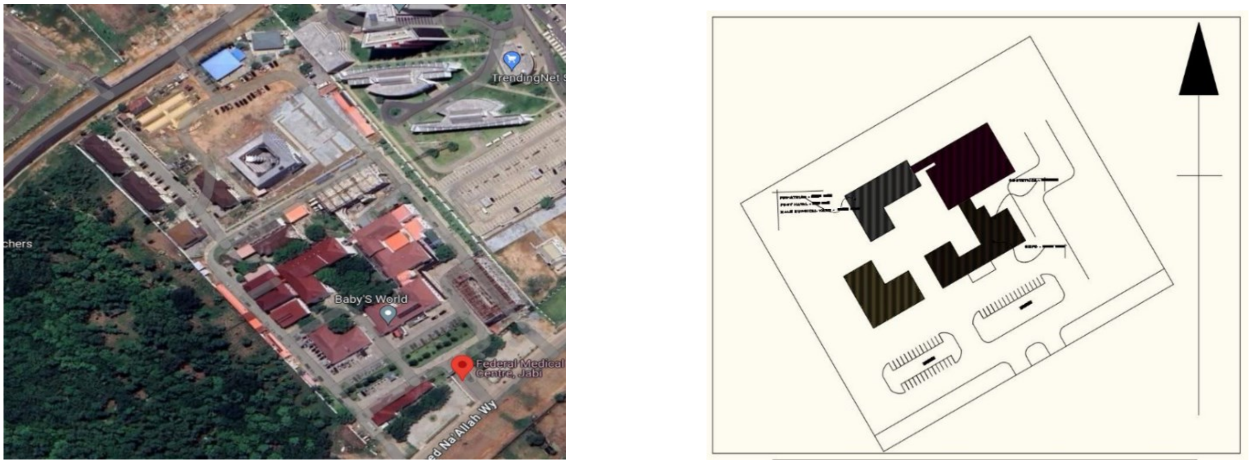


Figure 7: Akinbami A. (2022) Fieldnote: FMC Complex and Adjoining Sites.

Figure 8: Akinbami A. (2022) Fieldnote: Hospital Building Approach View.

The Private Wing is a one-story structure with nurse bays, consultant offices, a private ward, and other related facilities. The Children's Department is a separate building that caters to the specific medical needs of children. Patients in need of physiotherapy can easily access the Physiotherapy Department from the main parking garage.

The infrastructure of the FMC Abuja is designed to meet the highest standard of medical practice. The hospital is equipped with state-of-the-art medical equipment and facilities to cater to the needs of its patients. The FMC Abuja has also made significant strides in the implementation of e-health services to improve access to quality healthcare services.

According to the Federal Ministry of Health, the FMC Abuja is one of the best-equipped hospitals in the country, and it is recognised for its excellence in medical education, research, and patient care. The hospital has been at the forefront of providing quality healthcare services in Nigeria, and it has received several awards and accolades for its outstanding contributions to the healthcare sector.

3.9.1.3 ***Hospital Site and Surroundings***

Federal Medical Centre Jabi, Abuja is situated in the Research and Institution Cadastral District (Figure 9) of the city. This location places the hospital near various tertiary institutions and government agencies, such as the Nigerian Open University, Baze University, and Nile University. Furthermore, the hospital shares a boundary to the east with the Economic and Financial Crime Commission's headquarters.

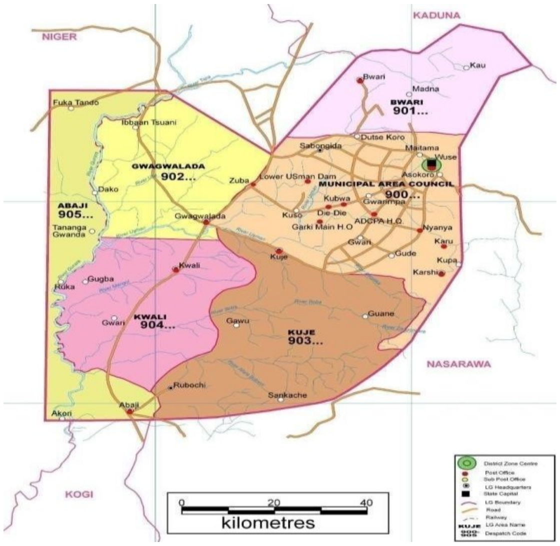


Figure 9: Map of Abuja Showing the Study Location.

The hospital is conveniently situated, as it is bounded by two roads at the north and south ends. This ensures easy access and exit from the facility, making it less burdensome for patients and staff alike. Additionally, the hospital's eastern boundary is a vacant plot of land, which helps to ensure a peaceful and calm environment for patients to receive care. Figure 10 presents a bird eye view of the medical facility and adjoining properties.

Figure 10: Overview Image of FMC, Jabi, Abuja: source -google map).

The Federal Medical Centre, Jabi, Abuja is a well-equipped and functional medical facility that provides quality healthcare services to patients. The hospital's facilities include state-of-the-art medical equipment, modern medical laboratories, and a well-stocked pharmacy. Moreover, the hospital's staff comprises highly trained and experienced medical professionals, including doctors, nurses, and support staff, who work tirelessly to provide patients with the best possible care. The hospital also offers a range of specialised services, including paediatric care, obstetrics and gynaecology, and mental health services.

In addition, the Federal Medical Centre Jabi, Abuja is fortunate to be in an area that allows for ample natural light to enter the facility. This not only benefits patients but also has a positive impact on the healthcare personnel who work in the hospital. Exposure to natural light has been linked to improved mood, reduced stress levels, and increased productivity.

In a healthcare environment, where the demands and pressures of the job can be high, it is essential to prioritise the mental health and wellbeing of the staff. Providing access to natural light and a peaceful environment can help reduce stress levels and improve job satisfaction among healthcare personnel. This, in turn, can lead to improved patient outcomes and a better overall healthcare experience for all involved.

3.9.1.4 ***Study Spaces***

The research was conducted in five different wards, namely, surgical, post-natal, paediatrics, obstetrics, and the general outpatient department (GOPD). The surgical, post-natal, and paediatrics wards were in the same building block, on the same stack, but on different levels. Specifically, the surgical ward was situated on the ground floor, the post-natal ward on the first floor, and the paediatric ward on the second floor, all towards the eastward side of the hospital (figure 11).

Figure 11: Architectural floor plans of surgical, postnatal, and paediatric wards on the ground, first, and second levels at the northeast end.

On the other hand, the obstetrics department was located towards the west on the second floor, while the GOPD was situated on the ground floor (figure 12).

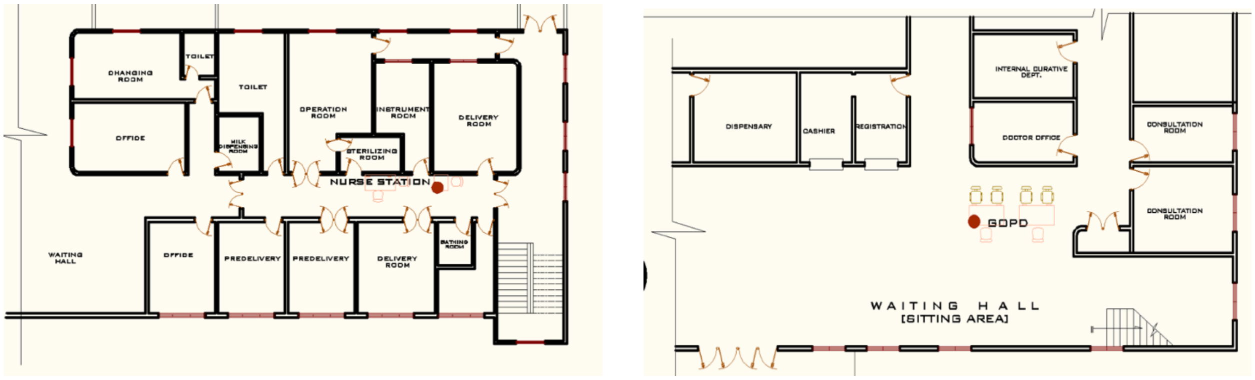


Figure 12: Architectural floor plans of GOPD and Obstetric ward on the ground and first levels at the southwest end.

The study explored the suitability of the nurse's stations in these wards as study spaces, taking into consideration their location, accessibility, and overall environment. Figure 13, as samples photos of the study spaces in the healthcare facility. By examining the different nurse's stations across the five wards, the study aimed to provide insights into the most suitable study spaces for healthcare professionals and students working or studying in these areas. Overall, the research aimed to contribute to the development of effective study spaces within hospital environments, which can help healthcare professionals and students optimise their learning and productivity.

Figure 13: Akinbami A. (2022) Fieldnote: Photographs of Study Spaces

3.9.2 **Data Collection**

The study began on January 11, 2022, and ended on May 05, 2022. The aim of the study is to investigate the effect of indoor lighting during the day on the staff's performance in a hospital setting. To address the challenges encountered during the pilot study, the questionnaire was adjusted to provide brief, direct, and relevant questions related to the effect of indoor lighting on the staff's performance.

Nine data loggers were deployed in five wards, including surgical (two data loggers), postnatal (two data loggers), paediatrics (two data loggers), obstetrics (one data logger), GOPD (one data logger), and roof (one data logger). Questionnaires were administered to the staff working in the wards, and 450 questionnaires were completed. Additionally, sixteen interviews were conducted at the end of the principal study to collect in dept information their assessment.

Some general information about the building was gathered to have a general understanding of the building, its occupants, and any difficulties in the building. The first step was to contact key people in the building and explain the purpose of the study. Site visits and interviews with key people in the building were arranged, and a checklist was used to collect necessary information at the site.

During the first visit, an introductory meeting was held with key people to describe the research purpose and procedure. This was followed by a tour, interview, and notes to get to know the building and its structure. Additionally, a combination of observation and a checklist was used for a visual inspection of the building, including rooms, to prepare for data collection and survey.

Following the initial visits, a comprehensive study was conducted to identify suitable locations for data loggers based on light intensity and to invite occupants to participate in the study. The schedule was prepared based on the availability of participants, with a focus on achieving a balance between genders, ages, and locations. Participation in the study was voluntary and depended on the willingness of occupants to take part. Criteria such as building location, willingness to participate, and the number of people in the room were considered.

Three types of workstations were chosen for monitoring: those next to windows, those away from windows but with an outside view, and those far from windows with no outside view. The participants were monitored according to the schedule, and a brief questionnaire was filled out by everyone. The daylight conditions in the workstations were measured at the same time when the curtains were drawn.

Prior to the site visit, management informed the occupants about the research. At the site visit, the availability of the participants for the interview and questionnaire was scheduled early on due to the limited timing and complexity of the schedule. The questionnaire was applied throughout the day, including in the morning, early afternoon, and late afternoon. To ensure that the participants had a more flexible response time during their day shift, the questionnaire was scheduled accordingly.

The site visit was limited to 2-3 days a week for a period of four months. Therefore, it was important to carefully consider and manage the schedule. The researcher needed to come back to apply the survey and take measurements whenever the participants were available since often, they were not present at their workstations. The schedule included times of entrance and departure, lunch break, and the time required to find the participants at their workstations. In cases where the participant was available for only a short period between meetings, their survey was prioritised.

In addition to the purposefully selected interviews, 108 participants were surveyed at various times of the day, yielding 450 responses. This heavy schedule was based on the experience gained from pilot studies, which helped to identify the time required to manage the participants and take measurements.

3.9.2.1 ***Physical Measurements***

Physical measurements provide a robust understanding of the environmental attributes making them essential tools in assessing the performance of buildings. In recording building performance, two environmental measures are commonly used: continuous and instant readings (Shahzad, 2013). Instant readings involve simultaneous spot measurement and questionnaire application at each workstation. On the other hand, continuous measurements are continuously recorded. In this study, continuous measurements mainly include light intensity and temperature.

To obtain data on light intensity, data logger sensors were horizontally mounted on desks 0.85 m above the finished floor level. This placement helps to understand the horizontal illuminance level at the work plane and provides information about the light intensity of the study area. The literature suggests arranging data loggers on grids based on the geometry of the study space. However, it was impossible to arrange data loggers on grids in this study due to the limited number of desks available for the placement of data loggers.

To compensate for this limitation, spot measurements were taken using a digital lux meter placed on tripods. This method was used to obtain accurate measurements of light intensity at various locations in the study area. To ensure that accurate data is captured, it is important to use the right equipment and to calibrate it regularly. In this study, new and pre-calibrated data loggers were used to guarantee reliable measurements. Furthermore, using a high-quality digital lux meter is important in obtaining precise spot measurements.

Like a previous study by Shepley et al. (2012), data were gathered on window attributes, including the distance of workstations to windows, the percentage of total wall area occupied by windows, and sill height. In the present study, a comprehensive understanding of the indoor environment was achieved through an instant survey of workstations, which included a self-administered questionnaire for users, instantaneous measurements of light levels, and surface measurements of the floor, desk, ceiling, and distance from windows.

To obtain more detailed and precise data, eight data logger sensors and one digital lux meter were employed to measure various indoor parameters such as illuminance, temperature, and humidity. Furthermore, outdoor measurements were taken by mounting one data logger outside the building to record outdoor natural light, which was used as a basis for comparing the availability of daylight and indoor measurements.

These physical measurements provide a robust understanding of the environmental attributes in buildings and can be used to inform design and operation decisions to enhance occupant performance and well-being.

3.9.2.1.1 **Measuring Equipment**

Physical measurements are essential in assessing the performance of buildings and requires specialised equipment for accurate results (Shahzad, 2013). There are two main types of measurements applied in research: continuous and instant measurements. Each type of measurement requires a distinct set of equipment for accurate results. Figure 14 shows the measuring equipment used during the study.

Fig.3.4a MX2202, HOBO MX Temp/Light

Fig.3.4b Digital Lux Meter

Fig.3.4c Tripod

Figure 14: Measuring Equipment.

In the case of continuous measurements, equipment such as sensors, data loggers, and other monitoring devices are required. These devices enable the continuous measurement of parameters such as temperature, light, and humidity over an extended period. On the other hand, instant measurements require equipment such as handheld devices, thermometers, and lux meter for immediate measurement of parameters such as temperature and light.

In this research project, both continuous and instant measurements were required, and therefore, two distinct types of equipment were utilised. For the continuous measurements, sensors and data loggers were used, while handheld devices such as a digital lux meter, laser measuring tape, a laptop, and a camera were utilised for instant measurements.

The laser measuring tape was used for measuring distances and dimensions, while the laptop was used to store and analyse the data collected from the sensors and data loggers. The camera was used to capture visual data that could not be measured using the other equipment.

3.9.2.1.2 **Continuous Recording of Environmental Conditions**

Continuous recording of environmental conditions is crucial in ensuring optimal functioning and performance of buildings, particularly healthcare facilities. Both horizontal illuminance and horizontal external illuminance (HEI) are constantly recorded using data logger sensors.

To capture daylight intensity readings at various parts of the facility, eight MX2202 HOBO MX Temp/Light data logger sensors are mounted at desk height. One data logger sensor is mounted on the roof of the building to measure unobstructed daylight light intensity. The device has a wide range of measurement capability, from 0 to 167,731 Lux, with a resolution of 1 unit of lux to 40 lux and an accuracy of 10%.

In addition, one data logger sensor was installed on the roof of the building to measure the unobstructed daylight light intensity. This sensor operates on the same range and resolution as the others, providing a comprehensive picture of the daylight intensity levels throughout the building. It is worth noting that the MX2202 HOBO MX Temp/Light data logger sensors comply with all relevant directives of the European Union (EU). Furthermore, to ensure continued accuracy and precision, these instruments are expected to be re-calibrated for light and temperature readings once a year.

3.9.2.1.3 **Recordings in Real Time**

To accurately assess lighting conditions, it is important to consider the recommended illuminance values and how they apply to different areas of a room. As research has shown, these values may only be applicable to the task area and not necessarily to the entire space (Dalke et al. 2004;

Dianat et al. 2013). Therefore, for the purposes of this study, illuminance measurements were specifically taken at the desk area.

To measure the light levels at each workstation, a digital lux metre was utilised. As shown in Fig. 14, this device was selected for its ability to provide accurate and reliable readings. When taking measurements, natural daylight illumination conditions were used, with all artificial lights turned off and curtains drawn back. To accurately reflect the pattern of natural light access by respondents throughout the day, spot measurements were taken between 9 a.m. and 4 p.m. on each occasion. Table 5 provides a summary of the workstations surveyed, considering weather conditions and the time of measurement.

Table 5: Summarising Surveyed Stations, Accounting for Weather Conditions and Time of Measurement.

Time of survey	**Surveyed stations in wards and weather**										**Total**
	GOPD		Obstetrics		Paediatrics		Postnatal		Surgical		
	Sunny	Cloudy	Sunny	Cloudy	Sunny	Cloudy	Sunny	Cloudy	Sunny	Cloudy	
10.00-11.59 am	9	3	3	1	13	6	40	13	42	13	143
12.00-1.59 pm	22	6	19	8	30	5	67	12	83	12	264
2.00-4.30 pm	2		5		4		9		23		43
	33	9	27	9	47	11	116	25	148	25	450

To provide a comprehensive assessment of overall room lighting, illuminance levels were measured in different areas of each workstation. This approach allowed for a more accurate representation of the mean day lighting level of the entire room. The digital lux metre used in this study was pre-calibrated by the manufacturer and capable of measuring light levels in three ranges, from 0.1 to 200,000 Lux, with a resolution of 0.1 Lux and an accuracy of 5% rdg + 10 dgt.

Importantly, the instrument was designed to comply with all relevant directives of the European Union (EU).

3.9.2.1.4 **Weather Conditions at Time of Measurement**

The impact of weather conditions on both light measurements and questionnaire administration is an important consideration during the study. Most of the days were sunny, which had a positive effect on the measurement of light. Sunny weather conditions provide abundant natural light that positively affects both light measurements and participant response rates. Mardaljevic (2009) notes that sunny weather conditions make it easier to perform measurements due to high illuminance levels, which also reduces the need for artificial lighting, resulting in energy savings. Additionally, sunny weather conditions have been shown to positively affect people's mood and productivity (Heschong Mahone Group, 2003). Table 6 provides a breakdown of measurements and questionnaire administration across various settings and time frames.

Table 6: Description of Measurements and Questionnaire Administrations Across Different Settings.

S/N	**Workstations surveyed**			**Settings**			**Weather conditions**	
	No of different workstations surveyed	No of time each surveyed	Total no surveyed	Time of survey	Daylit	Mixed mode	Sunny	Cloudy
1	1	7	7	10.00-11.59am	82	61	371	79
2	2	9	18					
3	5	8	40					
4	5	10	50	12.00-1.59pm	159	105		
5	8	4	32					
6	14	3	42					
7	16	5	80					
8	17	1	17	2.00-4.27pm	30	13		
9	19	2	38					
10	21	6	126					
Total	108	55	450		271	179	450	

However, partly cloudy days present challenges to accurate light measurements. Granzier and Valsecchi (2014) suggest that partly cloudy weather can cause significant variations in illuminance levels, leading to inaccuracies in the measurements. These variations can be particularly challenging when conducting long-term measurements. To mitigate the potential bias introduced by these inaccuracies, this study employed a combination of simultaneous continuous and spot measurements, using data logger sensors and handheld digital lux meters, respectively. By cross-referencing these readings, the study ensured data accuracy and minimised biases arising from irregular measurements.

Regarding the administration of questionnaires, sunny weather conditions also have a positive impact. Boubekri et al. (2020) note that the presence of natural light can improve cognitive performance, reduce mental fatigue, and increase motivation to complete tasks, resulting in improved concentration and better participant response rates. The presence of natural light during this was noted to make it easier for participants to read and complete the questionnaires.

3.9.2.1.5 **Contribution of Electric Light to Illuminance Level**

In a previous section (3.9.2.1.3), it was noted that typically, doors were locked, window blinds were drawn, and artificial lights were turned off when taking measurements. However, the contribution of electric light to the overall illuminance level was further investigated in the study. This was done by monitoring the light levels between 18:45 after sunset and 06:15 before sunrise. These light levels were then compared to the ones measured while the survey was being administered. The findings revealed that the illuminance levels measured on the work planes due to electric light were highly correlated with the horizontal illuminance measurements (p= 0.001).

This led to the assumption that any variations in light levels among workstations were due to differences in available natural light from sunrise and sunset (Izmir et al. 2022).

3.9.2.2 **Subjective Assessment**

This study aimed to assess the relationship between indoor lighting and personnel's wellbeing and performance in healthcare environments and the questionnaire design included the two methods used in this study for daylight assessment: seating location, and subjective rating. The questionnaire was designed to include multiple choice, Likert scale, and open-ended questions, and was divided into three sections.

The first section gathered information on lighting parameters, such as weather, measurement, use of blinds, use of daylight, distance from windows, and the second section gathered demographic information, including gender, job role, age, time spent working, and the type of ward. The third section contained specific questions and tasks related to participants' lighting perception, such as their current light level, satisfaction with light level, preference of light level, effect on performance and wellbeing, and the effect of glare and unwanted shadow.

To ensure a robust study, the procedure order of the questionnaire was carefully designed to start with open questions regarding lighting parameters and demographics, followed by lighting specific questions. This approach helped to prevent the latter questions from influencing the responses to the former ones. The study obtained ethical approval from the University of Plymouth, Arts and Humanities Faculty Research Ethics and Integrity Committee in October 2021.

According to a study conducted by Veitch and Newsham (2000), lighting can impact individuals' mood, performance, and overall well-being. Therefore, it is crucial to evaluate the impact of lighting on healthcare environments, where personnel’s wellbeing and performance can be affected by their physical environment. This study contributes to the existing body of literature on the topic and provides valuable insights for healthcare professionals, architects, and designers.

3.9.2.3 **Surveying Workstations**

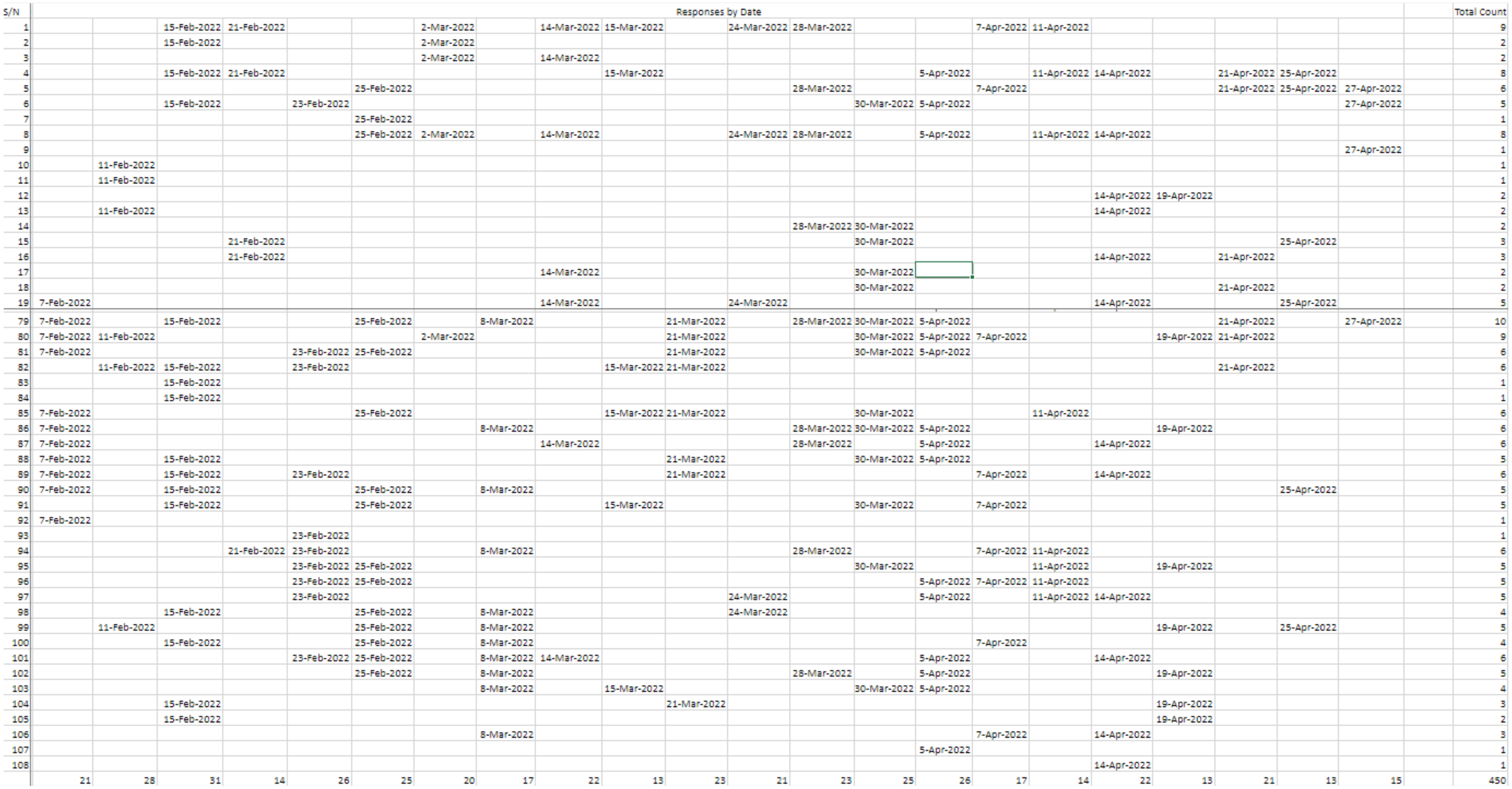
Lighting is an essential aspect of healthcare environments and can have a significant impact on the wellbeing, comfort, and performance of personnel. The response of personnel to the immediate daylight environment was studied in this research, with light intensity being the primary focus. Similar approaches to previous studies were utilised, including one conducted by Shepley et al. (2012), which measured light levels in ICU rooms on different sides and at the head of the bed. Another study by Walch et al. (2005) measured light levels twice a day at the centre of the window. Zadeh et al. (2014) used the orientation of nurses' working surface to measure light levels horizontally every 5 minutes to calculate average readings per hour.

In this study, workstations were surveyed at various times of the day, including in the morning, early afternoon, and late afternoon. Questionnaires were administered simultaneously with environmental measurements at the corresponding workstation. Additionally, HOBO MX202 Temp/Light sensor log data was collected in 5-minute intervals throughout the study duration. Personnel's preferred mode of questionnaire administration was paper-based, and questions were designed to record their view of the lighting conditions at the time of the measurements. These questions included user comfort, satisfaction, light level, glare, unwanted shadows, and use of daylight, all based on a 5-point Likert scale. The environmental measurements taken included instant readings of the light levels. A total of 450 data points were collected from February 2022 to April 2022 as shown by figures 10 and 11. Both survey and sensor data were stored on a local hard disk stored in a secure locker.

3.9.3 **Data Management and Analysis**

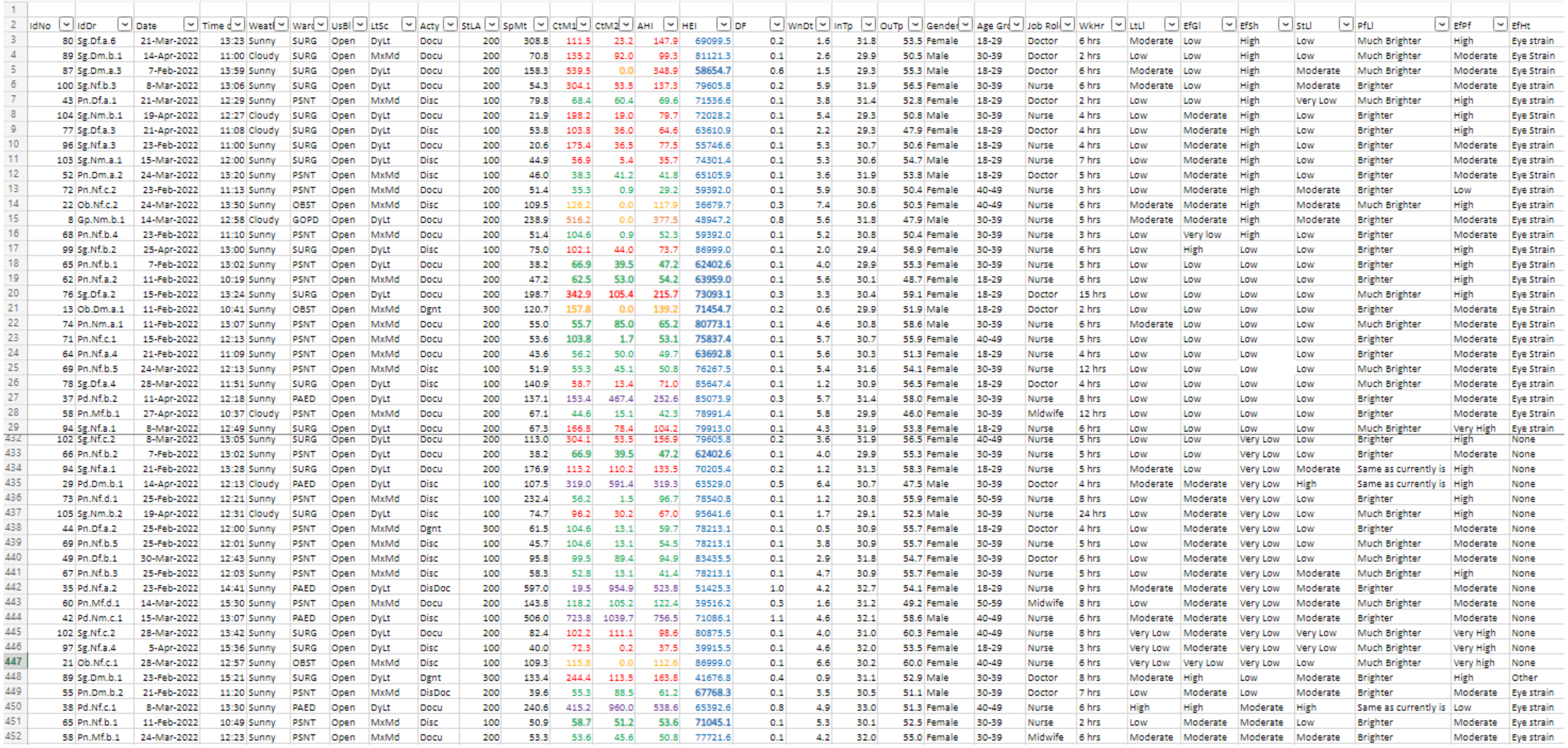
Quantitative analysis provides a valuable means of obtaining a broad overview of a field and drawing general conclusions. However, it often falls short in capturing contextual nuances and deeper insights. To address this inherent limitation, this study proposes the integration of qualitative methodologies for a more in-depth examination of the collected data regarding context and meaning. The distribution snapshot for data collection and the Excel entries for both physical measurements and subjective ratings can be seen in Figure 15 and Figure 16, respectively.

Quantitative data processing was carried out using a computer with the assistance of the Statistical Package for Social Science (SPSS) software. Descriptive and inferential statistics were applied to present essential information about the variables of interest, and the results were visually represented through tables and graphs. Various statistical techniques, including univariate, bivariate, and multivariate analyses, were employed to dissect the collected data. To confirm the nonparametric distribution of the survey data, normality tests such as the Kolmogorov–Smirnov and Shapiro–Wilk tests were performed. Subsequently, the Kendall Tau and Kruskal-Wallis tests were utilised to illuminate the strength and direction of relationships among variables, while the nonparametric Mann-Whitney U test allowed for comparisons of mean ranks. Significance was established at $p < .05$ when examining relationships among the study variables.



S/N	Responses by Date																							Total Count
1			15-Feb-2022	21-Feb-2022			2-Mar-2022		14-Mar-2022	15-Mar-2022		24-Mar-2022	28-Mar-2022			7-Apr-2022	11-Apr-2022							9
2			15-Feb-2022				2-Mar-2022																	2
3							2-Mar-2022		14-Mar-2022															2
4			15-Feb-2022	21-Feb-2022						15-Mar-2022					5-Apr-2022		11-Apr-2022	14-Apr-2022		21-Apr-2022	25-Apr-2022			8
5						25-Feb-2022							28-Mar-2022			7-Apr-2022				21-Apr-2022	25-Apr-2022	27-Apr-2022		6
6			15-Feb-2022		23-Feb-2022									30-Mar-2022	5-Apr-2022							27-Apr-2022		5
7						25-Feb-2022																		1
8						25-Feb-2022	2-Mar-2022		14-Mar-2022			24-Mar-2022	28-Mar-2022		5-Apr-2022		11-Apr-2022	14-Apr-2022						8
9																						27-Apr-2022		1
10		11-Feb-2022																						1
11		11-Feb-2022																						1
12																		14-Apr-2022	19-Apr-2022					2
13		11-Feb-2022																14-Apr-2022						2
14													28-Mar-2022	30-Mar-2022										2
15				21-Feb-2022										30-Mar-2022							25-Apr-2022			3
16				21-Feb-2022														14-Apr-2022		21-Apr-2022				3
17									14-Mar-2022					30-Mar-2022										2
18														30-Mar-2022						21-Apr-2022				2
19	7-Feb-2022								14-Mar-2022			24-Mar-2022						14-Apr-2022			25-Apr-2022			5
79	7-Feb-2022		15-Feb-2022			25-Feb-2022		8-Mar-2022			21-Mar-2022		28-Mar-2022	30-Mar-2022	5-Apr-2022					21-Apr-2022		27-Apr-2022		10
80	7-Feb-2022	11-Feb-2022					2-Mar-2022				21-Mar-2022			30-Mar-2022	5-Apr-2022	7-Apr-2022			19-Apr-2022	21-Apr-2022				9
81	7-Feb-2022				23-Feb-2022	25-Feb-2022					21-Mar-2022			30-Mar-2022	5-Apr-2022									6
82		11-Feb-2022	15-Feb-2022		23-Feb-2022					15-Mar-2022	21-Mar-2022									21-Apr-2022				6
83			15-Feb-2022																					1
84			15-Feb-2022																					1
85	7-Feb-2022					25-Feb-2022				15-Mar-2022	21-Mar-2022			30-Mar-2022			11-Apr-2022							6
86	7-Feb-2022							8-Mar-2022					28-Mar-2022	30-Mar-2022	5-Apr-2022				19-Apr-2022					6
87	7-Feb-2022								14-Mar-2022				28-Mar-2022		5-Apr-2022			14-Apr-2022						6
88	7-Feb-2022		15-Feb-2022								21-Mar-2022			30-Mar-2022	5-Apr-2022									5
89	7-Feb-2022		15-Feb-2022		23-Feb-2022						21-Mar-2022					7-Apr-2022		14-Apr-2022						6
90	7-Feb-2022		15-Feb-2022			25-Feb-2022		8-Mar-2022													25-Apr-2022			5
91			15-Feb-2022			25-Feb-2022				15-Mar-2022				30-Mar-2022		7-Apr-2022								5
92	7-Feb-2022																							1
93					23-Feb-2022																			1
94				21-Feb-2022	23-Feb-2022			8-Mar-2022					28-Mar-2022			7-Apr-2022	11-Apr-2022							6
95					23-Feb-2022	25-Feb-2022								30-Mar-2022			11-Apr-2022		19-Apr-2022					5
96					23-Feb-2022	25-Feb-2022									5-Apr-2022	7-Apr-2022	11-Apr-2022							5
97					23-Feb-2022							24-Mar-2022			5-Apr-2022		11-Apr-2022	14-Apr-2022						5
98			15-Feb-2022			25-Feb-2022		8-Mar-2022				24-Mar-2022												4
99		11-Feb-2022				25-Feb-2022		8-Mar-2022											19-Apr-2022		25-Apr-2022			5
100			15-Feb-2022			25-Feb-2022		8-Mar-2022								7-Apr-2022								4
101					23-Feb-2022	25-Feb-2022		8-Mar-2022	14-Mar-2022						5-Apr-2022			14-Apr-2022						6
102						25-Feb-2022		8-Mar-2022					28-Mar-2022		5-Apr-2022				19-Apr-2022					5
103								8-Mar-2022		15-Mar-2022				30-Mar-2022	5-Apr-2022									4
104			15-Feb-2022								21-Mar-2022								19-Apr-2022					3
105			15-Feb-2022																19-Apr-2022					2
106								8-Mar-2022								7-Apr-2022		14-Apr-2022						3
107															5-Apr-2022									1
108																		14-Apr-2022						1
	21	28	31	14	26	25	20	17	22	13	23	21	23	25	26	17	14	22	13	21	13	15		450

Figure 15: Akinbami A. (2022) Fieldnote: Snapshot of Data Collection Distribution.



2	IdNo	IdDr	Date	Time o	Weatl	Ward	UsBl	LtSc	Acty	StLA	SpMt	CtM1	CtM2	AHI	HEI	DF	WnDt	InTp	OuTp	Gender	Age Gr	Job Rol	WkHr	LtLl	EfGl	EfSh	StLl	PfLl	EfPf	EfHt
3	80	Sg.Df.a.6	21-Mar-2022	13:23	Sunny	SURG	Open	DyLt	Docu	200	308.8	111.5	23.2	147.9	69099.5	0.2	1.6	31.8	53.5	Female	18-29	Doctor	6 hrs	Moderate	Low	High	Low	Much Brighter	High	Eye strain
4	89	Sg.Dm.b.1	14-Apr-2022	11:00	Cloudy	SURG	Open	MxMd	Docu	200	70.8	135.2	92.0	99.3	81121.3	0.1	2.6	29.9	50.5	Male	30-39	Doctor	2 hrs	Low	Low	High	Low	Much Brighter	Moderate	Eye Strain
5	87	Sg.Dm.a.3	7-Feb-2022	13:59	Sunny	SURG	Open	DyLt	Docu	200	158.3	539.5	0.0	348.9	58654.7	0.6	1.5	29.3	55.3	Male	18-29	Doctor	6 hrs	Moderate	Low	High	Moderate	Much Brighter	Moderate	Eye Strain
6	100	Sg.Nf.b.3	8-Mar-2022	13:06	Sunny	SURG	Open	DyLt	Docu	200	54.3	304.1	53.5	137.3	79605.8	0.2	5.9	31.9	56.5	Female	30-39	Nurse	6 hrs	Moderate	Low	High	Moderate	Brighter	Moderate	Eye strain
7	43	Pn.Df.a.1	21-Mar-2022	12:29	Sunny	PSNT	Open	MxMd	Disc	100	79.8	68.4	60.4	69.6	71536.6	0.1	3.8	31.4	52.8	Female	18-29	Doctor	2 hrs	Low	Low	High	Very Low	Much Brighter	High	Eye strain
8	104	Sg.Nm.b.1	19-Apr-2022	12:27	Cloudy	SURG	Open	DyLt	Docu	200	21.9	198.2	19.0	79.7	72028.2	0.1	5.4	29.3	50.8	Male	30-39	Nurse	4 hrs	Low	Moderate	High	Low	Brighter	High	Eye Strain
9	77	Sg.Df.a.3	21-Apr-2022	11:08	Cloudy	SURG	Open	DyLt	Disc	100	53.8	103.8	36.0	64.6	63610.9	0.1	2.2	29.3	47.9	Female	18-29	Doctor	4 hrs	Low	Moderate	High	Low	Brighter	High	Eye Strain
10	96	Sg.Nf.a.3	23-Feb-2022	11:00	Sunny	SURG	Open	DyLt	Docu	200	20.6	175.4	36.5	77.5	55746.6	0.1	5.3	30.7	50.6	Female	18-29	Nurse	4 hrs	Low	Moderate	High	Low	Brighter	Moderate	Eye strain
11	103	Sg.Nm.a.1	15-Mar-2022	12:00	Sunny	SURG	Open	DyLt	Disc	100	44.9	56.9	5.4	35.7	74301.4	0.1	5.3	30.6	54.7	Male	18-29	Nurse	7 hrs	Low	Moderate	High	Low	Brighter	Moderate	Eye strain
12	52	Pn.Dm.a.2	24-Mar-2022	13:20	Sunny	PSNT	Open	MxMd	Disc	100	46.0	38.3	41.2	41.8	65105.9	0.1	3.6	31.9	53.8	Male	18-29	Doctor	5 hrs	Low	Moderate	High	Low	Brighter	Moderate	Eye Strain
13	72	Pn.Nf.c.2	23-Feb-2022	11:13	Sunny	PSNT	Open	MxMd	Docu	200	51.4	35.3	0.9	29.2	59392.0	0.1	5.9	30.8	50.4	Female	40-49	Nurse	3 hrs	Low	Moderate	High	Moderate	Brighter	Low	Eye strain
14	22	Ob.Nf.c.2	24-Mar-2022	13:50	Sunny	OBST	Open	MxMd	Disc	100	109.5	126.2	0.0	117.9	36679.7	0.3	7.4	30.6	50.5	Female	40-49	Nurse	6 hrs	Moderate	Moderate	High	Moderate	Much Brighter	High	Eye strain
15	8	Gp.Nm.b.1	14-Mar-2022	12:58	Cloudy	GOPD	Open	DyLt	Docu	200	238.9	516.2	0.0	377.5	48947.2	0.8	5.6	31.8	47.9	Male	30-39	Nurse	5 hrs	Moderate	Moderate	High	Moderate	Brighter	Moderate	Eye strain
16	68	Pn.Nf.b.4	23-Feb-2022	11:10	Sunny	PSNT	Open	MxMd	Docu	200	51.4	104.6	0.9	52.3	59392.0	0.1	5.2	30.8	50.4	Female	30-39	Nurse	3 hrs	Low	Very low	High	Low	Brighter	Moderate	Eye strain
17	99	Sg.Nf.b.2	25-Apr-2022	13:00	Sunny	SURG	Open	DyLt	Disc	100	75.0	102.1	44.0	73.7	86999.0	0.1	2.0	29.4	56.9	Female	30-39	Nurse	6 hrs	Low	High	Low	Low	Brighter	High	Eye Strain
18	65	Pn.Nf.b.1	7-Feb-2022	13:02	Sunny	PSNT	Open	DyLt	Docu	200	38.2	66.9	39.5	47.2	62402.6	0.1	4.0	29.9	55.3	Female	30-39	Nurse	5 hrs	Low	Low	Low	Low	Brighter	High	Eye Strain
19	62	Pn.Nf.a.2	11-Feb-2022	10:19	Sunny	PSNT	Open	MxMd	Docu	200	47.2	62.5	53.0	54.2	63959.0	0.1	5.6	30.1	48.7	Female	18-29	Nurse	6 hrs	Low	Low	Low	Low	Brighter	High	Eye Strain
20	76	Sg.Df.a.2	15-Feb-2022	13:24	Sunny	SURG	Open	DyLt	Docu	200	198.7	342.9	105.4	215.7	73093.1	0.3	3.3	30.4	59.1	Female	18-29	Doctor	15 hrs	Low	Low	Low	Low	Much Brighter	High	Eye Strain
21	13	Ob.Dm.a.1	11-Feb-2022	10:41	Sunny	OBST	Open	MxMd	Dgnt	300	120.7	157.8	0.0	139.2	71454.7	0.2	0.6	29.9	51.9	Male	18-29	Doctor	2 hrs	Low	Low	Low	Low	Brighter	Moderate	Eye Strain
22	74	Pn.Nm.a.1	11-Feb-2022	13:07	Sunny	PSNT	Open	MxMd	Docu	200	55.0	55.7	85.0	65.2	80773.1	0.1	4.6	30.8	58.6	Male	30-39	Nurse	6 hrs	Moderate	Low	Low	Low	Much Brighter	Moderate	Eye Strain
23	71	Pn.Nf.c.1	15-Feb-2022	12:13	Sunny	PSNT	Open	MxMd	Docu	200	53.6	103.8	1.7	53.1	75837.4	0.1	5.7	30.7	55.9	Female	40-49	Nurse	5 hrs	Low	Low	Low	Low	Brighter	Moderate	Eye strain
24	64	Pn.Nf.a.4	21-Feb-2022	11:09	Sunny	PSNT	Open	MxMd	Docu	200	43.6	56.2	50.0	49.7	63692.8	0.1	5.6	30.3	51.3	Female	18-29	Nurse	4 hrs	Low	Low	Low	Low	Brighter	Moderate	Eye Strain
25	69	Pn.Nf.b.5	24-Mar-2022	12:13	Sunny	PSNT	Open	MxMd	Disc	100	51.9	55.3	45.1	50.8	76267.5	0.1	5.4	31.6	54.1	Female	30-39	Nurse	12 hrs	Low	Low	Low	Low	Much Brighter	Moderate	Eye Strain
26	78	Sg.Df.a.4	28-Mar-2022	11:51	Sunny	SURG	Open	DyLt	Disc	100	140.9	58.7	13.4	71.0	85647.4	0.1	1.2	30.9	56.5	Female	18-29	Doctor	4 hrs	Low	Low	Low	Low	Much Brighter	Moderate	Eye strain
27	37	Pd.Nf.b.2	11-Apr-2022	12:18	Sunny	PAED	Open	DyLt	Docu	200	137.1	153.4	467.4	252.6	85073.9	0.3	5.7	31.4	58.0	Female	30-39	Nurse	8 hrs	Low	Low	Low	Low	Brighter	Moderate	Eye strain
28	58	Pn.Mf.b.1	27-Apr-2022	10:37	Cloudy	PSNT	Open	MxMd	Docu	200	67.1	44.6	15.1	42.3	78991.4	0.1	5.8	29.9	46.0	Female	30-39	Midwife	12 hrs	Low	Low	Low	Low	Brighter	Moderate	Eye Strain
29	94	Sg.Nf.a.1	8-Mar-2022	12:49	Sunny	SURG	Open	DyLt	Docu	200	67.3	166.8	78.4	104.2	79913.0	0.1	4.3	31.9	53.8	Female	18-29	Nurse	6 hrs	Low	Low	Low	Low	Much Brighter	Very High	Eye strain
432	102	Sg.Nf.c.2	8-Mar-2022	13:05	Sunny	SURG	Open	DyLt	Docu	200	113.0	304.1	53.5	156.9	79605.8	0.2	3.6	31.9	56.5	Female	40-49	Nurse	5 hrs	Low	Low	Very Low	Low	Brighter	High	None
433	66	Pn.Nf.b.2	7-Feb-2022	13:02	Sunny	PSNT	Open	DyLt	Docu	200	38.2	66.9	39.5	47.2	62402.6	0.1	4.0	29.9	55.3	Female	30-39	Nurse	5 hrs	Low	Low	Very Low	Low	Brighter	Moderate	None
434	94	Sg.Nf.a.1	21-Feb-2022	13:28	Sunny	SURG	Open	DyLt	Docu	200	176.9	113.2	110.2	133.5	70205.4	0.2	1.2	31.3	58.3	Female	18-29	Nurse	5 hrs	Moderate	Low	Very Low	Moderate	Same as currently is	High	None
435	29	Pd.Dm.b.1	14-Apr-2022	12:13	Cloudy	PAED	Open	DyLt	Disc	100	107.5	319.0	591.4	319.3	63529.0	0.5	6.4	30.7	47.5	Male	30-39	Doctor	4 hrs	Moderate	Moderate	Very Low	High	Same as currently is	High	None
436	73	Pn.Nf.d.1	25-Feb-2022	12:21	Sunny	PSNT	Open	MxMd	Disc	100	232.4	56.2	1.5	96.7	78540.8	0.1	1.2	30.8	55.9	Female	50-59	Nurse	8 hrs	Low	Moderate	Very Low	Low	Brighter	High	None
437	105	Sg.Nm.b.2	19-Apr-2022	12:31	Cloudy	SURG	Open	DyLt	Disc	100	74.7	96.2	30.2	67.0	95641.6	0.1	1.7	29.1	52.5	Male	30-39	Nurse	24 hrs	Low	Moderate	Very Low	Low	Much Brighter	High	None
438	44	Pn.Df.a.2	25-Feb-2022	12:00	Sunny	PSNT	Open	MxMd	Dgnt	300	61.5	104.6	13.1	59.7	78213.1	0.1	0.5	30.9	55.7	Female	18-29	Doctor	4 hrs	Low	Moderate	Very Low	Low	Brighter	Moderate	None
439	69	Pn.Nf.b.5	25-Feb-2022	12:01	Sunny	PSNT	Open	MxMd	Disc	100	45.7	104.6	13.1	54.5	78213.1	0.1	3.8	30.9	55.7	Female	30-39	Nurse	5 hrs	Low	Moderate	Very Low	Low	Much Brighter	Moderate	None
440	49	Pn.Df.b.1	30-Mar-2022	12:43	Sunny	PSNT	Open	MxMd	Disc	100	95.8	99.5	89.4	94.9	83435.5	0.1	2.9	31.8	54.7	Female	30-39	Doctor	6 hrs	Low	Moderate	Very Low	Low	Much Brighter	Moderate	None
441	67	Pn.Nf.b.3	25-Feb-2022	12:03	Sunny	PSNT	Open	MxMd	Disc	100	58.3	52.8	13.1	41.4	78213.1	0.1	4.7	30.9	55.7	Female	30-39	Nurse	5 hrs	Low	Moderate	Very Low	Moderate	Much Brighter	High	None
442	35	Pd.Nf.a.2	23-Feb-2022	14:41	Sunny	PAED	Open	DyLt	DisDoc	200	597.0	19.5	954.9	523.8	51425.3	1.0	4.2	32.7	54.1	Female	18-29	Nurse	9 hrs	Moderate	Moderate	Very Low	Moderate	Brighter	Moderate	None
443	60	Pn.Mf.d.1	14-Mar-2022	15:30	Sunny	PSNT	Open	MxMd	Docu	200	143.8	118.2	105.2	122.4	39516.2	0.3	1.6	31.2	49.2	Female	50-59	Midwife	8 hrs	Low	Moderate	Very Low	Moderate	Much Brighter	Moderate	None
444	42	Pd.Nm.c.1	15-Mar-2022	13:07	Sunny	PAED	Open	DyLt	Disc	100	506.0	723.8	1039.7	756.5	71086.1	1.1	4.6	32.1	58.6	Male	40-49	Nurse	6 hrs	Moderate	Moderate	Very Low	Moderate	Brighter	Moderate	None
445	102	Sg.Nf.c.2	28-Mar-2022	13:42	Sunny	SURG	Open	DyLt	Docu	200	82.4	102.2	111.1	98.6	80875.5	0.1	4.0	31.0	60.3	Female	40-49	Nurse	8 hrs	Very Low	Moderate	Very Low	Very Low	Much Brighter	Very High	None
446	97	Sg.Nf.a.4	5-Apr-2022	15:36	Sunny	SURG	Open	DyLt	Disc	100	40.0	72.3	0.2	37.5	39915.5	0.1	4.6	32.0	53.5	Female	18-29	Nurse	3 hrs	Very Low	Moderate	Very Low	Very Low	Much Brighter	Very High	None
447	21	Ob.Nf.c.1	28-Mar-2022	12:57	Sunny	OBST	Open	MxMd	Disc	100	109.3	115.8	0.0	112.6	86999.0	0.1	6.6	30.2	60.0	Female	40-49	Nurse	6 hrs	Very Low	Very Low	Very Low	Low	Much Brighter	Very high	None
448	89	Sg.Dm.b.1	23-Feb-2022	15:21	Sunny	SURG	Open	DyLt	Dgnt	300	133.4	244.4	113.5	163.8	41676.8	0.4	0.9	31.1	52.9	Male	30-39	Doctor	8 hrs	Moderate	High	Low	Moderate	Brighter	High	Other
449	55	Pn.Dm.b.2	21-Feb-2022	11:20	Sunny	PSNT	Open	MxMd	DisDoc	200	39.6	55.3	88.5	61.2	67768.3	0.1	3.5	30.5	51.1	Male	30-39	Doctor	7 hrs	Low	Moderate	Low	Moderate	Brighter	Moderate	Eye strain
450	38	Pd.Nf.c.1	8-Mar-2022	13:30	Sunny	PAED	Open	DyLt	Docu	200	240.6	415.2	960.0	538.6	65392.6	0.8	4.9	33.0	51.3	Female	40-49	Nurse	6 hrs	High	High	Moderate	High	Same as currently is	Low	Eye strain
451	65	Pn.Nf.b.1	11-Feb-2022	10:49	Sunny	PSNT	Open	MxMd	Disc	100	50.9	58.7	51.2	53.6	71045.1	0.1	5.3	30.1	52.5	Female	30-39	Nurse	2 hrs	Low	Moderate	Moderate	Low	Brighter	Moderate	Eye strain
452	58	Pn.Mf.b.1	24-Mar-2022	12:23	Sunny	PSNT	Open	MxMd	Docu	200	53.3	53.6	45.6	50.8	77721.6	0.1	4.2	32.0	55.0	Female	30-39	Midwife	6 hrs	Moderate	Moderate	Moderate	Moderate	Brighter	Moderate	Eye strain

Figure 16: Akinbami A. (2022) Fieldnote: Snapshot of Physical Measurements and Personnel Responses.

Descriptive analysis was used to offer an overview of personal and work-related characteristics, satisfaction aspects, and indoor lighting conditions. Differences among the five ward types were computed using a Pearson Chi-Square test, with Bonferroni correction applied for categorical questions, and the Kruskal-Wallis test for continuous scales, as the latter were found to be non-normally distributed (Shapiro-Wilk $p < 0.001$). To assess relationships between dependent and independent variables, categorical multiple regression analysis was employed. Furthermore, correlation analysis was utilised to scrutinise the data gathered from respondents' questionnaires regarding their evaluation of lighting condition variables. A significance level of 0.05 was set to determine associations between variables.

In this research, the qualitative data obtained through interviews, underwent a deductive coding and analysis process using thematic analysis, primarily due to the study's small sample size and mixed-methods design. Furthermore, the outcomes generated from the quantitative analysis underwent triangulation in the qualitative study, after conducting data analysis using SPSS. Qualitative analysis served to complement the themes and concepts that emerged from the quantitative analysis, thereby reducing bias, and enhancing the overall credibility of the data. Upon completing survey questions, participants were given the option to participate in further interviews. Sixteen health professionals, comprising ten females and six males, were interviewed. These semi-structured interviews were conducted on-site, and discussions centred around three main themes: lighting conditions supporting workstation tasks, lighting's impact on general well-being, and overall satisfaction with lighting conditions. Participant identification was linked to job roles and gender, ensuring anonymity. Among those interviewed were six doctors, six nurses, two midwives, one pharmacist, and one physiotherapist. Interviews were recorded and transcribed to capture all statements accurately and used the thematic analysis to highlight themes and trend.

Thematic analysis as a research technique is useful to uncover patterns within qualitative data, such as interviews, surveys, and discussions (Braun & Clarke, 2006; Nowell et al. 2017). Useful across fields like healthcare and social sciences, thematic analysis informs policy decisions, generates research questions, and supports practice development (Nowell et al. 2017). Thematic analysis's strength lies in its flexibility as it applies to textual, visual, and audio data (Braun & Clarke, 2006) in exploring diverse themes and patterns aligned with research objectives. The process involves coding data, identifying patterns, and defining themes. Codes label data segments, from surface-level to interpretive, forming themes that connect codes (Braun & Clarke, 2006). Clear theme descriptions are crucial, reflecting data and research questions. This systematic method ensures reliable, replicable results. Although, thematic analysis can introduce bias due to subjectivity and theoretical influence (Braun & Clarke, 2006), it benefits remains valuable for qualitative research.

Therefore, the use of both qualitative and quantitative data analysis techniques helped to provide a more complete understanding of the research topic. This mixed method approach ensures a comprehensive and robust understanding of the research questions at hand. Furthermore, the appropriate use of statistical methods and software tools ensured that the data was processed accurately and efficiently. Overall, the study's rigorous methodology provides confidence in the validity of its conclusions.

3.9.3.1 ***Respondents Profile***

Survey responses have been analysed to generate participants' profile. There are four profile questions in the survey.

Q1. How do you describe your Gender?

a. Female
b. Male
c. Prefer not to say

The question collates the data on the gender ratio of the participants (figures 17 and 18). The literature review highlighted that male and female have different physical comfort preferences. The data shows that 72% are female and 28% are male. This data would help to identify any correlation between gender and responses of the participants.

Gender	**Count**
Female	78.44%
Male	21.56%
Grand Total	**100.00%**

Figure 17: Survey Response- Gender Profile.

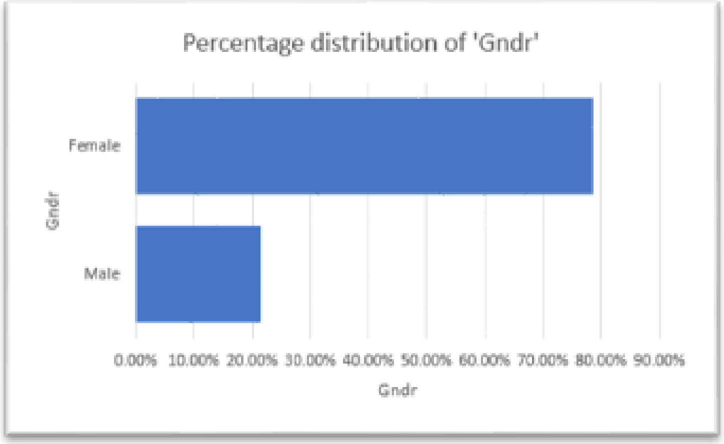


Figure 18: Survey Response- Gender Profile.

Q2. What is your age group do you belong?

  a. 18-29
  b. 30-39
  c. 40-49
  d. 50-59

This question outlines the age profile of the survey participants (Figures 19, 20, 21, 22). The majority (43%) of the participants belong to the 18-29 age group, 40% of participants are aged 30-39, 16% are within 40-49 age group and 1% are 50-59. The literature has indicated that age significantly influences occupant physical comfort. The participant's age data would help to analyse any difference in response based on the participant's age.

Age Group	**Count**
18-29	43.56%
30-39	40.22%
40-49	15.56%
50-59	0.67%
Grand Total	**100.00%**

Figure 19: Survey Response- Age Profile.

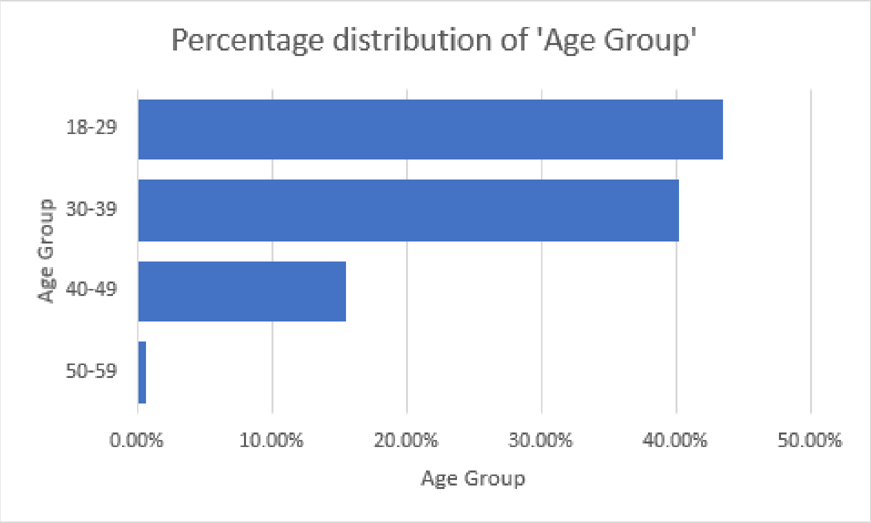


Figure 20: Survey Response-Age Profile.

Age Group	**Gender**	**Count**
18-29	Female	33.78%
	Male	9.78%
18-29 Total		**43.56%**
30-39	Female	30.89%
	Male	9.33%
30-39 Total		**40.22%**
40-49	Female	13.11%
	Male	2.44%
40-49 Total		**15.56%**
50-59	Female	0.67%
50-59 Total		**0.67%**
Grand Total		**100.00%**

Figure 21: Survey Response- % Distribution of 'Age Group' by 'Gender'.

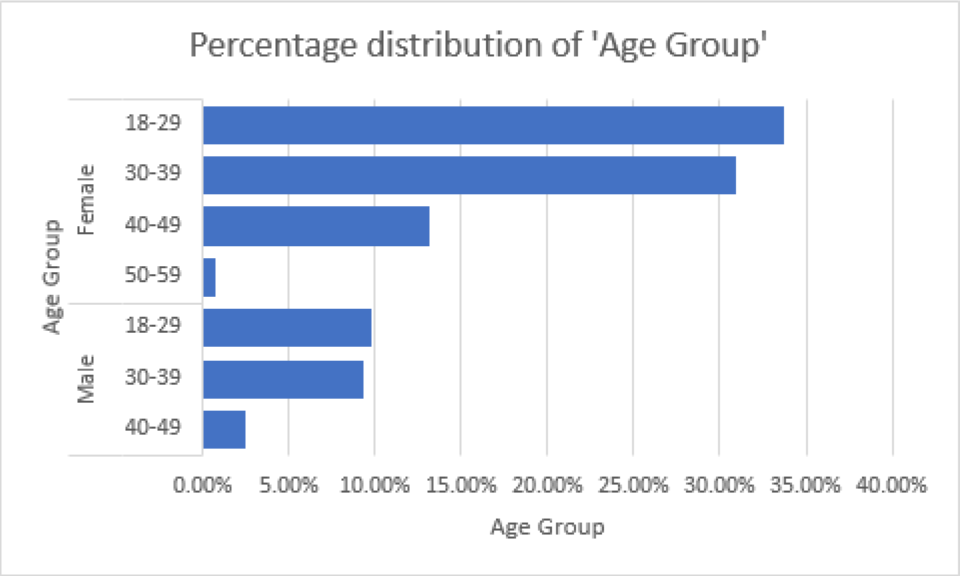


Figure 22: Survey Response- % Distribution of 'Age Group' by 'Gender'.

Q3. How would you describe your job role?

a. Nurse
b. Doctor
c. Midwife
d. Pharmacist
e. Physiotherapist

This question collates data on the job profile of the survey participants (Figure 23). There are 58% nurses and midwives participating in the survey. 40% of the participants are doctors and consultants at various levels. 2% participants are other health professionals like pharmacist and physiotherapist. This data will be analysed with occupant response to identifying any patterns of response based on the profiles of the participants.

Gender/A. Group		**Female**				**Total**	**Male**			**Total**	**Total**
Job Role	**Ward**	**18-29**	**30-39**	**40-49**	**50-59**		**18-29**	**30-39**	**40-49**		
Doctor	OBST	2	2			4	2			2	6
	PAED	4	5			9	1	2	2	5	14
	PSNT	37	9			46	9	8	2	19	65
	SURG	59	12	2		73	22	16	1	39	112
Total		**102**	**28**	**2**		**132**	**34**	**26**	**5**	**65**	**197**
Midwife	GOPD			9		9					9
	OBST	2	6	4		12					12
	PAED	2	11			13					13
	PSNT	1	8	2	1	12					12
	SURG		1			1					1
Total		**5**	**26**	**15**	**1**	**47**					**47**
Nurse	GOPD	4	14	5		23	1	8	1	10	33
	OBST		11	7		18					18
	PAED	8	11	3	1	23	5	1	2	8	31
	PSNT	12	34	16	1	63		1		1	64
	SURG	21	14	11		46	4	5	3	12	58
Total		**45**	**84**	**42**	**2**	**173**	**10**	**15**	**6**	**31**	**204**
Pharm	SURG		1			1					1
Total			**1**			**1**					**1**
Physio	SURG							1		1	1
Total								**1**		**1**	**1**
Grand Total		**152**	**139**	**59**	**3**	**353**	**44**	**42**	**11**	**97**	**450**

Figure 23: Survey Response- Distribution of 'Job Role' by 'Ward' 'Gender' by 'Age Group'.

Q4. How many hours have you been working today?

The question outlines the number of hours spent at the workplace at the time of survey. This data can help highlight any correlation between occupant response and the number of hours worked in the ward. The data suggests that 60% of the respondents have been working for 4 hours to 6 hours at the time of the survey. About 16% of participants have spent less than 4 hours in the workplace. Another 15% of the participants have been at their workplace for a period of over 6 hours to 8 hours. Only 9% of participants have worked more than 8 hours at the time of administration of questionnaire.

The analysis from the above questions will contribute to the formulation of personnel profiles. These profiles will be instrumental in creating a personalised assessment of individual's subjective performance pattern and how they react to different indoor lighting conditions. Such analyses have the potential to unveil distinctive correlations between occupant subjective performance and indoor lighting within healthcare environments. Notably, these personnel profiles underscore the diverse nature of the participants, encompassing various backgrounds, genders, ages, and job role. This highlights the fact that the outcomes from the analyses reflect the occupant experience within the healthcare environment and are not limited to a single category or occupant.

3.10 Chapter Summary

This chapter, explore the design and execution of fieldwork interactions within the context of healthcare indoor lighting research. Building upon the previous chapter, which shows the positive impact of lighting conditions on personnel’s well-being and performance, this chapter examines the methodologies employed to investigate this subject.

The chapter critically evaluates six selected studies to establish an evidence-based methodology for data collection and analysis. These studies utilised a combination of surveys, interviews, experiments, and lighting measurements to understand the impact of healthcare lighting on staff.

Philosophical foundations, particularly the pragmatic approach, are discussed as the guiding principle for the research methodological design. This approach underlines the importance of a mixed-method approach during fieldwork to comprehend the complexities of the subject.

The chapter discusses the implications and limitations of the research methods employed, emphasising the importance of the perceptual context of well-being and performance in healthcare. The flexible and collaborative approach, guided by pragmatism, aims to bring about positive change by revealing the hidden depths of the healthcare indoor lighting environment.

Additionally, the chapter examines the quantitative data collection methods used in the study, focusing on healthcare workers' perceptions of indoor lighting's impact on their well-being and performance.

It details the use of physical measurements and subjective ratings through surveys, emphasising the importance of data validity and reliability as shown in figures 24, 25, and 26.

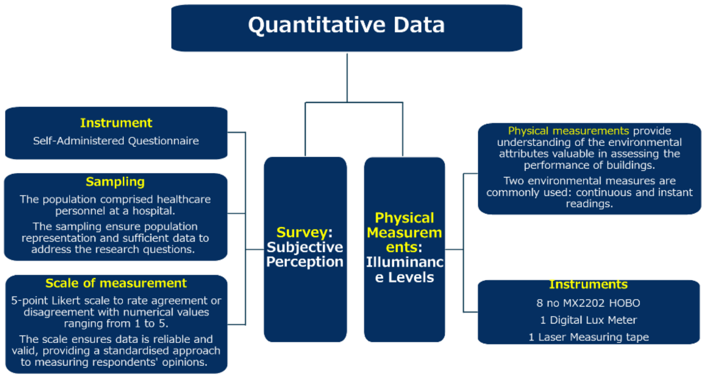
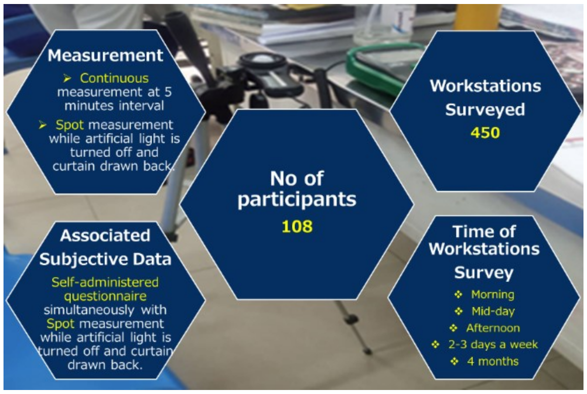


Figure 24: Quantitative Data.


Measurement

- Continuous measurement at 5 minutes interval
- Spot measurement while artificial light is turned off and curtain drawn back

No of participants
108

Workstations Surveyed
450

Associated Subjective Data
Self-administered questionnaire simultaneously with Spot measurement while artificial light is turned off and curtain drawn back.

Time of Workstations Survey

- Morning
- Mid-day
- Afternoon
- 2-3 days a week
- 4 months

Figure 25: Details of Quantitative Data Collected.


Various health professional collaborating in case management and individuals completing questionnaire.

Fieldnote Illustrating Data Logger's Placement

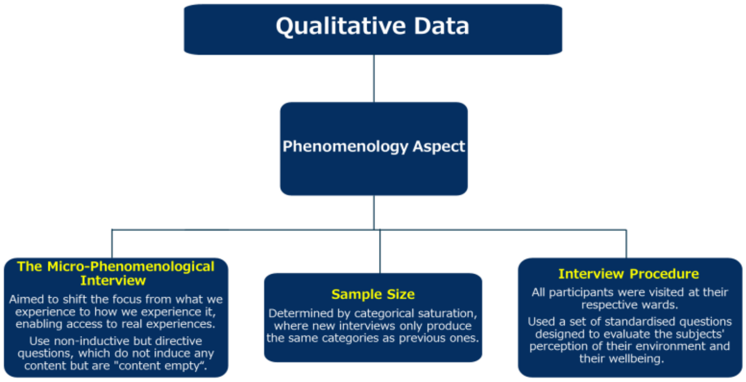
Nearby Building obstructing Natural Light and using digital lux meter on tripod.

Personnel engaged and Completing Questionnaire

Fieldnote Illustrating the Entry of Natural Light

Figure 26: Surveying Workstations.

Furthermore, the integration of qualitative data collection methods, including phenomenology, is highlighted for capturing nuances beyond numerical data as shown figures 27, 28, and 29. The chapter concludes with insights into the study's site location, microclimate, and data collection process, all aimed at evaluating the impact of indoor lighting on healthcare workers.



Qualitative Data

Phenomenology Aspect

The Micro-Phenomenological Interview

Aimed to shift the focus from what we experience to how we experience it, enabling access to real experiences.

Use non-inductive but directive questions, which do not induce any content but are "content empty".

Sample Size

Determined by categorical saturation, where new interviews only produce the same categories as previous ones.

Interview Procedure

All participants were visited at their respective wards.

Used a set of standardised questions designed to evaluate the subjects' perception of their environment and their wellbeing.

Figure 27: Qualitative Data.

No Participants
16 of 108

Participants demography

- ❖10 females
- ❖6 males
  - 6 doctors
  - 6nurses
  - 2 midwives
  - 1 pharmacist
  - 1 physiotherapist

Insights from Study

Interviews were recorded and transcribed to capture all statements accurately.

Procedure

All participants in the study were visited at their respective wards.

The interview contained eight standardised questions designed to evaluate the subjects' perception of their environment and their wellbeing.

Figure 28: Details of Qualitative Data Collected

Fieldnote capturing research's briefing personnel prior to interview session.

Fieldnote Illustrating Interview Session at Obstetric

Fieldnote capturing entrance to room where interview was conducted at GOPD.

Fieldnote capturing Nursing Mother at Post Natal unit as Personnel was being interviewed privately

Fieldnote Illustrating the Entry of Natural Light

Figure 29: Capturing Interview Procedures.

To address the limitations of quantitative data, the study proposes the integration of qualitative methodologies to examine contextual nuances and deeper insights. Quantitative data processing using SPSS software and various statistical techniques is detailed, along with normality tests and significance levels.

The chapter also discusses the use of descriptive analysis, Chi-Square tests, Kruskal-Wallis tests, multiple regression analysis, and correlation analysis to extract meaningful insights from the collected data.

Incorporating qualitative data obtained through interviews, the study utilised thematic analysis to complement and enhance the credibility of quantitative findings. The process involved deductive coding and analysis to identify themes and patterns emerging from interviews.

The chapter highlights the strengths of thematic analysis in uncovering patterns within qualitative data, emphasising its flexibility and systematic approach. While acknowledging potential biases, it underscores the value of thematic analysis in qualitative research.

Therefore, the use of both qualitative and quantitative data analysis techniques helped to provide a better understanding of the research topic. This mixed method approach ensures a better understanding of the research questions at hand. Furthermore, the appropriate use of statistical methods and software tools ensured that the data was processed accurately and efficiently. Overall, the study's rigorous methodology provides confidence in the validity of its conclusions.

Chapter IV: Quantitative: Results and Findings

The results of analysed quantitative data collected is presented in this chapter along with the findings. It describes how various indoor lighting conditions impact personnel' well-being and performance. The chapter is divided into five parts. The first section introduces the chapter and describes the factors considered in the analysis of each indoor lighting conditions and their impact on subjective performance. Section two describes the results of various lighting condition, followed by an outline of the results on the perception of illuminance levels at various workstations compare with measured illuminance in section 3. Section four introduces the results on the effect of intrinsic variables (age, gender, job role) on personnel wellbeing and performance which is then followed by explanations of the effect of natural light on personnel wellbeing and performance. A summary of the primary results and findings is provided.

4.1 Introduction

This study’s field investigation focuses on environmental lighting conditions, which were identified in the literature review outlined in chapter 2. Using the proposed methodology detailed in chapter 3, exploring, and characterising three key lighting characteristics as well as two sources of lighting disturbances. The investigation method employed both quantitative and qualitative approaches. Quantitative data, shown in fig 22, including measured illuminance levels collected through lux instruments and respondents' perceptions of lighting conditions using self-administered questionnaires, were analysed by the statistical software SPSS 26. The data analysis is performed at the group level. As highlighted in section 1.8., subjective performance response data of individuals from different wards in the healthcare facility were aggregated to determine correlations between indoor lighting conditions and overall personnel performance.

The study's objective was to examine the correlations of the lighting conditions with the well-being and performance of personnel at their respective workstations across different wards. The identified lighting conditions include:

Lighting Characteristics:

- Light Source
- Illumination Levels
- Use of Daylight

Lighting Disturbances:

- Glare
- Unwanted Shadows

The evaluation of these lighting parameters yielded significant findings.

This research assumed that personnel within various wards would experience varying lighting conditions compared to each other, and this pattern would remain consistent across different wards included in the study. To assess this assumption, the study analysed the level of agreement among nurses, midwives, and doctors regarding their perceptions of lighting conditions in the five studied wards. The calculated averages for each ward were then compared to the overall average of the other wards. This comparison was conducted for all possible pairs to determine whether any significant rating differences were statistically significant or within the margin of error. The Kruskal-Wallis ranks test was utilised to assess the satisfaction level with different lighting conditions.

The study also posited that across different wards, there would generally be a shared perception among nurses, midwives, and doctors concerning illuminance levels at various workstations, and this assessment would align with measured illuminance. In other words, it was expected that consensus would emerge on certain locations being dimmer while others were brighter and that these perceptions would correlate with measured light levels. To investigate this, participants rated the light level in each workstation of the five wards on a scale from 'very low' to 'very high.'

Moreover, the study suggested that specific locations within the ward might be preferred to have light levels different from those currently observed. Participants were asked to rate the preferred light level at each workstation in the five wards, using a scale ranging from 'much less bright' to 'much brighter.' The Mann–Whitney test was employed to compare the ranks of light level preferences. The survey also gathered data on whether lighting disturbances, such as glare and shadows, affected nurses, midwives, and doctors.

The investigation probe into the potential impact of intrinsic variables on participants' responses, aiming to account for variations in results. Factors explored included variations in responses based on working hours, age, and overall well-being. Survey data was categorised into two groups: responses from those working more than 6 hours during day shifts and responses from those working fewer than 6 hours during day shifts.

Furthermore, the study assumed that satisfaction rankings could significantly differ among nurses, midwives, and doctors within different age groups. To test this, the satisfaction ratings for each age group were compared within each ward. Additionally, an aggregate variable of overall satisfaction scores across all wards was analysed to identify variations among different age groups. The study also proposed that different age groups might be differently affected by glare and shadows. A Mann–Whitney test was employed to investigate this assumption, dividing the dataset into three age categories. Additionally, the study stated that overall satisfaction rankings would vary based on the hours worked in each ward. The study also aimed to compare nurses, midwives, and doctors based on their engagement in different activities, recognising that various activities require distinct light levels. It was assumed that overall satisfaction rankings would significantly differ between individuals engaged in different activities.

4.2 Lighting Measurements

Based on the background provided in section 4.1, this study conducted physical measurements of illuminance levels at various workstations within selected hospital wards. The purpose of these measurements was to determine whether the illuminance levels at these workstations met the prescribed standards for their specific activities. It encompassed a total of 450 lighting assessments conducted across five wards of the hospital. The primary objective was to identify instances where the illuminance levels either met or fell short of the required standards. This enquiry was particularly motivated by the lack of available literature on indoor illumination levels in Nigeria and other developing African nations, as highlighted in section 1.4 (problem statement). Existing standards such as CIE-ISO, IESNA, and EN offer guidelines for minimal indoor illumination levels in healthcare facilities.

The results of the study showed significant variations in illuminance levels across workstations, with some workstations recording low levels of illuminance while others received high levels of illuminance. The illuminance levels ranged from 14 lux, observed in a southeast facing window, to 788 lux during an early morning sunrise, as depicted in Table 7.

Table 7: Measurements of Physical Illuminance in Different Wards.

Department/Ward	**Participants** n	**Workstations surveyed** n	**Illuminance (lux)**	
			Min-Max	Mean
GOPD	9	42	226-688	402
Obstetrics	14	36	55-145	112
Paediatrics	19	58	78-788	390
Post Natal	32	141	18-137	67
Surgical	34	173	14-500	139
Total	108	450		

The EN 12464-1 standard for various task or activity in ward environment is provided in Table 8.

Table 8: Standard for Light Levels in Wards, Including Maternity Wards, for Various Task or Activity.

Type of interior, task or activity	**Ēm**	**UGRL**	**Uo**	**Ra**
General lighting	100	19	0.4	80
Reading lighting	300	19	0.7	80
Pre examinations	200	19	0.7	80
Examination and treatment	1000	19	0.7	90
Staff break	300	19	0.7	80

N.B:

- Maintained illuminance (Ēm): Value below which the average illuminance on the specified surface is not allowed to fall.
- Unified Glare Rating Limit (UGRL): The term is used to present maximum *unified glare rating.*
- Illuminance uniformity (U0): Ratio of minimum illuminance to average illuminance on a surface
- Colour Rendering index (Ra): The maximum value of Ra is 100.

Unfortunately, more than half of the workspaces did not meet the required illuminance levels, which could have adverse effects on the patients and staff in the hospital as shown in Table 9.

In addition to physical illuminance measurements, participants were asked to rate the illuminance levels subjectively. The participants' subjective ratings corresponded to the measured illuminance levels and the EN 12464-1 standard, indicating the subjective assessment was reliable when the illuminance levels met the standard. Table 9 presents the mean ratings of the light levels assessed by the participants, the physical illuminance measurements, and the EN 12464-1 standard.

Table 9: Comparing Subjective Light Level Assessment to Objective Illuminance Measurements in Reference to the EN 12464-1 Standard.

	Met the standard		Did not meet the standard		
Department/Wards	n[a]	Personnel's assessment of the light level Mean rating (SD)	n[a]	Personnel's assessment of the light level Mean rating (SD)	**Contingency coefficient**
GOPD	42	4.1(0.96)	0		Invalid
Obstetrics	28	3.1(0.63)	8	3.2 (0.55)	0.645
Paediatrics	53	3.6(0.69)	5	3.1 (0.61)	0.722
Post-natal	12	3.0(0.74)	129	2.7 (0.59)	0.695
Surgical	68	2.5(0.57)	105	2.9 (0.64)	0.685
Total	203		247		

[a] Number of workstations surveyed.

4.3 Lighting Characteristics and Disturbances

Around seventy percent of the participants expressed dissatisfaction with at least one of the three lighting characteristics, including light sources, light levels, and use of daylight. Their ratings predominantly fell within the lower ends of the scale. The mean scores for evaluating the appropriateness of the three lighting characteristics generally ranged from low to moderate, with the lowest rating recorded for the use of daylight at a score of 2.33.

No statistically significant differences were found in the ratings (with a p-value above 0.05), indicating that participants' perceptions of the lighting characteristics were relatively consistent across the board. Additionally, slightly more than half of the respondents (52%) reported experiencing some level of disturbance due to at least one of the two lighting disturbances. These disturbances were rated as high or very high on the scale.

The highest average score among the two lighting disturbances was observed for the unwanted shadow condition, with a score of 3.16, which falls between moderate and high on the scale. The results revealed notable differences in the ratings between the two categories, as evidenced by the statistically significant p-value of less than 0.001 obtained from non-parametric Friedman tests. Table 10 presents the average ratings along with their standard deviations for both the three lighting characteristics and two lighting disturbances.

Table 10: Subjective Ratings of Lighting Characteristics and Disturbances

Lighting characterises and disturbances	**Respondents (%)**					**Mean ratings (SD)**
	Very Low	Low	Moderate	High	Very High	
Appropriateness of lighting						
Light sources	75(16.7)	225(50)	38(8.3)	75(16.7)	37(8.3)	2.835 (0.58)
Light level	41(9.1)	246(54.6)	149(33.3)	14(3.6)	0	3.073 (0.859)
Use of daylight	149(33.3)	149(33.3)	38(8.3)	74(16.7)	38(8.3)	2.331 (0.427)
Sources of disturbance						
Glare	1(0.3)	12(2.7)	302(67)	126(28)	9(2)	2.583 (0.2.58)
Unwanted shadow	1(0.3)	31(6.9)	169(37.5)	216(48)	33(7.3)	3.164 (1.412)

It is noted that only about 8% of the respondents expressed high to very high levels of satisfaction with the lighting at their working environment as noted in Table 11.

Table 11: Subjective Satisfaction Ratings Regarding Light Levels

Department/Wards	Degree of satisfaction with light level							
	Very Low	Low	Moderate	High	Very High	Total for low to very low	Rank	Total
GOPD	4	10	24	4	-	14	5	42
Obstetrics	-	21	14	1	-	21	4	36
Paediatrics	-	27	16	15	-	27	3	58
Post Natal	11	72	56	-	2	83	2	141
Surgical	15	84	66	6	2	99	1	173
Total	30	214	176	26	4	244		450

In contrast, 75% observed experiencing a negative impact due to the lighting conditions on their task performance with this impact ranging from moderate to very high on the rating scale. Furthermore, 52% of the respondents indicated that lighting condition at their working environment contributed to issues such as eyestrain, headaches, and shifts in mood changes. Similarly, 87% of respondents expressed preference for brighter or much brighter lighting at their workstations. This preference for better lighting not only signifies a desire for enhanced visual clarity but also suggests the pivotal role that adequate lighting plays in creating an environment conducive to productive work.

4.4 Prevalent Personal Wellbeing Concerns

During the six-month study period, more than half of the healthcare personnel (52%) encountered at least one symptom that improved when they were away from the healthcare facility, as indicated in table 12. The three most prevalent symptoms, as shown in the table, were eyestrain (67%), mood disturbances (21%), and headaches (12%).

In terms of variations due to weather conditions, a quarter of the participants reported experiencing eyestrain (20%), mood disturbances (15%), and headaches (11%) during specific seasons, particularly the rainy season (20% and 19%, respectively). Throughout the day, eyestrain, mood disturbances, and headaches were prevalent during the afternoon for two out of three participants (65%, 71%, and 81% respectively). Conversely, for at least one in three participants, these symptoms were not experienced during specific parts of the day (45% and 35% respectively).

4.5 Personnel's Characteristics and the Perception of Lighting

The results of this study confirm that environmental variables such as location, light level and disturbances in the wards can affect personnel's satisfaction and perception of lighting. However, this study also explores the impact of other intrinsic variables on the personnel's responses that could possibly explain the variations in the results. Among many others, this study looks at the variation of responses based on the personnel's gender, age, health effect, and working hours.

4.5.1 **Respondence**

A total of 450 questionnaires were successfully completed by healthcare professionals working in five different wards. The distribution of respondents varied among different wards, job roles, and activities achieved a 100% response rate. Despite the relatively small number of pharmacists and physiotherapists, their inclusion was deemed valuable for facilitating comparisons related to job-specific aspects. All respondents completed the provided questions, using instantaneous readings that involved concurrent spot measurements and questionnaire administration at each workstation, as detailed in section 3.9.2.1. The dataset was devoid of any missing values across the questions, variables, and constructs. Within the confines of this study, the internal consistency of the scales exhibited satisfactory performance, with a Cronbach's alpha coefficient of 0.7. Table 12 presents personnel’s assessment of the various lighting conditions impact. Additionally, the table illustrates demographic distribution of respondents showing that 78.2% identified as female. Among these, 37% were doctors, 13% midwives, 49% nurses, and only 0.35% were pharmacists. In contrast, 22.8% of respondents were male, comprising 67% doctors, 32% nurses, and merely 1% physiotherapists.

Table 12: Comparison Personal and Lighting-Related Aspects Across the Five Wards.

Item	**Category/scale**	**GOPD**	**Obstetrics**	**Paediatrics**	**Postnatal**	**Surgical**	**Mean**
N							
Age (mean)	Years	30-39	30-39	18-29	18-29	18-29	18-29
Gender (%)	Female Male	32(9) 10(10.3)	34(9.7) 2(2.1)	45(12.7) 13(13.4)	121(34.3) 20(20.6)	121(34.3) 52(53.6)	70.6 19.4
Job role (%)	Doctors Midwives Nurses Pharmacist Physiotherapist	 9(19.2) 33(16.1)	6(3.1) 12(25.5) 18(8.8)	14(7.1) 13(27.6) 31(15.1)	65(33) 12(25.5) 64(31.4)	112(56.8) 1(2.2) 58(28.4) 1(100) 1(100)	49.25 11.4 40.8 1 1
Light sources							
Light level (mean)		3.042	2.333	2.985	2	2.144	2.500
Use of daylight (mean)		3.833	2.25	3.388	1.828	2.785	2.817
Effect of glare (mean)		3.119	3.138	3.137	3.390	3.329	3.221
Effect of shadow (mean)		3.380	3.380	3.5	3.633	3.549	3.488
Preferred light level (mean)		3.619	4.361	3.500	4.347	4.265	4.018
Satisfaction with lighting							
Effect on performance (mean)		3.363	3.219	3.229	3.081	3.534	3.285
Effect on wellbeing (mean)	Eyestrain Headache Mood	18(11.7) 3(9.1) 2(4.9)	6(3.9) 6(18.2)	6(3.9) 1(3.2) 8(19)	55(35.7) 7(21.2) 18(42.8)	69(44.8) 16(48.5) 14(33.3)	30.8 6.6 10.5

In terms of activities, 42% of participants participated in discussions with colleagues and/or patients, while 36% were engaged in documentation while completing the questionnaire.

Another 22% of participants engaged in various other activities, like pre-examination, therapy, and personal time.

More than half of the respondents (51%) noted that lighting conditions had an impact on their overall well-being. The most prevalent issues reported were eye strain (67.3%), headaches (14.4%), and changes in mood (18.3%). These responses indicate that respondents felt negatively affected by poor lighting conditions. In general, 55% of the respondents expressed a moderate level of dissatisfaction with the impact of lighting conditions on their performance, while 21% reported a high level of dissatisfaction. Consequently, 87.3% of the participants expressed a desire for brighter workstations compared to what is currently available.

Across different wards, personal aspects showed a balanced pattern, with similar levels of dissatisfaction regarding lighting conditions. The only exception was the use of daylight in the GOPD (General Out-Patient Department).

4.5.1.1 ***Activity related aspects***

The responses collected were distributed across different units, with 38% recorded in the surgical unit and 31% in the postnatal unit. Paediatrics accounted for 13%, GOPD for 10%, and the obstetrics unit for 8%. The distribution of activities varied among these units. Of all participants, 42% participated in discussions, 36% in documentation, and the remaining individuals were engaged in various other activities while responding to the questionnaires. Table 13 presents the respondents distribution along with activities.

Table 13: Distribution of Respondent and Associated Activities

Variables	Frequency (%)	Interpretation
Gender		21.6% of the respondents are male while 78.2% are female
Male	97(21.6)	
Female	353(78.2)	
Age group		43.6% of the respondents are between the ages of 18-29 years while 40.2% are within 30-39 years of age and 15.6% are within 40-49 years of age.
18-29	196(43.6)	
30-39	181(40.2)	
40-49	70(15.6)	
50-59	3(0.7)	
Job role		43.3 % of the respondent are doctors while 45.3% are nurses and only 10.5% are midwife
Nurse	204(45.3)	
Doctor	197(43.8)	
Midwife	47(10.5)	
Pharmacist	1(0.2)	
Physiotherapist	1(0.2)	
Activity		
Diagnostics	40(8.8)	
Diagnostic/Documentation	7(1.6)	
Diagnostic/Therapy	5(1.1)	
Discussion	189(42)	
Discussion/Documentation	8(1.8)	
Documentation	164(36.4)	
Personal time	3(0.7)	
Pre-examination	30(6.8)	
Therapy	4(0.8)	
Light source		
Mixed Mode	179(39.8)	
Daylight	271(60.2)	

Among physicians, 52% were predominantly engaged in discussing cases, while approximately half of the nurses (49%) focused on documentation. Discussion activities were carried out by less than half (45%) of midwives, pharmacists, and physiotherapists. The results highlighted notable differences in activity preferences across job roles. Specifically, 44% of participants engaged in active discussions with patients or colleagues, in contrast to 36% who primarily dealt with documentation, and 20% who participated in other activities such as therapy, pre-examinations, and personal time. These differences in activities were statistically significant among job roles, as indicated by Pearson Chi-square tests ($p < 0.05$), except for therapy and personal time, which were only undertaken by less than 1% of personnel in obstetrics and postnatal units ($p = 0.322$), and personal time not involving patients ($p = 0.130$). Table 13 provides an overview of activities, job role and age distribution.

4.5.1.2 ***Personal aspects***

The flexibility of working hours also differed significantly among job roles (Pearson Chi-square p < 0.000). For instance, 49% of doctors reported working more than 4 hours in the surgical unit, with 53% of them engaged in discussion activities. In contrast, 38% of nurses in the postnatal unit participated in similar discussion activities. Age distribution varied based on job roles as well (Pearson Chi-square p < 0.000). Among doctors, 61% in the 18-29 age group were engaged in discussion activities in the surgical unit, while nurses in the 30-39 age group accounted for 40% of discussion activities in the postnatal unit.

Across all ward units, the number of individuals involved in different activities exhibited variations. Notably, in the GOPD unit, 69% of activities consisted of pre-examinations. The distribution of individuals differed significantly (Pearson Chi-square p < 0.000), with 78% of GOPD nurses predominantly working alongside others. This was compared to 53% in paediatrics, 50% in obstetrics, 45% in postnatal, and 34% in the surgical unit.

4.5.2 **Lighting Conditions and Age**

Recognising that aging eyes require more light for vision, the study presumed like some other studies (Farage et al. 2012; Anshel, 2007) that the overall satisfaction ranks might vary significantly between personnel in different age-groups. In fact, some studies have reported that personnel like nurses over the age of 40 have more difficulty performing care tasks in each light level than do younger nurses (Kamali & Abbas, 2012). To assess this, the satisfaction rates for each age-group were compared at each ward. The results of a Kruskal-Wallis test conducted to analyse the differences in satisfaction with light level, preference of light level, effect of glare, effect of shadow, light level, and effect on performance, among five different wards of a hospital, categorised by age group (18-29, 30-39, and 40 and above).

For the GOPD ward, there were no significant differences in satisfaction with light level and preference of light level across age groups (p > .05). However, there was a significant difference in the effect of glare (p = .001), where older age groups reported more negative effects of glare. There was also a significant difference in the effect of shadow (p = .086), where the 30-39 age group reported more negative effects of shadow. In terms of light level and its effect on performance, there was a significant difference (p = .131), where the 30-39 age group reported the highest mean rank for light level and the 40 and above age group reported the highest mean rank for effect on performance.

For the Obstetrics ward, there were no significant differences in satisfaction with light level, preference of light level, effect of glare, effect of shadow, light level, and effect on performance across age groups (p > .05).

For the Paediatric ward, there were no significant differences in satisfaction with light level and effect of glare across age groups (p > .05). However, there was a significant difference in preference of light level (p = .205), where the 30-39 age group reported a significantly higher preference for light level. There was also a significant difference in the effect of shadow (p = .652), where there were no significant differences across age groups. In terms of light level and its effect on performance, there was a significant difference (p = .335), where the 40 and above age group reported the highest mean rank for light level and the 30-39 age group reported the highest mean rank for effect on performance.

For the Post-Natal ward, there were significant differences in satisfaction with light level (p = .138) and preference of light level (p = .313), where the 30-39 age group reported the highest mean ranks for both. There were no significant differences in effect of glare, effect of shadow, and light level across age groups (p > .05). However, there was a significant difference in effect on performance (p = .284), where the 40 and above age group reported the highest mean rank.

For the Surgical ward, there were no significant differences in satisfaction with light level and preference of light level across age groups (p > .05). However, there were significant differences in effect of glare (p = .037), where the 40 and above age group reported more negative effects of glare. There were no significant differences in effect of shadow and light level across age groups (p > .05). However, there was a significant difference in effect on performance (p = .293), where the 30-39 age group reported the highest mean rank.

Overall, the results suggest that there are some significant differences in how different age groups perceive and are affected by lighting conditions in different wards of the hospital.

4.5.3 **Lighting Conditions and Job Role**

Satisfaction across different job roles in terms of various aspects of lighting conditions in the workplace. The analysis involved a sample of 448 out of the 450 responses, comprising nurses, doctors, and midwives.

The results revealed significant differences in satisfaction and preference of light level across job roles. Nurses, on average, reported the highest level of satisfaction and preference for light level, with a mean rank of 225.52 and 232.34, respectively (χ^2=18.118, df=2, p<.001; χ^2=9.266, df=2, p=.010). Doctors had a mean rank of 207.95 and 208.24, respectively, while midwives had a mean rank of 289.44 and 258.66, respectively. These results suggest that job roles may have varying preferences for lighting levels in the workplace.

Furthermore, the study found a significant difference in light levels across job roles, with midwives reporting the highest mean rank of 266.24, followed by nurses with a mean rank of 229.66, and doctors with a mean rank of 209.20 ($\chi^2=9.962$, df=2, p=.007). This finding suggests that there may be a need for job-specific lighting conditions to optimise job satisfaction and performance.

However, the study found no significant differences in the effect of glare and shadow on job satisfaction and performance across job roles ($\chi^2=4.153$, df=2, p=.125; $\chi^2=1.316$, df=2, p=.518). This result indicates that these factors may have a similar impact on job satisfaction and performance across different job roles, and there may not be a need for job-specific considerations when designing lighting conditions to minimise glare and shadow.

Finally, the study found no significant differences in the effect of lighting on task performance across job roles ($\chi^2=3.554$, df=2, p=.169). This result suggests that lighting conditions may have similar effects on task performance across different job roles.

Overall, the findings of this study suggest that lighting plays a significant role in the satisfaction and preference of healthcare professionals in their work environments. Nurses expressed the lowest satisfaction with light levels and the highest preference for increased light levels compared to doctors and midwives. Moreover, there was a significant difference in the light levels preferred by the three job roles, with midwives expressing the highest preference.

The study also found that there were no significant differences in the effects of glare and shadow across job roles. However, the light level significantly affected the job roles, and nurses expressed a higher preference for increased light levels. Additionally, there was no significant difference in the effect on performance across job roles. These findings have implications for the design and implementation of lighting environments in healthcare environments.

4.5.4 **Lighting Conditions and Working Hours**

The analysis of the lighting conditions and working hours across different wards in healthcare facilities provides valuable insights into the effects of these factors on the quality of healthcare services. The findings suggest that glare and shadow are the two most significant lighting conditions that impact the quality of healthcare services in different wards. For each ward, the analysis compares the effects of two levels of working hours (less than 6 hours and greater than 6 hours) on three lighting conditions: effect of glare, effect of shadow, and satisfaction with light level. The analysis also provides the number of participants (N), the mean rank, and the t-statistic or z-score for each comparison.

In the GOPD ward, working hours of less than 6 hours were associated with higher mean ranks for the effects of glare and shadow, indicating that these lighting conditions were perceived to be more problematic during shorter working hours (SIG=0.004). On the other hand, there was no significant difference in satisfaction with light level between shorter and longer working hours in this ward.

In the Obstetrics ward, no significant differences were found between shorter and longer working hours in terms of the effects of glare and satisfaction with light level. However, a higher mean rank for the effect of shadow was observed during longer working hours, indicating that this lighting condition was perceived to be more problematic during longer working hours.

In the Paediatric ward, no significant differences were found between shorter and longer working hours in terms of the effects of glare and shadow. However, a higher mean rank for satisfaction with light level was observed during shorter working hours, indicating that satisfaction with lighting was higher during shorter working hours. In the post-natal ward, no significant differences were found between shorter and longer working hours in terms of the effects of glare and shadow, as well as satisfaction with light level.

In the Surgical ward, no significant difference was observed between shorter and longer working hours in terms of the effect of glare and shadow. However, a higher mean rank for satisfaction with light level was observed during longer working hours, indicating that satisfaction with lighting was higher during longer working hours.

The findings of this study have several implications for healthcare facilities lighting. Firstly, it highlights the importance of considering different lighting conditions and their effects on staff in different wards. Secondly, it suggests that staff satisfaction with lighting may be influenced by the duration of their working hours, and this should be considered when designing lighting systems. Finally, the study emphasises the importance of monitoring and evaluating lighting conditions in healthcare facilities to ensure that they meet the needs of staff and contribute to a safe and efficient work environment.

4.6 Correlations Among the Variables

The relationship between lighting conditions and employee satisfaction, wellbeing, and task performance has long been a topic of interest for researchers and organisations alike. This section explores the findings of the survey to highlight the impact of lighting conditions on personnel's satisfaction, wellbeing, and task performance.

The survey is a sample of 108 personnel with 450 responses in as many workstations in five wards of the healthcare facility, and the results were concerning. Only 7.1% of respondents reported high or very high levels of satisfaction with the lighting at their working environment. This suggests that most personnel are dissatisfied with the lighting conditions in their workplace, which may have significant implications for their overall job satisfaction and productivity. In addition to low levels of satisfaction, the survey also revealed that 75.3% of respondents believed that lighting had an adverse effect on their task performance, ranging from moderate to very high on the scale as seen in Table 14.

Table 14: Subjective Ratings on the Impact of Light Levels on Performance.

Department/Wards	Degree of impact of light level on performance							
	Very Low	Low	Moderate	High	Very High	Total for High to very High	Rank	Total
GOPD	1	13	27	1	-	1	5	42
Obstetrics	1	10	16	7	2	9	3	36
Paediatrics	4	8	39	7	-	7	4	58
Post Natal	2	26	86	25	2	27	2	141
Surgical	9	37	77	42	8	50	1	173
Total	17	94	245	82	12	94		450

The responses also showed that lighting conditions have a significant impact on personnel’s wellbeing. As indicated in Table 15, over half of the respondents (52%) reported adverse effects of lighting conditions on their wellbeing, with eye strain being the most common complaint (33%). Other adverse effects included headaches (14.4%) and mood (18.3%).

Table 15: Effects of Lighting Conditions on Personnel.

How would you describe the impact of lighting conditions on your wellbeing		Frequency	Percent	Rank
Valid	Eyestrain	154	35	2
	Headache	27	6	4
	Mood	48	11	3
	None	221	48	1
	Total	450	100	

Interestingly, the survey also found that most respondents (87.3%) indicated a preference for brighter lighting conditions at their workstations as shown in Table 16.

Table 16: Subjective Ratings of Preferred Light Levels.

Department/Wards	**Preference of light level**							
	Much less bright	Less bright	Same as current	Brighter	Much brighter	Total for brighter to much brighter	Rank	Total
GOPD	-	2	15	21	3	24	5	42
Obstetrics	-	-	1	21	14	35	3	36
Paediatrics	1	1	27	26	3	29	4	58
Post Natal	-	-	1	90	50	140	2	141
Surgical	-	-	9	107	57	164	1	173
Total	17	94	245	82	12	94		450

In addition, the survey recorded that glare and unwanted shadows were a common complaint among respondents, with 70% and 54.2% of respondents reporting these issues, respectively. These findings suggest that design of healthcare facilities should pay closer attention to the lighting conditions in the work environment and take steps to reduce glare and unwanted shadows.

4.6.1 **Effects of Glare and Age**

A further post hoc Mann-Whitney test was conducted to determine where the differences lie among the three age groups (ages 18-29, 30-39, and 40 and above) for two variables: GODP (glare on task performance) and Surgical (glare on surgical performance). The results of the Mann-Whitney tests are presented with mean rank, t-statistics (Z), and significant value (Sig) for each comparison.

For the GODP variable, the Mann-Whitney test revealed that there were no significant differences in the effect of glare between ages 18-29 and ages 30-39 (M.W = 112.000, Z = -1.395, Sig = 0.163). However, there were significant differences in the effect of glare between ages 18-29 and ages 40 and above (M.W = 35, Z = -2.981, Sig = 0.026) and between ages 30-39 and ages 40 and above (M.W = 47.5, Z = -2.613, Sig = 0.059). These results suggest that the effect of glare on driving performance is more pronounced for participants aged 40 and above compared to those aged 18-29 and 30-39.

For the Surgical variable, the Mann-Whitney test showed no significant differences in the effect of glare between ages 18-29 and ages 30-39 (M.W = 2806, Z = -0.269, Sig = 0.788). However, there were significant differences in the effect of glare between ages 18-29 and ages 40 and above (M.W = 441, Z = -2.563, Sig = 0.010) and between ages 30-39 and ages 40 and above (M.W = 266.0, Z = -2.369, Sig = 0.018). These findings indicate that the effect of glare on surgical performance is more significant for participants aged 40 and above than for those aged 18-29 and 30-39.

Overall, the post hoc Mann-Whitney test suggests that the effect of glare on performance in both GOPD and Surgical is more pronounced for individuals aged 40 and above compared to those aged 18-29 and 30-39 with a p-value of 0.010 and 0.018 respectively which is less than 0.05.

4.6.2 **Effects of Lighting and Job Role**

The mean rank for nurses (94.14) is higher than that of doctors (80.23) which suggests that nurses perceive the effect of glare more than doctors in the surgical ward. The Mann-Whitney U test shows a significant difference ($p<0.05$) between nurses and doctors regarding the effect of glare. The mean rank for doctors (91.50) is higher than that of nurses (72.56) which suggests that doctors prefer higher light levels in the surgical ward than nurses. The Mann-Whitney U test shows a significant difference ($p<0.05$) between doctors and nurses regarding the light level. Between Nurses and Midwife, the mean rank for midwives (9) is lower than that of nurses (31.24) which suggests that midwives perceive the effect of glare less than nurses in the surgical ward. However, the Mann-Whitney U test shows no significant difference ($p>0.05$) between nurses and midwives regarding the effect of glare. For the light level, the mean rank for midwives is higher than that of nurses which suggests that midwives prefer slightly higher light levels than nurses. However, the Mann-Whitney U test shows no significant difference ($p>0.05$) between nurses and midwives regarding the light level.

Regarding doctor and midwife, the mean rank for midwives is lower than that of doctors and suggests that doctors perceive the effect of glare more than midwives in the surgical ward. However, the Mann-Whitney U test shows no significant difference (p>0.05) between doctors and midwives regarding the effect of glare. For the light level, the mean rank for midwives (44is lower than that of doctors which suggests that midwives prefer lower light levels than doctors. However, the Mann-Whitney U test shows no significant difference (p>0.05) between doctors and midwives regarding the light level.

It is important to note that the Mann-Whitney U test is a non-parametric test used to compare two independent groups when the data is not normally distributed. Therefore, the test was appropriate in this study since the data was collected using ordinal scales.

4.6.3 **Effect of Lighting and Wellbeing**

The study examined the effects of glare and shadow, as well as satisfaction with light level on personnel wellbeing with adverse effects such as eyestrain, fatigue, and mood disturbances noted across diverse departments.

In the GOPD department, no significant differences were observed in the impact of glare, shadow, or satisfaction with light levels on wellbeing between individuals reporting health impacts and those not reporting such impacts.

In the Obstetrics department, while there were no notable differences in glare's effect on wellbeing between individuals reporting health impacts and those not, those reporting health impacts indicated a more negative impact of shadows. Satisfaction with light levels remained consistent across both groups.

In the Paediatric department, individuals reporting health impacts experienced more adverse effects of both glare and shadow on their wellbeing compared to counterparts without such impacts. However, satisfaction with light levels did not significantly differ between the two groups.

In the Post-Natal department, individuals reporting health impacts indicated a more negative glare impact on wellbeing. Although no significant difference was observed in shadow effect, those reporting health impacts expressed lower satisfaction with light levels.

In the Surgical department, individuals reporting health impacts experienced more adverse effects of both glare and shadow on their wellbeing, alongside lower satisfaction with light levels.

Overall, the findings underscore the significant influence of lighting conditions on personnel wellbeing, particularly in surgical departments among individuals reporting health impacts. This emphasises the necessity of adopting tailored lighting strategies to foster a conducive work environment, especially for healthcare professionals facing health-related challenges.

4.6.4 **Effect of Lighting and Hospital Activities**

The section aimed to investigate the impact of lighting conditions on different activities in various wards within a hospital setting. To achieve this, the analysis was divided into five parts: light level, glare effect, shadow effect, satisfaction with light level, and preference for light level.

The results showed that lighting conditions have a significant impact on satisfaction and preference for light level across different activities. In terms of light level, there was a significant difference observed across various activities (χ2 = 42.552, p < .001), with the mean rank for personal time being the highest (354.53). The other activities had relatively similar mean ranks, with diagnostics at 215.6, discussion at 211.63, documentation at 218.09, therapy at 261.50, and discussion and documentation at 247.13.

In terms of glare effect, there was no significant difference observed across different activities (χ2 = 13.328, p = .065). The mean ranks for different activities were relatively close, ranging from 210.08 for documentation to 285.50 for therapy. The highest mean rank of glare was observed for therapy, while the lowest was observed for discussion and documentation, indicating that the effect of glare has the most significant impact on therapy and the least impact on discussion and documentation.

Similarly, there was no significant difference in the effect of shadow across different activities (χ2 = 10.390, p = .168), with the mean rank of shadow being the highest for personal time and the lowest for therapy. This indicates that the effect of shadow has the most significant impact on personal time and the least impact on therapy.

Regarding satisfaction with light level, there was a significant difference across different activities (χ2 = 23.557, p < .001), with therapy having the highest mean rank (344.50), followed by personal time (310.83), diagnostics (250.08), discussion (240.38), pre-examination (238.76), documentation (214.26), and discussion and documentation (211.63). Therefore, satisfaction with light level has the most significant impact on therapy and the least impact on discussion and documentation.

The preference for light level also showed a significant difference across different activities (χ2 = 30.190, p < .001), with the mean rank for pre-examination being the highest (327.05), followed by therapy (298.63), diagnostics (228.92), document (216.51), discussion (211.93), discussion and documentation (205.50), and personal time (193.83). Therefore, the preference for light level has the most significant impact on pre-examination and the least impact on personal time.

Moreover, there was no significant difference in the effect of lighting conditions on performance across different activities (χ2 = 7.398, p = .389). The highest mean rank of effect on performance was observed for therapy, while the lowest was observed for personal time, indicating that the effect on performance has the most significant impact on therapy and the least impact on personal time.

In summary, the findings indicate that lighting conditions have a significant impact on satisfaction and preference for light level across different activities in different wards, with the highest impact on personal time and therapy. Light level, preference for light level, and satisfaction with light level have the most significant effects, while the effect of glare, shadow, and effect on performance have less significant effects. Therefore, improving lighting conditions in hospital wards can lead to higher levels of satisfaction and preference for light level among patients and staff, enhancing their experiences and improving their well-being.

4.6.5 **Comparisons of Effects Across Different Job Roles**

This section presents the mean ranks, t-statistics, and significant values for the satisfaction level, preference level, and light level across different job roles - nurses, doctors, and midwives.

The Mann-Whitney U test was used to compare the mean ranks, and significant value were reported to indicate whether the differences in the mean ranks were statistically significant.

In terms of satisfaction with light level, the mean rank for nurses was higher than that for doctors (208.72 vs. 193.01), but the difference was not statistically significant (sig = 0.137). For nurses and midwives, the mean rank for nurses was significantly higher than that for midwives (185.20 vs. 155.06, sig = 0.001). Similarly, for doctors and midwives, the mean rank for doctors was significantly higher than that for midwives (158.37 vs. 113.94, Z = -4.254, sig = 0.000).

Regarding the preference level for light, the mean rank for nurses was lower than that for doctors (211.53 vs. 190.09), and the difference was statistically significant (sig = 0.034). For nurses and midwives, the mean rank for nurses was also lower than that for midwives, but the difference was not statistically significant (185.20 vs. 155.06, sig = 0.169). Similarly, for doctors and midwives, the mean rank for doctors was lower than that for Midwives, and the difference was statistically significant (144.95 vs. 117.14, sig = 0.005).

For the light level, the mean rank for nurses was higher than that for doctors, but the difference was not statistically significant (209.93 vs. 191.75, sig = 0.077). For nurses and midwives, the mean rank for nurses was higher than that for midwives, but the difference was not statistically significant (182.72 vs. 142.37, sig = 0.059). However, for doctors and midwives, the mean rank for doctors was significantly higher than that for midwives (147.87 vs. 116.45, sig = 0.002).

The results suggest that there are some significant differences in the satisfaction level, preference level, and light level across different job roles. Specifically, nurses are more satisfied with the light level than midwives, and doctors are more satisfied with the light level than midwives. Nurses prefer brighter light than doctors, and doctors prefer brighter light than midwives. The light level is not significantly different between nurses and doctors, nurses, and midwives, but it is significantly higher for doctors than midwives.

4.6.6 **Comparisons of Effects Across Different Activities**

The objective of this section was to compare the light levels, satisfaction with light level, and preference for light levels among different activity categories. To achieve this, the Mann-Whitney U test was used to compare two independent groups when the dependent variable is measured on an ordinal or continuous scale. The survey responses on light level, satisfaction with light level, and preference for light level were analysed using a significance level of 0.05. The six pairs of activity categories assessed were documentation and personal Time; discussion and documentation; discussion and pre-examination; diagnostic and discussion; diagnostic and documentation; and diagnostic and personal time.

The results of the Mann-Whitney U test indicate a significant difference in satisfaction with light level and preference of light between all categories except for discussion and documentation. The p-values for all the significant tests were less than 0.05, indicating a high degree of statistical significance. The mean rank values obtained from the Mann-Whitney U test suggest that the satisfaction with light level and preference of light varied significantly across the different activity categories. The pre-examination activity category consistently showed the highest preference and satisfaction with light level across all pairwise comparisons.

Specifically, for the documentation and pre-examination category, the Mann-Whitney U test showed a significant difference between the two groups for both satisfaction with light level (U=963.5, Z=-5.853, p<0.001) and preference of light (U=1397, Z=-4.110, p<0.001).

For the discussion and pre-examination category, the Mann-Whitney U test also showed a significant difference between the two groups for both satisfaction with light level (U=1018, Z=-6.175, p<0.001) and preference of light (U=1553, Z=-4.369, p<0.001).

For the diagnostic and pre-examination category, the Mann-Whitney U test showed a significant difference between the two groups for both satisfaction with light level (U=213.5, Z=-4.986, p<0.001) and preference of light (U=344, Z=-3.273, p=0.001).

For the diagnostic and discussion category, no significant difference was found between the two groups for either satisfaction with light level (U=3577.5, Z=-0.211, p=0.833) or preference of light (U=3637.5, Z=-0.027, p=0.979).

For the discussion and documentation category, no significant difference was found between the two groups for either satisfaction with light level (U=14891.5, Z= -0.528, p=0.597) or preference of light (U=15112, Z= -0.257, p=0.797).

Overall, the results suggest that there is a significant difference in satisfaction with light level and preference of light between the categories of activities, except for the Discussion and Documentation category where no significant difference was found. The Pre-examination category consistently showed a significantly higher preference of light and satisfaction with light level compared to the other categories. In particular, the results suggest that the Pre-examination activity category may require brighter light levels and more attention to their lighting preferences than the other categories.

4.7 Chapter Summary

This study investigates how environmental lighting conditions impact the well-being and performance of healthcare personnel. Data from illuminance measurements and participant surveys are statistically analysed. Across different wards, lighting conditions assessed, revealed variations in preferences and levels. A detailed analysis highlights correlations between lighting conditions and employee satisfaction, well-being, and task performance. The result of personnel's perceptions reveals variations in lighting conditions and preferences across different wards. The findings indicate low satisfaction with lighting, impacting task performance and well-being. Symptoms such as eyestrain, mood disturbances, and headaches are prevalent, influenced by weather and time of day. Weather and time of day were found to influence these effects on healthcare personnel.

Besides, the observable environmental lighting conditions, the analysis also present the results of intrinsic factors such age, job role, work hours, and activities. Various impacts emerge based on age and job roles, and specific medical departments are affected differently. Age and job roles are shown as determinants, with older group more susceptible to glare and midwives prefer brighter light. Nurses are more satisfied than doctors and midwives. Moreover, the duration of work hours exerts an effect on perception.

The analysis also shows how lighting conditions impact various hospital activities, with findings indicating significant differences in satisfaction and light level preferences. Personal time and therapy emerge as the most impacted tasks. Interestingly, the "Pre-examination" task consistently reports the highest levels of satisfaction and preference for the prevailing lighting conditions. Collectively, the findings establish a strong connection between lighting conditions and the overall work experience of healthcare personnel as illustrated by figure 30.

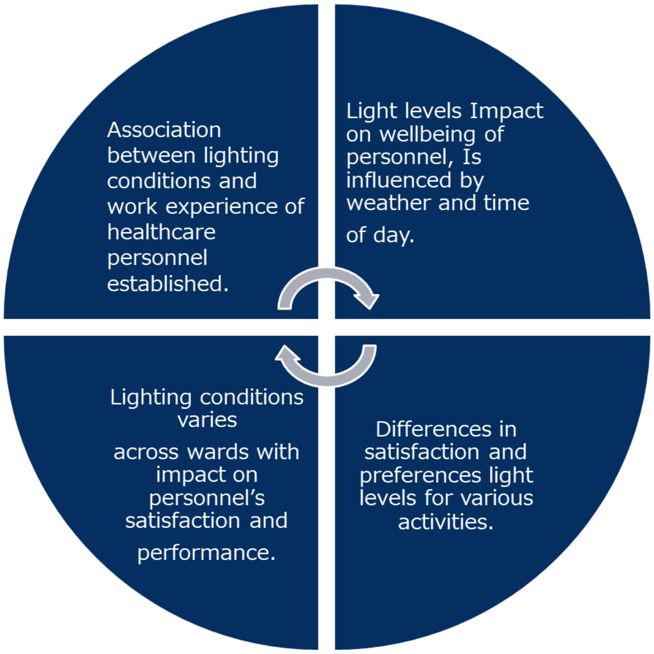


Figure 30: Summary of Quantitative Findings.

Chapter V: Qualitative: Results and Findings

This study examines the impact of environmental lighting on the well-being and performance of healthcare personnel. The preceding chapter had focused on the quantitative analysis of illuminance data and participant surveys, showing variations in lighting preferences and levels across different wards. It establishes correlations between lighting, personnel satisfaction, well-being, and task performance. Additionally, it explores intrinsic factors such as age, job role, work hours, and activities, highlighting their varying influences. Overall, the quantitative findings establish the connection between lighting conditions and the work experience of healthcare personnel.

This chapter is explored to offer in-depth insights and capture the richness of human experiences as described in section 3.5. The results of analysed qualitative data collected as shown in fig 28, is presented in this chapter along with the findings. It evaluates in depth the influence of human factors of perception and preferences on various indoor lighting conditions and impact personnel' well-being and performance.

The chapter is divided into five parts. The first section presents the data analysis chapter and describes the thematic analysis used for the indoor lighting conditions and their impact on subjective performance. Section two describes the results and findings of the analysis, followed by an outline of the emerging themes. Section four introduces the results and explanations of the effect of natural light on personnel wellbeing and performance. To conclude, a summary of the qualitative results and findings is provided.

5.1 Introduction

Using thematic analysis offer a flexible research approach to uncover patterns and themes in qualitative data like interviews. It involves stages like data familiarisation, coding, theme identification, review, and report writing. In the data familiarisation stage, this researcher become familiar with the data by reading and re-reading it, taking notes, and identifying initial ideas and patterns. In the coding stage, researcher assign codes to the data based on relevant concepts, patterns, or themes. In the theme identification stage, the codes are grouped into higher-level themes, which are then reviewed and refined in the theme review stage (Vaismoradi et al. 2016; 2013). Finally, in the report writing stage, the themes and subthemes are described and discussed, along with examples from the data. This method helps the research to understand data and generate new insights. Thematic analysis is versatile, fitting different research questions and data types. While it is adaptable, it is also subjective and can be influenced by bias. Clear descriptions of themes are crucial. This process offers systematic and replicable results. In this study, thematic analysis was used to provide depth to the association between indoor lighting, wellbeing, and performance in healthcare environments. Furthermore, it provides invaluable insight to the healthcare workers' preference for natural light and implications for healthcare facility design. This demonstrates how thematic analysis aids qualitative research by systematically analysing data to reveal meaningful themes.

5.2 Analysis and Results

After reviewing the interview data, it became clear that no added information emerged beyond the ninth interview. This observation was validated by an independent analysis of the interview transcript conducted by a colleague. Their analysis confirmed that after approximately the ninth interview, no fresh insights or information were gained. As previously discussed in section 3.7.4, the number of interviewees is less critical in phenomenological studies. Instead, the sample size is often determined by categorical saturation, where new interviews only yield the same categories as previous ones. Thus, it is concluded that a total of sixteen interviews provided a comprehensive dataset, reaching the point of data saturation. This approach aligned with the overarching goal of the PhD research project and the specific objectives outlined in the first chapter.

The result is presented using six overarching themes that include “Patient Care and Management”, “Challenges and Coping with Inadequate Lighting”, and “Effects of Lighting on Health, Wellbeing, and Performance”. Furthermore, the study explores the “Dynamics of Natural and Artificial Light Interaction in Built Environments”, “Advocacy for Improved Lighting Environments”, and “Preferences for Natural Lighting and its Benefits”.

The analysis underscores the significance of comprehensive and holistic patient care, encompassing various aspects such as medication administration, wound care, vital sign monitoring, and emotional support. It emphasises the importance of prioritising patient well-being, tailoring care plans, and addressing both physical and emotional needs. Healthcare professionals are dedicated to preparing patients for surgeries, collaborating with surgical teams, and ensuring stable conditions for successful outcomes. Accurate medication administration and vigilant monitoring for adverse effects are considered essential. Patient interaction is highlighted, alongside thorough assessments, interdisciplinary collaboration, and patient-centred treatment approaches. These practitioners maintain high standards of care, focusing on empathy, cultural sensitivity, and continuous improvement, while also placing significant importance on proper documentation and case management.

In the context of patient care, staff efficiency, and the overall healthcare environment, adequate lighting emerges as a fundamental element. Its profound impact on mood, patient recovery, and the well-being of healthcare personnel is emphasised. Additionally, illumination plays a pivotal role in facilitating precise medical procedures and enhancing safety protocols. The responses acknowledge the significant challenges posed by inadequate lighting. Reports indicate that insufficient lighting strains vision, diminishes focus, and causes discomfort among healthcare professionals. The potential consequences for the quality of patient care, including reduced visibility and compromised accuracy, are apparent issues.

To address these challenges, practical solutions such as supplementary lighting tools are explored to mitigate the effects of low illumination. Furthermore, the discussion delves into practical strategies aimed at effectively managing these challenges, with a strong emphasis on the importance of sustainable and efficient lighting solutions for optimal healthcare environments.

Natural light is identified as a key factor in fostering a healing environment, boosting staff morale, and enhancing productivity. The documented positive effects of natural light on circadian rhythms, vitamin D synthesis, and patient recovery underscore the importance of architectural designs that prioritise maximising the integration of natural light within healthcare facilities.

The analysis also evaluates the effectiveness of artificial lighting systems in maintaining consistent illumination throughout healthcare workspaces. While these systems are essential, their current configurations have drawbacks that affect work performance. Thus, there is a suggestion to improve artificial lighting, encompassing brightness optimisation, stability, and adaptability.

Furthermore, the health consequences of insufficient lighting are highlighted, ranging from eyestrain and headaches to potential mood disturbances. The correlation between adequate illumination and both patient outcomes and the well-being of healthcare staff is well-documented and emphasised.

The findings strongly advocate for lighting solutions that prioritise the health and comfort of both patients and healthcare professionals. This involves endorsing architectural redesigns and upgrades to lighting systems to ensure consistent and sufficient illumination. Strategies such as optimising building layouts, increasing window openings, and enhancing lighting fixtures are explored as potential avenues to yield significant benefits, ultimately enhancing patient recovery rates, staff motivation, and overall healthcare efficiency.

5.2.1 **Preliminary Analysis**

5.2.1.1 ***Participants Profile***

Like quantitative data, provision of an overview of sample demographics is valuable in qualitative research. It provides a comprehensive insight into the sample's characteristics. Consequently, Table 17 provides an overview of the participants' demographic information in the qualitative study. It includes participant’s gender, job roles, departments, and age groups.

These intrinsic factors are linked to individuals' perceptions and preferences, enriching our understanding of the research context.

The participants in this study represent a diverse range of healthcare roles, such as doctors, nurses, midwives, pharmacist, and physiotherapist. The total number of participants is sixteen, with the majority being female and a minority being male. Out of the sixteen participants, ten are female and six are male. These participants are engaged in various departments including surgical, postnatal, paediatrics, General Outpatient Department (GOPD), and obstetrics. In terms of age distribution, the participants are from 18 to 49 years old, with a significant portion falling within the 30-39 age range as shown in Table 17.

Table 17: Participants Profile for Interviews.

Participant ID	Gender	Job Role	Department	Age Group
PT 1	Female	Doctor	Surgical	18-29 years
PT 2	Female	Doctor	Postnatal	30-39 years
PT 3	Female	Doctor	Paediatrics	18-29 years
PT 4	Male	Doctor	Surgical	30-39 years
PT 5	Male	Doctor	Postnatal	30-39 years
PT 6	Male	Doctor	Surgical	18-29 years
PT 7	Female	Midwife	Obstetrics	30-39 years
PT 8	Female	Midwife	Postnatal	30-39 years
PT 9	Female	Nurse	GOPD	40-49 years
PT 10	Female	Nurse	Paediatrics	18-29 years
PT 11	Female	Nurse	Postnatal	18-29 years
PT 12	Female	Nurse	Paediatrics	30-39 years
PT 13	Male	Nurse	Surgical	40-49 years
PT 14	Male	Nurse	GOPD	30-39 years
PT 15	Female	Pharmacist	Surgical	40-49 years
PT 16	Male	Physiotherapist	Surgical	30-39 years

5.2.2 **Results**

5.2.2.1 ***Descriptive statistics of interview questions and responses***

The data reveals that most participants identified as female (62.5%), while males made up 37.5% of the respondents. In terms of the job role distribution, the respondents primarily consisted of doctors (37.5%) and nurses (37.5%), with the remaining 25% comprising other healthcare professionals. A substantial 68.75% of those interviewed indicated that the lighting levels in their workplaces were insufficient, while 18.75% considered them adequate, and 12.5% rated them as moderate.

An overwhelming 81.25% believed that the available natural lighting is insufficient with negative impact on their job performance, contrasting with the 18.75% who did not share this perspective.

Approximately 75% of respondents reported that these illuminance levels affected both their health and wellbeing, whereas 18.75% felt unaffected, and 6.25% were uncertain of its impact.

An impressive 81.25% of the participants expressed the view that daylight provision in their workplaces should be improved, while 12.5% believed it was not feasible with the present building, and 6.25% were unsure. Interestingly, every respondent (100%) favoured improved illuminance levels in their workplaces. Preferences for lighting sources varied: 25% preferred a combination of artificial and natural lighting, 12.5% opted for artificial light alone, and the majority (62.5%) exclusively preferred natural light. An overview of the interview questions and the demographic statistics of the respondents and their responses can be seen in Table 18 and 19, respectively.

Table 18: Tabulated Interview Questions and Participants Responses.

S/N	Nature of job	Job description	Is Illuminance adequate	Is the level of Natural illuminance and lighting provided enable or hinder performance	Do illuminance level in your workplace affect your health or limit performance	Do you think daylighting provision can be improved in the building	Will you prefer an improvement to the illuminance level in your workplace and why	Will you prefer artificial or natural lighting and why
1	Doctor Female	Consult surgeries Take care of patients	Surgeries light is dull Not bright	Natural lighting not enough Hinder performance	Yes, affect health Affect task performance	Yes, with more windows for more lighting	Yes	**Natural light** because its inspires and brings life If not improve in artificial light
2	Doctor Female	Take care of patients Set line	Not adequate During the day not bright enough	Natural light not adequate	Yes, affect health causes eye strain	Yes, with more windows on both sides of the ward.	Yes, because it makes work efficient and effective	**Preferred natural light** for its brightest and brilliances and artificial light could be brightest.
3	Doctor Female	Care for patients Set line Call doctor	At evening, light not adequate Low level lighting	Natural lighting hinder performance	Yes, affect health and limit performance	Yes, with increase in openings and windows	Yes, because it hinders efficiency, assess to Vitamin D	Both Natural and artificial light especially natural light because of vitamin D
4	Doctor Male	Attend to patients Ward round. Attend to emergences post-operative and surgeries	Light is dim if there is no artificial light	Natural light is not enough Not adequate	Yes, affect health causes eye strain Headache General discomfort	Yes, with more opening through windows and doors	Yes, because it enhances work	Both artificial and natural light because they augment each other
5	Doctor Male	Treat patient Ward round Diagnostic treatment	Illuminance level not enough	Natural light not adequate Hinder performance	The impact on health is minimal	Yes, with more window opening and support with artificial light	Yes, because it sometimes gets dark	**Natural lighting** for general feeling of wellbeing, liveliness, and no health effect
6	Doctor Male	Plan with consultants Ensure patients get good quality care	Illuminance is okay	Natural light not adequate Hinder performance when no electricity	I do not know. Do not pay attention to it	Yes, with more lighting	Yes, because it improves work performance	Prefer natural lighting and more on artificial light because it difficult to expose the ward to natural light
7	Midwife	Administer drugs Work with mother and child in labour ward	Not adequate when there is no electricity or when it is cloudy	dark when there is no electricity	It affects health Hinder performance and cause discomfort	Yes, with more windows through restructuring	Yes	**Natural light** because of comfortability
8	Midwife	Take care of women in labour and take delivery	Not adequate when there is no light	Natural light is okay	It does not affect health	No, it is comfortable	Yes, prefer improvement	**Prefer Natural lighting** because it has no negative effect on health More artificial light at night or cloudy weather
9	Nurse Female	Helping patient with care plan. Give medication Dress wound. Sort out file	Illuminance level not enough. Hinder performance	Not enough hinder performance	Yes, affect health causes eye straining Difficulty in reading and writing. Headache	Yes, with more window and more opening	Yes, because it improves work standard	**Natural light** because it has no side effect and soothing

S/N	Nature of job	Job description	Is Illuminance adequate	Is the level of Natural illuminance and lighting provided enable or hinder performance	Do illuminance level in your workplace affect your health or limit performance	Do you think daylighting provision can be improved in the building	Will you prefer an improvement to the illuminance level in your workplace and why	Will you prefer artificial or natural lighting and why
10	Nurse Female	Attend to patient Give medication Dress wound	Illuminance level is poor when there is no artificial light	It depends on the weather condition and time of the day. It does hinder performance	Yes, it affects health Eye straining	Yes, with more opening for lighting and ventilation more window	Yes	**Natural light because** of its brilliance and beauty it does not generate heat At night more artificial light
11	Nurse Female	Care for patients Deliver good quality care	Illuminance level not at its best but is okay	Natural light is okay.	No. it does not have a negative effect on health	Yes, more window for proper adequate light inside the building	Yes	Artificial light
12	Nurse Female	Admit patient Administer drugs Take patient vital sign, treatment documentation	Not sufficient though moderate	Natural light is pleasant but when the weather is cloudy it hinders performance	Yes, it affects health Causes headache Eye straining Affect mood	Yes, more windows Increase in opening	Yes, for more effectiveness in workplace and better performance of task	Both Natural lighting and artificial light should be brighter and more consistent during the night
13	Nurse Male	Take care of patient Give medication Monitor vitals	Illuminance level not adequate	It affects performance and causes difficulties to work effectively and efficiency	No, does not affect health because I adopt to any condition	Yes, Improve ventilation, natural lighting, circulation more opening and window	Yes, because it allows to carry out assigned task adequately and satisfactory	Artificial light is preferred because natural light is sufficient outside the building
14	Nurse Male	Attend to patients, work in surgical ward Serve medications Dress wound	Illuminance level is moderate though not very bright as it should be	Natural illuminances hinder performance when there is no light. Illuminance not adequate but better in the daytime than at night	Yes, it affects health also causes occupational hazard like picking with the needle or syringe	Yes, let there be alternative artificial light when the light goes off as soon as possible	Yes, because it helps to deliver good quality service to patients and prevent occupational hazard	Both artificial and natural light because both are not adequate at night
15	Pharmacist	Give medication, check drugs interactions and counselling. Drug therapy/render pharmaceutical care to patient	Illuminance level not adequate	Natural light not adequate during the night, rainy or cloudy days	Yes, it affects performance. Causes eyestrain	Daylight cannot be improved because other building serves as obstruction, but artificial light can be improved	Yes, for adequate lighting	**Natural lighting** because it is more reliable and contain vitamin D and healthier, save energy and save money
16	Physiotherapist	Attend to inpatients and outpatients Orthopaedic surgeries	It is adequate but can be better	Level of natural illuminance is not good	Yes, it affects health	Cannot say for sure but the building should give room for adequate ventilation (neutral)	Yes, improvement in illuminance level allow for more natural illuminance into the building	**Natural light** because no health implication, no economic stress, and other benefits.

Table 19: Statistics on Participants and their Responses.

Variables	**Frequency**(percentage)	**Interpretation**
Gender		62.5% of the respondents are female while 37.25 are male.
Female	10 (62.5)	
Male	6 (37.5)	
Job Role		37.5% are doctors another 37.5% are nurses and 12.5% are midwife
Doctor	6(37.5)	
Nurse	6(37.5)	
Midwife	2(12.5)	
Pharmacist	1(6.25)	
Physiotherapist	1(6.25)	
Is illuminance level adequate in work areas?		68.75% of the respondents declare that the illuminance level is not adequate while 18.75% declare that the illuminance level is adequate and 12.5 declare that it is moderate.
Adequate	3(18.75)	
Not Adequate	11(68.75)	
Moderate	2(12.5)	
Is the level of natural illuminance and lighting provided enable or hinder performance?		81.25% of the respondent agree that the natural illuminance and lighting provided hinder performance while 18.75% declared that it does not hinder performance.
Yes, hinder performance.	13(81.25)	
No does not hinder performance.	3(18.75)	
Do illuminance level in workplace affect your health or limit performance.		75% of the respondents declared that the illuminance level in the workplace affects their health and limit performance while 18.75% declared that it does not affect their health while only 6.25% are not sure.
Yes	12(75)	
No	3(18.75)	
Not sure	1(6.25)	
Do you think daylight provision can be improved in the building to enhance performance?		81.25% of the respondents agree that daylight provision can be improved in the building to enhance performance while only 6.25 are not sure of it and 12.5 agree that it is not possible.
Yes	13(81.25)	
No	2(12.5)	
Not sure	1(6.25)	
Will you prefer improvement to illuminance level in your workplace?		100% of the respondents will prefer improvement to illuminance level in the workplace
Yes	16(100)	
No	0	
Will you prefer artificial or natural lighting?		25% prefer both artificial and natural light and 12.50% prefer only artificial light and 62.5 prefer natural light.
Both	4(25.0)	
Only artificial light	2(12.50)	
Only natural light	10(62.5)	

5.2.2.2 ***Initial Codes and the Emerging Themes***

The process of this thematic analysis revealed inherent patterns and concepts within the dataset, thereby enhancing the understanding of the subject being investigated. Table 20 functions as an asset, resembling foundational building blocks in the form of codes. These codes play a significant role in identifying and analysing the key concepts within the overarching themes. It is essential to emphasise that these codes mark the initial phase of the analytical process. They provide the starting point for a deeper exploration and systematic organisation of textual data, ultimately

Table 20: Initial Codes.

Initial code	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Admitting and general care of patient	5	8	Take care of patients, delivering good quality care that makes them happy and better and ready to go back home soon. (PT 11). Attend to the patients that are admitted on the wards and then continue the management on the ward patients (PT 4)
Preparing and stabilising patients for admission and surgery	3	6	That is, IVC (Inferior Vena Cava) lines, or blood transfusions. I'm expected to run all those. (PT 2)
Handling patient files and documentations	4	6	Also sorting out case files, documentations. (PT 9)
Checking and Observing patients' vitals	4	4	I monitor their vitals and make sure that patients are safe and served in a particularly good and conducive environment. (PT 13)
Administering medications, delivering injections, and dressing wounds	7	7	Give medications, deliver jab, dress wounds, take patients vitals, and provide general medical care to patients (PT 10)
Providing pharmaceutical care	1	1	We do medication reconciliation, check for drug interaction, do medication counselling to patients, and tell them about their medication allocations (PT 15)
Addressing patient concerns	2	4	Usually collect the patients and help set lines and usually move concerns or questions and report back to my residents doctor any complaint to help manage the patient. (PT 3)
Low-Level Illumination	13	14	The illumination level in my work area cannot be described as sufficient for most task being carried out. (PT 12)
Fluctuations in Illumination	4	4	Often, the illumination level varies and depend on the location within the ward. (PT 5).
Influence of Environmental and External Factors	6	9	This is necessary in case of change in weather as we see during this raining season when the cloud will be dark, and the illumination level becomes low. (PT 11)
Adaptation and Coping mechanism	8	10	In many instances I use my small flashlight as a coping mechanism to carry on with the work at such times of low illumination. (PT 15)
Physical and Health Impacts	11	17	Reduce any potential health effects like eyestrains and headache associated with inadequate light. (PT 13)
Strain, headache, and general discomfort	12	21	But overall, the challenge is when there is no light and you are doing something that needs to be completed you have to strain the eyes which can give discomfort, maybe headache and if it is for a prolonged period. (PT 4)
Psychological and Emotional Response Mood and Feelings: Positive Emotional States	5 5	8	I don't like low light situations, I don't. It just makes me feel very dull. A place that is dull and just feel genuinely like, I don't even feel like working today. That kind of thing/thought. (PT 1) Though, difficult to explain why but a general feeling of wellbeing and liveliness natural lighting provides. (PT 5)
Task Performance and Efficiency	11	20	You cannot concentrate to do what you must do. In essence affects our concentration. In essence, though try to work when the illumination level is not adequate but won't be able to work optimally or nor perform at best. (PT 15)
Artificial lighting complementing the qualities of natural light	12	13	In the daytime with or without artificial light, I carry out the required task, that in the daytime, but at night rely solely on the artificial light. (PT 13)
Challenges of Inadequate Daylight	10	15	But the illumination from the natural lighting is extremely poor (PT 10). Depending on the insufficient illumination of the natural light, we are prone to occupational hazard including picking yourself with needles, syringes, and other things like that and even fall. (PT 14)
Architectural Impact on Light: Building Design's Impact on Illumination	12	14	Because of the new buildings there, which serves as obstruction to receiving the lighting from the sun. (PT 3)

Initial code	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Enhancing Lighting Conditions	12	12	There is need for improvement on the illumination in the work area. This is because better illumination will allow to see and carry out the assigned task adequately and satisfactorily as expected. If also, the illumination level is improved, this will reduce any potential health effects like eyestrains and headache associated with inadequate light. (PT 13)
Advancing Architectural Design	7	7	The building spacing should be one of the focus areas. Not only looking at the light, but also the ventilation and circulation around the wards or in between the wards should be improved. (PT 13)
Potential Benefits of Change	3	8	It helps in to deliver good and quality services to the patients and prevent the occupational hazard earlier talked about. (PT 14)
Increasing Window Presence for Improved Light Inflow	12	12	Restructuring of the building in a way to have more windows, increase the number of windows and position them in a way that allows more illumination from the outside into the building. (PT 7)
Natural light as the preferred lighting choice	13	13	Personally natural lighting. Well, there's something about nature. (PT 1)
Positive Associations with Natural Light	10	13	I prefer natural lighting for its brightness and brilliance. (PT 2)
Health and Wellbeing Benefits of Natural Light	2	3	I will prefer to have natural lighting. Though, difficult to explain why but a general feeling of wellbeing and liveliness natural lighting provides. Also, it ensures less or no strains and stress. (PT 5)
Energy Efficiency and Reliability of Natural Light	2	2	Natural light is also healthier. Oh, this way save energy save money which is better. Besides, natural lighting is more reliable. (PT 15)
Positive Impacts on Human Factors	2	2	Make the work, help patient's health very efficient and to meet expected health outcome. (PT 13)
Incorporating Natural Light in Architecture for Optimal Results	5	6	Restructuring of the building in a way to have more windows, increase the number of windows and position them in a way that allows more illumination from the outside into the building. (PT 7)

leading to the emergence of coherent themes and discernible patterns.

Table 21 goes a step further by illustrating how these codes are grouped, shedding light on the emerging themes revolving around the impact of indoor lighting on healthcare personnel. These themes bring into focus a broad spectrum of effects, ranging from emotional well-being and physical health to task performance and personal preferences. Particularly intriguing is the significance attributed to natural light and the complementary role of artificial lighting in providing environments that promote well-being and productivity among healthcare professionals.

Table 21: Formation of Themes by Grouping of Initial Codes.

Theme	n of participants contributing	n of transcript excerpts assigned. Table 17 & 19
Theme 1: Patient Care and Management 1. Patients’ interactions 2. Handling patient files and documentations 3. Checking and Observing patients' vitals 4. Administering medications, delivering injections, and dressing wounds	16	36
Theme 2: Challenges and Coping with Inadequate Lighting 1. Importance of illumination 2. Inadequate Illumination 3. Fluctuation in Illumination 4. Influence of external and environmental factors 5. Adaptations and coping mechanism	16	37
Theme 3: Effects of Lighting on Health, Wellbeing, and Performance 1. Physical and health impacts 2. Psychological and emotional responses 3. Task performance and efficiency	14	56
Theme 4: Dynamics of Natural and Artificial Light Interaction in Built Environments 1. Harmonising source of light 2. Artificial lighting during the night hours 3. Challenges of inadequate daylight 4. Architectural impact on light: Building design’s impact on illumination	15	42
Theme 5: Advocation of Improved Lighting Environment 1. Enhancing lighting conditions 2. Suggested remediations 3. Advancing architectural design 4. Anticipated positive outcomes	12	39
Theme 6: Preference for Natural Lighting and its Benefits 1. Perception and preference for natural light 2. Positive associations with natural light 3. Health and wellbeing benefits of natural light 4. Energy efficiency and reliability of natural light 5. Positive impact on human factors 6. Incorporating natural light in architecture for optimal results	14	40

Thus, these identified themes act as lenses through which this study scrutinises the impact of lighting on individuals and their immediate surroundings. In doing so, they make a substantial contribution to enhancing our collective knowledge and insights around research dedicated to this subject matter.

5.2.2.2.1 **Theme 1: Patient Care and Management**

This theme presents the intricate relationship between various professional in providing patient care and management within a healthcare environment. It provides an in-depth look at the various roles and responsibilities of medical professionals, focusing on patient care, monitoring, documentation, and patient interactions.

Medical professionals in hospitals includes surgeons and general practitioners among medical doctors, each with distinct duties ranging from patient admission and surgery preparation to emergency stabilisation and routine clinic or ward rounds. General practitioners manage patient diagnoses, treatment, ward rounds, and care administration. House officers, with less experience, manage patient intake, line placement, and sample collection, reporting issues to resident doctors for further action.

Midwives work in shifts and are primarily responsible for maternal and foetal care. Their tasks include delivering babies, monitoring vital signs and measurements, and gathering crucial newborn information before transferring infants to post-natal care. Nurses are pivotal in-patient care, undertaking responsibilities such as medication administration, wound dressing, general medical care, patient admission, drug administration, and meticulous treatment documentation.

They also follow care plans, especially for malnourished patients, and prepare patients for surgery. Table 22 provides details of patient's care and management.

Table 22: Patient Care and Management.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Patients' interactions	10	12	I do take care of patients. I consult, I do surgeries and just generally take care of the patients. (PT 4)
Checking and Observing patients' vitals	8	6	I work through shifts in a day... we deal with mother and child, and we keep monitoring them including observations of vital signs. (PT 7)
Handling patient files and documentations	6	6	I take patient's vital signs, document details of treatment, and carry out other duties assigned. (PT 9)
Administering medications	7	7	Provide pharmaceutical care to patients in the hospital, including medication reconciliation, drug interaction checks, and medication counselling.". (PT 15)

This theme underscores the importance of delivering high-quality patient care, underpinned by seamless collaboration among medical professionals. According to the responses, key components include the nature of medical work like patient care, ward rounds, emergency response, teamwork, documentation, patient monitoring, and the environment within which they operate.

5.2.2.2.2 **Theme 2: Challenges and Coping with Inadequate Lighting**

This theme presents the perspectives of healthcare professionals concerning the levels of illumination and how these levels affect their work performance. It emphasises the pivotal role of adequate lighting in patient care, staff productivity, and overall well-being. The results as shown in Table 23 underscore the positive influence of lighting on mood, patient recovery, and the health of healthcare personnel, highlighting its critical role in enabling precise medical procedures and ensuring safety.

Table 23: Challenges and Coping with Inadequate Lighting.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Importance of illumination	10	11	In essence, though try to work when the illumination level is not adequate but won't be able to work optimally or nor perform at best. (PT 15)
Inadequate Illumination	10	10	In this work area the illumination is not enough currently. (PT 7)
Fluctuation in Illumination	6	6	illumination varies during the day which makes it sometimes adequate and sometimes not adequate. (PT 2)
Influence of external and environmental factors	7	7	There is adjacent one blocking the access to light from the door and windows ". (PT 3)
Adaptations and coping mechanism	9	12	In such instances, one looks for other means and have employ coping mechanisms to perform duties. (PT 10)

The findings highlight the challenges associated with inadequate lighting. Many healthcare professionals, express dissatisfaction with low light conditions, while others note that illumination levels can vary based on location and are frequently inadequate. Some emphasise the importance of artificial lighting and backup power, particularly for night time tasks. Moreover, fluctuations in illumination due to environmental factors, such as adverse weather conditions, are mentioned as occasional hindrances to task performance.

The findings bring to attention the impact of inadequate lighting, highlighting concerns such as visual strain, reduced focus, and discomfort. The responses suggest possible consequences for patient care, including potential inaccuracies due to compromised visibility. Practical approaches such as supplemental lighting tools are seen as strategies for managing low illumination challenges. Moreover, the findings emphasise the limitations of relying solely on coping mechanisms, suggesting sustainable and effective lighting solutions in healthcare environments.

Therefore, these findings point to the importance of consistent and sufficient lighting in healthcare environments, noting the significant effects on the ability of healthcare professionals to perform their duties effectively. These insights from healthcare professionals' experiences reveal various challenges related to lighting in their workspaces, ranging from variable availability and quality to personal preferences. These challenges not only impact task performance but also contribute to discomfort and general wellbeing and they stated an urgent need for improved lighting solutions in their work environment.

5.2.2.2.3 **Theme 3: Effects of Lighting on Health, Wellbeing, and Performance**

This theme explores the effects of illumination levels on the well-being and work performance of healthcare professionals, encompassing roles like doctors, nurses, midwives, pharmacists, and physiotherapists. It identifies three main adverse effect of insufficient lighting: physical health consequences, emotional and psychological reactions, and variations in task efficiency. The theme as presented in Table 24 underscores that inadequate illumination negatively affects different aspects of healthcare work, from eyesight and mood to documentation precision and the risk of occupational hazards like needle injuries and falls.

Table 24: Effects of Lighting on Health, Wellbeing, and Performance.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Physical and health impacts	9	14	Sometimes I must squint my eyes short for some time before I continue what I'm doing, and it is usually results in headache thereafter. (PT 4)
Psychological and emotional responses	5	5	Sometimes affect my mood, to be honest, it is difficult to have best output when you have headache or have mood swing, but we always try to give our best. (PT 12)
Task performance and efficiency	11	14	Yes, the room is not adequately illuminated and so hinders performance of task at hand. (PT 5). Yes, it affects interpreting of prescriptions, verifications of prescriptions and hinder them. (PT 15).

Numerous participants reported experiencing health and work-related problems due to poor illumination, including eye strain, headaches, and difficulties in reading and documenting information. Some participants, however, adapted to varying conditions and believed that illumination levels did not affect them significantly. Interestingly, there was a contrast in responses between genders, with females expressing more concerns about the impact of inadequate lighting on their health and job performance. Another key finding was the essential role of natural light in maintaining the health of healthcare professionals. Access to natural light emerged as a crucial factor, influencing vitamin D intake, bone and teeth health, and overall well-being.

This theme provides valuable insights into how illumination levels affect the health and performance of healthcare professionals. It emphasises the necessity of proper lighting, including access to natural light, in healthcare environments to ensure optimal conditions for both physical and mental well-being. The theme also acknowledges that individual factors such as visual acuity, workload, and working conditions can mediate the impact of illumination levels on healthcare professionals.

5.2.2.2.4 **Theme 4: Dynamics of Natural and Artificial Light Interaction in Built Environments**

This theme underscores the pivotal role of artificial lighting in harmonising with the inherent qualities of natural light, thereby enhancing the aesthetics and functionality of indoor built environments. The findings shed light on the intricate balance between the two, revealing the critical significance of their collaboration. Several participants drew attention to the challenges arising from limited access to natural light, highlighting the adverse impacts it can impose. Such deficiencies are shown to be detrimental to the well-being of occupants and the overall energy efficiency of buildings. The result in Table 25 also indicated the barriers hindering the penetration of natural light into built environments, with environmental factors and architectural choices playing pivotal roles.

Table 25: Dynamics of Natural and Artificial Light Interaction in Built Environments.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Challenges of inadequate daylight	8	8	Basically, because the natural light is not enough and inadequate. (PT 14) But the illumination from the natural lighting is extremely poor when the artificial light is not available. (PT 10)
Artificial lighting during the night hours	10	14	In the daytime with or without artificial light, I carry out the required task, that in the daytime, but at night rely solely on the artificial light. (PT 13)
Harmonising source of light	12	15	So, if possible, the two sources could come into play. The artificial light as the source of lighting, because the natural is not enough, and inadequate, especially in the night. (PT 14)
Architectural impact on light: Building design's impact on illumination	8	12	And because of the new buildings there, which serves as obstruction to receiving the lighting from the sun (PT 3).

Participants noted the dynamic nature of natural light, which can fluctuate due to changing weather conditions and the transition from day to night. These fluctuations significantly influence the overall lighting experience within buildings. Consequently, some participants highlighted the crucial role of artificial lighting, particularly during nighttime hours when natural light is unavailable or inadequate. They stressed the necessity for architectural spaces to be equipped to provide sufficient illumination during these times.

Furthermore, many participants discussed how building design plays a pivotal role in determining the availability and distribution of light. They emphasised the significance of strategically placing windows and organising architectural layouts to optimise illumination within a space. Participants offered insights into methods for enhancing lighting conditions in their work environments, including optimising window placement, and efficiently using artificial lighting to ensure well-lit spaces.

The theme also shed light on discussions regarding the advancement of architectural design practices. Integrating natural and artificial lighting seamlessly emerged as a key consideration in these conversations. Overall, this theme emphasises the mutual reinforcement of natural and artificial light sources. Rather than being in competition, these sources were viewed as complementary elements in achieving optimal lighting conditions. The theme encompasses various facets of how light interacts with architectural spaces and the challenges and opportunities it presents.

5.2.2.2.5 **Theme 5: Advocation of Improved Lighting Environment**

This study presents the perceptions of healthcare professionals regarding the lighting conditions, wellbeing, and performance in their workplaces. The theme advocating for improved illumination resulted from a multitude of factors, encompassing visual comfort, overall well-being, improved work efficiency and uninterrupted workflow to facilitate best patient care. As presented in Table 26, the insights from the findings underscore the pivotal role that adequate lighting plays in healthcare environments, impacting both the wellbeing and efficiency of healthcare professionals.

It is worth noting that this study is situated within the context of recent enquiries into illumination levels in healthcare facilities. Within this study, the perceived need for improved illumination levels among healthcare professionals is emphasised, irrespective of gender or job role differences. Additionally, a range of recommendations surfaces. These include strategies such as optimising architectural layouts, expanding window openings to harness natural light, and upgrading lighting fixtures. Advocating for architectural redesigns and lighting system enhancements emerges as a proactive approach to ensure consistent and sufficient illumination, with the aim of improving patient recovery, motivating staff, and enhancing overall healthcare efficiency.

Table 26: Advocating for a Better Lighting Environment.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Enhancing lighting conditions	11	11	It will be good to have improvement because sometimes get really dark with little illumination from sunlight and lack of artificial light as a result of power outage. (PT 5)
Suggested remediations.	8	10	Maybe restructuring of the building in a way to have more windows, increase the number of windows and position them in a way that allows more illumination from the outside into the building. (PT 7).
Advancing architectural design	6	6	Not only looking at the light, but also the ventilation and circulation around the wards or in between the wards should be improved. (PT 13). The structure of the building and the arrangement within the ward make it difficult working when the light is not available. (PT 7)
Anticipated positive outcomes.	12	12	This is because better illumination will allow to see and carry out the assigned task adequately and satisfactorily as expected. If also, the illumination level is improved, this will reduce any potential health effects like eyestrains and headache associated with inadequate light. (PT 13).

Inadequate illumination within healthcare facilities is revealed as a factor impacting work performance, resulting from discomfort, eyestrain, and mood disturbances among healthcare practitioners. Additionally, the findings express concerns about potential occupational hazards and heightened stress levels arising from insufficient lighting conditions. Interestingly, respondents also emphasised the need for adequate illumination during power outages, underscoring the importance of lighting levels for practicality and safety. This finding highlights the significance of emergency lighting systems in healthcare facilities to ensure that healthcare professionals can effectively and safely carry out their duties in the event of power failures.

While there were no significant gender differences in the responses, some participants emphasised the importance of good illumination more strongly than others, likely due to their personal experiences with inadequate lighting, including eyestrain and mood disturbances. However, it is noteworthy that participants did not exhibit notable differences in their responses based on their job roles. All healthcare professionals expressed similar concerns and preferences regarding illumination levels in their work environment. One notable finding in the analysis revolves around the pivotal role of natural light within the healthcare work environment to promote the well-being and professional performance of healthcare practitioners. Healthcare professionals underscore the significance of increased natural light in their workspaces, viewing it as a crucial alternative to artificial lighting.

5.2.2.2.6 **Theme 6: Preference for Natural Lighting and its Benefits**

The impact of lighting within a workplace is undeniably profound, influencing productivity, safety, and the overall wellbeing of employees. Whether in an office or a healthcare facility, two primary lighting sources play a pivotal role: natural and artificial light. Each source carries its own advantages and disadvantages. Table 27 presents the preferences of healthcare professionals regarding lighting in their work environments, exploring its significance, their reasons for favouring specific lighting options, and the implications for designing workspaces. The focus is on the perception and preference for natural light and its positive associations, including its benefits for health and wellbeing, energy efficiency, its positive effects on human factors, and strategies for integrating natural light into architectural designs to optimise outcomes.

Table 27: Preference for Natural Lighting and its Benefits.

Subtheme	***n* of participants contributing**	***n* of transcript excerpts assigned**	**Sample quote**
Perception and preference for natural light	14	16	Natural lighting is preferred. For obvious reasons, I know everyone prefer natural lighting. (PT 7)
Positive associations with natural light	12	14	That, do I say, inspires or brings life kind of and that just makes you upbeat. Yeah. (PT 1).
Health and wellbeing benefits of natural light	12	15	I will prefer natural lighting because what is available is not enough. Besides, natural light will not have negative effects on health. (PT 8)
Energy efficiency and reliability of natural light	8	12	One, it does not make any economic sense that in the daytime having to use electricity (artificial light) in a place with abundant sunlight. (PT 16).
Positive impact on human factors	4	6	Natural lighting improvement would be preferred for use during the day. First, for the brilliance, and beauty it offers. (PT 10)
Incorporating natural light in architecture for optimal results	8	8	Making sure that these openings also have direct access windows where lighting can still possible even though there's a building there. (PT 3)

The results emphasise healthcare professionals' leaning towards natural light. Their preference is grounded in the recognition of its superior brightness and the myriad positive associations tied to it. The findings reveal that these associations include the calming qualities, invigorating effects, comforting nature, and inspirational aspects of natural light. Additionally, the theme sheds light on the substantial health and wellbeing advantages linked with natural light. Respondents view it as a superior lighting source, acknowledging its multiple benefits, including its positive impact on health and its contribution to overall wellbeing through regular exposure. Beyond these points, the findings also underscore the energy-saving potential and reliability of natural light, aspects highly valued by healthcare professionals. According to the analysis natural light not only conserves energy but also serves as a dependable illumination source, even during power outages. Perhaps most significantly, the results highlight the positive effects of natural light on human factors. It is suggested to lead to improved patient outcomes, boosting staff morale, increased productivity, and the regulation of circadian rhythms, all which respondents deem essential in healthcare environments.

The findings of this analysis conclude with a recommendation: the incorporation of natural light into architectural designs to maximise its benefits. Suggestions include integrating architectural elements that optimise natural light in the workspace and employing design strategies that harness its full potential. While healthcare professionals strongly favour natural lighting, they acknowledge the occasional need for artificial lighting, particularly during nighttime or adverse weather conditions.

This theme underscores the preference of healthcare professionals for natural lighting in their workplaces. This preference arises from a variety of factors, encompassing personal choice, associated health benefits, the consistent and reliable nature of natural light, the specific location and structure of the workplace, and the availability of electricity. The positive impact of natural light on both their wellbeing and work performance is cited. However, the findings also acknowledge that there are situations where artificial lighting remains indispensable.

5.3 Chapter Summary

This chapter presents into the intricate qualitative findings that illuminate the effects of indoor lighting on the well-being and performance of healthcare personnel. While the previous chapter centred on a quantitative analysis, examining illuminance data and participant surveys to uncover variations in lighting levels and preferences across different wards, this chapter adopts a thematic analysis approach. This methodology offers a deeper comprehension of the human experiences, shedding light on the interplay between perception, preferences, and the influence of indoor lighting on personnel.

The thematic analysis methodology is elaborated upon to underscore its versatility in discerning patterns and themes within qualitative data. The stages of data familiarisation, coding, theme identification, review, and report writing are elucidated, emphasising the systematic process used to extract meaningful insights.

One noteworthy finding is the observation that no new information surfaced beyond the ninth interview, a validation corroborated by an independent analysis performed by a colleague. This observation aligns with the concept of categorical saturation within phenomenological studies, concluding that a total of sixteen interviews yielded a comprehensive dataset, aligning with the research objectives.

The qualitative results and findings are presented in six overarching themes:

1. Patient Care and Management: This theme underscores the nature of patient care, encompassing various responsibilities like medication administration, documentations, and patient interactions. The narratives emphasise healthcare professionals' dedication to patient well-being, interdisciplinary collaboration, and patient-centric treatment strategies.
2. Challenges and Coping with Inadequate Lighting: Highlighting the strain posed by insufficient lighting on healthcare personnel, leading to vision strain, reduced focus, and discomfort. The potential adverse effects on patient care quality are acknowledged.

3. Effects of Lighting on Health, Wellbeing, and Performance: This theme underscores the profound influence of lighting on mood, patient recovery, and staff well-being. It stated that lighting is important for precise medical procedures and safety protocols.
4. Dynamics of Natural and Artificial Light Interaction in Built Environments: Natural light is identified as a key factor in creating a healing environment, enhancing staff morale, and boosting productivity. The efficacy of artificial lighting systems is critically evaluated.
5. Advocacy for Improved Lighting Environments: Advocating for architectural designs that maximise the integration of natural light and proposing enhancements to artificial lighting systems. The health ramifications of inadequate lighting are also underscored.
6. Preferences for Natural Lighting and its Benefits: Healthcare personnel express a strong preference for natural light, citing its positive impact on their work environment and personal well-being. These qualitative insights harmonise with quantitative findings, reinforcing the connection between natural lighting and an enriched work experience.

This qualitative analysis offers an exploration of the intricate connection between lighting conditions and the overall well-being and performance of healthcare personnel. The emergence of consistent themes throughout the interviews indicates that data saturation has been achieved, aligning with the study's objectives. Table 28 serves to illuminate how these emergent themes contribute to the fulfilment of the study's research objectives.

Table 28: Emerging Themes and Research Objectives.

Research objectives	Themes that address the objective
RO1. Assess personnel's perception of light level with measured illuminance level at each workstation	Theme 2: Challenges and Coping with Inadequate Lighting Theme 4: Dynamics of Natural and Artificial Light Interaction in Built Environments
RO2. Assess the subjective assessments of personnel's satisfaction, wellbeing, and task performance in relation to lighting conditions.	Theme 3: Effects of Lighting on Health, Wellbeing, and Performance
RO3. Assess personnel's preference for use of daylight and the implication for healthcare facility design	Theme 5: Advocation of Improved Lighting Environment Theme 6: Preference for Natural Lighting and its Benefits

The identified themes emphasise the pressing need for lighting solutions that prioritise the utilisation of natural light to enhance patient care, staff well-being, and the overall efficiency of healthcare delivery. Thus, these qualitative insights as illustrated in figure 31, complement the quantitative results, offering a comprehensive perspective on the complex interplay between lighting, well-being, and performance within healthcare environments.

Figure 31: Summary of Qualitative Findings.

Chapter VI: Discussions

"You should be aiming to illuminate your indoor daytime environment with natural outdoor light, not electrical lighting products."
— Steven Magee, Light Forensics

This chapter presents the main discussion highlighting the practical implications for the design and construction of healthcare facilities, drawing upon the results and findings from previous chapters. It combines a qualitative approach to analyse contextual and meaningful data, complementing the quantitative approach focused on indoor lighting. Both methods underpin the analysis and findings presented in this research. The chapter is structured into six sections, each addressing specific aspects of the research findings and their relevance:

The first section provides an introductory background to set the stage for the subsequent discussions. It gives context to the research, its objectives, and the importance of the topic.

The second section presents the literary evidence related to how lighting conditions affect the wellbeing and performance of healthcare personnel. This includes findings on how lighting influences factors like mood, productivity, and job satisfaction.

The third section focuses on the measured illuminance levels within the healthcare facility. It discusses finding on the actual lighting conditions in different areas of the facility and discusses their significance in relation to healthcare personnel's needs.

The next section presents and discusses the results of subjective assessments conducted with healthcare personnel. This involves the results of the surveys and interviews on lighting characteristics and disturbances and how these factors relate to their job satisfaction, performance, and overall wellbeing. It also includes a comparison of these subjective assessments with the measured illuminance levels.

The fifth section discusses healthcare personnel's preferences for lighting in their work environment. The discussion includes opinions on preferred light levels, use of daylight and how these preferences affect their work experience. This can shed light on their ideal lighting conditions and may inform recommendations for facility design.

The closing section presents and discusses how the design of the healthcare facility impact the wellbeing and performance of personnel. It touches on architectural features like window placement, lighting fixtures, and overall layout enhance or hinder the effects of lighting on personnel. The chapter concludes with a summary of the key findings and implications discussed in the preceding sections.

6.1 Introduction

Despite advanced healthcare technology, hospital design has been a source of stress, depression, and anxiety for both patients and staff. Surprisingly, little attention has been given to the impact of lighting conditions in healthcare environments. This study examines the lighting conditions and its effects on personnel's satisfaction, wellbeing, and task performance, while also suggesting design improvements for better daylight access in healthcare facilities.

To gain deeper insights into user-centred design within healthcare environments, this study employs a combination of quantitative and qualitative research methods, including questionnaires and semi-structured interviews. This approach, known as triangulation, enhances the accuracy of assessments by merging different data sources. Triangulation ensures a more precise understanding of qualitative outcomes and complements the strengths and weaknesses of various research methods. However, maintaining consistency in research purpose, questions, and result interpretations is essential for harmonising qualitative and quantitative triangulation.

This study's main findings indicate that illumination levels in over half of the surveyed workstations fell below recommended standards, and personnel's assessments aligned with these conditions. The correlation coefficients provided additional evidence that each lighting characteristic or disturbance had a different effect on personnel’s satisfaction, wellbeing, and task performance. These findings suggest that lighting is a valuable tool that should have a key role in healthcare facility design to promote wellbeing in the design of healthcare facilities.

The correlation between lighting conditions and healthcare personnel's wellbeing and performance, indicated that inadequate lighting can reduce satisfaction and morale, but improved visibility can decrease errors and enhance patient outcomes. The reduction in medical errors due to better lighting conditions aligns with broader literature (Wingler & Keys, 2019; Ulrich et al. 2008) on environmental factors impacting healthcare worker performance and patient safety. Poor lighting conditions have been linked to increased stress and burnout rates among healthcare workers, affecting care quality. Adequate lighting has been shown to play a crucial role in regulating circadian rhythms and improving sleep patterns, as shown in previous research findings like Smolder et al. (2014) and Rea et al. (2008). Moreover, healthcare professionals working in well-lit environments are associated with enhanced care quality. Studies by Silvester and Konstantinou (2010) and Leccese et al. (2017) have linked poor lighting conditions to increased stress levels and burnout rates among healthcare workers, highlighting the practical implications of poor lighting conditions, which can result in physical discomfort and reduced performance.

Zadeh et al. (2014) added to this body of evidence by showing that nurses exposed to daylight at their workstation exhibited significantly improved physiological and psychological responses, suggesting that access to daylight can positively impact nurses and reduce nurse fatigue across physical, emotional, and psychosocial dimensions. The findings of this current study identify the positive impact of daylight exposure on personnel, boosting morale and promoting wellbeing various dimensions. These findings underscore the significance of healthcare facility design on personnel's wellbeing and performance.

This impact extends to both design principles and their practical application. However, a key aspect of this outcome centres on the concept of user-centred design within healthcare environments, an idea initially identified by Ulrich in 1991.

6.2 Evidence on Lighting and Impact on Wellbeing and Performance

The section presents and discusses the impact of indoor lighting on personnel’s wellbeing and performance in healthcare environments as gleaned from the review of relevant literature.

Role of Indoor Lighting: The literature review confirmed the pivotal role of indoor lighting in creating visual comfort for building occupants (Leccese et al. 2020). Understanding the factors that influence visual comfort is crucial for designing lighting environments that enhance well-being and productivity.

Observable and Implicit Components of Visual Comfort: Visual comfort was analysed as comprising both observable and implicit components (Jakubiec, 2023). Observable components pertain to lighting conditions, glare control, and access to outdoor views. Implicit components focus on subjective factors like perception, preference, and acceptance, influenced by individual characteristics such as age, gender, occupation, and activity.

Daylight’s Positive Effects: Adequate levels of daylight were found to have a positive impact on well-being and performance, supported by previous studies (Applebaum et al. 2010; Edwards & Torcellini, 2002). However, the review also highlighted the need to consider potential adverse effects of excessive daylight (Applebaum et al. 2010; Edwards & Torcellini, 2002), especially in regions with intense sunlight, necessitating UVB protection.

Evaluation Methods: The review emphasised the effectiveness of using occupant surveys and physical measurements to assess a building's performance concerning occupant comfort and productivity. Physical measurements should be supplemented by qualitative assessments to achieve a better understanding and a more detailed analysis of several different lighting parameters (Dianat et al. 2013). Additionally, it recognised independent variables like age, gender, job role, and activity type as factors influencing visual comfort (Reinhart et al. 2006).

6.3 Assessment of Illuminance Levels

This study employed a mixed-method approach for data collection and analysis, combining physical measurements, questionnaires, and interviews. This strategy provided depth and meaning to the results. By examining healthcare personnel's perceptions and experiences with various lighting conditions, this study provides valuable insights into how lighting impacts their well-being and performance in real-world settings. These findings underscore the importance of considering personnel's viewpoints when designing indoor lighting in healthcare facilities.

It is acknowledged that lighting serves a multiple purpose in healthcare environments, affecting not only visibility and task performance but also mood and well-being (Aries et al. 2015; Bellia et al. 2011). While it is evident that healthcare personnel do not universally appreciate or tolerate all aspects of lighting. This study significantly contributes to our understanding of lighting in healthcare environments, highlighting the diverse lighting needs across different job roles within healthcare organisations, as noted by Boyce et al. (2003).

One crucial finding in this study was that illuminance levels in about fifty five percent of the workstations surveyed fell below recommended standards especially in surgical, paediatric, and postnatal wards. Inadequate lighting in these critical areas could impact the quality of care and patient safety. Different areas and activities within healthcare environments indeed have varying lighting requirements, making it challenging to strike a balance between patient and staff needs, as discussed by Dianat et al. (2013), Ulrich et al. (2008), and Dalke et al. (2006). Interestingly, this study found a correspondence between personnel's perceptions of illuminance and the actual measured levels, suggesting that employees' assessments align with objective illuminance measurements in most cases. This finding contrasts with Ma et al.'s (2022) results, which reported no relationship between perceptions of illuminance and actual levels. The variation in lighting levels within a working environment may account for this discrepancy, as suggested by Dianat et al. (2013). This study also highlighted the challenges posed by inadequate lighting, including visual strain, reduced focus, and discomfort. It also identified potential repercussions for the quality of patient care, including compromised accuracy due to reduced visibility.

Contingency coefficients were employed in this study to evaluate the relationship between objective light level measurements and personnel's subjective assessments. These coefficients, ranging from 0.645 to 0.722, indicate a moderate to strong association between these variables.

This finding is crucial, as it establishes a connection between personnel's perceived light adequacy and the measured illuminance levels in different wards.

Consequently, this study's findings have implications for assessing light adequacy in various environments, especially in healthcare environments like hospitals. Suggesting that personnel assessments can serve as a practical and accessible tool for determining whether lighting conditions meet their task and comfort requirements, as shown in the study by Dianat et al. (2013). However, it is important to emphasise that while personnel assessments provide valuable insights, they should not replace objective measurements entirely. Objective measurements, such as illuminance levels in lux, as demonstrated in this and other studies, offer a precise and standardised way to quantify light levels. As suggested by Dianat et al. (2013), a better understanding of illuminance levels is achieved through a combined approach, integrating both personnel assessments and physical measurements.

This current study shows that about seventy percent of respondents considered at least one of the three evaluated lighting characteristics to be inappropriate, with the lowest rating of 2.33 given to the use of daylight. These findings indicate a strong correlation between light levels and employee satisfaction, with other lighting characteristics, such as light source and use of daylight, also significantly influencing satisfaction.

A higher percentage of respondents (approximately 72%) believed that lighting in their work environment negatively affected their job performance. Research evidence suggests that improving lighting in the workplace can enhance job performance, as demonstrated in studies among electronic assembly workers (Vahedi and Dianat, 2013) and nursing teams in operating rooms (Golvani, 2021). Therefore, providing suitable lighting in hospitals and healthcare environments is essential for enhancing employee performance and improving patient outcomes.

6.3.1 **Lighting Characteristics and Lighting Disturbances**

Furthermore, the assessment results underscore the critical importance of considering lighting characteristics and addressing disturbances when designing and managing healthcare facilities. This study's findings provide implications for the well-being and performance of healthcare personnel. Notably, the research emphasises the key role played by factors such as the qualities of light sources, light levels, and the incorporation of natural daylight in shaping the overall well-being of healthcare staff.

For instance, it becomes evident that maintaining appropriate light levels, particularly through the integration of natural light sources, yields many positive outcomes. One of the most noteworthy findings is the significant improvement of comfort, happiness, and job satisfaction among personnel working in well-illuminated environments. Adequate lighting, particularly natural light, has been consistently associated with improved moods, reduced anxiety levels, and increased overall job satisfaction. This study’s qualitative findings underscore the importance of optimal lighting conditions, including access to natural light, in promoting both physical and mental well-being. Additionally, it acknowledges the moderating role of individual factors such as visual acuity, work hours, and type of activities in shaping the impact of illumination levels on healthcare professionals. These findings align with prior research, exemplified by the Heschong

Mahone Group's 1999 study, which demonstrated that access to daylight in workplaces led to improved productivity and decreased absenteeism among employees.

Furthermore, this study highlights the adverse effects of lighting disturbances on the well-being and performance of healthcare personnel. Respondents expressed concerns related to issues like glare and unwanted shadows, which are associated with negative outcomes such as headaches, eyestrain, and physical discomfort. Glare poses a significant obstacle to visual tasks and concentration, potentially jeopardising the quality of patient care and personnel performance. According to the Commission Internationale de l'Eclairage (CIE) in 1987, glare can arise from an unsuitable range or distribution of luminance, luminance levels exceeding the visual system's adaptation, or extreme luminance contrasts. These findings align with previous research conducted by Leccese et al. (2020) and Konstantzos (2020) which demonstrated that glare could impair reading performance and visual comfort.

6.4 Personnel's Perception of Lighting

However, the degree of the impact of these design elements varies across different demographic factors, with age being a notable influencer in how personnel within the gender distribution of 78% female and 22% male, perceive and are affected by lighting conditions in hospital settings. Recent studies indicate substantial differences in how various age groups assess the appropriateness of light sources, as evidenced by Vahedi and Dianat (2013). The study implied that lighting preferences and needs may diverge across generations, necessitating designers to consider these variations in lighting system planning.

Job role is another crucial factor affecting the perception of design elements in healthcare facilities. This study shows that nurses and physicians hold differing views on the importance of lighting conditions, primarily based on the unique demands of their roles. Hence, healthcare facility designers may need to consider lighting solutions to cater to the distinct needs of different healthcare professionals, a point emphasised by Boyce et al. (2003).

The findings from this study also bring attention to the challenge of managing issues such as glare and unwanted shadows in healthcare environments. This study examined the perceived impact of glare and unwanted shadows on doctors, nurses, and midwives working in the different wards. Glare was identified as a significant source of disturbance and received high ratings in user surveys. For example, in the surgical ward, the Mann-Whitney U test revealed that while doctors tend to perceive the effect of glare more than midwives, no significant difference was found between them. Addressing these issues in the design of healthcare facilities is essential to create environments conducive to personnel wellbeing and performance, as suggested by Matusiak et al. (2022). Glare can disrupt the comfort and productivity of personnel, potentially impacting patient care. It is imperative to address glare issues through thoughtful design and the selection of appropriate lighting fixtures. This result underscores the need to address glare-related issues to ensure optimal working conditions for all healthcare personnel, regardless of their job role.

Regarding light levels, midwives were found to prefer lower light levels compared to doctors. However, like the glare perception, no significant difference in perceived light levels was observed between the two groups. This suggests that while there are differences in preferences, both doctors and midwives may perceive the actual light levels in a comparable manner. These findings highlight the complexity of lighting preferences and perceptions within healthcare environments and call for tailored lighting solutions that accommodate these variations. The mixed responses regarding flickering lights and unwanted shadows highlight the need for more nuanced approaches to lighting design. What may be tolerable for some personnel may be disruptive to others. Thus, healthcare facilities should aim for lighting solutions that can be adjusted or customised to accommodate the diverse preferences and needs of healthcare personnel.

6.4.1 **Differences Across Job Roles**

One of the key findings of the study is the variation in satisfaction levels with light levels across different job roles. Nurses express greater satisfaction with light levels compared to midwives. Additionally, doctors exhibit even higher levels of satisfaction than nurses. This divergence in satisfaction could be attributed to the varying demands and responsibilities associated with each job role. Moreover, the study identifies differences in lighting preferences among healthcare professionals. Nurses tend to prefer brighter lighting conditions compared to doctors, who, in turn, prefer brighter lighting than midwives. This preference for different light levels could be linked to the specific tasks and activities undertaken by each group. It is essential to recognise that the wellbeing and performance of healthcare personnel can be influenced by their satisfaction with the lighting conditions in their work environment.

6.4.2 **Lighting Impact According to Gender**

The present study presents significant insights into the preferences and requirements for lighting in healthcare environments to accommodate different gender preferences and needs. A significant observation was made regarding the impact of low light levels, indicating a greater sensitivity among females compared to males. This gender disparity was confirmed through post hoc Mann-Whitney tests, which revealed a more pronounced effect of light level on females across various hospital wards.

The statistical analyses not only validate the study's findings but also provide empirical evidence supporting gender-related differences in the perception and consequences of lighting conditions within hospital environments. These differences suggest that indoor lighting may have distinct emotional meanings for different genders.

A nuanced exploration of the interplay between age and gender revealed interesting dynamics. Older males exhibited a superior ability to maintain positive moods compared to their female counterparts, potentially influencing their overall satisfaction levels. On the other hand, younger females demonstrated a nuanced emotional resilience, preserving both positive and negative moods better than their male counterparts. This resilience was tentatively associated with improved satisfaction levels and task performance.

The evaluation of ward lighting further emphasised the impact of demographic variables, with older participants consistently perceiving room light as less bright and inappropriate compared to their younger counterparts. This difference may be attributed to age-related visual impairments among older adults.

This study not only highlights the need for targeted lighting approaches in healthcare environments but also reveals complex gender and age dynamics in the perception of lighting conditions. The findings contribute valuable insights into the emotional nuances associated with indoor lighting, emphasising the importance of a holistic understanding that considers demographic variables, gender, and task performance in lighting design strategies.

6.4.3 **Age-Related and Ward-Specific Variations**

This current study's findings suggest that lighting preferences and needs may vary among different age groups and across different hospital wards, suggesting targeted approaches to lighting design in healthcare environments.

Although, the findings show that glare, is a common lighting issue, it has a more pronounced effect on participants aged 40 and above compared to those aged 18-29 and 30-39. This suggests that older individuals could be more sensitive to glare and may experience greater discomfort or performance decrease when exposed to glare-inducing lighting. To confirm the age-related effects of glare, post hoc Mann-Whitney tests were conducted. These tests confirmed that the impact of glare is indeed more significant for individuals aged 40 and above, and this effect was observed in both the General Outpatient Department (GOPD) and Surgical wards. This statistical analysis strengthens the study's findings and provides empirical evidence for the age-related differences in the perception and effects of lighting conditions in hospital wards.

6.4.4 **Variations Across Activity Categories**

The study's findings indicate that differences in satisfaction with light levels and preferences for light exist across various healthcare job roles. Nurses express higher satisfaction with light levels than midwives and doctors, with doctors preferring brighter light levels than midwives. The current study identified variations in satisfaction with light levels and preferences for light levels in carrying out different activity categories, except for the “discussion” and “documentation” category, where no significant difference was found. Furthermore, it highlighted the “pre-examination” category as consistently exhibiting a significantly higher preference for light and satisfaction with light levels compared to other categories.

The study pointed out the “pre-examination” category as a standout in terms of personnel preferences for brighter lighting levels and higher satisfaction with existing lighting conditions. Notably this is consistent with EN 12464-1 standard, which requires an illuminance of 1000 lux for examination procedure. The right lighting in the examination room, combined with homely and clearly designed furnishings, form the basis for this. It is believed that brighter lighting in these spaces can contribute to better visual acuity, which is vital for diagnosis and treatment (Konstantzos et al., 2020). As a result, it is imperative for healthcare facilities to take note of these findings and adjust to ensure that “pre-examination” areas are adequately illuminated to meet personnel preferences and support their critical tasks.

While the specific lighting preferences vary, the study underscores the importance of creating customised lighting environments that cater to the diverse needs of healthcare professionals. This approach can contribute to improved wellbeing and performance among personnel in healthcare environments and enhance the overall quality of patient care.

6.5 Natural Light’s Positive and Impact in Facility Design

The qualitative findings in this study provided better understanding of how personnel perceive lighting conditions at various workstations, adding depth and meaning to their experiences. For instance, when participants were asked to assess the adequacy of illumination for their assigned tasks, it became evident that a significant majority of them found the lighting to be inadequate.

Approximately 75% of respondents expressed a desire improvement of the illumination level, while a about 85% indicated a preference for more natural light. These findings, while striking, are in line with anecdotal evidence that had previously hinted at issues related to building obstructions and insufficient access to proper illumination.

It is essential to recognise that the concept of lighting adequacy transcends natural light and extends to artificial lighting as well. Moreover, the strong preference for better access to natural lighting aligns with existing research. Studies conducted by Dianat et al. (2013) and Heschong et al. (2002) consistently underscore the significant impact of natural light on people's overall health, well-being, and performance.

Considering these findings, it is evident that adopting a participatory design approach is a plausible solution for improving facility design. This approach would involve personnel actively participating in the design process, ensuring that their lighting preferences and needs are given the utmost consideration.

One of the most key findings from this study is the repeated call for lighting solutions that prioritise the use of natural light. This priority is not driven solely by aesthetics; rather, it has profound implications for patient care, staff well-being, and the overall efficiency of healthcare delivery. Daylight emerged as a key contributor to both physical and mental well-being, distinctly different from artificial lighting. On the other hand, working in dimly lit operating rooms was perceived as detrimental to the well-being of personnel.

The study also provides details in the need for daylight, showing that it varies depending on factors such as the location within the ward, time of day, and time of year. For instance, personnel reported experiencing eyestrain and mood fluctuations during overcast weather when inadequate lighting was more pronounced. These observations align with previous studies, such as those conducted by Adamsson et al. (2018), which demonstrated the influence of weather conditions on well-being.

Creating a conducive visual environment is essential for promoting well-being, as highlighted by Hemphälä et al. (2020). In situations where personnel contend with poor artificial lighting and limited access to daylight, the adverse impact on mood becomes perceptible. The current study shows that working in dim light or inadequate illumination led to increased feelings of eye strain, headaches, and mood disturbances among personnel. This aligns with the findings of Dianat et al. (2013) and Küller et al. (2006).

Furthermore, the study aligns with the positive effects of exposure to natural light, as demonstrated by Kaida et al. (2006), where just thirty minutes of high-level natural light exposure yielded a lasting positive effect on mood. Studies like Zadeh et al. (2014) and Golvani et al. (2021) highlighted the benefits of access to windows and daylight, including increased social interactions and positive emotions. The present study aligns with these findings, indicating that personnel experienced positive emotions, inspiration, and an overall sense of well-being due to exposure to natural light. According to one of the interviewees a workspace exposed to natural light inspires and uplifts, contributing to improved well-being, which, in turn, enhances overall performance.

The physical environment surrounding the workspace also plays a pivotal role, with factors like frosted glass, nearby buildings, or obstructive vegetation negatively impacting the experience as shown in figure 32. Access to a window and outside view emerged as the most critical environmental factors during hospital renovations, and staff tend to adapt to their environment, often only fully realising the significance of natural light when they gain or lose access to it, as observed in this study.

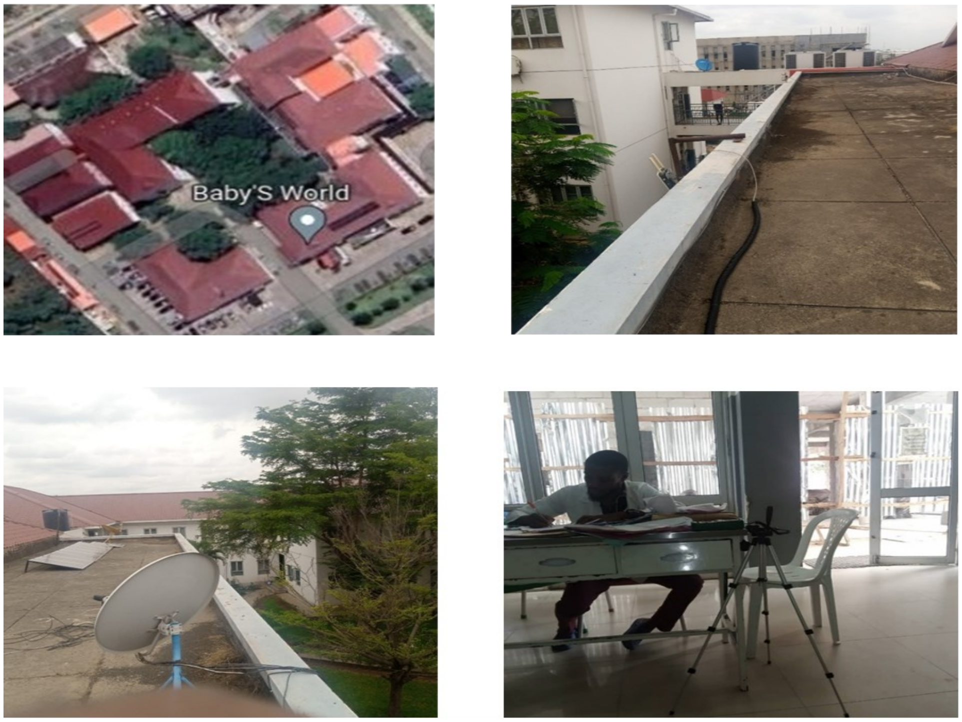


Figure 32: Showing frosted glass, nearby buildings, obstructive vegetation.

While this study did not explicitly address the impact on patient safety, it did provide insight on how working in dim or inadequate lighting conditions can lead to eyestrain, fatigue, and decreased concentration among personnel. These factors could potentially have effect on patient safety. Conversely, improved visibility through better lighting can reduce errors in critical tasks such as medication administration and surgical procedures, enhancing patient safety. This underscores the findings of Ulrich et al. (2008), who emphasised the substantial impact of healthcare environment design on patient outcomes and staff job satisfaction.

Enquiring about improvements to the lighting in their work environment yielded significant insights. Eighty seven percent of respondent desired brighter to much brighter lighting at their workstations. Specifically, 62.5 % favoured access to natural light for improvement, 25% of respondents desired both artificial and natural lighting, while 12.50% would rather have artificial lighting alone. This preference underscores the critical importance of addressing issues related to building obstructions and inadequate access to illumination. It is evident that improving lighting conditions, whether natural or artificial, necessitates a comprehensive approach that considers both objective and subjective factors.

The findings from this study provide a foundation for better understanding the crucial role of lighting conditions in the healthcare. They underscore the need for a comprehensive approach to lighting design that prioritises natural light, as it has profound implications for personnel well-being, performance, and, by extension, patient safety, and satisfaction. Additionally, the findings suggest active participation by personnel in the design process, emphasising the importance of a participatory design approach in creating well-lit, conducive work environments.

6.6 Chapter Summary

This chapter presents and discusses the impact of lighting conditions within healthcare facilities. The research findings show how lighting influences the satisfaction, wellbeing, and performance of healthcare personnel, providing valuable insights for healthcare facility improvements.

The results show a concerning trend, with more than half of the assessed workstations falling below the recommended lighting standards, particularly in high-stress areas like surgical suites, paediatric units, and postnatal wards. Inadequate lighting in these critical zones poses potential risks to patient care and safety. Remarkably, the perceptions of staff regarding lighting adequacy closely aligned with the objective measurements, highlighting the significance of personnel feedback.

The discussion shows the influence of factors such as light source, light level, and the use of daylight on personnel well-being. Lighting perceptions and preferences show diversity among various age groups and job roles within the healthcare environment. Nurses, midwives, and doctors show varying degree of satisfaction with light levels, underscoring the necessity for well thought lighting solutions. The overwhelming preference for increased natural light among healthcare professionals provides clear benefits on mood, well-being, and overall performance. It is demonstrated that absence of access to natural light result in eyestrain, headache, mood disturbances, and reduced focus, potentially endangering patient safety.

The implications of these findings are profound, emphasising the key role of lighting in healthcare facility design. Prioritising the incorporation of natural light sources while addressing issues like glare can substantially improve both personnel wellbeing and patient outcomes. An interactive design approach, involving healthcare personnel in the process, becomes imperative. Their lighting preferences and requirements should be carefully considered to ensure well-lit, conducive work environments.

Thus, this research shows that lighting is not a mere architectural element; it is a fundamental determinant of the healthcare environment. By giving precedence to natural light during daylight hours, healthcare facilities can promote personnel's well-being and performance, ultimately promoting the overall quality of patient care.

Chapter VII: Conclusions and Recommendations

"Of the elements of a room, the window is the most marvelous. The great American poet
Wallace Stevens prodded the architect, asking "What slice of the sun does your building have?"
To paraphrase: What slice of sun enters your room? What range of mood does the light offer
from morning to night, from day to day, from season to season and all through the years?
- Louis I. Kahn

This chapter serves as the conclusion of the study on the impact of lighting conditions on personnel's well-being and performance within healthcare environments. This research started with the aim of examining the effect of lighting conditions on personnel’s wellbeing and performance in healthcare environments. As mentioned in the first chapter (section 1.3 and 1.4), there is currently a lack of research and understanding of the effect of lighting conditions on personnel’s wellbeing and performance in healthcare environments.

Interestingly, existing standards and guidelines primarily focused on energy efficiency and carbon footprint reduction, often neglecting the influence of lighting on occupant wellbeing, performance, and productivity. This research study investigated this area by using mixed method approach and collecting both quantitative and qualitative data. It also used descriptive statistics and thematic to analyse data and produce results.

The study’s findings show the interwoven relationship between lighting conditions and personnel well-being and performance. Each analysis highlights the various interplay of lighting conditions and human factor variables, presenting a detailed picture of their impact. This chapter stands as the hallmark of the research, presenting the key achievements, and listing recommendations for practice and further research.

The chapter is divided into six sections, each contributing to the better understanding of the research's significance. The first section presents the attainment of research objectives, providing a sense of accomplishment and purpose. The subsequent section discusses the conclusion of the research, putting its essence into key insights. The third section discusses the contribution of the research study to both the research community and practical applications within healthcare environments.

However, no research endeavours are without its limitations, and these are discussed in the fourth section. The fifth section outlines recommendations for future research, highlighting new frontiers for research exploration. Finally, the last section summarises the chapter, providing a guide for the practical application of the research findings for better understanding of the relationship between lighting conditions, well-being, and performance in healthcare environments.

7.1 Achieving Objectives

The research aimed (chapter 1, section 1.5): “To investigate the impact of lighting conditions on healthcare work environments, with a focus on advocating for the integration of natural light.”

The research aim was achieved using a set of three main objectives. The breadth of achievement of these objectives is presented below:

1. To evaluate the current lighting conditions in healthcare environments and their effects on personnel wellbeing, considering factors such as circadian rhythm, mood, alertness, and subjective performance.

This objective was achieved by conducting the literature review of indoor lighting and occupant wellbeing and performance. The review encompassed a range of literature sources including journal articles, conference proceedings, and over 400 references spanning from 1937 to 2022. The literature review successfully identified five key lighting conditions that influence well-being and performance, namely the source of light, illuminance levels, use of daylight, glare, and unwanted shadow. These findings can be found in chapter two of the study.

The review confirmed the critical role of indoor lighting in creating visual comfort for occupants in buildings (Leccese et al. 2020). Understanding the factors that affect visual comfort is essential in designing lighting environments that promote well-being and productivity. Research in the field of visual comfort has been explored extensively in literature for over fifty years (Jakubiec, 2023). Visual comfort can be divided into observable and implicit components.

Observable components of visual comfort encompass the lighting conditions in the environment, including both natural and artificial lighting, effective glare control, and access to outdoor views. On the other hand, implicit components focus on human factors such as perception, preference, and acceptance of the visual state. These factors are subjective and vary based on individual characteristics such as age, gender, occupation, and activity.

The literature review revealed that adequate levels of daylight have positive effects on well-being and performance (Applebaum et al. 2010; Edwards & Torcellini, 2002). However, it is important to consider the potential adverse effects of excessive daylight on human health when designing lighting environments (Reinhart et al. 2006; Boyce et al. 2003). In regions with intense sunlight like Nigeria, incorporating daylighting and windows into the design should also prioritise UVB protection.

The review also highlighted the effectiveness of using occupant surveys and physical measurements to evaluate a building's performance in terms of occupant comfort and productivity (Al Horr et al. 2016; Heschong & Mahone, 2003). Furthermore, independent variables such as age, gender, job role, and activity type have been identified as factors influencing visual comfort (Reinhart et al. 2006).

Overall, the literature review provides valuable insights into the influence of indoor lighting on occupant well-being and performance. It establishes the significance of various lighting conditions and highlights the importance of considering both observable and implicit components of visual comfort. The findings emphasise the positive effects of adequate daylight while cautioning against potential adverse effects. Additionally, the review underscores the importance of occupant surveys and physical measurements in evaluating lighting performance and identifies several influential factors that impact visual comfort.

2. To establish a correlation between subjective perceptions of illuminance levels among healthcare personnel and objective measurements and assess the alignment of these findings with established standards for workstation activities.

The second objective of the study focused on evaluating illumination levels within a healthcare environment. To accomplish this objective, a field investigation was conducted to gather physical data from the existing hospital building, specifically the Federal Medical Centre in Abuja. The findings revealed significant variations in illuminance levels across different workstations. While some areas received high levels of illuminance, others suffered from insufficient lighting.

The measured illuminance levels ranged from a minimum of 14 lux, observed in a southeast facing window, to a maximum of 788 lux during an early morning sunrise. Unfortunately, more than half of the workspaces examined failed to meet the required illuminance levels, which could have adverse effects on both patients and hospital staff. It is crucial to maintain appropriate illuminance levels as they have a substantial impact on patient care and staff productivity. Insufficient lighting can lead to errors, increase the risk of falls, and negatively affect the mood and well-being of staff members.

Moreover, low illuminance levels can also have detrimental effects on patients, resulting in decreased comfort and slower recovery times. On the other hand, excessively high illuminance levels can cause discomfort and eye strain among staff members. Therefore, ensuring optimal illuminance levels is essential to create an ideal hospital environment.

In addition to the physical illuminance measurements, the study also incorporated subjective ratings provided by the participants. These subjective assessments correlated with the measured illuminance levels and were in line with the EN 12464-1 standard. This indicates that the subjective evaluation of illuminance levels proved reliable when the levels met the standard. By considering both objective measurements and subjective ratings, a better understanding of the lighting conditions in the healthcare environment was obtained
The results of the survey revealed a concerning trend. Only 7.1% of the respondents reported high or very high levels of satisfaction with the lighting in their work environment. This indicates a widespread dissatisfaction among personnel regarding the lighting conditions, which could potentially have far-reaching implications for job satisfaction and productivity.

In addition to the low satisfaction levels, the survey findings indicated that a significant majority of respondents, accounting for 75.3%, believed that lighting conditions had an adverse effect on their task performance. The degree of this impact ranged from moderate to very high on the scale. This highlights the crucial role of appropriate lighting conditions in optimising task performance and emphasises the need for healthcare facilities to prioritise and improve the lighting in the workplace.

Furthermore, the survey responses shed light on the influence of lighting conditions on personnel's overall wellbeing. More than half of the respondents, precisely 52%, reported experiencing adverse effects on their wellbeing due to lighting conditions. The most common complaint among these individuals was eye strain, accounting for 35% of the cases. Other reported adverse effects included headaches (6%), and mood disturbances (11%). These findings underscore the negative impact that inadequate lighting conditions can have on employee health and wellbeing, necessitating employers to take proactive measures to address this issue.

Interestingly, the survey also revealed that a significant majority of respondents (87.3%) expressed a preference for brighter lighting conditions at their workstations. This indicates that personnel are not only cognisant of the importance of adequate lighting for their task performance and wellbeing but are also willing to voice their preferences.

Additionally, the survey data highlighted common complaints related to lighting conditions. Glare and unwanted shadows emerged as prevalent issues among respondents, with 70% and 54.2% reporting these problems, respectively. These findings emphasise the need for healthcare facility designs to pay closer attention to lighting conditions within the work environment, implementing measures to reduce glare and unwanted shadows.

3. To explore and analyse healthcare professionals' preferences regarding the use of natural light, their perceived impact on wellbeing and job performance.
4. To examine potential implications for the design of healthcare facilities.

To achieve these objectives, a thematic analysis of the semi-interviews with healthcare professionals working in hospital wards with varying levels of natural light was carried out.

It is noteworthy that there were no significant differences in responses, as all healthcare professionals expressed similar concerns about lighting levels. The desire for improved lighting did not vary by gender or job role. The responses also highlight the key role of natural light as the best source of illumination. Moreover, the importance of improved lighting levels is contextualised within the contexts of visual comfort, overall well-being, task performance, and uninterrupted workflow, all of which contribute to an improved quality of patient care.

The study shows that inadequate illumination in healthcare facilities can adversely affect work performance due to discomfort, eyestrain, mood disturbances, and potential occupational hazards. This aligns with previous research on lighting conditions in healthcare environments (Golvani et al., 2021; Dianat et al., 2013), indicating a universal demand for improved lighting among healthcare professionals, irrespective of gender or job role.

Interrogating the ward architectural design and its impact on indoor lighting shows that improving the design of these wards can ensure better access to natural light. Factors such as window placement, ward layout, building orientation, and lighting fixtures are suggested as architectural elements for improving the well-being of healthcare personnel. The findings strongly advocate for healthcare organisations to prioritise the design of hospital wards to increase access to natural light, incorporating strategies such as green spaces, appropriate window placement, and thoughtful lighting fixtures.

The preference for natural lighting as the preferred source of light is rooted in its positive effects on human health and well-being. The investigation shows that access to natural light is indispensable for maintaining best physical and mental health. Natural light is favoured for its brightness, calming qualities, invigorating impact, and its positive influence on health and well-being. Additionally, healthcare professionals appreciate its energy-saving potential, reliability during power outages, and its positive impact on various human factors, including improved patient outcomes, staff morale, productivity, and regulation of circadian rhythms. There is a strong desire among healthcare personnel towards gaining access to natural light to enhance their overall well-being. The incorporation of natural light into architectural designs to maximise its benefits is highly recommended.

This research study acts as a catalyst for transformative advancements in healthcare facility design and lighting policies. By advocating for the use of daylight to improve personnel satisfaction, well-being, and task performance, it establishes a new standard for holistic approaches that can be applied across academia, industry practices, and regulatory frameworks. This collective effort contributes to the development of healthcare environments that prioritise the overall well-being and performance of personnel.

Thus, this study achieves its objectives as shown in table 29, with significant implications for healthcare practice.

Table 29: Findings Addressing Research Objectives.

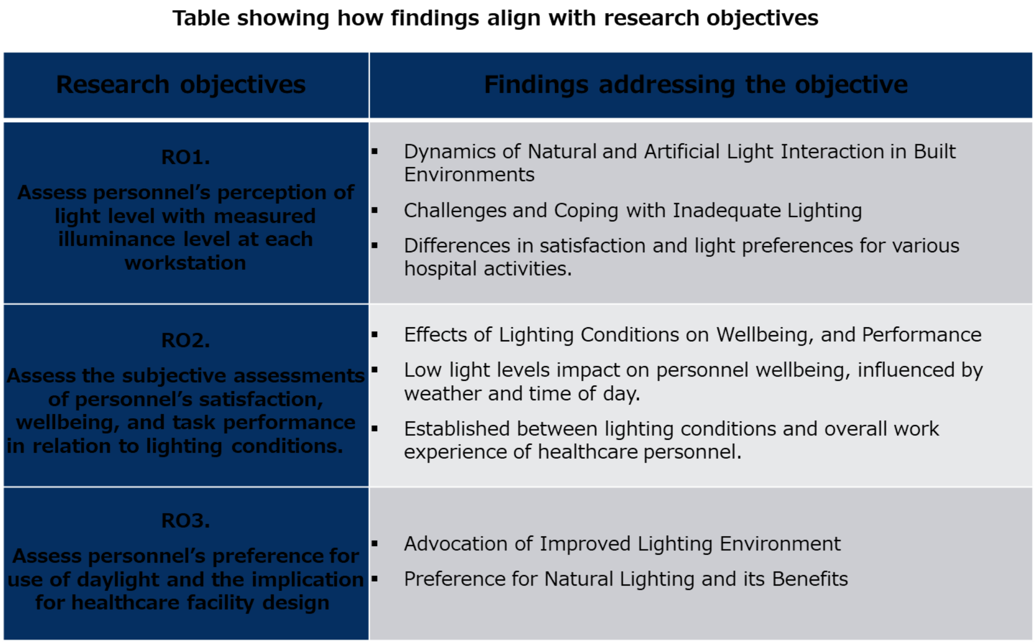


Table showing how findings align with research objectives

Research objectives	Findings addressing the objective
RO1. **Assess personnel's perception of light level with measured illuminance level at each workstation**	▪ Dynamics of Natural and Artificial Light Interaction in Built Environments ▪ Challenges and Coping with Inadequate Lighting ▪ Differences in satisfaction and light preferences for various hospital activities.
RO2. **Assess the subjective assessments of personnel's satisfaction, wellbeing, and task performance in relation to lighting conditions.**	▪ Effects of Lighting Conditions on Wellbeing, and Performance ▪ Low light levels impact on personnel wellbeing, influenced by weather and time of day. ▪ Established between lighting conditions and overall work experience of healthcare personnel.
RO3. **Assess personnel's preference for use of daylight and the implication for healthcare facility design**	▪ Advocation of Improved Lighting Environment ▪ Preference for Natural Lighting and its Benefits

Healthcare organisations can enhance the design of hospital wards to improve access to natural light, to promote the well-being of healthcare personnel. While there may be potential challenges and obstacles to implementing necessary changes, such as cost constraints and resistance from decision-makers, healthcare personnel assert that organisations should develop effective strategies to address these barriers while prioritising the well-being of their healthcare staff.

7.2 Conclusion

This study's findings underscore critical impact of lighting in healthcare work environments, revealing poor conditions that significantly affect personnel and, consequently, patient care. Inadequate lighting was consistently reported across various ward environments, falling below recommended standards. Surprisingly, respondents' perceptions of illuminance levels aligned with the objective measurements, emphasising the validity of the concerns. Healthcare professionals unanimously emphasised the importance of better lighting for their well-being and performance. Notably, the strong desire for natural light was a shared sentiment, crucial for both job satisfaction and quality patient care.

This study makes a compelling case for healthcare organisations to prioritise access to natural light in their facility designs. Incorporating green spaces, optimising window placement, and thoughtful lighting fixtures are essential strategies. This study underscores the importance of combining objective measurements with subjective assessments, providing valuable insights into how personnel perceive their work environments. The evidence clearly supports the integration of natural light as a central element in the design of healthcare facilities, ensuring safer environments for both staff and patients.

Access to natural light is not just a luxury; it is a necessity for safer and more conducive healthcare environments. Enhancing lighting provisions is not just about aesthetics but directly impacts the well-being of both personnel and patients. Evidently, a shift toward comprehensive natural lighting integration is pivotal for fostering a safer and more conducive healthcare environment, thereby promoting the overall quality of care. Therefore, the clear directive stands enhance healthcare facility design to promote personnel satisfaction, performance, and well-being through optimised natural light exposure.

7.3 Contributions

This section outlines the contributions made by this research study, considering indoor lighting in the context of personnel wellbeing and performance within a healthcare facility in the African region, particularly Nigeria. These contributions are twofold, benefiting both the industry and academia. In the industry this study serves as a foundation for architects, planners, and building professionals in Nigeria, highlighting on the key role of lighting in healthcare facility design, while in academia, it advances knowledge in the domains of wellbeing, performance, and lighting conditions.

7.3.1 **Contributions to Knowledge**

- **Wellbeing-Centric Analysis in Healthcare Facilities:** This research study stands as a pioneering endeavour by being one of the first to rigorously analyse indoor lighting's direct impact on personnel wellbeing and performance within a healthcare facility situated in the African context. Its findings serve as a vital resource for architects and planners involved in healthcare facility design in Nigeria. By shedding light on the relationship between personnel performance and lighting conditions, it offers invaluable insights that can inform design decisions, contributing to the creation of health-promoting and productivity-enhancing environments for healthcare professionals in Nigeria.
- **Expanding Knowledge on Lighting and Wellbeing:** This research makes a substantial contribution to the existing knowledge base regarding the intricate interplay between wellbeing, performance, and lighting conditions. It contributes to the existing body of literature by presenting five essential physical lighting conditions that have a significant impact on both wellbeing and performance. These conditions include the characteristics of the light source, the light level, the use of natural daylight, the presence of glare, and the occurrence of unwanted shadows.

- **Unveiling Unique Interdependencies:** The study presents various inter-dependencies and indirect effects among occupant comfort, wellbeing, and productivity. These untapped relationships represent a significant contribution to the literature, offering a promising avenue for future research in the field of indoor lighting.
- **Advancements in Methodologies:** The research provides a better understanding of the metrics and methodologies essential for analysing the impact of indoor lighting on occupant comfort and wellbeing within a healthcare facility, particularly in Abuja. Leveraging the use of HOBO MX202 data sensors and handheld digital lux meters as measuring instruments. The data analysis process combined statistical and thematic approaches, contributing to the existing knowledge base on metrics and methodologies for assessing indoor lighting's impact.
- **A Blueprint for Future Research:** This research sets a precedent by being the first of its kind in this specific context. It encourages and provides a strong illustration for conducting similar studies in diverse building types, such as schools, universities, and offices, across different climate zones. This blueprint aims to improve comfort, wellbeing, and performance on a broader scale, surpassing healthcare facilities. Thereby broadening the applicability of the findings and contributing to more sustainable building practices.

7.3.2 **Implications for Future Research**

- **Propelling Future Research and Development:** This study serves as a significant milestone by defining lighting conditions that influence personnel wellbeing and performance in healthcare environments. Despite the potential benefits of indoor daylighting in healthcare environments, prevailing standards and guidelines have focused on energy efficiency and carbon footprint reduction, often neglecting the influence of indoor lighting on occupant performance and productivity. By addressing this critical gap, the study inspires researchers to develop new criteria for lighting standards that encompass the utilisation of natural light and advocate for the revision of existing guidelines for healthcare buildings, aligning them with the latest insights.

- **Informing Regulatory Frameworks:** By underlining the critical lighting conditions identified within healthcare facilities, this research study has the potential of positive changes in existing building codes and healthcare facility design guidelines in Nigeria. The findings serve as a foundation for advocating improvements in lighting standards, thereby ensuring that future healthcare environments prioritise personnel wellbeing and performance.
- **Methodological Approach for Industry Practitioners:** The adoption of a mixed-method approach in this study, combining physical measurements, questionnaires, and interviews, presents a versatile framework that industry professionals can employ to collect essential data for designing healthcare spaces that prioritise wellbeing and boost personnel performance and satisfaction levels. This innovative approach has the potential to become an integral component of healthcare facilities in the African region.

Thus, this research study provides contribution to academic researchers with implication for future research. It not only informs the design and construction of healthcare facilities in Nigeria but also advances the global understanding of how indoor lighting impacts occupant wellbeing and performance, opening new avenues for research and development in this critical field.

7.4 Limitation of Research

The section presents an examination of the limitations associated with this research study that aimed to investigate indoor lighting and their impact on personnel's wellbeing and performance in healthcare environments. The study's objective was to enhance healthcare facility design and operation while improving the wellbeing and performance of personnel.

- **Impact of External Events**: One significant limitation of this research study is the unforeseen impact of external events, such as the COVID-19 pandemic. The study faced difficulties in accessing healthcare facilities for fieldwork due to pandemic-related constraints, resulting in a reduced investigation period and limited geographic diversity. Reduced investigation period hindered the observation of daylight variations across different seasons of the year. These unforeseen circumstances hindered the original research objectives, highlighting the vulnerability of long-term studies to external disruptions.
- **Exclusion of Individual Behavioural Factors**: The research primarily focused on physical environmental factors and subjective assessments, neglecting the influence of individual behavioural characteristics of occupants. Personal preferences and psychological aspects were not considered due to their complexity and variability, potentially leading to an incomplete understanding of how these factors affect personnel's wellbeing and performance in healthcare environments.
- **Subjective Performance Measurement**: Another limitation is the reliance on subjective assessments obtained through surveys and interviews to measure personnel

performance. This approach is susceptible to response biases and inaccuracies, as respondents may provide socially desirable or positively biased responses. The subjectivity inherent in this measurement method may compromise the accuracy of assessing the true impact of indoor lighting conditions on personnel performance. Incorporating objective measures or complementary assessment methods could enhance the research's reliability and validity.

- **Limited Generalisability to Different Climates**: The research focused exclusively on a healthcare facility in a specific climatic region (Abuja, Nigeria), which may limit the generalisability of its findings to healthcare environments in other geographical regions with distinct climatic conditions. Variations in natural light availability, lighting needs, preferences, and the influence of indoor lighting on wellbeing and performance across different climates were not accounted for, necessitating caution when applying the study's conclusions to diverse climatic contexts. Further research is required to establish broader applicability.
- **Isolation of Indoor Lighting Conditions**: Lastly, the research primarily focuses on indoor lighting conditions in isolation, without explicit consideration of potential interactions with other environmental factors present in healthcare environments, such as noise levels, air quality, and temperature. Neglecting these interactions may result in an incomplete understanding of the overall impact of the environment on personnel outcomes. Future research should explore these potential synergistic or moderating effects to provide a more comprehensive understanding of the complex relationship

between indoor lighting, personnel wellbeing, and performance in healthcare environments.

Addressing these five distinct research limitations is crucial for future studies to enhance the depth and breadth of knowledge regarding indoor lighting's influence on personnel wellbeing and performance in healthcare environments.

7.5 Recommendation and Future Research

This research has provided valuable insight on the relationship between indoor lighting and personnel wellbeing and performance in healthcare facilities, however, there are several avenues for future research to explore. These recommendations aim to address the limitations of the current study and further advance our understanding of how lighting impacts healthcare professionals in diverse contexts.

- **Replication in Diverse Geographical Regions**: Future research should replicate this study in various climatic regions and geographic settings to assess the generalisability of findings. This will help understand how different natural light availability, lighting needs, and preferences impact personnel wellbeing and performance in healthcare environments. Comparing results from diverse locations can lead to more robust lighting recommendations.
- **Longitudinal Studies**: Conducting longitudinal studies over extended periods can mitigate the vulnerability of research to external disruptions like pandemics. Long-term observations would allow researchers to capture seasonal variations in daylight and

provide more robust insights into how lighting conditions affect personnel across different times of the year.

- **Incorporate Individual Behavioural Factors**: To gain a comprehensive understanding of the relationship between lighting conditions and personnel wellbeing and performance, future studies should consider individual behavioural characteristics of occupants. Exploring the influence of personal preferences and psychological aspects can help uncover additional factors affecting personnel outcomes in healthcare environments.
- **Objective Performance Measures**: To enhance the reliability and validity of research findings, future studies should incorporate objective performance metrics alongside subjective assessments. Utilising performance indicators that are less susceptible to response biases and inaccuracies would contribute to a more accurate evaluation of the true impact of indoor lighting on personnel wellbeing and performance.
- **Interactions with Other Environmental Factors**: Future research should explore potential interactions between indoor lighting and other environmental factors in healthcare environments, such as noise levels, air quality, and temperature. Investigating these synergistic or moderating effects will contribute to a more thorough understanding of the overall impact of the environment on personnel outcomes.

Incorporating these recommendations into future research endeavours will not only address the limitations of the current study but also contribute to the ongoing advancement of knowledge in the field of indoor lighting's impact on personnel wellbeing and performance, ultimately benefiting both the healthcare industry and broader building design practices.

7.6 Chapter Summary

This chapter concludes the research investigation into how lighting conditions affect the well-being and performance of healthcare personnel. The research aimed to bridge the existing gap in knowledge regarding the impact of lighting conditions on healthcare professionals in healthcare environments, where energy efficiency and carbon footprint are prioritised over occupant well-being. Using a mixed-method approach including quantitative and qualitative data analysis, this research reaches significant conclusions:

Interplay Between Lighting Conditions and Human Factors: This research has illuminated the complex relationship between lighting conditions and the well-being and performance of personnel, providing a nuanced understanding of their interconnectedness.

Key Lighting Conditions Influencing Well-being and Performance: Through the review of relevant literature, the study identified five pivotal lighting conditions that affect well-being and performance including light source, illuminance levels, use of daylight, glare, and the presence of unwanted shadows. Together, these factors shape visual comfort and occupant satisfaction.

Importance of Daylight and Visual Comfort: This current study has shown that adequate levels of natural daylight have positive effects on well-being and performance, but caution is necessary regarding excessive daylight, particularly in regions with intense sunlight.

Role of Occupant Surveys and Measurements: Employing occupant surveys and physical measurements is essential for evaluating a building's performance in terms of occupant comfort, wellbeing, and performance. Various human factors, including age, gender, job role, and activity type, can influence visual comfort.

Adverse Effects of Inadequate Lighting Conditions: Inadequate lighting conditions were associated with various adverse effects on personnel, including eye strain, headaches, mood disturbances, and reduced task performance. Most respondents preferred brighter lighting conditions at their workstations.

Natural Light as a Preferred Source: Healthcare professionals consistently expressed a preference for natural light due to its positive effects on well-being and performance, including improved patient outcomes, staff morale, and regulation of circadian rhythms.

Architectural Design Implications: This current study suggests that healthcare facility design should prioritise access to natural light by considering factors such as window placement, ward layout, building orientation, and thoughtful lighting fixtures.

Recommendations for Practice and Further Research: This research provides practical recommendations for enhancing lighting conditions in healthcare environments, addressing both industry and academic implications.

Recommendations:

The current study paves the way for future research and practice. To build upon these findings and overcome the study's limitations, the study proposes the following recommendations:

Replication in Diverse Geographical Regions: Future research should replicate this study in various climatic regions and geographic settings to assess the generalisability of findings and tailor lighting recommendations accordingly.

Longitudinal Studies: Conducting longitudinal studies over extended periods can provide a more comprehensive understanding of seasonal variations in daylight and lighting's impact on personnel.

Incorporate Individual Behavioural Factors: Consider individual behavioural characteristics, including personal preferences and psychological aspects, to deepen our understanding of the relationship between lighting conditions and personnel outcomes.

Objective Performance Measures: To enhance research validity, future studies should incorporate objective performance metrics alongside subjective assessments to provide a more accurate evaluation of lighting's impact.

Explore Interactions with Other Environmental Factors: Investigate potential interactions between indoor lighting and other environmental factors in healthcare environments, such as noise levels, air quality, and temperature, to understand their combined effects.

Enhance Healthcare Facility Design: Advocate for healthcare organisations to prioritise hospital ward designs that facilitate greater access to natural light, incorporating green spaces, optimal window placement, and thoughtful lighting fixtures.

Influence Regulatory Frameworks: Use the findings as a foundation for advocating improvements in lighting standards within building codes and healthcare facility design guidelines to prioritise personnel well-being.

Expand Research Scope: Extend this research blueprint to diverse building types, such as schools, universities, and offices, across different climate zones, to enhance comfort, well-being, and performance on a broader scale.

Incorporating these recommendations into future research endeavours will contribute to the ongoing advancement of knowledge in the field of indoor lighting's impact on personnel well-being and performance. This research serves as a critical foundation for both industry practitioners and academic researchers, ultimately benefiting healthcare professionals and their patients.

Researcher’s Reflection

Reflecting on this study investigating the impact of lighting during the day on the wellbeing and performance of healthcare personnel, it is interesting to note the profound connections between the findings and the timeless wisdom contained within spiritual texts.

In the context of healthcare, the challenges the society face in addressing human ill-health require a comprehensive understanding of the factors that influence health outcomes. Healthcare professionals bear a significant burden in this endeavour, as their comfort, wellbeing, and performance are closely intertwined with the quality of care they provide.

Remarkably, throughout human history, the importance of day-lit environments has been recognised (Aries et al. 2015; Joseph, 2006; Heschong et al. 2002). This concept resonates with the biblical account of creation, where light is introduced as a symbol of illumination and vitality. The notion of "Let there be light" (Genesis 1:3) evokes the idea of a radiant force that can positively influence human health, wellbeing, and performance.

In this context, there is also the references to a healing force likened to the "Sun of Righteousness". It rises, bearing the promise of healing in its rays, just like the life-giving light. For those who hold reverence for His name, this healing force brings not only physical rejuvenation but also spiritual nourishment (Malachi 4:2). Just as the sun's rays bring physical and spiritual nourishment, healthcare personnel, who often work in environments lacking natural light, can benefit from well-illuminated spaces that foster their physical and emotional well-being, enabling them to thrive and flourish in their roles.

In the grand design of the universe, this divine Light, this Word, stands as a symbol of illumination and guidance. It serves as a beacon of clarity for individuals navigating the complexities of life, just as natural light can illuminate healthcare spaces, making them more conducive to healing and well-being.

The idea that "the light shines in the darkness, and the darkness does not comprehend it" (John 1:5) speaks to the enduring presence of the divine Word, which has been with us since the beginning, offering humanity the essential elements for a productive existence—health, well-being, and the foundation upon which to build a brighter future.

Thus, this reflection underscores the profound resonance between the study's findings on the impact of natural light on healthcare personnel and the timeless wisdom embedded in spiritual and religious texts. It serves as a reminder of the interconnectedness of human existence and the potential for light, both literal and metaphorical, to positively influence human health, well-being, and performance in the noble pursuit of healing and productive life.

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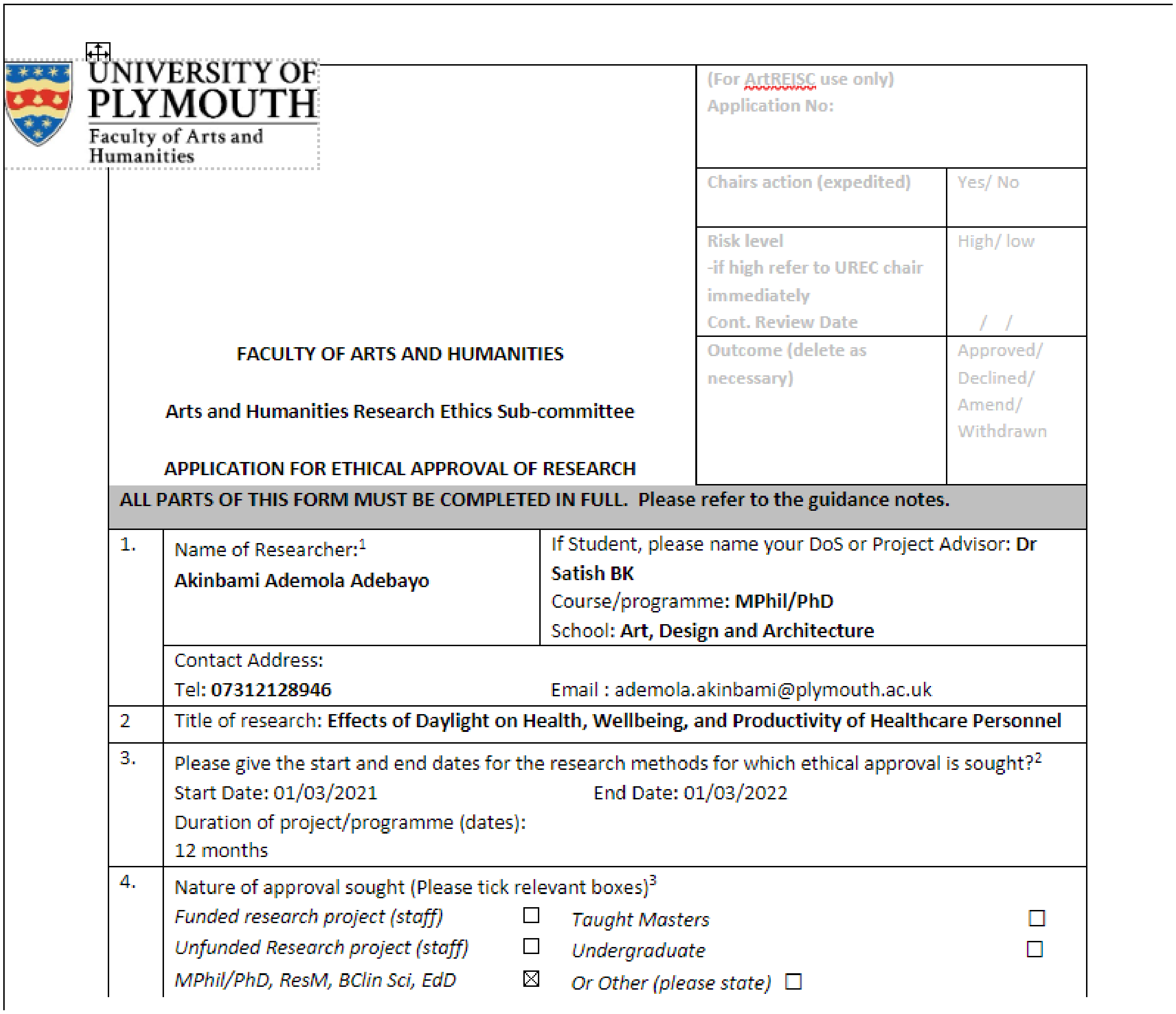
Appendix A

Ethical Approval and Protocol

The ethical approvals below anticipated the design of fieldwork enquiry and as such include discounted methods and approaches that were not used in the enquiry. The appropriate trajectory and outputs from the research necessarily adjusted to follow the data.



UNIVERSITY OF PLYMOUTH
Faculty of Arts and Humanities

(For ArtREISC use only) Application No:	
Chairs action (expedited)	Yes/ No
Risk level -if high refer to UREC chair immediately Cont. Review Date	High/ low / /
Outcome (delete as necessary)	Approved/ Declined/ Amend/ Withdrawn

FACULTY OF ARTS AND HUMANITIES

Arts and Humanities Research Ethics Sub-committee

APPLICATION FOR ETHICAL APPROVAL OF RESEARCH

ALL PARTS OF THIS FORM MUST BE COMPLETED IN FULL. Please refer to the guidance notes.

1.	Name of Researcher:[1] **Akinbami Ademola Adebayo**	If Student, please name your DoS or Project Advisor: **Dr Satish BK** Course/programme: **MPhil/PhD** School: **Art, Design and Architecture**
	Contact Address: Tel: **07312128946**	Email : ademola.akinbami@plymouth.ac.uk
2	Title of research: **Effects of Daylight on Health, Wellbeing, and Productivity of Healthcare Personnel**	
3.	Please give the start and end dates for the research methods for which ethical approval is sought?[2] Start Date: 01/03/2021 Duration of project/programme (dates): 12 months	End Date: 01/03/2022
4.	Nature of approval sought (Please tick relevant boxes)[3] *Funded research project (staff)* ☐ *Unfunded Research project (staff)* ☐ *MPhil/PhD, ResM, BClin Sci, EdD* ☒	*Taught Masters* ☐ *Undergraduate* ☐ *Or Other (please state)* ☐

5.	**Risk:** Please answer either YES or NO to ALL questions below by placing an X in the relevant box. Do any of your research methods include research:	
	With vulnerable groups – for example, children, young people, or adults, those with a learning disability or cognitive impairment, or individuals in a dependent or unequal relationship?	Yes☐ No ☒
	That involves sensitive topics – for example, participants' sexual behaviour, their illegal or political behaviour, their experience of violence, their abuse or exploitation, their mental health, or their gender or ethnic status?	Yes☐ No ☒
	With groups where permission of a gatekeeper is normally required for initial access to members – for example, ethnic or cultural groups, native peoples, or indigenous communities?	Yes☐ No ☒
	That involves deception or which is conducted without participants' full and informed consent at the time the study is carried out?	Yes☐ No ☒
	That involves access to records of personal or confidential information, including genetic or other biological information, concerning identifiable individuals?	Yes☐ No ☒
	That may induce psychological stress, anxiety or humiliation or cause more than minimal pain?	Yes☐ No ☒
	That involves intrusive interventions – for example, the administration of drugs or other substances, vigorous physical exercise, or techniques such as hypnotherapy (i.e., interventions that your participants would not normally encounter, or which may cause them to reveal information which causes concern, in the course of their everyday life)?	Yes☐ No ☒
	If you answered yes to any of the above questions, please provide further details of these potentially ethically sensitive aspects of your research.	
6.	**Aims and Objectives:** Please provide a 200-word description of your project **in non-specialist language:** *State briefly what your study will achieve and any hypotheses. Include how you anticipate the fulfilment of the aims and key questions will move forward knowledge and where appropriate, policy or practice.* The research gap presents an opportunity to investigate the relationship between daylight and personnel's productivity in healthcare environment. Therefore, the aim of this study is: To examine the effect of daylight on health, wellbeing, and productivity of healthcare personnel and to develop a model that shows the relationship between daylight and health and productivity of personnel in healthcare facilities in different climatic zones. The following identified objectives are proposed to achieve the above aim: 1. To examine daylight variables and assesses their impact on personnel's health, and productivity in healthcare environment. 2. To show quantitative relationship between daylight and productivity of personnel in healthcare environments. 3. To compare the impact of daylight variables on healthcare personnel productivity in different climatic zones. 4. To develop a model to incorporate healing effect of daylight in the design of hospital personnel rooms, effectively. The ultimate objective is to inform policies and decisions made by designers and planners of healthcare environments.	

7. **Methods:** Please provide a 200-word description of your project **in non-specialist language:** Explain briefly, how participants will be recruited (where, by whom, how many; inclusion and exclusion criteria), what data will be collected, how it will be analysed (statistical tests, sample size considerations). This should include references of the particular methodology being used; how it will be employed in relation to this study; which techniques of analysis will be used once data are collected and how this will be applied to the particular data set.
Note: If you have indicated that you are using questionnaires or semi-structured interviews, etc. you are expected to attach indicative samples to this application.

This study proposes to measure daylight variables and capture personnel response to those daylight variables. The study will use statistical analysis to show the patterns and correlational relationship between daylight and personnel response. The study will be nonexperimental in nature because the physical parameters will be measured based on current conditions. The study will use measured parameters to identify patterns and develop a relationship model between daylight and productivity of personnel in different climatic zones.

The data collection will be carried using a post-occupancy evaluation method (Survey and Physical measurement data collection). The physical measure will include illuminance level and daylight access. Data logger sensors will be installed for physical measure of daylight variables in two healthcare facilities in Plymouth, UK and two healthcare facilities in Abuja, Nigeria. The sensors selected will be programmed to send measurements to an online database. Data will be collected at four periods to measure the daylight and the productivity level for each season.

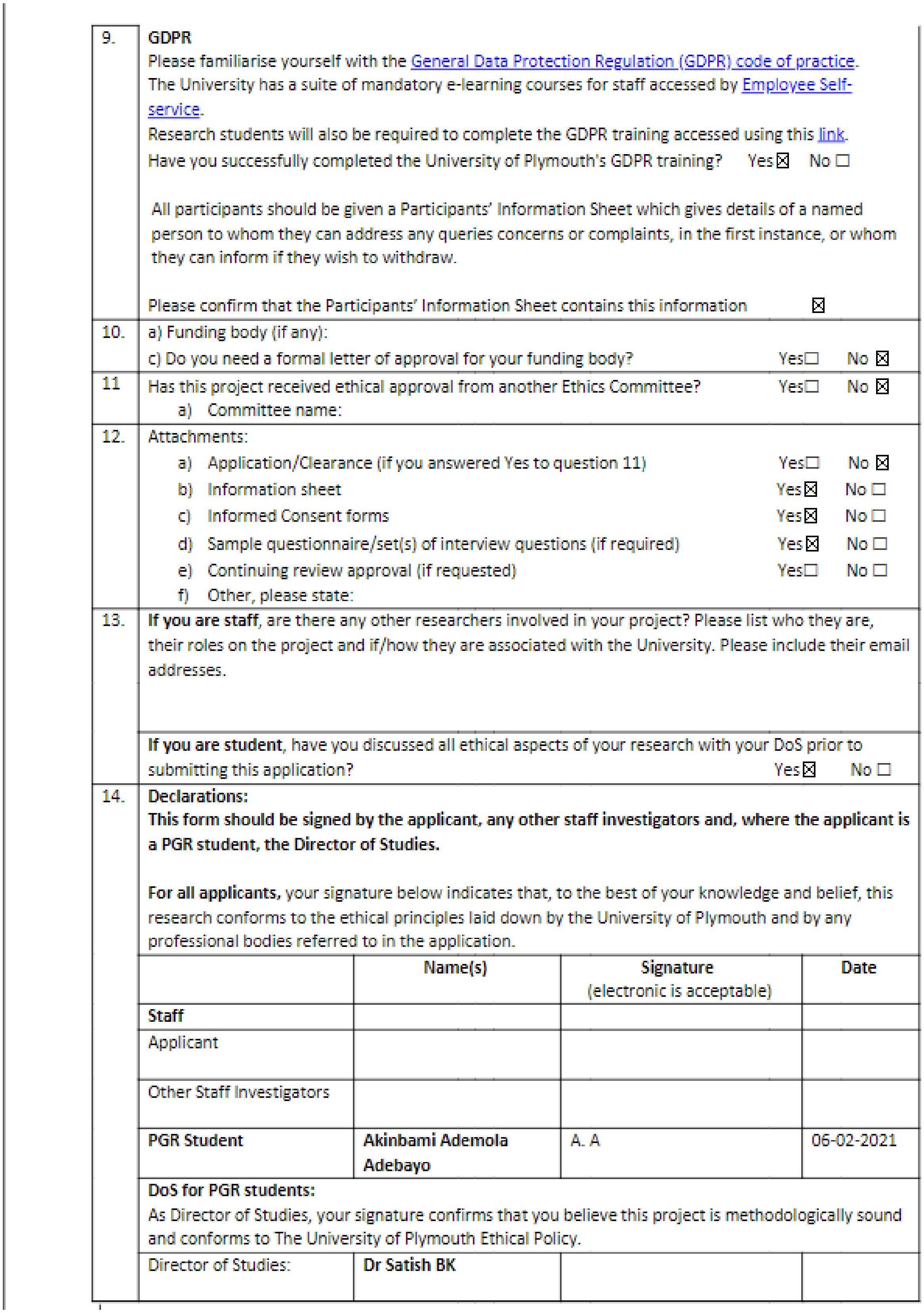
The survey will be designed to collect personnel response on the five-point Likert scale for feedback surveys to analyse and develop results. This study will use this tool for personnel responses to the questioned daylight variables. It ranges from 0 to 5: A self-administered questionnaire will be developed to measure the respondents' perception scores on daylight variables. This research study aims to outline the effects of the daylight variables on personnel's productivity. The questionnaire administration will be web-based given the current COVID-19 pandemic and its effects on face-to-face contact.

8. What are the anticipated outcomes of this project?

The findings are expected to give planners, architects, and policy makers a strong evidence to take onboard the importance of good daylight in the design of healthcare facilities that will promote health, wellbeing, and productivity of healthcare personnel. This study will provide evidence-based information to architects and planners for incorporation of healing effect of daylight in the design of rooms like nurse's station and staff breakroom to enhance performance and productivity in healthcare environments.

This study would be beneficial in numerous ways to the people in the built-environment sector both in research and academia. The anticipated outcomes and contributions of this project to the body of knowledge are listed as follows:

1. Contribution to existing knowledge on daylight and personnel productivity.
2. Contribution to better understanding of daylight parameters that are important for personnel productivity and highlight the extent of impact of these parameters.
3. Contribution to existing knowledge of metrics and methodologies that assess the daylight and personnel productivity in a healthcare environment.
4. The research outcomes will be beneficial to architecture and built environment professionals to design a healthy healthcare environment for personnel in different climatic zones.



9\. **GDPR**

Please familiarise yourself with the General Data Protection Regulation (GDPR) code of practice.

The University has a suite of mandatory e-learning courses for staff accessed by Employee Self-service.

Research students will also be required to complete the GDPR training accessed using this link.

Have you successfully completed the University of Plymouth's GDPR training? Yes ☒ No ☐

All participants should be given a Participants' Information Sheet which gives details of a named person to whom they can address any queries concerns or complaints, in the first instance, or whom they can inform if they wish to withdraw.

Please confirm that the Participants' Information Sheet contains this information ☒

10\. a) Funding body (if any):

c) Do you need a formal letter of approval for your funding body? Yes☐ No ☒

11 Has this project received ethical approval from another Ethics Committee? Yes☐ No ☒

a) Committee name:

12\. Attachments:

a)	Application/Clearance (if you answered Yes to question 11)	Yes☐	No ☒
b)	Information sheet	Yes☒	No ☐
c)	Informed Consent forms	Yes☒	No ☐
d)	Sample questionnaire/set(s) of interview questions (if required)	Yes☒	No ☐
e)	Continuing review approval (if requested)	Yes☐	No ☐
f)	Other, please state:		

13\. **If you are staff**, are there any other researchers involved in your project? Please list who they are, their roles on the project and if/how they are associated with the University. Please include their email addresses.

If you are student, have you discussed all ethical aspects of your research with your DoS prior to submitting this application? Yes☒ No ☐

14\. **Declarations:**

This form should be signed by the applicant, any other staff investigators and, where the applicant is a PGR student, the Director of Studies.

For all applicants, your signature below indicates that, to the best of your knowledge and belief, this research conforms to the ethical principles laid down by the University of Plymouth and by any professional bodies referred to in the application.

	Name(s)	**Signature** (electronic is acceptable)	**Date**
Staff			
Applicant			
Other Staff Investigators			
PGR Student	**Akinbami Ademola Adebayo**	A. A	06-02-2021

DoS for PGR students:

As Director of Studies, your signature confirms that you believe this project is methodologically sound and conforms to The University of Plymouth Ethical Policy.

Director of Studies:	**Dr Satish BK**		

Application Process

Submission deadlines are published on the intranet (Applying for Research Ethics Approval in the Faculty of Arts and Humanities).

Completed Forms should be forwarded by email to Faculty Research Ethics Administrator (artsresearchethics@plymouth.ac.uk). Please ensure that your application reaches the Research Ethics Administrator by the published deadline to ensure that your application is reviewed in that batch.

We aim to issue notification of approval and/or feedback on your application within three weeks of the deadline date.

Participant Information and Informed Consent Sheets

UNIVERSITY OF PLYMOUTH
Faculty of Arts and Humanities

Information Sheet

Project: Effects of Daylight on Health, Wellbeing, and Productivity of Healthcare Personnel.

Project contact details:
Name of researcher/student: **Akinbami Ademola Adebayo**
Contact details: **School of Art, Design and Architecture, Plymouth University, Devon, UK**

Name of Supervisor: **Dr Satish BK**
Contact details of Supervisor: **School Art, Design and Architecture**
Name of Course/Module

What is this project about?
(Describe the project in a way that is transparent, intelligible; easily accessible; and uses clear and plain language in about 200-300 words.)
This study investigates how indoor environments with lighting during the day affect personnel productivity in a healthcare facility, by measuring and evaluating the daylight environments in nurse's stations and staff breakroom and comparing results to their productivity. Personnel's productivity data will be compiled at two healthcare facilities in Plymouth, UK and two healthcare facilities in Abuja, Nigeria. The physical, environmental, and daylight conditions in the buildings will be assessed. The variables to be considered in this study are each personnel productivity level as an index of health outcome, and the differences in environments during daylight hours, including illuminance, luminance ratio, and daylight access in the study rooms of the healthcare facilities. This study will consider how these components can affect personnel productivity in healthcare facilities. The data will be categorised based on the orientation of each room and in relation to window views. Comparisons will be made between the different orientations of the study rooms of the selected healthcare facilities. It will discuss the relationship between indoor daylight environments and productivity, as well as both the seasonal weather factor and climatic zone effect on indoor daylight that could potentially influence personnel productivity. This study can serve as a basis for the development of recommendations for designing nurses' stations and staff breakrooms in healthcare facilities that will result in more effective healing environments.

What will you have to do if you agree to take part?
The study will be for a period of 12 months in which daylight variables will be measured in four seasons using data loggers' sensors. Potential participants will be expected to take part in a self-administered questionnaire survey once a fortnight. The survey will be designed to collect personnel response on the five-point Likert scale for feedback surveys to analyse and develop results. This study will use this tool for personnel responses to the questioned daylight variables. It ranges from 0 to 5: A self-administered questionnaire will be developed to measure the respondents' perception scores on daylight variables. The participant will rely on her/his own experiences in the daylight parameters of the healthcare facility. The participant may stop the survey at any time she/he do not wish to answer, or that which makes feel uncomfortable. The survey will remain confidential hence names of participants will not be collected.

Informed consent
Your participation is voluntary, and it is up to you whether you wish to participate.

Right to withdraw
We hope that you feel able to help us with this study. If that you do not want to continue to take part in the study, you are free to withdraw any time up until about 6-8 weeks after the survey.

What are the advantages or disadvantages of taking part?
The aim of this study is to examine the effect of daylight on personnel's productivity, but the outcome is not known.
Sometimes participants may end up benefiting directly, but such direct benefits cannot be promised. However, there may be indirect benefits such as empowering participants to learn more about daylight and its effect on productivity. More so, because of discovery through the study, healthcare facilities will benefit personnel productivity in the future.
Also, background information to the research could be provided and the outcome of the research work will be made available.
You may not want to take part in this study if you are not comfortable talking about any issue of personal concern.

Debriefing
There will be an opportunity to learn about the outcomes of the research by early 2023. You may obtain information on my progress and request copies of outputs at any time by contacting the researcher through the above contact details.

Confidentiality[1]
Describe your purposes for processing their personal data, your retention periods for that personal data, and who it will be shared with. This is called 'privacy information'.[2]

Records identifying participants will not be made publicly available. However, the government regulatory agencies and the relevant departments of Plymouth University may inspect and/or copy the records for quality assurance and data analysis. These records may contain private information. To ensure confidentiality, the following measures will be taken: completed surveys forms will not be seen by anyone else other than the researcher. These forms will be kept for a short period to resolve any inconsistencies that may arise and later be destroyed by shredding or burning. Moreover, the participants' details will not be recorded in statistical analysis nor shared with any third party. The respondent names on survey forms for daylight assessment would be replaced by a code in the response spreadsheet and respondents' positions marked with unique codes before files are handed to any third-party researchers.

Planned Outputs
The results of the study will be part of the PhD work and will be used in the thesis writeup. They will be published in the national/international conferences and journal publications.

Feedback
Please feel free to contact *Akinbami Ademola, ademola.akinbami@plymouth.ac.uk , 07312128946* at any time if you have questioned this research study.

Further Contact Details:
The Faculty of Arts and Humanities Ethics and Integrity Committee is responsible for ethical approval. If you have any queries or concerns about the research or about how it is being conducted (or if you wish to make a complaint) please contact:
Faculty Research Ethics Administrator artsresearchethics@plymouth.ac.uk

UNIVERSITY OF
PLYMOUTH
Faculty of Arts and
Humanities

Informed Consent Form

Project: Effects of Daylight on Performance of Personnel in Healthcare Facilities in Different Climatic Zones.

Project contact details:
Name of Student researcher: Akinbami Ademola Adebayo
Contact details: School of Art, Design and Architecture
Email : ademola.akinbami@plymouth.ac.uk
Phone : +234 805602132 ; +44 7312128946

Name of Supervisor: Dr Satish BK
Contact details of Supervisor: Room 301, Roland Levinsky Building, Drake Circus
satish.bk@plymouth.ac.uk

What is this project about?
(Describe the project in a way that is transparent; intelligible; easily accessible; and uses clear and plain language in about 200-300 words.)

This study is aimed at investigating how indoor environments with lighting during the day affect performance by measuring and evaluating the daylight environments in workplace and comparing results with occupants' subjective performance. The participants subjective performance will be compiled using survey questionnaire and semi-structured interviews. Daylight conditions in the building will be assessed using non-intrusive data sensor loggers. The physical, environmental, and daylight conditions in the buildings will be assessed. The variables to be considered in this study are each personnel performance level as an index of health outcome, and the differences in environments during daylight hours, including illuminance, luminance ratio, and daylight access in the study rooms in the facility. This study will consider how daylight conditions can affect personnel performance in their working environment. The data will be categorised based on the orientation of each room and in relation to window views. Comparisons will be made between the different orientations of the study rooms of the facility. It will discuss the relationship between indoor daylight environments and performance, as well as the seasonal weather factor on indoor daylight that could potentially influence the personnel performance. Beyond the building type, the result may be transferable to other types of buildings with observed human performance.

I, confirm that (please tick box as appropriate):

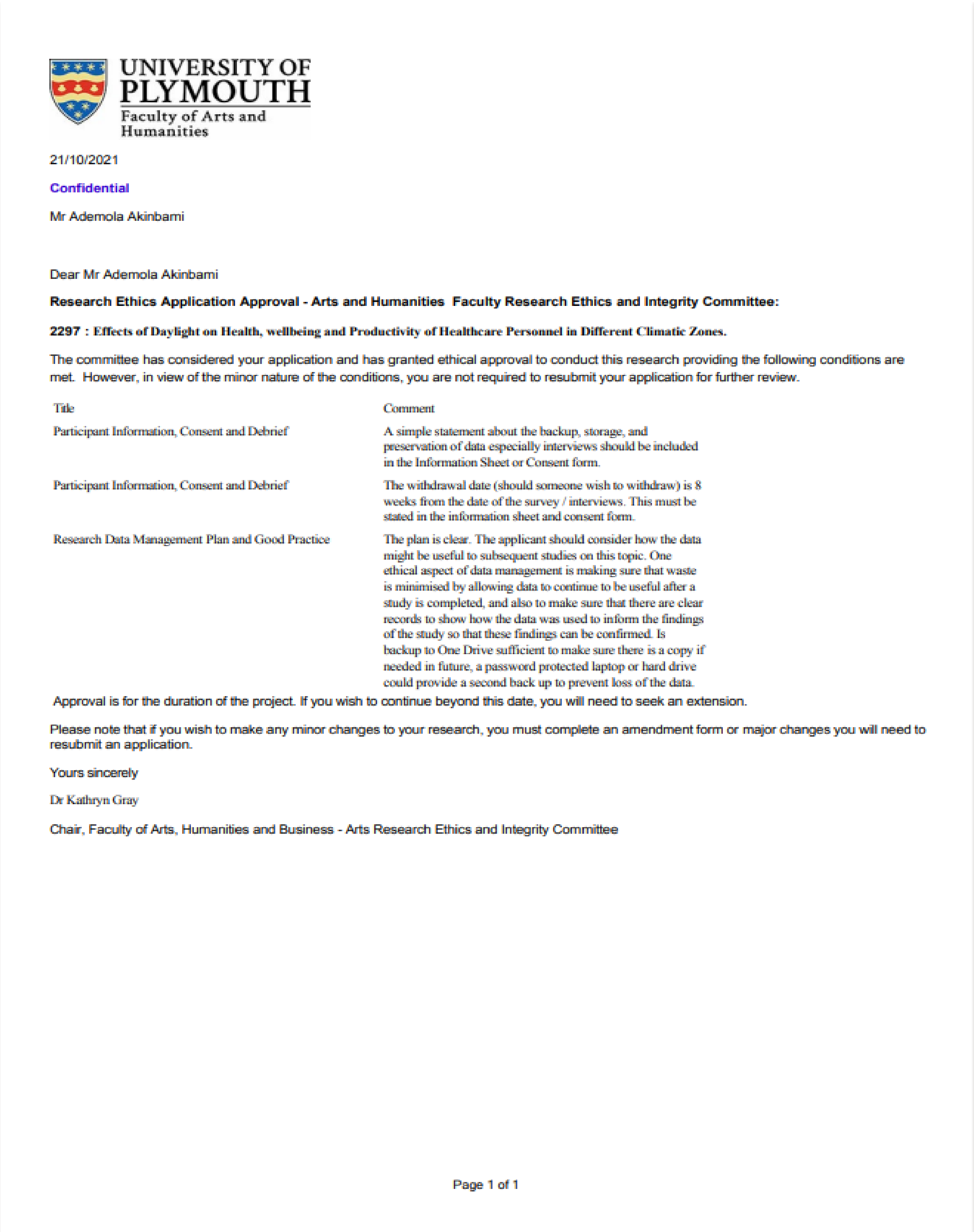
- I have been given the opportunity to ask questions about the project and my participation.
- I voluntarily agree to participate in the project.
- I understand I can withdraw up until 8 weeks from the date of survey/interview without giving reasons and that I will not be penalised for withdrawing nor will I be questioned on why I have withdrawn.
- The procedures regarding confidentiality and privacy information have been clearly explained to me.

I, along with the Student Researcher, agree to sign and date this informed consent form.
Participant:

________________________ ___________________________ ________________
Name of Participant Signature Date
Student Researcher:

Akinbami Ademola Adebayo _____ A. A________ _______ 06/02/2021 _____
Name of Student Researcher Signature Date

Applications and Approvals



UNIVERSITY OF
PLYMOUTH
Faculty of Arts and
Humanities

21/10/2021

Confidential

Mr Ademola Akinbami

Dear Mr Ademola Akinbami

Research Ethics Application Approval - Arts and Humanities Faculty Research Ethics and Integrity Committee:

2297 : Effects of Daylight on Health, wellbeing and Productivity of Healthcare Personnel in Different Climatic Zones.

The committee has considered your application and has granted ethical approval to conduct this research providing the following conditions are met. However, in view of the minor nature of the conditions, you are not required to resubmit your application for further review.

Title	Comment
Participant Information, Consent and Debrief	A simple statement about the backup, storage, and preservation of data especially interviews should be included in the Information Sheet or Consent form.
Participant Information, Consent and Debrief	The withdrawal date (should someone wish to withdraw) is 8 weeks from the date of the survey / interviews. This must be stated in the information sheet and consent form.
Research Data Management Plan and Good Practice	The plan is clear. The applicant should consider how the data might be useful to subsequent studies on this topic. One ethical aspect of data management is making sure that waste is minimised by allowing data to continue to be useful after a study is completed, and also to make sure that there are clear records to show how the data was used to inform the findings of the study so that these findings can be confirmed. Is backup to One Drive sufficient to make sure there is a copy if needed in future, a password protected laptop or hard drive could provide a second back up to prevent loss of the data.

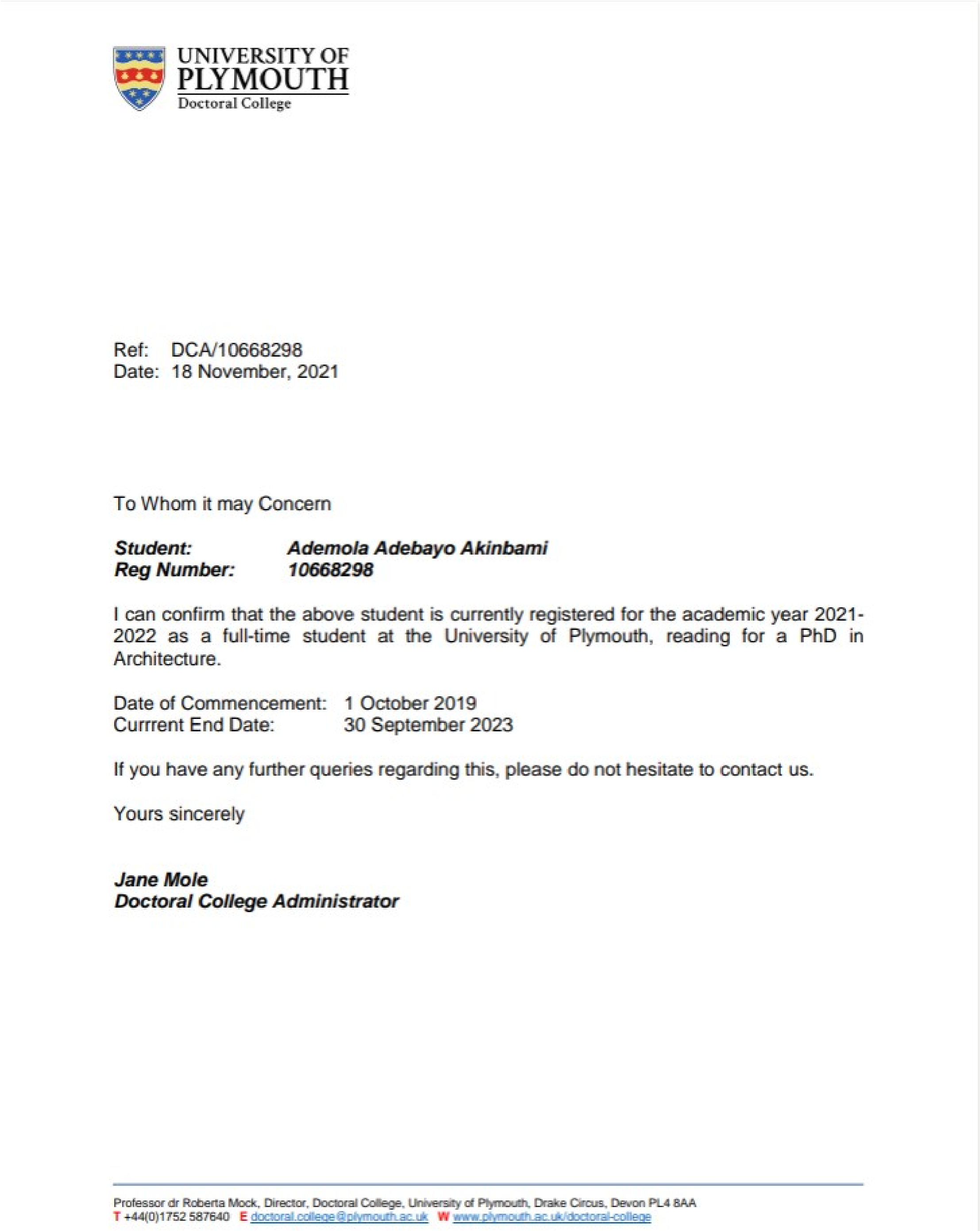
Approval is for the duration of the project. If you wish to continue beyond this date, you will need to seek an extension.

Please note that if you wish to make any minor changes to your research, you must complete an amendment form or major changes you will need to resubmit an application.

Yours sincerely

Dr Kathryn Gray

Chair, Faculty of Arts, Humanities and Business - Arts Research Ethics and Integrity Committee



UNIVERSITY OF
PLYMOUTH
Doctoral College

Ref: DCA/10668298
Date: 18 November, 2021

To Whom it may Concern

Student: ***Ademola Adebayo Akinbami***
Reg Number: ***10668298***

I can confirm that the above student is currently registered for the academic year 2021-2022 as a full-time student at the University of Plymouth, reading for a PhD in Architecture.

Date of Commencement: 1 October 2019
Currrent End Date: 30 September 2023

If you have any further queries regarding this, please do not hesitate to contact us.

Yours sincerely

Jane Mole
Doctoral College Administrator

Professor dr Roberta Mock, Director, Doctoral College, University of Plymouth, Drake Circus, Devon PL4 8AA
T +44(0)1752 587640 E doctoral.college@plymouth.ac.uk W www.plymouth.ac.uk/doctoral-college

FEDERAL MEDICAL CENTRE, ABUJA, NIGERIA
HEALTH RESEARCH ETHICS COMMITTEE (HREC)
Email: hrec.fmcabj@gmail.com

APPLICATION FORM

Instructions: Applications will only be considered if the following are met:

1. The application form must be fully filled in capital letters or typed. No question must be left unanswered. Where a question is not applicable, it is important to make this clear and not to leave it blank.
2. All necessary documents must be duly attached.
3. The application must be signed by the applicant, Head of Department/Unit where the research will be conducted and the applicant's supervisor (where applicable).
4. All abbreviations must be explained.
5. The language used must be simple and clear to lay persons.
6. Soft copies of all documents must be sent to the committee's email.

Checklist for documents (Tick yes/no/not applicable).

1. Two copies of Application form Yes No Not applicable
2. Two copies of Research protocol Yes No Not applicable
3. Two copies of Informed consent form Yes No Not applicable
4. Two copies of Participant information sheet Yes No Not applicable
5. Two copies of Questionnaire or Interview form to be used Yes No Not applicable
6. Recruitment materials: Letter of invitation/advertisement/ flyers/radio or television scripts/internet messages Yes No Not applicable
7. Compensation arrangement sheet Yes No Not applicable
8. Data sheet for all drugs Yes No Not applicable
9. Approval for use of radiation Yes No Not applicable

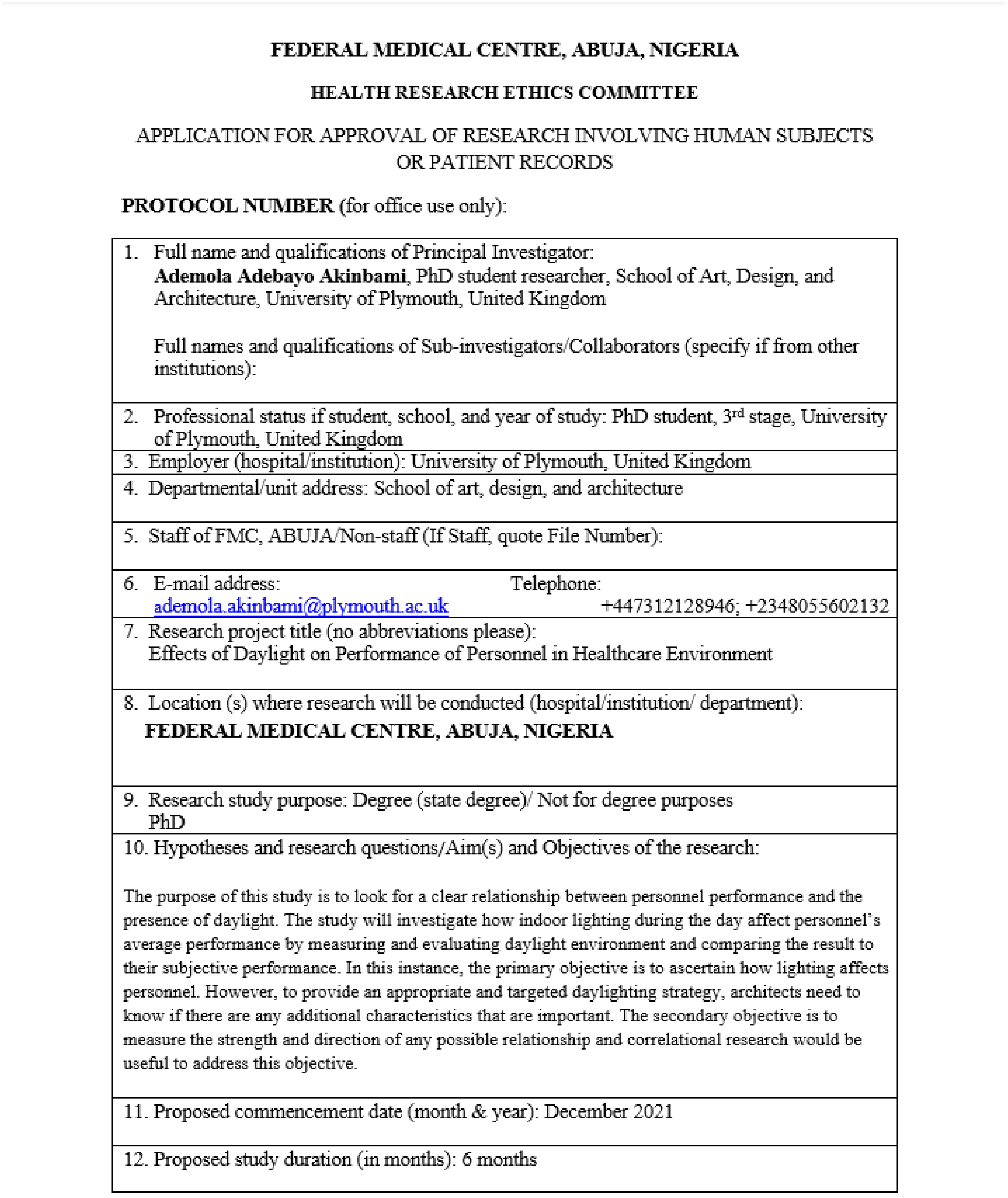
Enquiries:

Kindly quote the protocol number in all enquiries and correspondences with the committee.

All applications and enquiries should be directed to:

Mr. Peter Jegede
Secretary/Desk Officer, Health Research Ethics Committee
Administration Department
Federal Medical Centre, Abuja
hrec.fmcabj@gmail.com, +2348037779155

Application closing date or response time: All applications submitted after the 10th of the month will be considered the following month.



FEDERAL MEDICAL CENTRE, ABUJA, NIGERIA

HEALTH RESEARCH ETHICS COMMITTEE

APPLICATION FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS OR PATIENT RECORDS

PROTOCOL NUMBER (for office use only):

1. Full name and qualifications of Principal Investigator:
   Ademola Adebayo Akinbami, PhD student researcher, School of Art, Design, and Architecture, University of Plymouth, United Kingdom

   Full names and qualifications of Sub-investigators/Collaborators (specify if from other institutions):

2. Professional status if student, school, and year of study: PhD student, 3rd stage, University of Plymouth, United Kingdom

3. Employer (hospital/institution): University of Plymouth, United Kingdom

4. Departmental/unit address: School of art, design, and architecture

5. Staff of FMC, ABUJA/Non-staff (If Staff, quote File Number):

6. E-mail address: ademola.akinbami@plymouth.ac.uk Telephone: +447312128946; +2348055602132

7. Research project title (no abbreviations please):
   Effects of Daylight on Performance of Personnel in Healthcare Environment

8. Location (s) where research will be conducted (hospital/institution/ department):
   FEDERAL MEDICAL CENTRE, ABUJA, NIGERIA

9. Research study purpose: Degree (state degree)/ Not for degree purposes
   PhD

10. Hypotheses and research questions/Aim(s) and Objectives of the research:

The purpose of this study is to look for a clear relationship between personnel performance and the presence of daylight. The study will investigate how indoor lighting during the day affect personnel's average performance by measuring and evaluating daylight environment and comparing the result to their subjective performance. In this instance, the primary objective is to ascertain how lighting affects personnel. However, to provide an appropriate and targeted daylighting strategy, architects need to know if there are any additional characteristics that are important. The secondary objective is to measure the strength and direction of any possible relationship and correlational research would be useful to address this objective.

11. Proposed commencement date (month & year): December 2021

12. Proposed study duration (in months): 6 months

13. Potential value of the research results:

In step with the global concern about the quality of the indoor environment and its effect on human health and productivity, this study is envisaged as simulating collaborative approach to the neglected area of daylight research and human performance. Recognising the importance of daylight for human health, wellbeing, and performance as crucial to ensure that buildings and the indoor spaces provide humans with the desired level of comfort at both collective and individual levels. Also, to identify the visible link between the building elements and the occupants focus based on the needs and expectations as expressed by the people and how they experience the space.

pplication must be handwritten in capital letters. The form must be completed in full, or it will not be considered.

14. Requirements

Informed Consent Form is attached.
Yes ☒ No ☐ Informed consent is not necessary ☐

15. Is a questionnaire or interview to be used in the research? Yes ☒ No ☐

If yes, is the questionnaire attached? Yes ☒ No ☐

16. Recruitment

State where and how the participants will be recruited?
Potential participants will be healthcare personnel in wards within FMC. These participants will be identified by collaborators in FMC who will facilitate an initial approach email, inviting personnel to take part in the study.

17. Where the participants are not patients, will they be asked to volunteer and who will be asked to volunteer?
Healthcare personnel as participants will be asked to volunteer to take part in the study

18. State how the participants will be selected.
A total population sampling technique will be employed, inviting all healthcare personnel meeting inclusion criteria to take part through an email from the collaborators within FMC.

19. Will control participants be used? If yes, how they will be recruited?
No

20. Participant records

What records will be used and how will they be selected?
Participants response to daylight conditions will be recorded using questionnaire

21. Age range of participants: Age 18 years and above

If under 18 years, from whom will assent be obtained?

22. Gender of participants

Male ☒ Female ☒

23. Numbers of participants 50___________;

Patient participants______________ Non-patient participants 50___________;

Controls____________

24. Benefit/Compensation/Incentives

Will the research benefit the participants in any direct way? Yes ☐ No ☐
If yes, explain in what way:

25. Will participation or non-participation disadvantage them or expose them to injury in any way? Yes ☐ No☒

If yes, explain in what way and how this will be minimised:

26. Are there any arrangements for compensation should a subject suffer any injury as a result of the participation, if such an injury results from negligence? Yes ☐ No ☐

If yes, enumerate the arrangements

27. Will participants be given any incentive to participate in the study? Yes ☐ No ☐
If yes, give details:

28. Research procedures

Which of these procedures will be used?

Patients records ☐

Interview form ☒ (must be attached)

Questionnaire ☒ (must be attached)

Examination ☐ (state nature and frequency)

Substance administration ☐ (state name(s), dose(s) and frequency of administration:

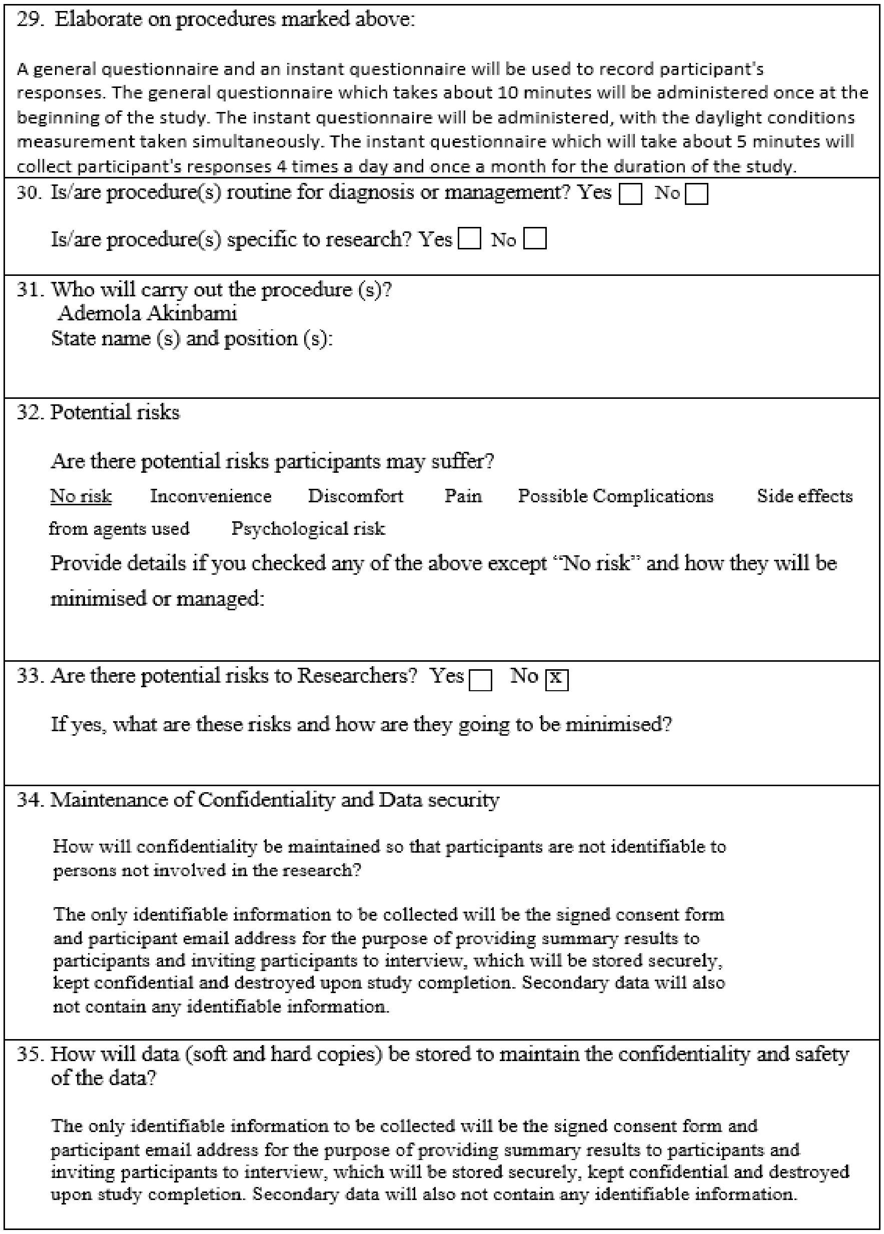
Radiographs ☐

Isotope administration ☐ (state the name(s) of isotope(s) and frequency)

Blood sampling; venous ☐; arterial ☐ (state amount to be taken and frequency of sampling)

Biopsy ☐

Other procedures ☐



29. Elaborate on procedures marked above:

A general questionnaire and an instant questionnaire will be used to record participant's responses. The general questionnaire which takes about 10 minutes will be administered once at the beginning of the study. The instant questionnaire will be administered, with the daylight conditions measurement taken simultaneously. The instant questionnaire which will take about 5 minutes will collect participant's responses 4 times a day and once a month for the duration of the study.

30. Is/are procedure(s) routine for diagnosis or management? Yes ☐ No ☐

Is/are procedure(s) specific to research? Yes ☐ No ☐

31. Who will carry out the procedure (s)?
Ademola Akinbami
State name (s) and position (s):

32. Potential risks

Are there potential risks participants may suffer?

[✓ No risk] Inconvenience Discomfort Pain Possible Complications Side effects from agents used Psychological risk

Provide details if you checked any of the above except "No risk" and how they will be minimised or managed:

33. Are there potential risks to Researchers? Yes ☐ No ☒

If yes, what are these risks and how are they going to be minimised?

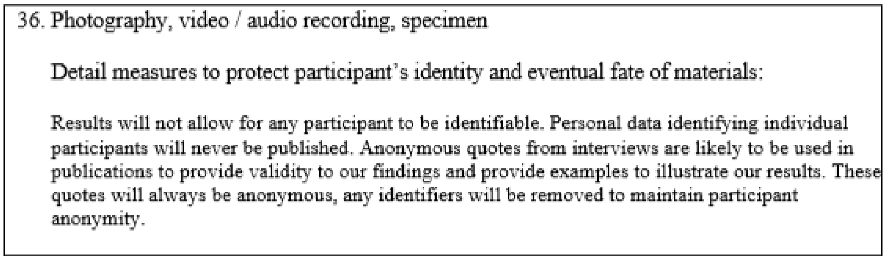
34. Maintenance of Confidentiality and Data security

How will confidentiality be maintained so that participants are not identifiable to persons not involved in the research?

The only identifiable information to be collected will be the signed consent form and participant email address for the purpose of providing summary results to participants and inviting participants to interview, which will be stored securely, kept confidential and destroyed upon study completion. Secondary data will also not contain any identifiable information.

35. How will data (soft and hard copies) be stored to maintain the confidentiality and safety of the data?

The only identifiable information to be collected will be the signed consent form and participant email address for the purpose of providing summary results to participants and inviting participants to interview, which will be stored securely, kept confidential and destroyed upon study completion. Secondary data will also not contain any identifiable information.



36. Photography, video / audio recording, specimen

Detail measures to protect participant's identity and eventual fate of materials:

Results will not allow for any participant to be identifiable. Personal data identifying individual participants will never be published. Anonymous quotes from interviews are likely to be used in publications to provide validity to our findings and provide examples to illustrate our results. These quotes will always be anonymous, any identifiers will be removed to maintain participant anonymity.

37. Are arrangements in place to handle the broader aspects of your study on participant

For example: Communication of medical information to a participant's medical/dental practitioner? Or communication of policy non-compliance to an employer? Or counselling of subjects/controls, where study results may have health implication? Or communication of criminal activity or child/elder abuse to relevant authorities? Or result dissemination to participants and the general public?

38. Funding

Will there be financial costs to:

Participants? Yes ☐ No ☒

FMC, ABUJA? Yes ☐ No ☒

Others? (If yes, please state the name…………………) Yes ☐ No ☐

Explain any box marked "yes":

How will the research be funded? (Please give the name of any sponsoring organisation and attach letter of sponsorship):

39. Organizational permissions and approvals

Has permission of relevant authority/ies been obtained? Yes ☒ No ☐

If No, refer to item 43 below.

40. Is this research being conducted by, or involves collaboration with an organisation external to FMC, ABUJA? Yes ☒ No ☐

If yes, has the study been referred to or agreed by any other Ethics Committee or Review board? Yes ☒ No ☐

If yes, attach to application.

41. Please provide any other information which may assist the committee to reach its decision:

42. Name of Supervisor of project:

Designation: Department/Unit & Institution:

Signature and date:

43. Head(s) of Department(s)/Unit (s) in which study will be conducted:

Name: Department/Unit:

Signature and date:

DECLARATION:

I declare that the contents of this application are true to the best of my knowledge. I am aware that any false statements will lead to my application being rejected. **Ademola A. Akinbami: 09/11/2021**

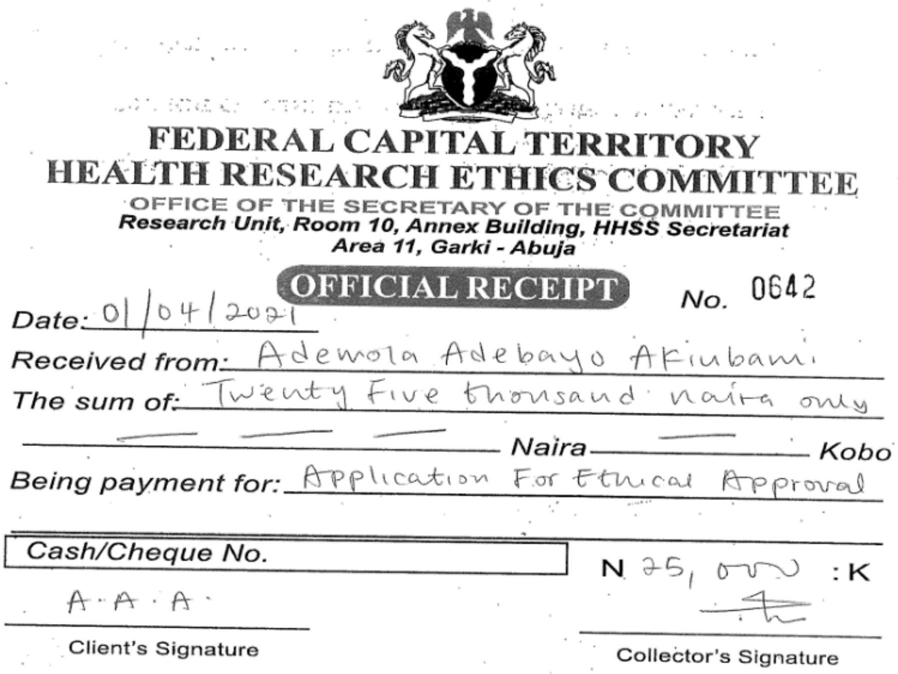
Name: Signature and date:

FOR OFFICE USE ONLY:

Review: Exempt/Expedited/Full committee (Tick as appropriate)

Refer to FMC, ABUJA HREC

Need for Revisions:



FEDERAL CAPITAL TERRITORY
HEALTH RESEARCH ETHICS COMMITTEE

OFFICE OF THE SECRETARY OF THE COMMITTEE
Research Unit, Room 10, Annex Building, HHSS Secretariat
Area 11, Garki - Abuja

OFFICIAL RECEIPT No. 0642

Date: 01/04/2021

Received from: Ademola Adebayo Akinbami

The sum of: Twenty Five thousand naira only

— — — *Naira* — *Kobo*

Being payment for: Application For Ethical Approval

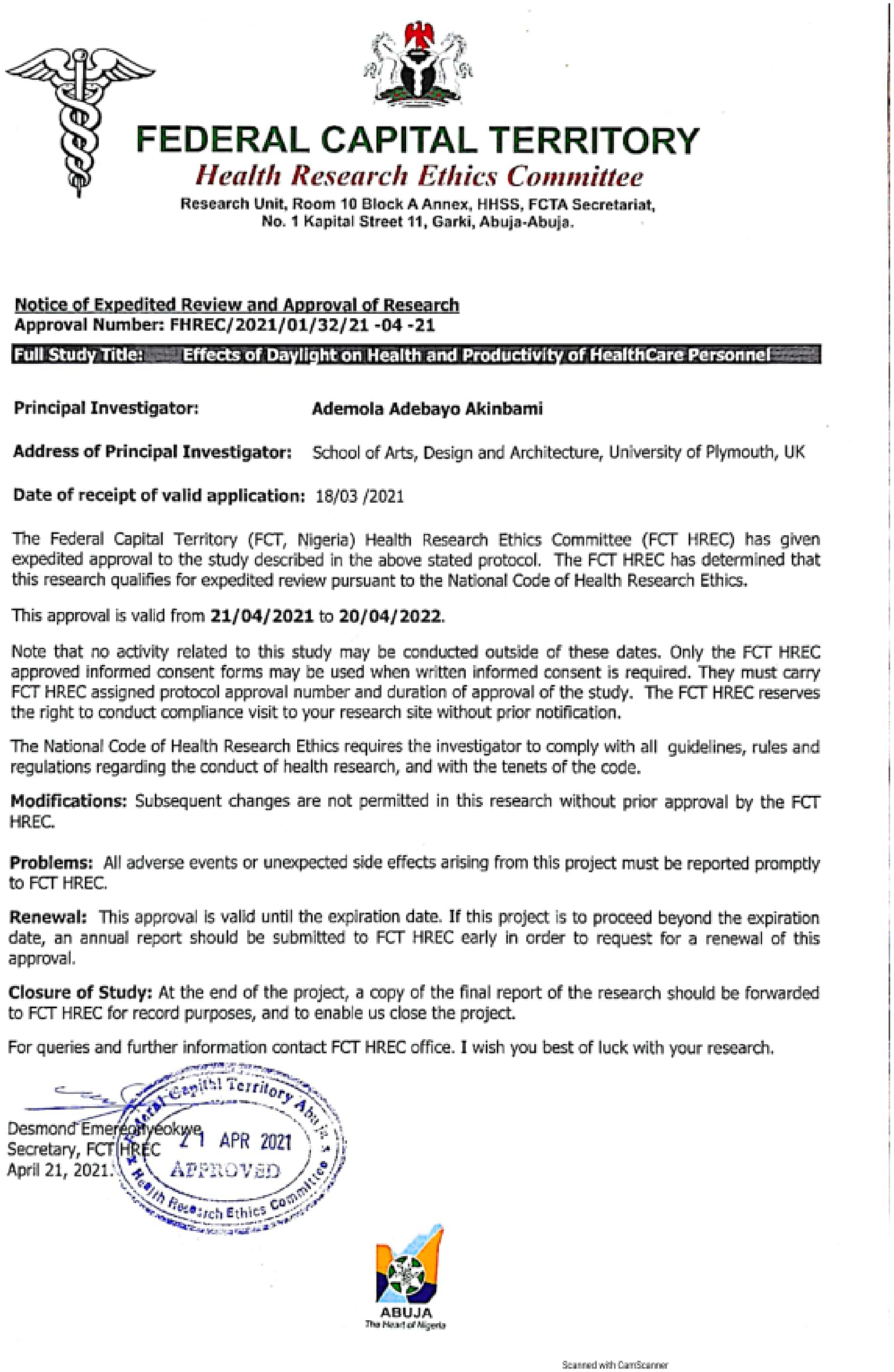
Cash/Cheque No.

N 25,000 :K

A·A·A·

Client's Signature

Collector's Signature



FEDERAL CAPITAL TERRITORY

Health Research Ethics Committee

Research Unit, Room 10 Block A Annex, HHSS, FCTA Secretariat,
No. 1 Kapital Street 11, Garki, Abuja-Abuja.

Notice of Expedited Review and Approval of Research
Approval Number: FHREC/2021/01/32/21 -04 -21

Full Study Title: Effects of Daylight on Health and Productivity of HealthCare Personnel

Principal Investigator: **Ademola Adebayo Akinbami**

Address of Principal Investigator: School of Arts, Design and Architecture, University of Plymouth, UK

Date of receipt of valid application: 18/03 /2021

The Federal Capital Territory (FCT, Nigeria) Health Research Ethics Committee (FCT HREC) has given expedited approval to the study described in the above stated protocol. The FCT HREC has determined that this research qualifies for expedited review pursuant to the National Code of Health Research Ethics.

This approval is valid from **21/04/2021** to **20/04/2022**.

Note that no activity related to this study may be conducted outside of these dates. Only the FCT HREC approved informed consent forms may be used when written informed consent is required. They must carry FCT HREC assigned protocol approval number and duration of approval of the study. The FCT HREC reserves the right to conduct compliance visit to your research site without prior notification.

The National Code of Health Research Ethics requires the investigator to comply with all guidelines, rules and regulations regarding the conduct of health research, and with the tenets of the code.

Modifications: Subsequent changes are not permitted in this research without prior approval by the FCT HREC.

Problems: All adverse events or unexpected side effects arising from this project must be reported promptly to FCT HREC.

Renewal: This approval is valid until the expiration date. If this project is to proceed beyond the expiration date, an annual report should be submitted to FCT HREC early in order to request for a renewal of this approval.

Closure of Study: At the end of the project, a copy of the final report of the research should be forwarded to FCT HREC for record purposes, and to enable us close the project.

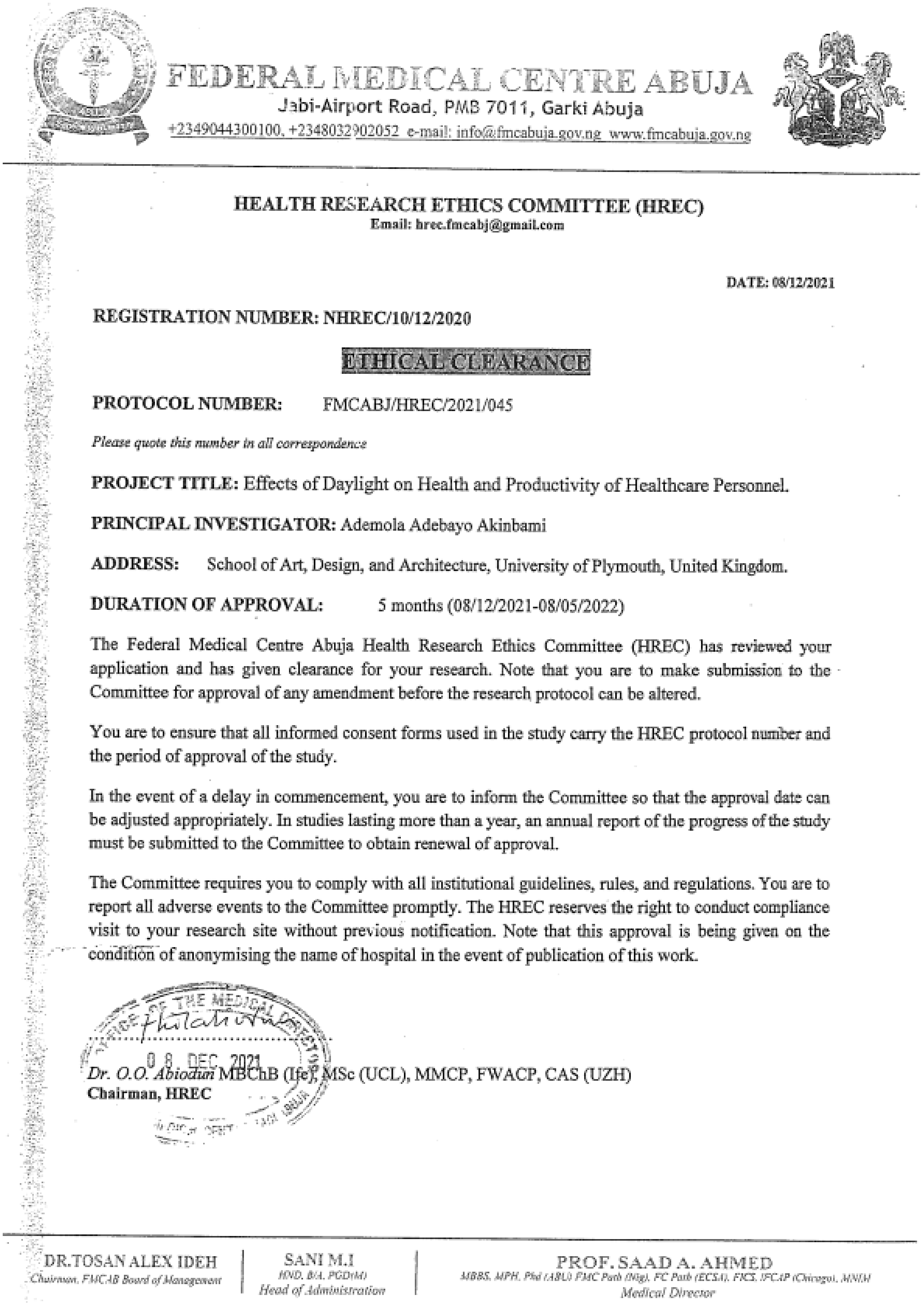
For queries and further information contact FCT HREC office. I wish you best of luck with your research.

21 APR 2021
APPROVED

Desmond Emereonyeokwe
Secretary, FCT HREC
April 21, 2021.

ABUJA
The Heart of Nigeria

Scanned with CamScanner



FEDERAL MEDICAL CENTRE ABUJA
Jabi-Airport Road, PMB 7011, Garki Abuja
+2349044300100, +2348032902052 e-mail: info@fmcabuja.gov.ng www.fmcabuja.gov.ng

HEALTH RESEARCH ETHICS COMMITTEE (HREC)

Email: hrec.fmcabj@gmail.com

DATE: 08/12/2021

REGISTRATION NUMBER: NHREC/10/12/2020

ETHICAL CLEARANCE

PROTOCOL NUMBER: FMCABJ/HREC/2021/045

Please quote this number in all correspondence

PROJECT TITLE: Effects of Daylight on Health and Productivity of Healthcare Personnel.

PRINCIPAL INVESTIGATOR: Ademola Adebayo Akinbami

ADDRESS: School of Art, Design, and Architecture, University of Plymouth, United Kingdom.

DURATION OF APPROVAL: 5 months (08/12/2021-08/05/2022)

The Federal Medical Centre Abuja Health Research Ethics Committee (HREC) has reviewed your application and has given clearance for your research. Note that you are to make submission to the Committee for approval of any amendment before the research protocol can be altered.

You are to ensure that all informed consent forms used in the study carry the HREC protocol number and the period of approval of the study.

In the event of a delay in commencement, you are to inform the Committee so that the approval date can be adjusted appropriately. In studies lasting more than a year, an annual report of the progress of the study must be submitted to the Committee to obtain renewal of approval.

The Committee requires you to comply with all institutional guidelines, rules, and regulations. You are to report all adverse events to the Committee promptly. The HREC reserves the right to conduct compliance visit to your research site without previous notification. Note that this approval is being given on the condition of anonymising the name of hospital in the event of publication of this work.

OFFICE OF THE MEDICAL DIRECTOR
08 DEC 2021

Dr. O.O. Abiodun MBChB (Ife), MSc (UCL), MMCP, FWACP, CAS (UZH)
Chairman, HREC

DR.TOSAN ALEX IDEH
Chairman, FMCAB Board of Management

SANI M.I
HND, B/A, PGD(M)
Head of Administration

PROF. SAAD A. AHMED
MBBS, MPH, Phd (ABU) FMC Path (Nig), FC Path (ECSA), FICS, IFCAP (Chicago), MNIM
Medical Director

Daylight and Performance Survey

The Study Information, Brief and Consent for the Survey

Thank you for your help with the study and the survey.

Who are the investigators of this research project?

Ademola Adebayo Akinbami, PhD student researcher
ademola.akinbami@plymouth.ac.uk

Dr Rory Jones, Director of Study, Lecturer in Built Environment
rory.jones@plymouth.ac.uk

Dr Alba Fuertes Casals, 2nd Supervisor, Associate Professor in Construction Technology
alba.fuertes@plymouth.ac.uk

Dr Satish BK, 3rd Supervisor Associate Head of School (Teaching & Learning)
satish.bk@plymouth.ac.uk

What is the aim of the Study?

The study, 'Impact of daylight on Performance of Personnel in Healthcare environment' has an overall aim of researching when and how daylight can impact human performance in healthcare environments.

Using continuous and spot measurements, the study investigates the relationship between daylight conditions and performance of personnel.

The study team really values and wants to hear about your thoughts and opinions on the availability of daylight and its impact on your performance in your work environment through this survey.

This Survey will take 3 minutes to complete.

Personal data like names and contact details will not be collected in the survey and all contributions will be aggregated, made anonymous and will be confidential.

You have the right to withdraw from the survey at any point in the survey and have data returned/destroyed in the future. You can do so by using the contacts below:

- Faculty Research Ethics Administrator: artsresearchethics@plymouth.ac.uk
- Principal Investigator: ademola.akinbami@plymouth.ac.uk

On completion of the study, the data will be analysed and reported to the hospital and in academic outputs.

I agree to take part in the study about Daylight and Performance and to use the data described above.
Yes

No

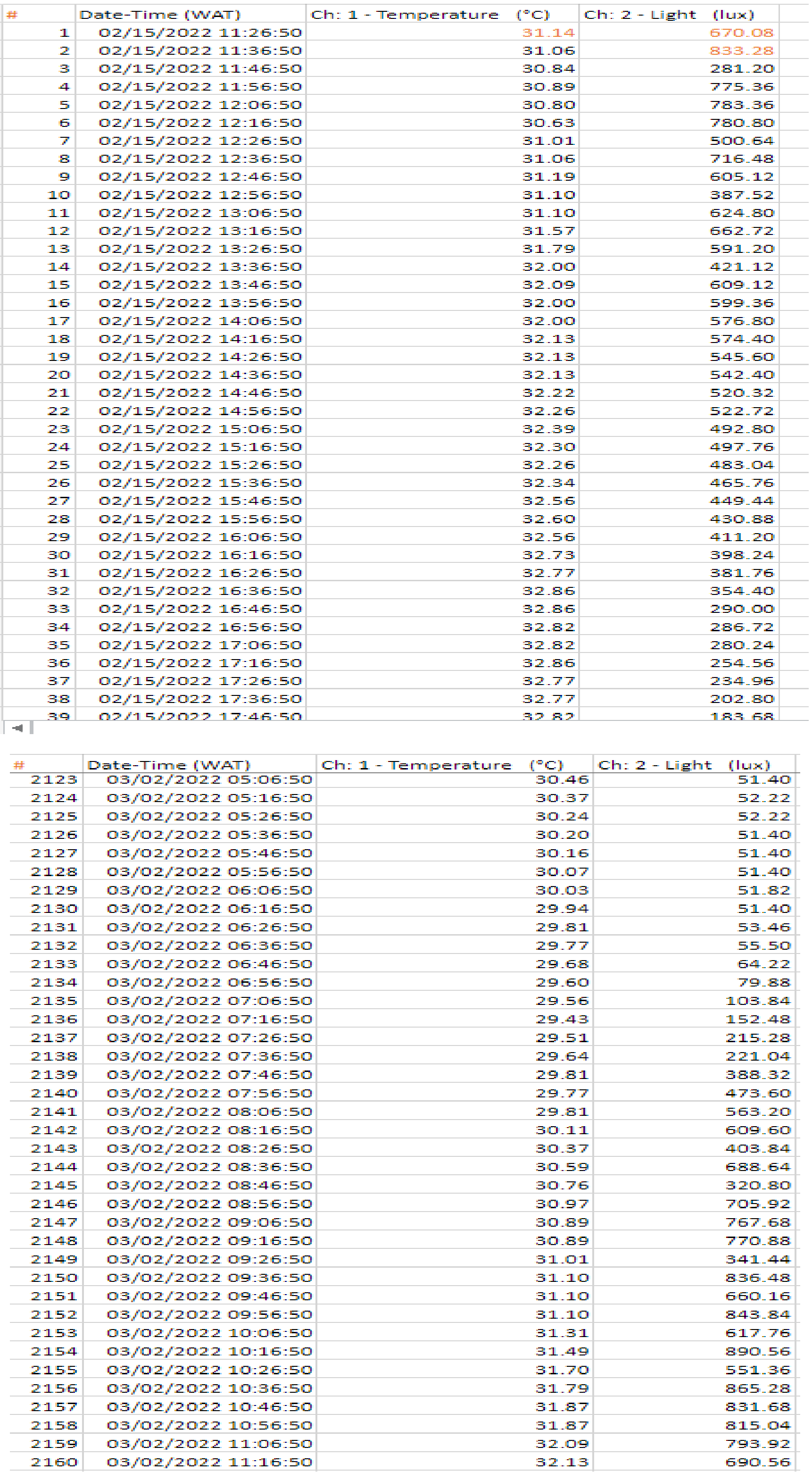
Appendix B

Sample Data and Analysis Records

This appendix contains samples from fieldwork data, both raw and coded, used in the study.

Data Collection Samples

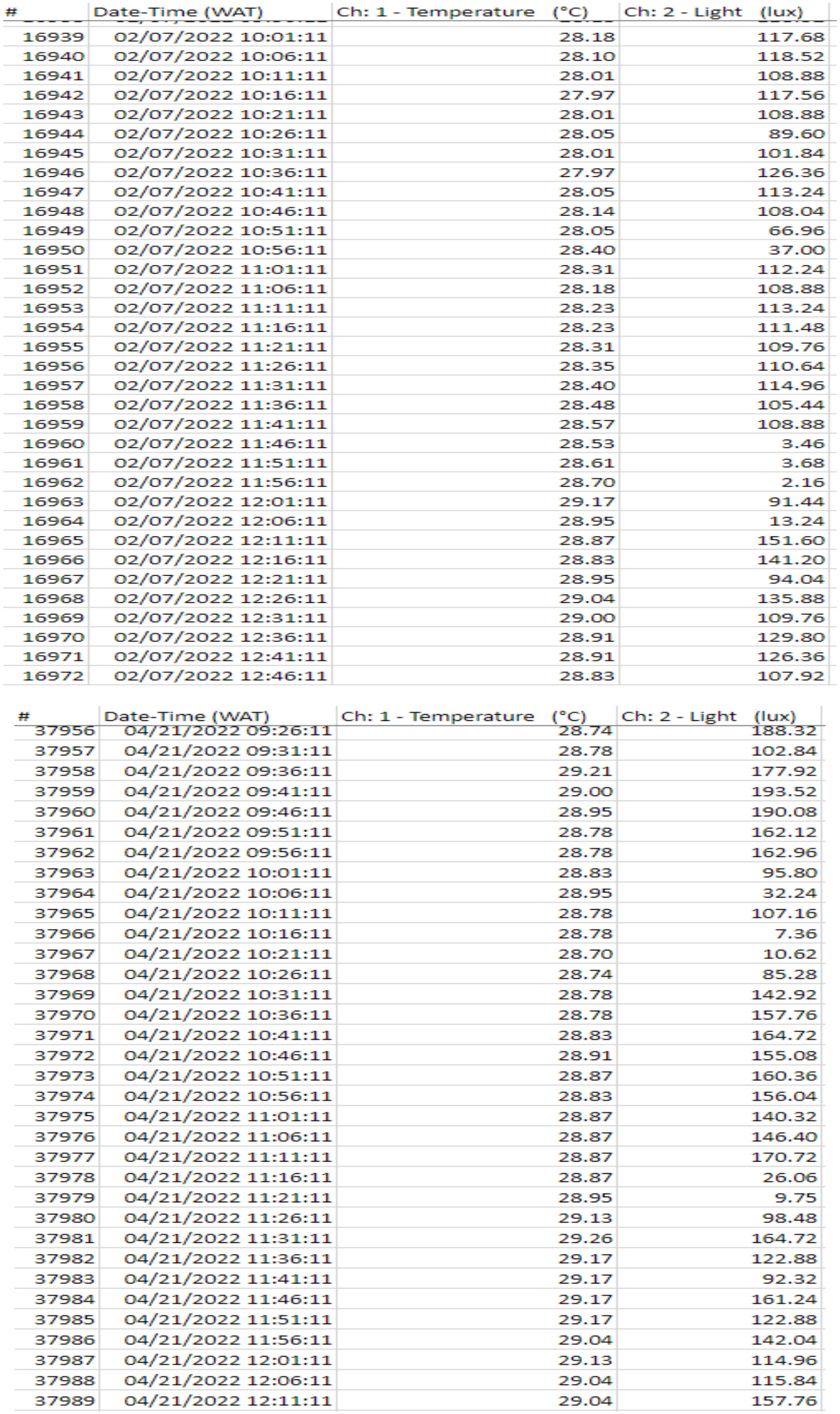
The following pages contain samples of data logger sensor readings and respondents' responses using self-administered questionnaire. These readings and responses were analysed to address the research objectives.



#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
1	02/15/2022 11:26:50	31.14	670.08
2	02/15/2022 11:36:50	31.06	833.28
3	02/15/2022 11:46:50	30.84	281.20
4	02/15/2022 11:56:50	30.89	775.36
5	02/15/2022 12:06:50	30.80	783.36
6	02/15/2022 12:16:50	30.63	780.80
7	02/15/2022 12:26:50	31.01	500.64
8	02/15/2022 12:36:50	31.06	716.48
9	02/15/2022 12:46:50	31.19	605.12
10	02/15/2022 12:56:50	31.10	387.52
11	02/15/2022 13:06:50	31.10	624.80
12	02/15/2022 13:16:50	31.57	662.72
13	02/15/2022 13:26:50	31.79	591.20
14	02/15/2022 13:36:50	32.00	421.12
15	02/15/2022 13:46:50	32.09	609.12
16	02/15/2022 13:56:50	32.00	599.36
17	02/15/2022 14:06:50	32.00	576.80
18	02/15/2022 14:16:50	32.13	574.40
19	02/15/2022 14:26:50	32.13	545.60
20	02/15/2022 14:36:50	32.13	542.40
21	02/15/2022 14:46:50	32.22	520.32
22	02/15/2022 14:56:50	32.26	522.72
23	02/15/2022 15:06:50	32.39	492.80
24	02/15/2022 15:16:50	32.30	497.76
25	02/15/2022 15:26:50	32.26	483.04
26	02/15/2022 15:36:50	32.34	465.76
27	02/15/2022 15:46:50	32.56	449.44
28	02/15/2022 15:56:50	32.60	430.88
29	02/15/2022 16:06:50	32.56	411.20
30	02/15/2022 16:16:50	32.73	398.24
31	02/15/2022 16:26:50	32.77	381.76
32	02/15/2022 16:36:50	32.86	354.40
33	02/15/2022 16:46:50	32.86	290.00
34	02/15/2022 16:56:50	32.82	286.72
35	02/15/2022 17:06:50	32.82	280.24
36	02/15/2022 17:16:50	32.86	254.56
37	02/15/2022 17:26:50	32.77	234.96
38	02/15/2022 17:36:50	32.77	202.80
39	02/15/2022 17:46:50	32.82	183.68

#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
2123	03/02/2022 05:06:50	30.46	51.40
2124	03/02/2022 05:16:50	30.37	52.22
2125	03/02/2022 05:26:50	30.24	52.22
2126	03/02/2022 05:36:50	30.20	51.40
2127	03/02/2022 05:46:50	30.16	51.40
2128	03/02/2022 05:56:50	30.07	51.40
2129	03/02/2022 06:06:50	30.03	51.82
2130	03/02/2022 06:16:50	29.94	51.40
2131	03/02/2022 06:26:50	29.81	53.46
2132	03/02/2022 06:36:50	29.77	55.50
2133	03/02/2022 06:46:50	29.68	64.22
2134	03/02/2022 06:56:50	29.60	79.88
2135	03/02/2022 07:06:50	29.56	103.84
2136	03/02/2022 07:16:50	29.43	152.48
2137	03/02/2022 07:26:50	29.51	215.28
2138	03/02/2022 07:36:50	29.64	221.04
2139	03/02/2022 07:46:50	29.81	388.32
2140	03/02/2022 07:56:50	29.77	473.60
2141	03/02/2022 08:06:50	29.81	563.20
2142	03/02/2022 08:16:50	30.11	609.60
2143	03/02/2022 08:26:50	30.37	403.84
2144	03/02/2022 08:36:50	30.59	688.64
2145	03/02/2022 08:46:50	30.76	320.80
2146	03/02/2022 08:56:50	30.97	705.92
2147	03/02/2022 09:06:50	30.89	767.68
2148	03/02/2022 09:16:50	30.89	770.88
2149	03/02/2022 09:26:50	31.01	341.44
2150	03/02/2022 09:36:50	31.10	836.48
2151	03/02/2022 09:46:50	31.10	660.16
2152	03/02/2022 09:56:50	31.10	843.84
2153	03/02/2022 10:06:50	31.31	617.76
2154	03/02/2022 10:16:50	31.49	890.56
2155	03/02/2022 10:26:50	31.70	551.36
2156	03/02/2022 10:36:50	31.79	865.28
2157	03/02/2022 10:46:50	31.87	831.68
2158	03/02/2022 10:56:50	31.87	815.04
2159	03/02/2022 11:06:50	32.09	793.92
2160	03/02/2022 11:16:50	32.13	690.56

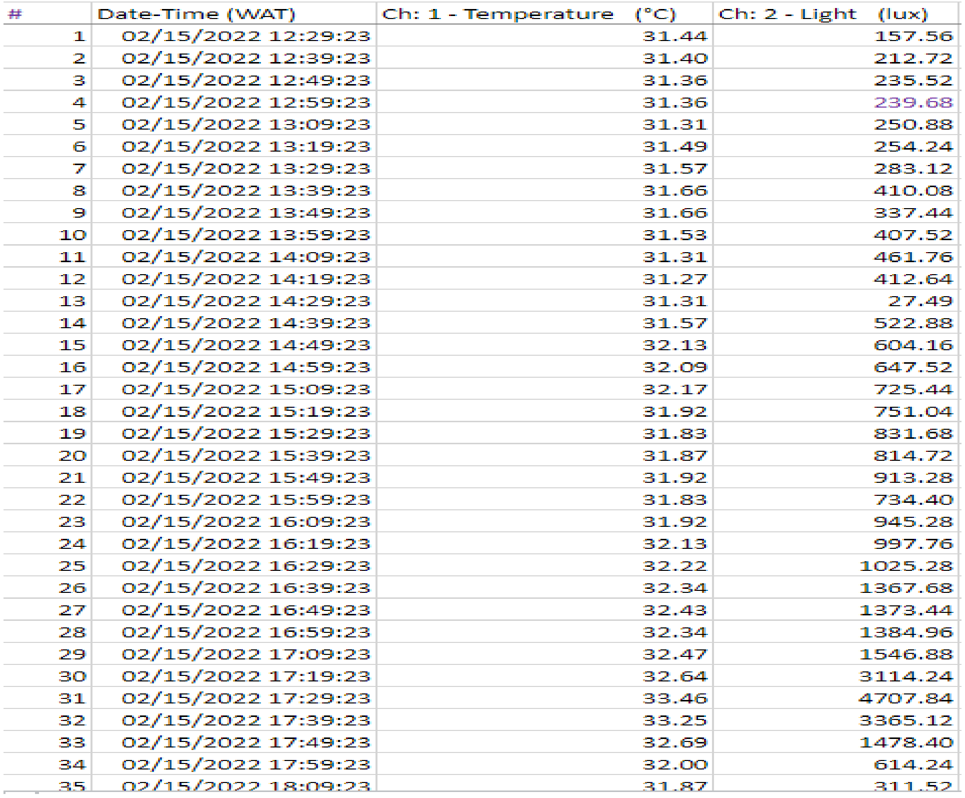
Figure 33: Akinbami A. (2022) Fieldnote: Screenshot of GOPD Department Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 11:26 am 02/15/2022 to 11:16 am 03/02/2022.



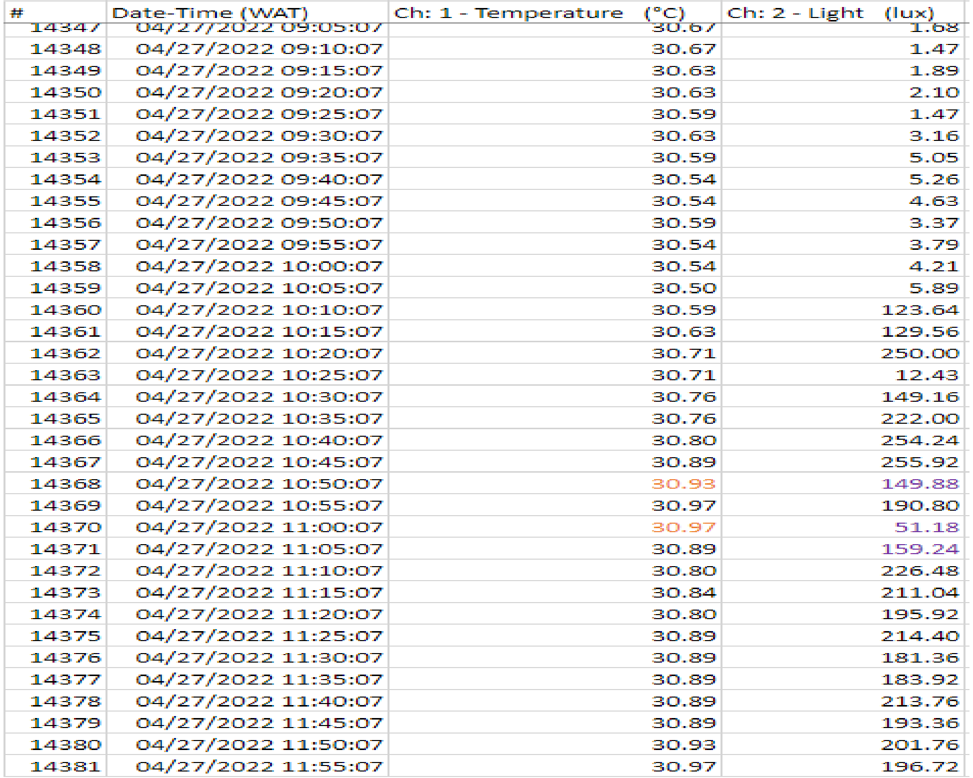
#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
16939	02/07/2022 10:01:11	28.18	117.68
16940	02/07/2022 10:06:11	28.10	118.52
16941	02/07/2022 10:11:11	28.01	108.88
16942	02/07/2022 10:16:11	27.97	117.56
16943	02/07/2022 10:21:11	28.01	108.88
16944	02/07/2022 10:26:11	28.05	89.60
16945	02/07/2022 10:31:11	28.01	101.84
16946	02/07/2022 10:36:11	27.97	126.36
16947	02/07/2022 10:41:11	28.05	113.24
16948	02/07/2022 10:46:11	28.14	108.04
16949	02/07/2022 10:51:11	28.05	66.96
16950	02/07/2022 10:56:11	28.40	37.00
16951	02/07/2022 11:01:11	28.31	112.24
16952	02/07/2022 11:06:11	28.18	108.88
16953	02/07/2022 11:11:11	28.23	113.24
16954	02/07/2022 11:16:11	28.23	111.48
16955	02/07/2022 11:21:11	28.31	109.76
16956	02/07/2022 11:26:11	28.35	110.64
16957	02/07/2022 11:31:11	28.40	114.96
16958	02/07/2022 11:36:11	28.48	105.44
16959	02/07/2022 11:41:11	28.57	108.88
16960	02/07/2022 11:46:11	28.53	3.46
16961	02/07/2022 11:51:11	28.61	3.68
16962	02/07/2022 11:56:11	28.70	2.16
16963	02/07/2022 12:01:11	29.17	91.44
16964	02/07/2022 12:06:11	28.95	13.24
16965	02/07/2022 12:11:11	28.87	151.60
16966	02/07/2022 12:16:11	28.83	141.20
16967	02/07/2022 12:21:11	28.95	94.04
16968	02/07/2022 12:26:11	29.04	135.88
16969	02/07/2022 12:31:11	29.00	109.76
16970	02/07/2022 12:36:11	28.91	129.80
16971	02/07/2022 12:41:11	28.91	126.36
16972	02/07/2022 12:46:11	28.83	107.92

#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
37956	04/21/2022 09:26:11	28.74	188.32
37957	04/21/2022 09:31:11	28.78	102.84
37958	04/21/2022 09:36:11	29.21	177.92
37959	04/21/2022 09:41:11	29.00	193.52
37960	04/21/2022 09:46:11	28.95	190.08
37961	04/21/2022 09:51:11	28.78	162.12
37962	04/21/2022 09:56:11	28.78	162.96
37963	04/21/2022 10:01:11	28.83	95.80
37964	04/21/2022 10:06:11	28.95	32.24
37965	04/21/2022 10:11:11	28.78	107.16
37966	04/21/2022 10:16:11	28.78	7.36
37967	04/21/2022 10:21:11	28.70	10.62
37968	04/21/2022 10:26:11	28.74	85.28
37969	04/21/2022 10:31:11	28.78	142.92
37970	04/21/2022 10:36:11	28.78	157.76
37971	04/21/2022 10:41:11	28.83	164.72
37972	04/21/2022 10:46:11	28.91	155.08
37973	04/21/2022 10:51:11	28.87	160.36
37974	04/21/2022 10:56:11	28.83	156.04
37975	04/21/2022 11:01:11	28.87	140.32
37976	04/21/2022 11:06:11	28.87	146.40
37977	04/21/2022 11:11:11	28.87	170.72
37978	04/21/2022 11:16:11	28.87	26.06
37979	04/21/2022 11:21:11	28.95	9.75
37980	04/21/2022 11:26:11	29.13	98.48
37981	04/21/2022 11:31:11	29.26	164.72
37982	04/21/2022 11:36:11	29.17	122.88
37983	04/21/2022 11:41:11	29.17	92.32
37984	04/21/2022 11:46:11	29.17	161.24
37985	04/21/2022 11:51:11	29.17	122.88
37986	04/21/2022 11:56:11	29.04	142.04
37987	04/21/2022 12:01:11	29.13	114.96
37988	04/21/2022 12:06:11	29.04	115.84
37989	04/21/2022 12:11:11	29.04	157.76

Figure 34: Akinbami A. (2022) Fieldnote: Screenshot of Obstetrics Department Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 10:01 am 02/07/2022 to 12:11 pm 04/21/2022.

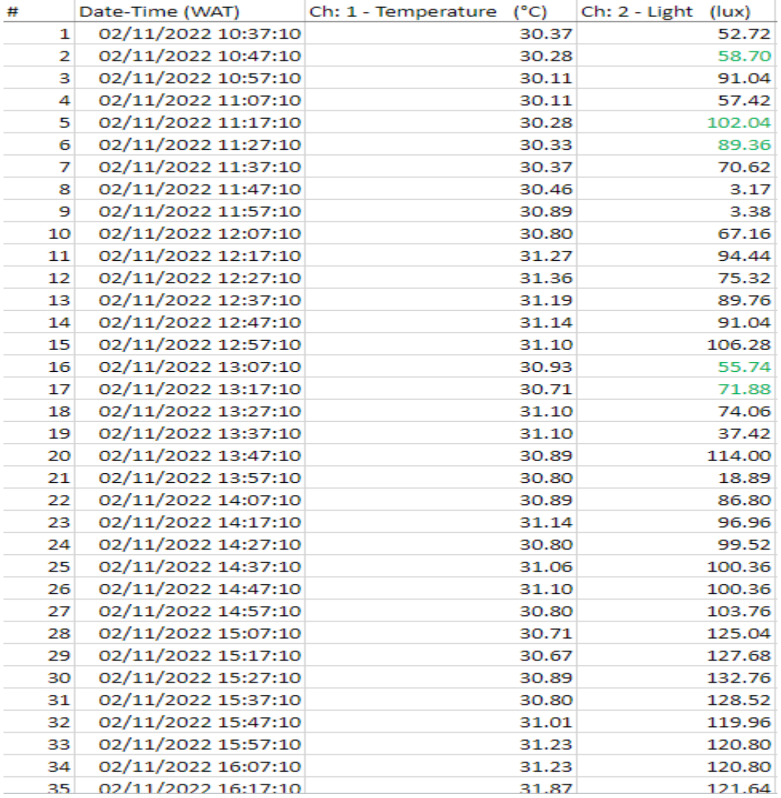


#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
1	02/15/2022 12:29:23	31.44	157.56
2	02/15/2022 12:39:23	31.40	212.72
3	02/15/2022 12:49:23	31.36	235.52
4	02/15/2022 12:59:23	31.36	239.68
5	02/15/2022 13:09:23	31.31	250.88
6	02/15/2022 13:19:23	31.49	254.24
7	02/15/2022 13:29:23	31.57	283.12
8	02/15/2022 13:39:23	31.66	410.08
9	02/15/2022 13:49:23	31.66	337.44
10	02/15/2022 13:59:23	31.53	407.52
11	02/15/2022 14:09:23	31.31	461.76
12	02/15/2022 14:19:23	31.27	412.64
13	02/15/2022 14:29:23	31.31	27.49
14	02/15/2022 14:39:23	31.57	522.88
15	02/15/2022 14:49:23	32.13	604.16
16	02/15/2022 14:59:23	32.09	647.52
17	02/15/2022 15:09:23	32.17	725.44
18	02/15/2022 15:19:23	31.92	751.04
19	02/15/2022 15:29:23	31.83	831.68
20	02/15/2022 15:39:23	31.87	814.72
21	02/15/2022 15:49:23	31.92	913.28
22	02/15/2022 15:59:23	31.83	734.40
23	02/15/2022 16:09:23	31.92	945.28
24	02/15/2022 16:19:23	32.13	997.76
25	02/15/2022 16:29:23	32.22	1025.28
26	02/15/2022 16:39:23	32.34	1367.68
27	02/15/2022 16:49:23	32.43	1373.44
28	02/15/2022 16:59:23	32.34	1384.96
29	02/15/2022 17:09:23	32.47	1546.88
30	02/15/2022 17:19:23	32.64	3114.24
31	02/15/2022 17:29:23	33.46	4707.84
32	02/15/2022 17:39:23	33.25	3365.12
33	02/15/2022 17:49:23	32.69	1478.40
34	02/15/2022 17:59:23	32.00	614.24
35	02/15/2022 18:09:23	31.87	311.52

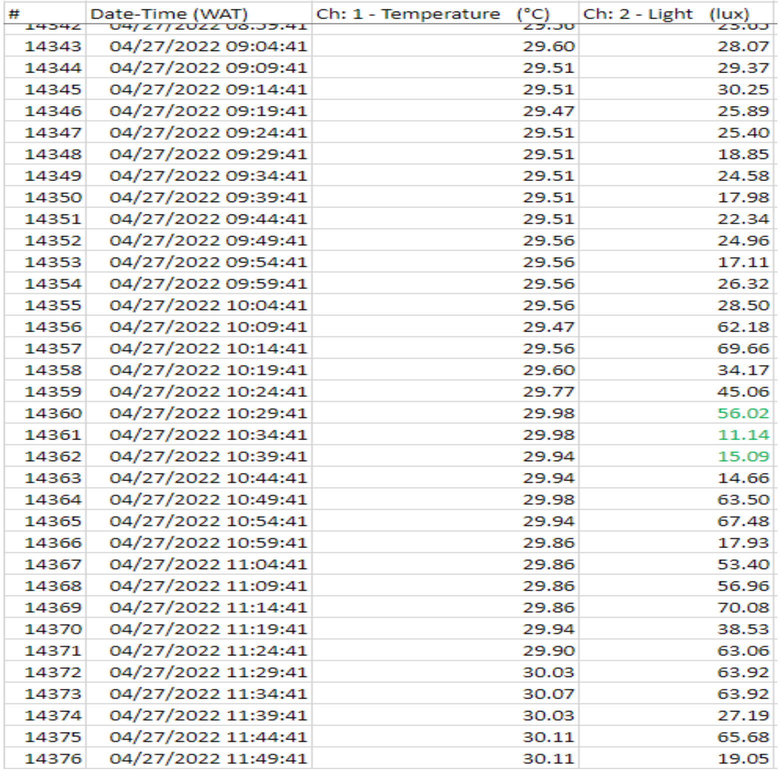


#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
14347	04/27/2022 09:05:07	30.67	1.68
14348	04/27/2022 09:10:07	30.67	1.47
14349	04/27/2022 09:15:07	30.63	1.89
14350	04/27/2022 09:20:07	30.63	2.10
14351	04/27/2022 09:25:07	30.59	1.47
14352	04/27/2022 09:30:07	30.63	3.16
14353	04/27/2022 09:35:07	30.59	5.05
14354	04/27/2022 09:40:07	30.54	5.26
14355	04/27/2022 09:45:07	30.54	4.63
14356	04/27/2022 09:50:07	30.59	3.37
14357	04/27/2022 09:55:07	30.54	3.79
14358	04/27/2022 10:00:07	30.54	4.21
14359	04/27/2022 10:05:07	30.50	5.89
14360	04/27/2022 10:10:07	30.59	123.64
14361	04/27/2022 10:15:07	30.63	129.56
14362	04/27/2022 10:20:07	30.71	250.00
14363	04/27/2022 10:25:07	30.71	12.43
14364	04/27/2022 10:30:07	30.76	149.16
14365	04/27/2022 10:35:07	30.76	222.00
14366	04/27/2022 10:40:07	30.80	254.24
14367	04/27/2022 10:45:07	30.89	255.92
14368	04/27/2022 10:50:07	30.93	149.88
14369	04/27/2022 10:55:07	30.97	190.80
14370	04/27/2022 11:00:07	30.97	51.18
14371	04/27/2022 11:05:07	30.89	159.24
14372	04/27/2022 11:10:07	30.80	226.48
14373	04/27/2022 11:15:07	30.84	211.04
14374	04/27/2022 11:20:07	30.80	195.92
14375	04/27/2022 11:25:07	30.89	214.40
14376	04/27/2022 11:30:07	30.89	181.36
14377	04/27/2022 11:35:07	30.89	183.92
14378	04/27/2022 11:40:07	30.89	213.76
14379	04/27/2022 11:45:07	30.89	193.36
14380	04/27/2022 11:50:07	30.93	201.76
14381	04/27/2022 11:55:07	30.97	196.72

Figure 35: Akinbami A. (2022) Fieldnote: Screenshot of Paediatrics Department Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 12:29 pm 02/15/2022 to 11:55 am 04/27/2022.

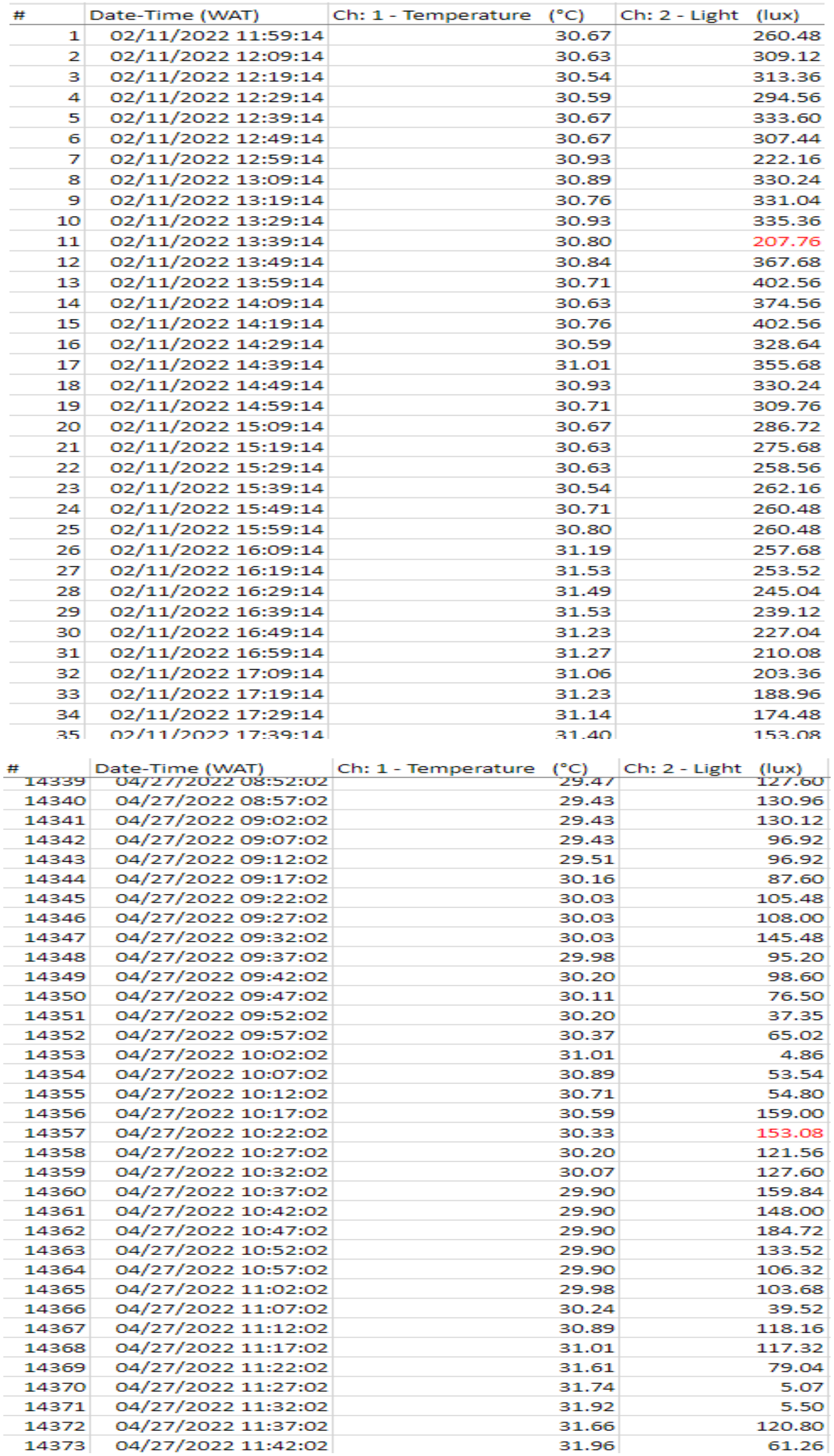


#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
1	02/11/2022 10:37:10	30.37	52.72
2	02/11/2022 10:47:10	30.28	58.70
3	02/11/2022 10:57:10	30.11	91.04
4	02/11/2022 11:07:10	30.11	57.42
5	02/11/2022 11:17:10	30.28	102.04
6	02/11/2022 11:27:10	30.33	89.36
7	02/11/2022 11:37:10	30.37	70.62
8	02/11/2022 11:47:10	30.46	3.17
9	02/11/2022 11:57:10	30.89	3.38
10	02/11/2022 12:07:10	30.80	67.16
11	02/11/2022 12:17:10	31.27	94.44
12	02/11/2022 12:27:10	31.36	75.32
13	02/11/2022 12:37:10	31.19	89.76
14	02/11/2022 12:47:10	31.14	91.04
15	02/11/2022 12:57:10	31.10	106.28
16	02/11/2022 13:07:10	30.93	55.74
17	02/11/2022 13:17:10	30.71	71.88
18	02/11/2022 13:27:10	31.10	74.06
19	02/11/2022 13:37:10	31.10	37.42
20	02/11/2022 13:47:10	30.89	114.00
21	02/11/2022 13:57:10	30.80	18.89
22	02/11/2022 14:07:10	30.89	86.80
23	02/11/2022 14:17:10	31.14	96.96
24	02/11/2022 14:27:10	30.80	99.52
25	02/11/2022 14:37:10	31.06	100.36
26	02/11/2022 14:47:10	31.10	100.36
27	02/11/2022 14:57:10	30.80	103.76
28	02/11/2022 15:07:10	30.71	125.04
29	02/11/2022 15:17:10	30.67	127.68
30	02/11/2022 15:27:10	30.89	132.76
31	02/11/2022 15:37:10	30.80	128.52
32	02/11/2022 15:47:10	31.01	119.96
33	02/11/2022 15:57:10	31.23	120.80
34	02/11/2022 16:07:10	31.23	120.80
35	02/11/2022 16:17:10	31.87	121.64



#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
[illegible]	[illegible]	[illegible]	[illegible]
14343	04/27/2022 09:04:41	29.60	28.07
14344	04/27/2022 09:09:41	29.51	29.37
14345	04/27/2022 09:14:41	29.51	30.25
14346	04/27/2022 09:19:41	29.47	25.89
14347	04/27/2022 09:24:41	29.51	25.40
14348	04/27/2022 09:29:41	29.51	18.85
14349	04/27/2022 09:34:41	29.51	24.58
14350	04/27/2022 09:39:41	29.51	17.98
14351	04/27/2022 09:44:41	29.51	22.34
14352	04/27/2022 09:49:41	29.56	24.96
14353	04/27/2022 09:54:41	29.56	17.11
14354	04/27/2022 09:59:41	29.56	26.32
14355	04/27/2022 10:04:41	29.56	28.50
14356	04/27/2022 10:09:41	29.47	62.18
14357	04/27/2022 10:14:41	29.56	69.66
14358	04/27/2022 10:19:41	29.60	34.17
14359	04/27/2022 10:24:41	29.77	45.06
14360	04/27/2022 10:29:41	29.98	56.02
14361	04/27/2022 10:34:41	29.98	11.14
14362	04/27/2022 10:39:41	29.94	15.09
14363	04/27/2022 10:44:41	29.94	14.66
14364	04/27/2022 10:49:41	29.98	63.50
14365	04/27/2022 10:54:41	29.94	67.48
14366	04/27/2022 10:59:41	29.86	17.93
14367	04/27/2022 11:04:41	29.86	53.40
14368	04/27/2022 11:09:41	29.86	56.96
14369	04/27/2022 11:14:41	29.86	70.08
14370	04/27/2022 11:19:41	29.94	38.53
14371	04/27/2022 11:24:41	29.90	63.06
14372	04/27/2022 11:29:41	30.03	63.92
14373	04/27/2022 11:34:41	30.07	63.92
14374	04/27/2022 11:39:41	30.03	27.19
14375	04/27/2022 11:44:41	30.11	65.68
14376	04/27/2022 11:49:41	30.11	19.05

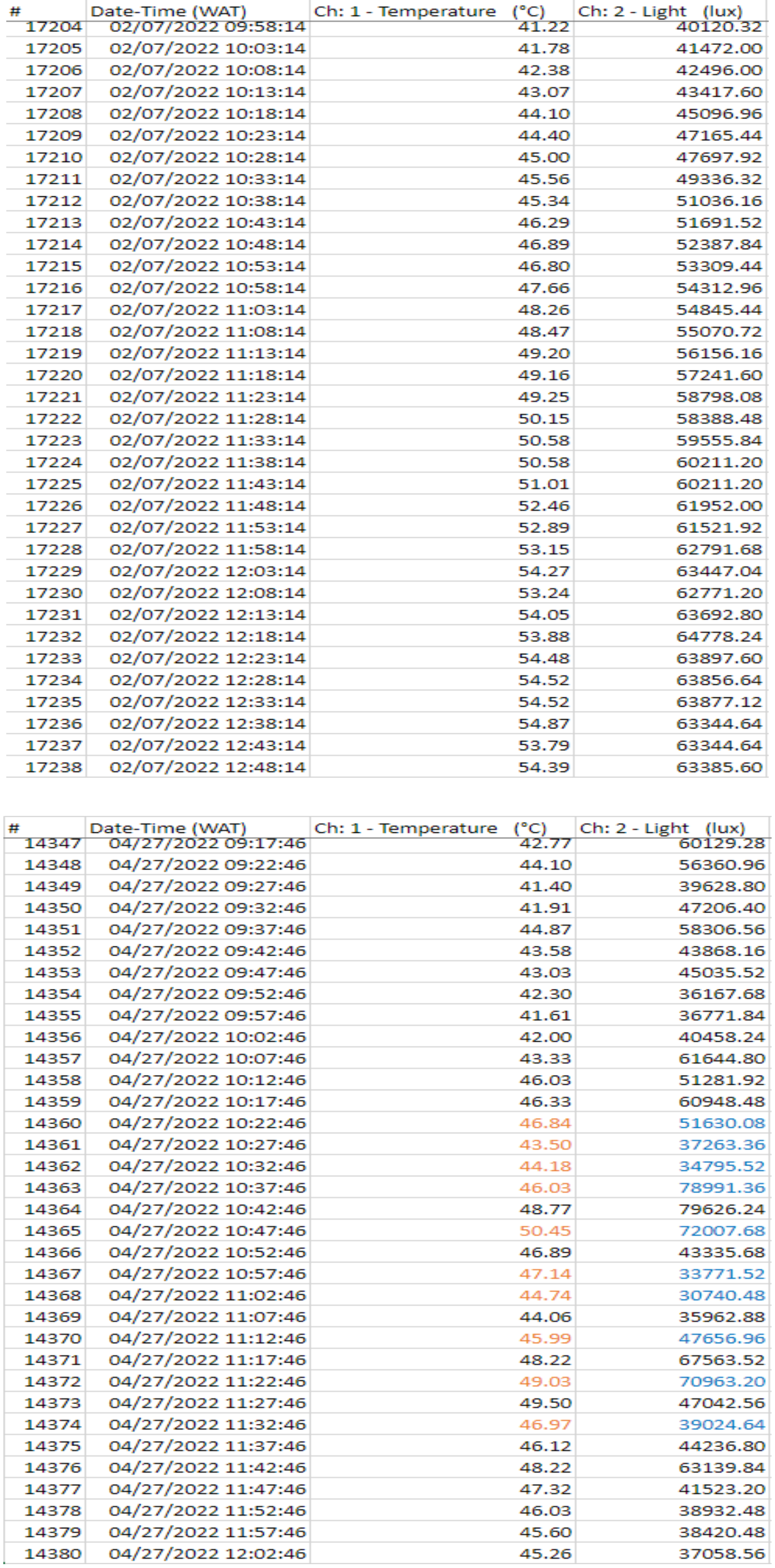
Figure 36: Akinbami A. (2022) Fieldnote: Screenshot of Postnatal Department Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 10:37 am 02/11/2022 to 11:47 am 04/27/2022.



#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
1	02/11/2022 11:59:14	30.67	260.48
2	02/11/2022 12:09:14	30.63	309.12
3	02/11/2022 12:19:14	30.54	313.36
4	02/11/2022 12:29:14	30.59	294.56
5	02/11/2022 12:39:14	30.67	333.60
6	02/11/2022 12:49:14	30.67	307.44
7	02/11/2022 12:59:14	30.93	222.16
8	02/11/2022 13:09:14	30.89	330.24
9	02/11/2022 13:19:14	30.76	331.04
10	02/11/2022 13:29:14	30.93	335.36
11	02/11/2022 13:39:14	30.80	207.76
12	02/11/2022 13:49:14	30.84	367.68
13	02/11/2022 13:59:14	30.71	402.56
14	02/11/2022 14:09:14	30.63	374.56
15	02/11/2022 14:19:14	30.76	402.56
16	02/11/2022 14:29:14	30.59	328.64
17	02/11/2022 14:39:14	31.01	355.68
18	02/11/2022 14:49:14	30.93	330.24
19	02/11/2022 14:59:14	30.71	309.76
20	02/11/2022 15:09:14	30.67	286.72
21	02/11/2022 15:19:14	30.63	275.68
22	02/11/2022 15:29:14	30.63	258.56
23	02/11/2022 15:39:14	30.54	262.16
24	02/11/2022 15:49:14	30.71	260.48
25	02/11/2022 15:59:14	30.80	260.48
26	02/11/2022 16:09:14	31.19	257.68
27	02/11/2022 16:19:14	31.53	253.52
28	02/11/2022 16:29:14	31.49	245.04
29	02/11/2022 16:39:14	31.53	239.12
30	02/11/2022 16:49:14	31.23	227.04
31	02/11/2022 16:59:14	31.27	210.08
32	02/11/2022 17:09:14	31.06	203.36
33	02/11/2022 17:19:14	31.23	188.96
34	02/11/2022 17:29:14	31.14	174.48
35	02/11/2022 17:39:14	31.40	153.08

#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
14339	04/27/2022 08:52:02	29.47	127.60
14340	04/27/2022 08:57:02	29.43	130.96
14341	04/27/2022 09:02:02	29.43	130.12
14342	04/27/2022 09:07:02	29.43	96.92
14343	04/27/2022 09:12:02	29.51	96.92
14344	04/27/2022 09:17:02	30.16	87.60
14345	04/27/2022 09:22:02	30.03	105.48
14346	04/27/2022 09:27:02	30.03	108.00
14347	04/27/2022 09:32:02	30.03	145.48
14348	04/27/2022 09:37:02	29.98	95.20
14349	04/27/2022 09:42:02	30.20	98.60
14350	04/27/2022 09:47:02	30.11	76.50
14351	04/27/2022 09:52:02	30.20	37.35
14352	04/27/2022 09:57:02	30.37	65.02
14353	04/27/2022 10:02:02	31.01	4.86
14354	04/27/2022 10:07:02	30.89	53.54
14355	04/27/2022 10:12:02	30.71	54.80
14356	04/27/2022 10:17:02	30.59	159.00
14357	04/27/2022 10:22:02	30.33	153.08
14358	04/27/2022 10:27:02	30.20	121.56
14359	04/27/2022 10:32:02	30.07	127.60
14360	04/27/2022 10:37:02	29.90	159.84
14361	04/27/2022 10:42:02	29.90	148.00
14362	04/27/2022 10:47:02	29.90	184.72
14363	04/27/2022 10:52:02	29.90	133.52
14364	04/27/2022 10:57:02	29.90	106.32
14365	04/27/2022 11:02:02	29.98	103.68
14366	04/27/2022 11:07:02	30.24	39.52
14367	04/27/2022 11:12:02	30.89	118.16
14368	04/27/2022 11:17:02	31.01	117.32
14369	04/27/2022 11:22:02	31.61	79.04
14370	04/27/2022 11:27:02	31.74	5.07
14371	04/27/2022 11:32:02	31.92	5.50
14372	04/27/2022 11:37:02	31.66	120.80
14373	04/27/2022 11:42:02	31.96	61.26

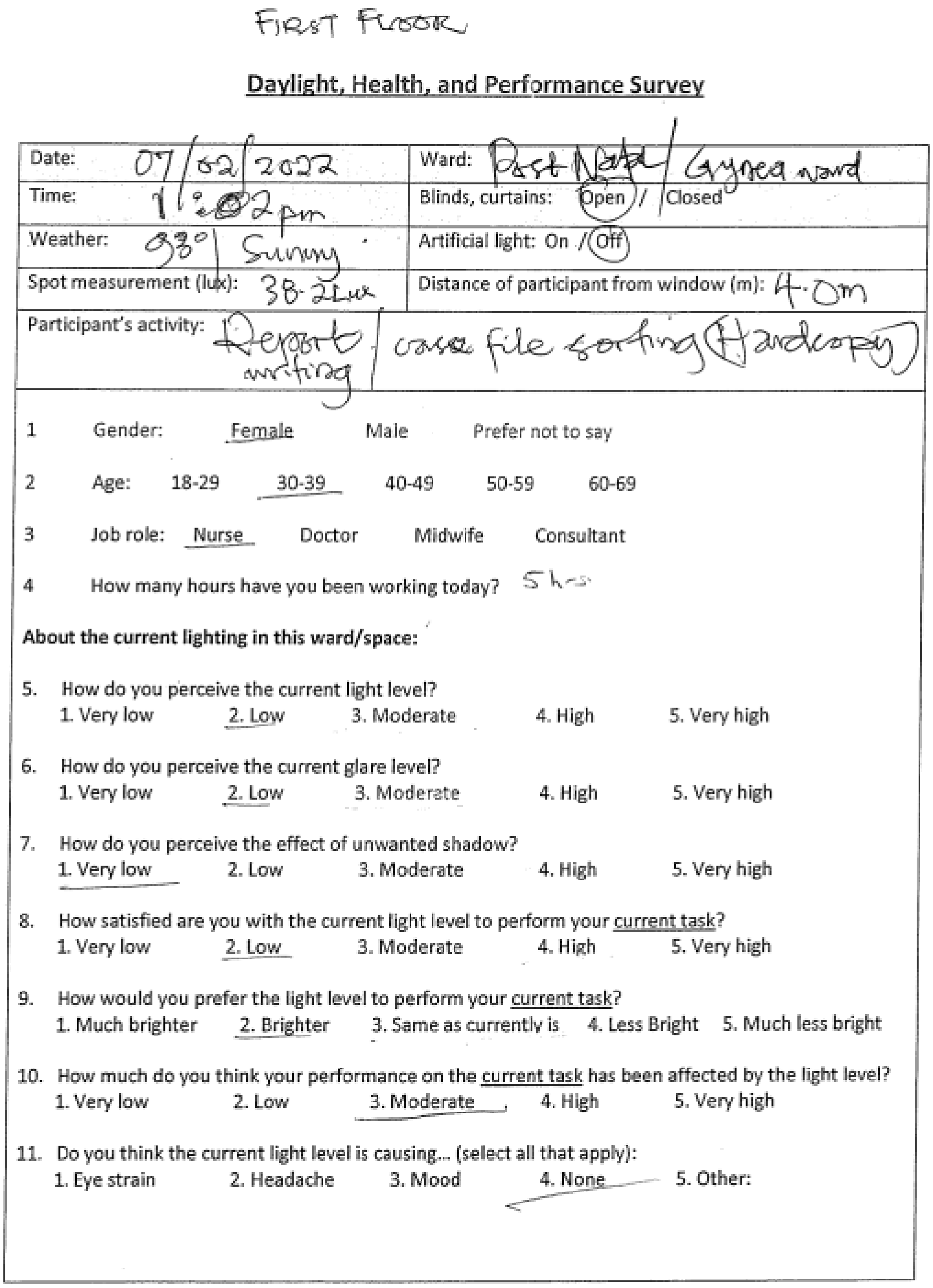
Figure 37: Akinbami A. (2022) Fieldnote: Screenshot of Surgical Department Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 11:59 am 02/11/2022 to 11:42 am 04/27/2022.



#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
17204	02/07/2022 09:58:14	41.22	40120.32
17205	02/07/2022 10:03:14	41.78	41472.00
17206	02/07/2022 10:08:14	42.38	42496.00
17207	02/07/2022 10:13:14	43.07	43417.60
17208	02/07/2022 10:18:14	44.10	45096.96
17209	02/07/2022 10:23:14	44.40	47165.44
17210	02/07/2022 10:28:14	45.00	47697.92
17211	02/07/2022 10:33:14	45.56	49336.32
17212	02/07/2022 10:38:14	45.34	51036.16
17213	02/07/2022 10:43:14	46.29	51691.52
17214	02/07/2022 10:48:14	46.89	52387.84
17215	02/07/2022 10:53:14	46.80	53309.44
17216	02/07/2022 10:58:14	47.66	54312.96
17217	02/07/2022 11:03:14	48.26	54845.44
17218	02/07/2022 11:08:14	48.47	55070.72
17219	02/07/2022 11:13:14	49.20	56156.16
17220	02/07/2022 11:18:14	49.16	57241.60
17221	02/07/2022 11:23:14	49.25	58798.08
17222	02/07/2022 11:28:14	50.15	58388.48
17223	02/07/2022 11:33:14	50.58	59555.84
17224	02/07/2022 11:38:14	50.58	60211.20
17225	02/07/2022 11:43:14	51.01	60211.20
17226	02/07/2022 11:48:14	52.46	61952.00
17227	02/07/2022 11:53:14	52.89	61521.92
17228	02/07/2022 11:58:14	53.15	62791.68
17229	02/07/2022 12:03:14	54.27	63447.04
17230	02/07/2022 12:08:14	53.24	62771.20
17231	02/07/2022 12:13:14	54.05	63692.80
17232	02/07/2022 12:18:14	53.88	64778.24
17233	02/07/2022 12:23:14	54.48	63897.60
17234	02/07/2022 12:28:14	54.52	63856.64
17235	02/07/2022 12:33:14	54.52	63877.12
17236	02/07/2022 12:38:14	54.87	63344.64
17237	02/07/2022 12:43:14	53.79	63344.64
17238	02/07/2022 12:48:14	54.39	63385.60

#	Date-Time (WAT)	Ch: 1 - Temperature (°C)	Ch: 2 - Light (lux)
14347	04/27/2022 09:17:46	42.77	60129.28
14348	04/27/2022 09:22:46	44.10	56360.96
14349	04/27/2022 09:27:46	41.40	39628.80
14350	04/27/2022 09:32:46	41.91	47206.40
14351	04/27/2022 09:37:46	44.87	58306.56
14352	04/27/2022 09:42:46	43.58	43868.16
14353	04/27/2022 09:47:46	43.03	45035.52
14354	04/27/2022 09:52:46	42.30	36167.68
14355	04/27/2022 09:57:46	41.61	36771.84
14356	04/27/2022 10:02:46	42.00	40458.24
14357	04/27/2022 10:07:46	43.33	61644.80
14358	04/27/2022 10:12:46	46.03	51281.92
14359	04/27/2022 10:17:46	46.33	60948.48
14360	04/27/2022 10:22:46	46.84	51630.08
14361	04/27/2022 10:27:46	43.50	37263.36
14362	04/27/2022 10:32:46	44.18	34795.52
14363	04/27/2022 10:37:46	46.03	78991.36
14364	04/27/2022 10:42:46	48.77	79626.24
14365	04/27/2022 10:47:46	50.45	72007.68
14366	04/27/2022 10:52:46	46.89	43335.68
14367	04/27/2022 10:57:46	47.14	33771.52
14368	04/27/2022 11:02:46	44.74	30740.48
14369	04/27/2022 11:07:46	44.06	35962.88
14370	04/27/2022 11:12:46	45.99	47656.96
14371	04/27/2022 11:17:46	48.22	67563.52
14372	04/27/2022 11:22:46	49.03	70963.20
14373	04/27/2022 11:27:46	49.50	47042.56
14374	04/27/2022 11:32:46	46.97	39024.64
14375	04/27/2022 11:37:46	46.12	44236.80
14376	04/27/2022 11:42:46	48.22	63139.84
14377	04/27/2022 11:47:46	47.32	41523.20
14378	04/27/2022 11:52:46	46.03	38932.48
14379	04/27/2022 11:57:46	45.60	38420.48
14380	04/27/2022 12:02:46	45.26	37058.56

Figure 38: Akinbami A. (2022) Fieldnote: Screenshot of the Building Roof Data Sensor Continuous Measurements of Illuminance Levels at 5 Minutes Interval Recorded from 09:58 am 02/07/2022 to 12:02 am 04/27/2022.



FIRST FLOOR

Daylight, Health, and Performance Survey

Date: 07/02/2022	Ward: Post Natal / Gynea ward
Time: 1:02pm	Blinds, curtains: [✓ Open] / Closed
Weather: 33° Sunny	Artificial light: On / [✓ Off]
Spot measurement (lux): 38.2Lux	Distance of participant from window (m): 4.0m
Participant's activity: Report writing / case file sorting (Hardcopy)	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: 18-29 [✓ 30-39] 40-49 50-59 60-69

3 Job role: [✓ Nurse] Doctor Midwife Consultant

4 How many hours have you been working today? 5hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

6. How do you perceive the current glare level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

7. How do you perceive the effect of unwanted shadow?
   [✓ 1. Very low] 2. Low 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
   1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
   1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing… (select all that apply):
   1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:

Daylight, Health, and Performance Survey

Date: 07/02	Ward: Male Surgical
Time: 2.02 pm	Blinds, curtains: [✓ Open] / Closed
Weather: Sunny	Artificial light: On / [✓ Off]
Spot measurement (lux): 422	Distance of participant from window (m): 1.985
Participant's activity: Sitting | writing	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 6hrs +

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

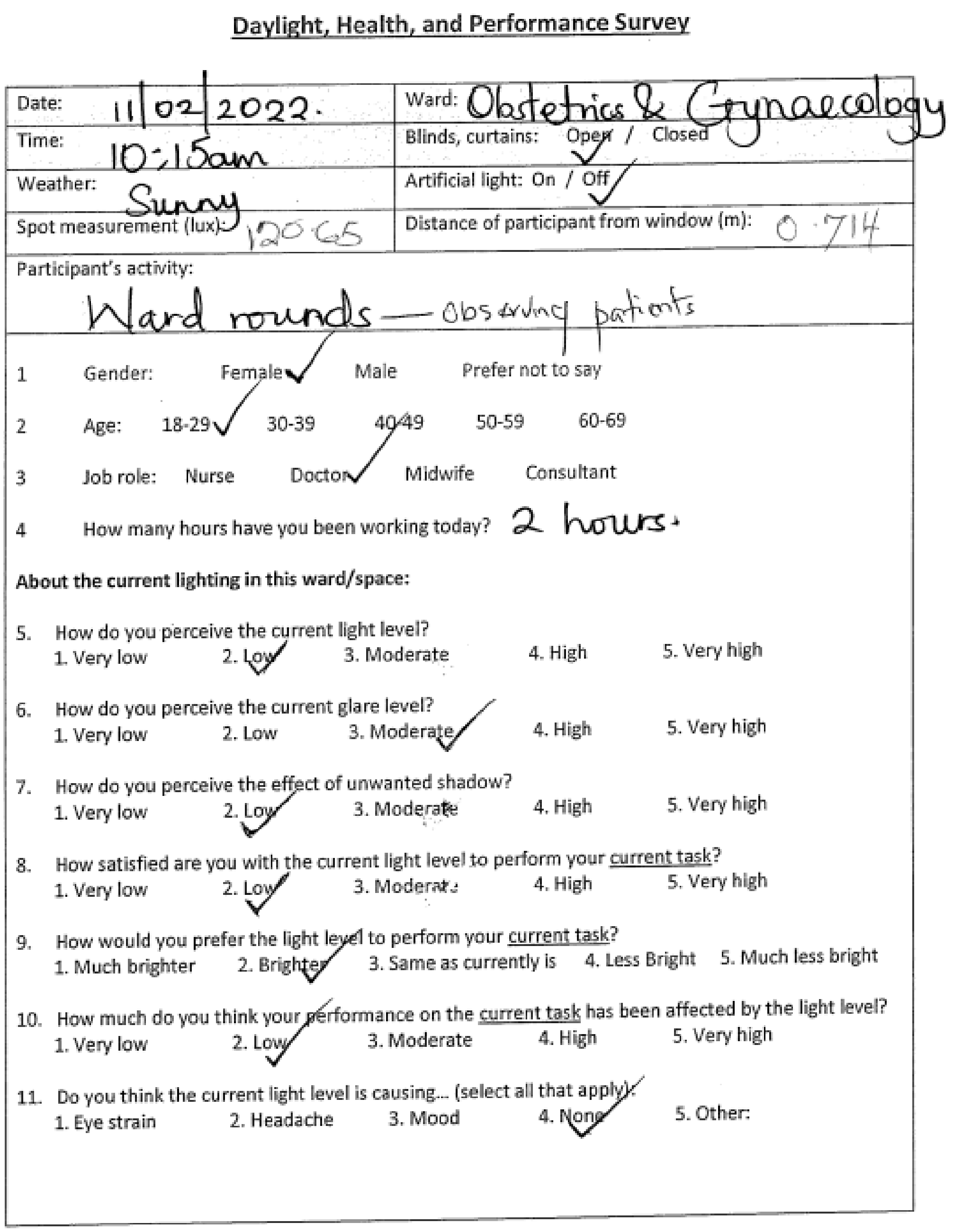
7. How do you perceive the effect of unwanted shadow?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing… (select all that apply):
1. Eye strain [✓ 2. Headache] 3. Mood 4. None 5. Other:



Daylight, Health, and Performance Survey

Date: 11/02/2022.

Ward: Obstetrics & Gynaecology

Time: 10:15am

Blinds, curtains: [✓ Open] / Closed

Weather: Sunny

Artificial light: On / [✓ Off]

Spot measurement (lux): 120·65

Distance of participant from window (m): 0·714

Participant's activity:

Ward rounds — observing patients

1 Gender: [✓ Female] Male Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 2 hours.

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

7. How do you perceive the effect of unwanted shadow?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your <u>current task</u>?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

9. How would you prefer the light level to perform your <u>current task</u>?
1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the <u>current task</u> has been affected by the light level?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:

Daylight, Health, and Performance Survey

Date: 11/02/2022	Ward: Postnatal / Gynae
Time: 11:13 -	Blinds, curtains: [✓ Open] / Closed
Weather: Sunny	Artificial light: [✓ On] / Off
Spot measurement (lux): 52.6	Distance of participant from window (m): 5.85m
Participant's activity: Report writing.	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: 18-29 [✓ 30-39] 40-49 50-59 60-69

3 Job role: [✓ Nurse] Doctor Midwife Consultant

4 How many hours have you been working today? 3hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

6. How do you perceive the current glare level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

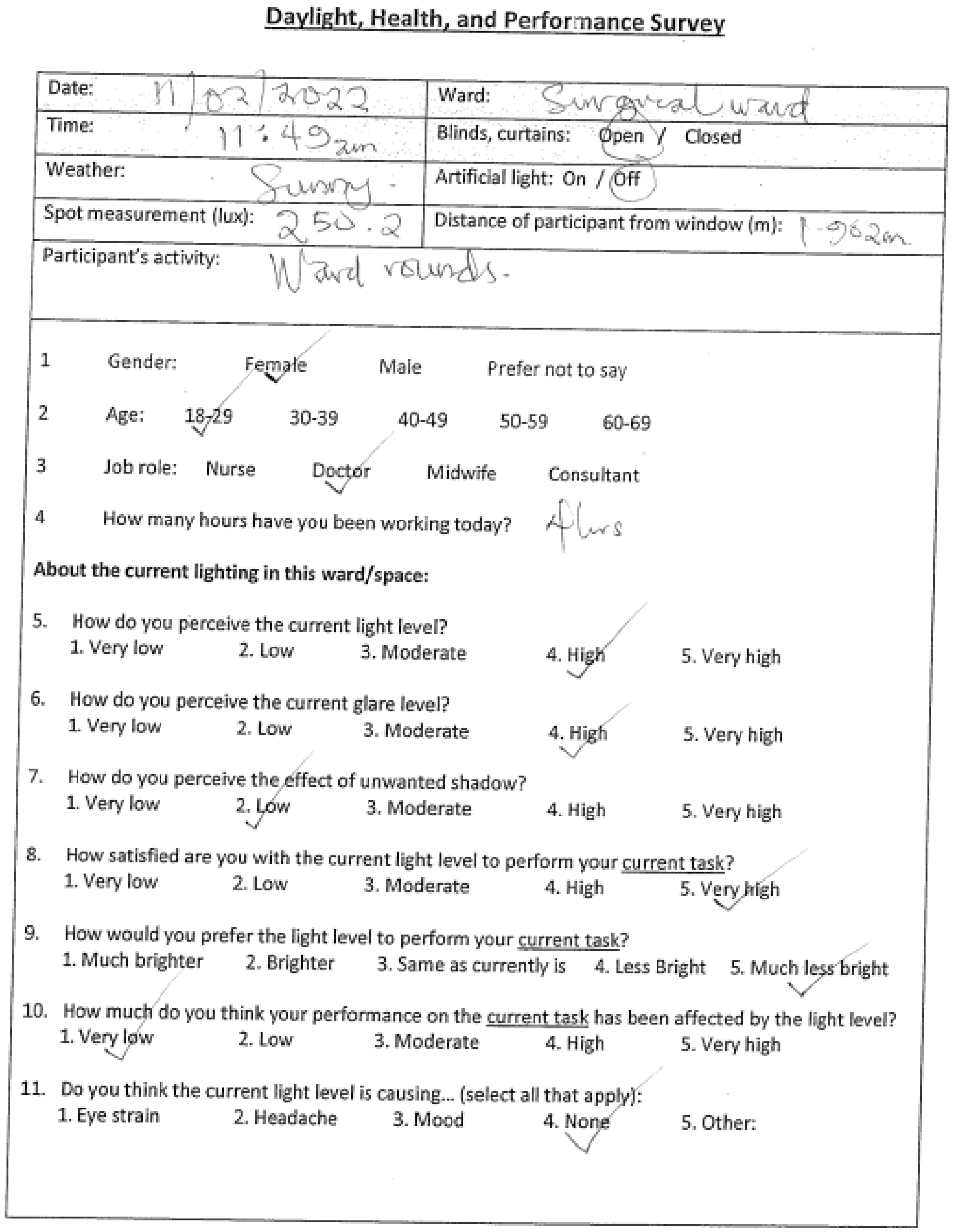
7. How do you perceive the effect of unwanted shadow?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
   [✓ 1. Very low] 2. Low 3. Moderate 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
   1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
    1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
    1. Eye strain [✓ 2. Headache] 3. Mood 4. None 5. Other:



Daylight, Health, and Performance Survey

Date: 11/02/2022	Ward: Surgical ward
Time: 11:49am	Blinds, curtains: [✓ Open] / Closed
Weather: Sunny.	Artificial light: On / [✓ Off]
Spot measurement (lux): 250.2	Distance of participant from window (m): 1.962m
Participant's activity: Ward rounds.	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 4hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

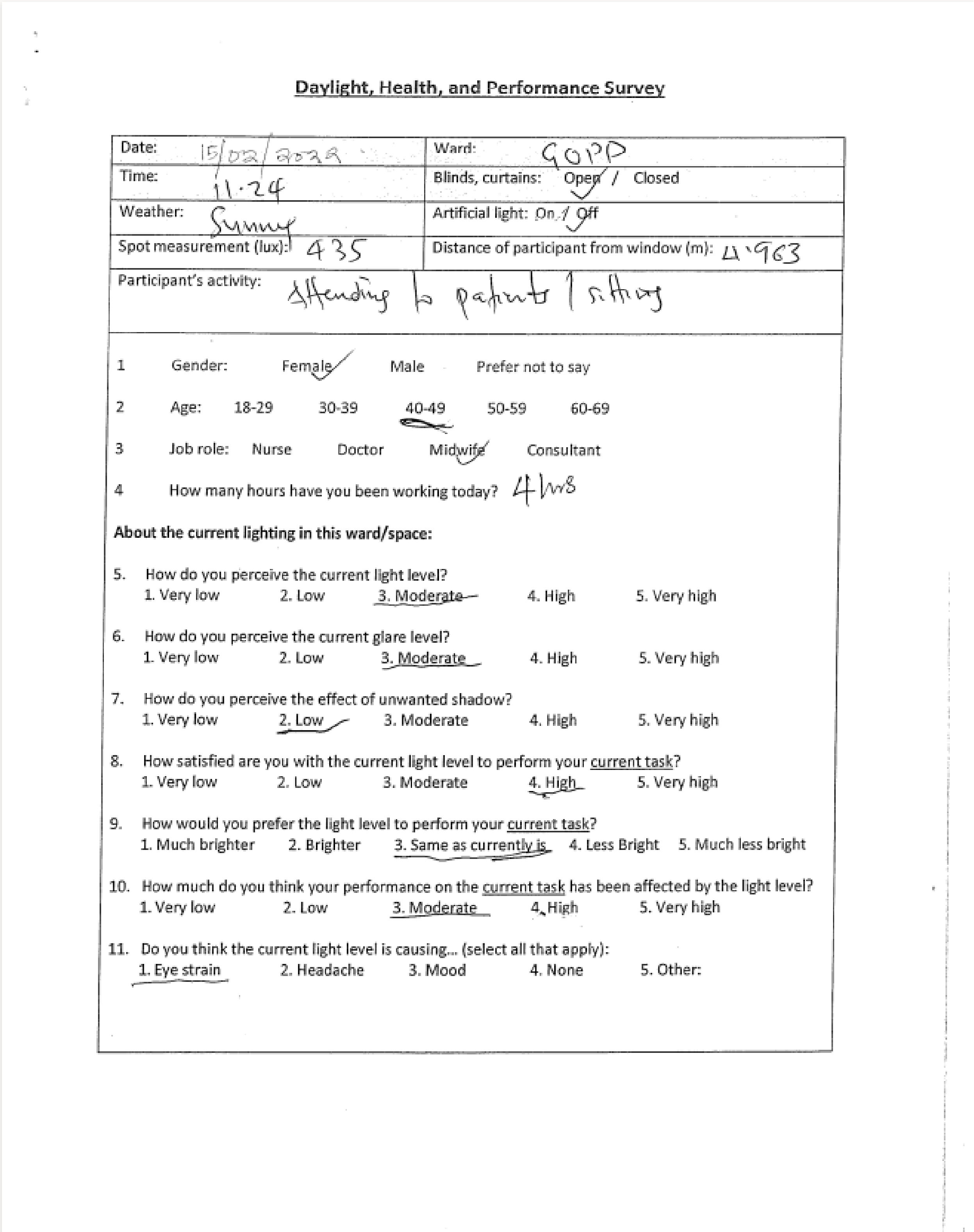
7. How do you perceive the effect of unwanted shadow?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low 3. Moderate 4. High [✓ 5. Very high]

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter 3. Same as currently is 4. Less Bright [✓ 5. Much less bright]

10. How much do you think your performance on the current task has been affected by the light level?
[✓ 1. Very low] 2. Low 3. Moderate 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:



Daylight, Health, and Performance Survey

Date: 15/02/2022
Ward: GOPD
Time: 11·24
Blinds, curtains: [✓ Open] / Closed
Weather: Sunny
Artificial light: On / [✓ Off]
Spot measurement (lux): 435
Distance of participant from window (m): 4·963
Participant's activity: Attending to patients / sitting

1 Gender: [✓ Female] Male Prefer not to say

2 Age: 18-29 30-39 [✓ 40-49] 50-59 60-69

3 Job role: Nurse Doctor [✓ Midwife] Consultant

4 How many hours have you been working today? 4 hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

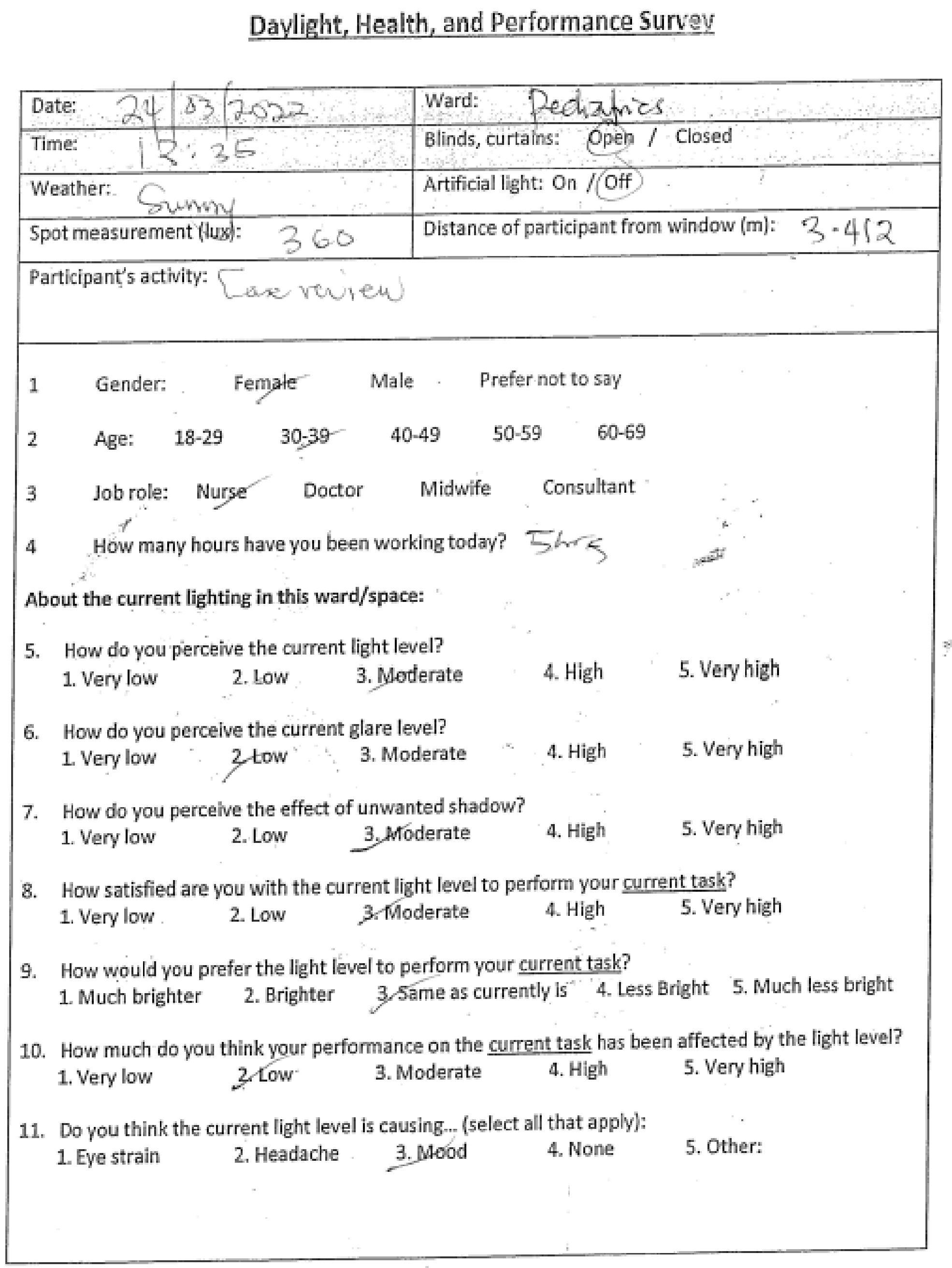
7. How do you perceive the effect of unwanted shadow?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter [✓ 3. Same as currently is] 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
[✓ 1. Eye strain] 2. Headache 3. Mood 4. None 5. Other:



Daylight, Health, and Performance Survey

Date: 24/03/2022
Ward: Pediatrics
Time: 12:35
Blinds, curtains: [✓ Open] / Closed
Weather: Sunny
Artificial light: On / [✓ Off]
Spot measurement (lux): 360
Distance of participant from window (m): 3.412
Participant's activity: Case review

1 Gender: [✓ Female] Male Prefer not to say

2 Age: 18-29 [✓ 30-39] 40-49 50-59 60-69

3 Job role: [✓ Nurse] Doctor Midwife Consultant

4 How many hours have you been working today? 5hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

6. How do you perceive the current glare level?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

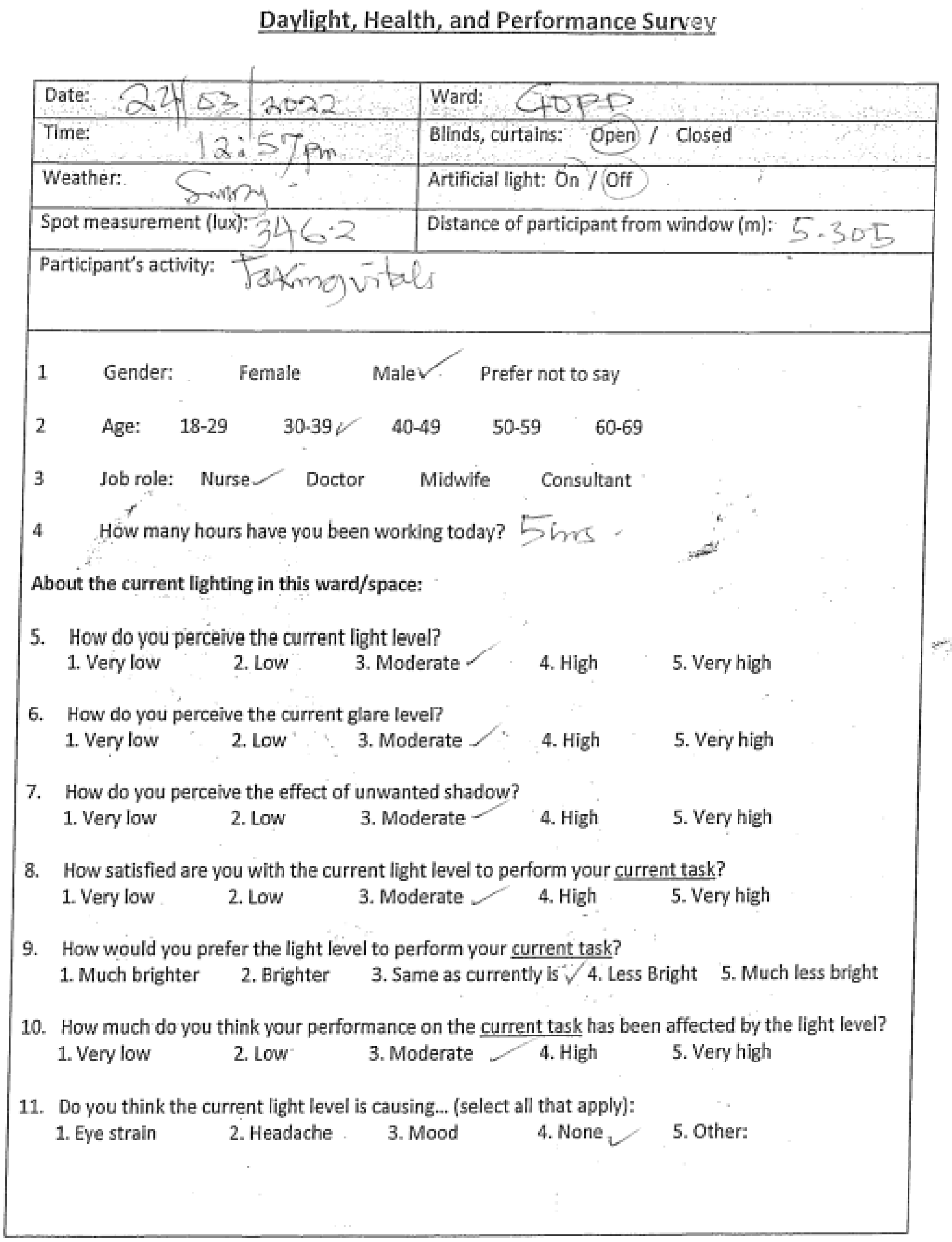
7. How do you perceive the effect of unwanted shadow?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter [✓ 3. Same as currently is] 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache [✓ 3. Mood] 4. None 5. Other:



Daylight, Health, and Performance Survey

Date: 24/03/2022	Ward: GOPD
Time: 12:57pm	Blinds, curtains: [✓ Open] / Closed
Weather: Sunny	Artificial light: On / [✓ Off]
Spot measurement (lux): 346·2	Distance of participant from window (m): 5.305
Participant's activity: Taking vitals	

1 Gender: Female [✓ Male] Prefer not to say

2 Age: 18-29 [✓ 30-39] 40-49 50-59 60-69

3 Job role: [✓ Nurse] Doctor Midwife Consultant

4 How many hours have you been working today? 5hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

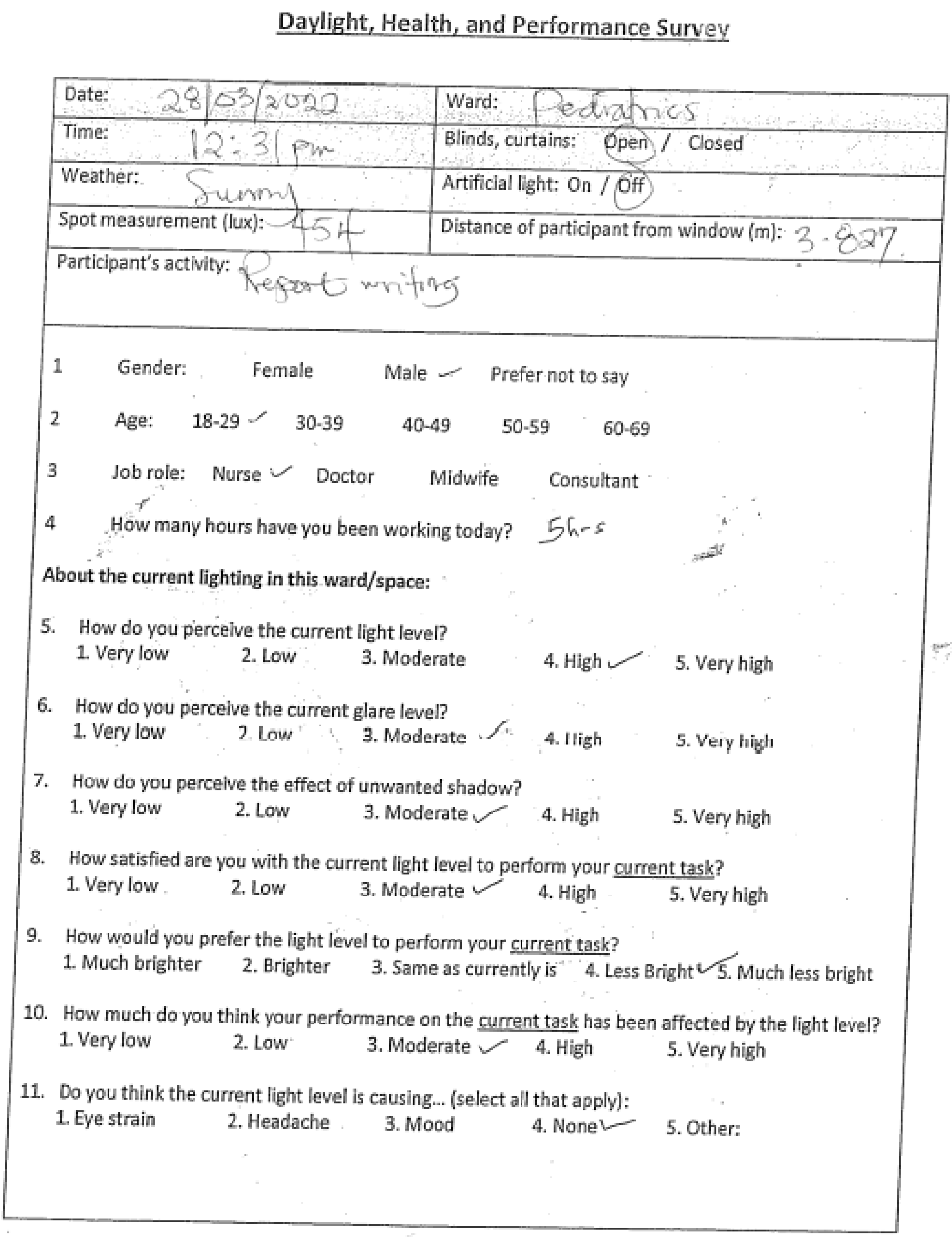
7. How do you perceive the effect of unwanted shadow?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter [✓ 3. Same as currently is] 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:



Daylight, Health, and Performance Survey

Date: 28/03/2022	Ward: Pediatrics
Time: 12:31 pm	Blinds, curtains: [✓ Open] / Closed
Weather: Sunny	Artificial light: On / [✓ Off]
Spot measurement (lux): 454	Distance of participant from window (m): 3.827
Participant's activity: Report writing	

1 Gender: Female [✓ Male] Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: [✓ Nurse] Doctor Midwife Consultant

4 How many hours have you been working today? 5hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

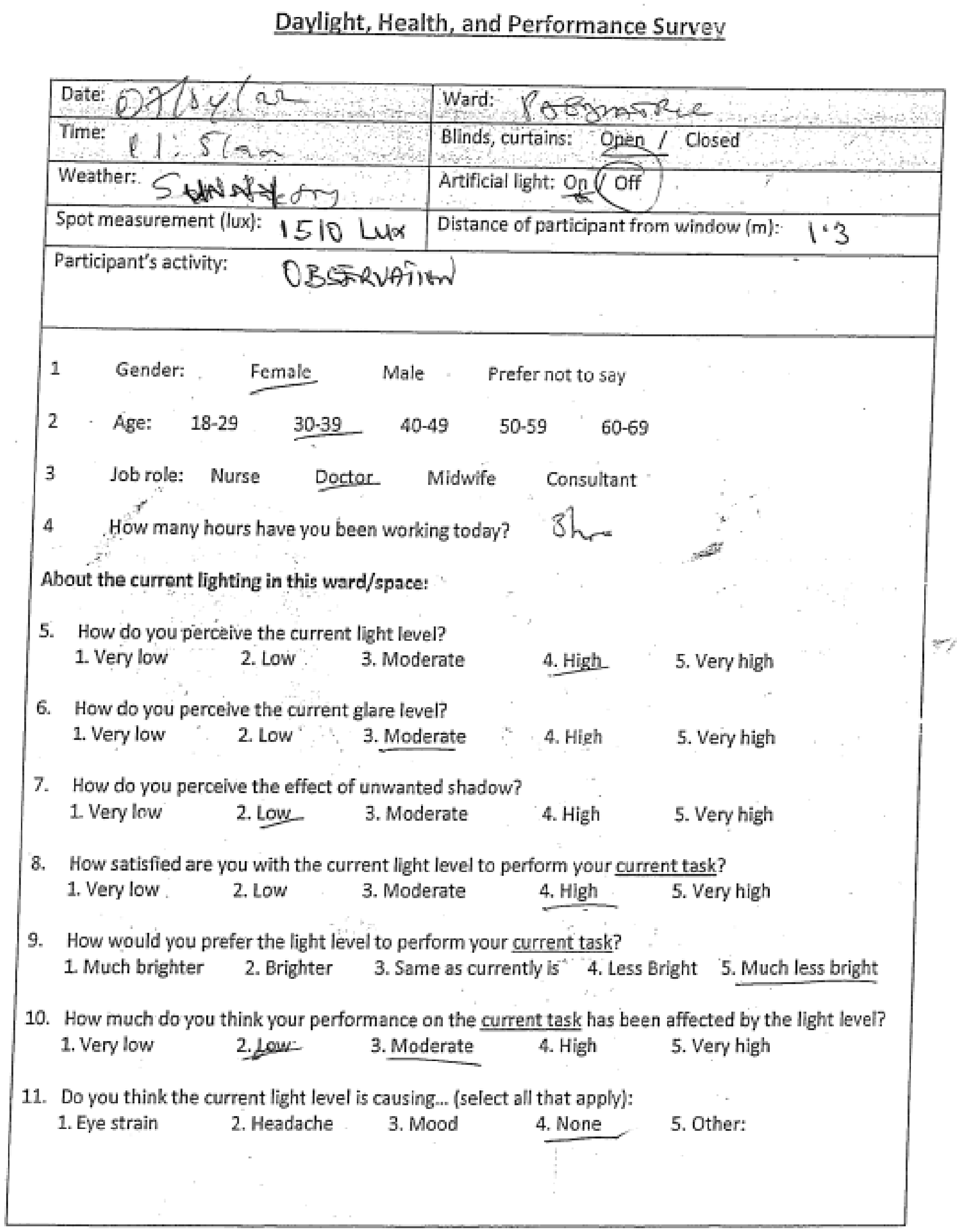
7. How do you perceive the effect of unwanted shadow?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter 3. Same as currently is [✓ 4. Less Bright] 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:



Daylight, Health, and Performance Survey

Date: 07/04/22	Ward: [illegible]
Time: 11:51am	Blinds, curtains: [✓ Open] / Closed
Weather: S~~unny~~dry	Artificial light: ~~On~~ / [✓ Off]
Spot measurement (lux): 1510 Lux	Distance of participant from window (m): 1·3
Participant's activity: OBSERVATION	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: 18-29 [✓ 30-39] 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 8hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

6. How do you perceive the current glare level?
1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

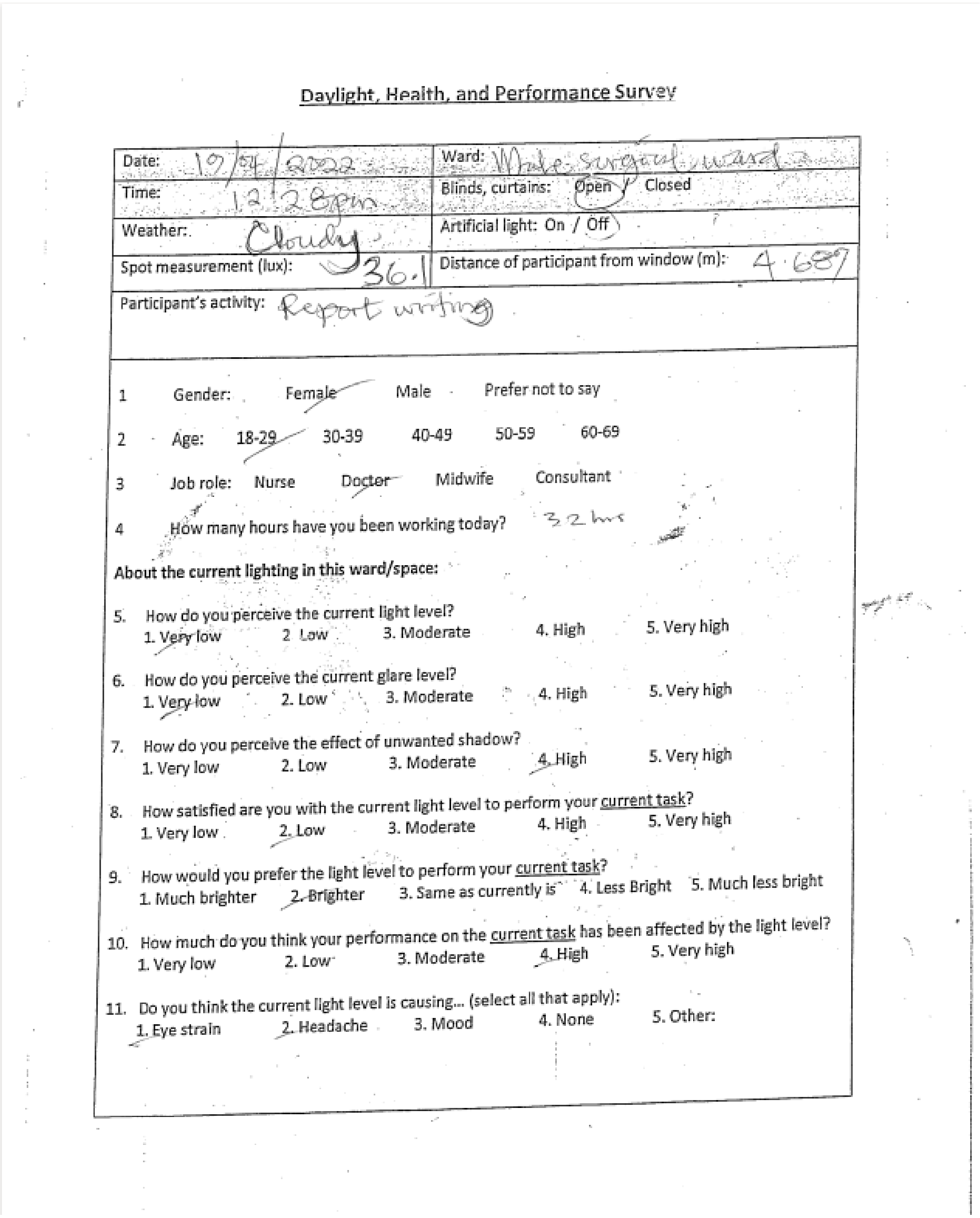
7. How do you perceive the effect of unwanted shadow?
1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

8. How satisfied are you with the current light level to perform your current task?
1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

9. How would you prefer the light level to perform your current task?
1. Much brighter 2. Brighter 3. Same as currently is 4. Less Bright [✓ 5. Much less bright]

10. How much do you think your performance on the current task has been affected by the light level?
1. Very low 2. ~~Low~~ [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
1. Eye strain 2. Headache 3. Mood [✓ 4. None] 5. Other:



Daylight, Health, and Performance Survey

Date: 19/04/2022

Ward: Male surgical ward 2

Time: 12:28pm

Blinds, curtains: [✓ Open] / Closed

Weather: Cloudy

Artificial light: On / [✓ Off]

Spot measurement (lux): 36.1

Distance of participant from window (m): 4.689

Participant's activity: Report writing

1 Gender: [✓ Female] Male Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 32 hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
   [✓ 1. Very low] 2 Low 3. Moderate 4. High 5. Very high

6. How do you perceive the current glare level?
   [✓ 1. Very low] 2. Low 3. Moderate 4. High 5. Very high

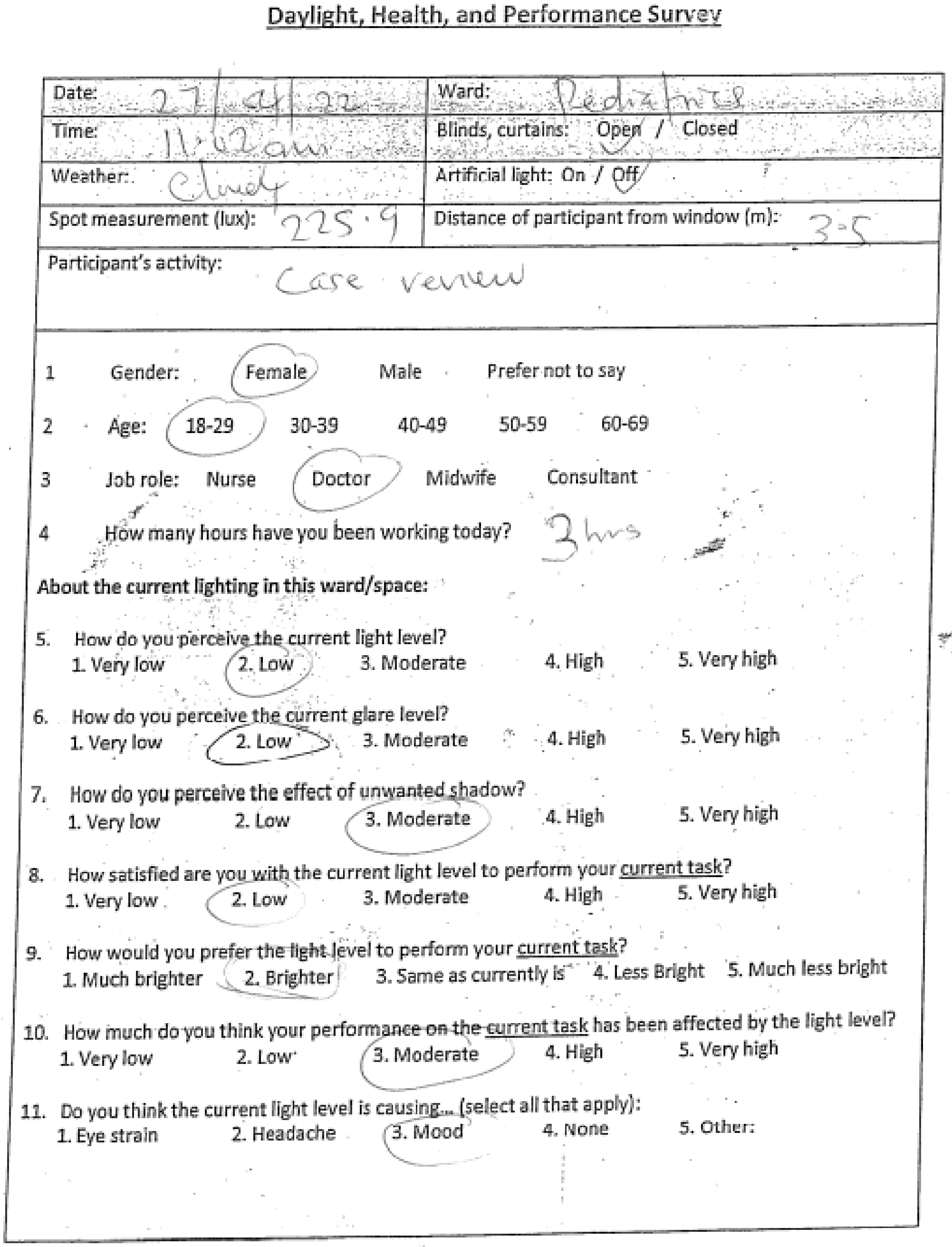
7. How do you perceive the effect of unwanted shadow?
   1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

8. How satisfied are you with the current light level to perform your current task?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

9. How would you prefer the light level to perform your current task?
   1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the current task has been affected by the light level?
    1. Very low 2. Low 3. Moderate [✓ 4. High] 5. Very high

11. Do you think the current light level is causing… (select all that apply):
    [✓ 1. Eye strain] [✓ 2. Headache] 3. Mood 4. None 5. Other:



Daylight, Health, and Performance Survey

Date: 27/4/22	Ward: Pediatrics
Time: 11:42am	Blinds, curtains: [✓ Open] / Closed
Weather: Cloudy	Artificial light: On / [✓ Off]
Spot measurement (lux): 225·9	Distance of participant from window (m): 3·5
Participant's activity: Case review	

1 Gender: [✓ Female] Male Prefer not to say

2 Age: [✓ 18-29] 30-39 40-49 50-59 60-69

3 Job role: Nurse [✓ Doctor] Midwife Consultant

4 How many hours have you been working today? 3hrs

About the current lighting in this ward/space:

5. How do you perceive the current light level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

6. How do you perceive the current glare level?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

7. How do you perceive the effect of unwanted shadow?
   1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

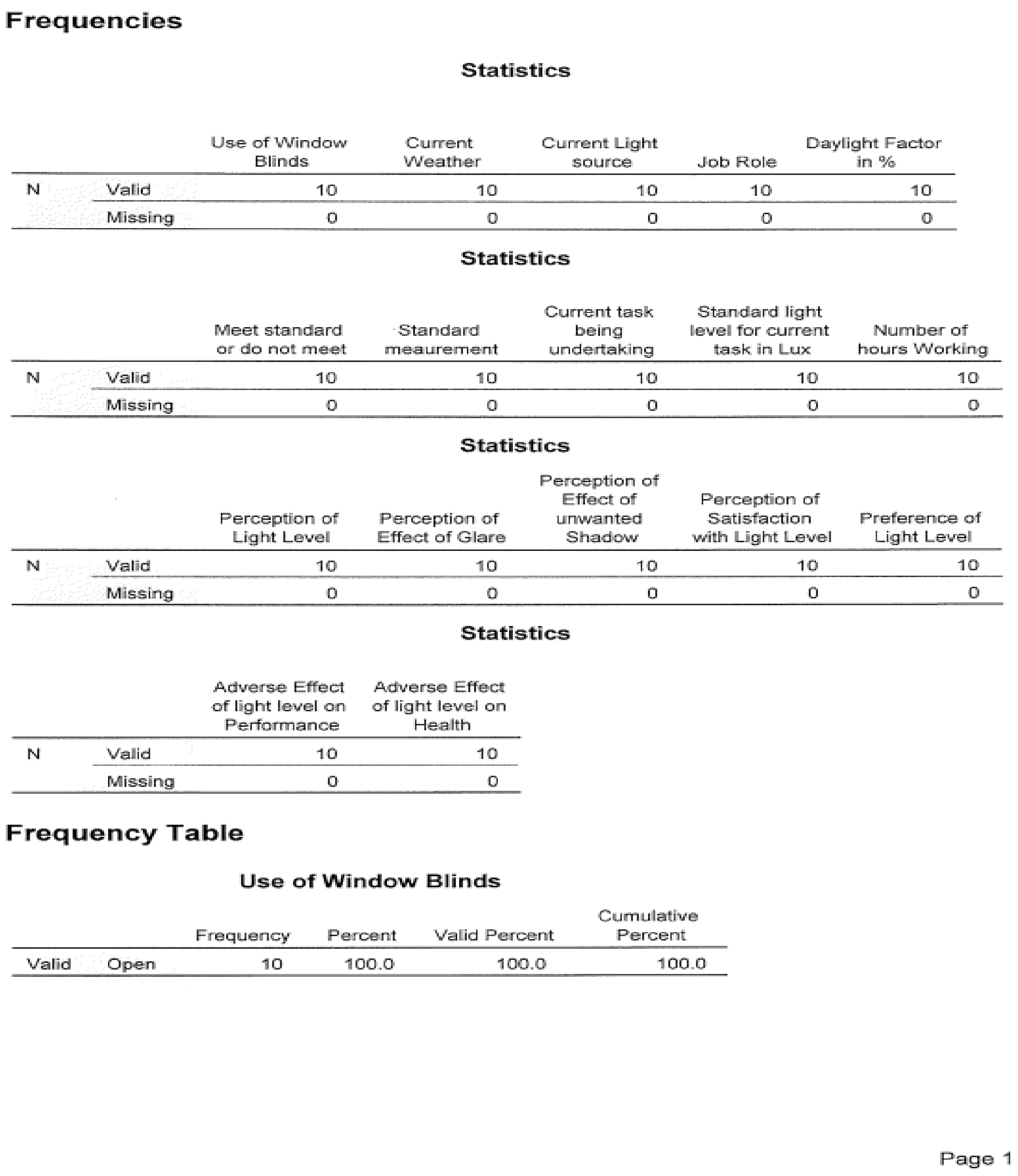
8. How satisfied are you with the current light level to perform your <u>current task</u>?
   1. Very low [✓ 2. Low] 3. Moderate 4. High 5. Very high

9. How would you prefer the light level to perform your <u>current task</u>?
   1. Much brighter [✓ 2. Brighter] 3. Same as currently is 4. Less Bright 5. Much less bright

10. How much do you think your performance on the <u>current task</u> has been affected by the light level?
    1. Very low 2. Low [✓ 3. Moderate] 4. High 5. Very high

11. Do you think the current light level is causing... (select all that apply):
    1. Eye strain 2. Headache [✓ 3. Mood] 4. None 5. Other:

Figure 39: Akinbami A. (2022) Fieldnote: Snapshots of Self-administered Questionnaires Completed by Participants.



Frequencies

Statistics

		Use of Window Blinds	Current Weather	Current Light source	Job Role	Daylight Factor in %
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0

Statistics

		Meet standard or do not meet	Standard meaurement	Current task being undertaking	Standard light level for current task in Lux	Number of hours Working
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0

Statistics

		Perception of Light Level	Perception of Effect of Glare	Perception of Effect of unwanted Shadow	Perception of Satisfaction with Light Level	Preference of Light Level
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0

Statistics

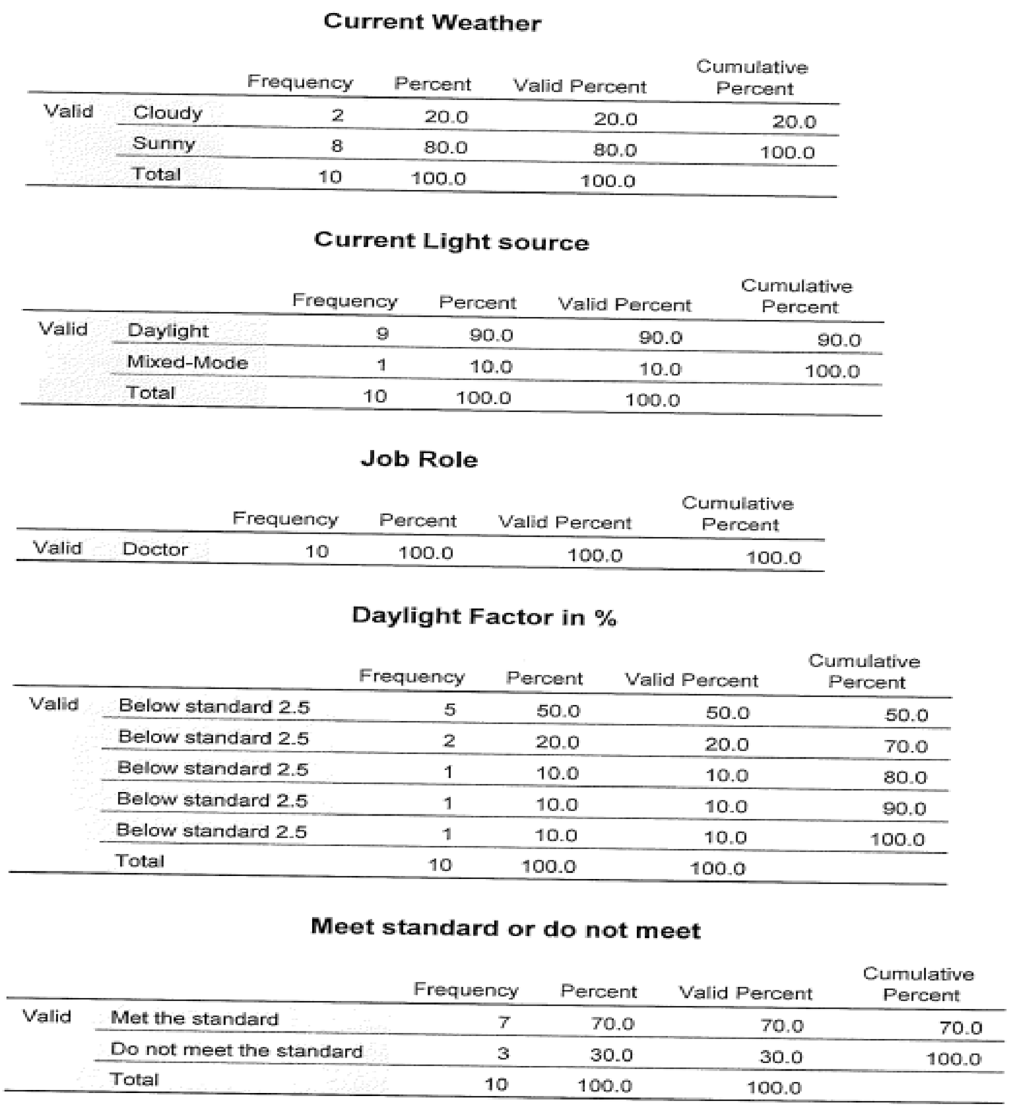
		Adverse Effect of light level on Performance	Adverse Effect of light level on Health
N	Valid	10	10
	Missing	0	0

Frequency Table

Use of Window Blinds

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Open	10	100.0	100.0	100.0

Page 1



Current Weather

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cloudy	2	20.0	20.0	20.0
	Sunny	8	80.0	80.0	100.0
	Total	10	100.0	100.0	

Current Light source

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Daylight	9	90.0	90.0	90.0
	Mixed-Mode	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Job Role

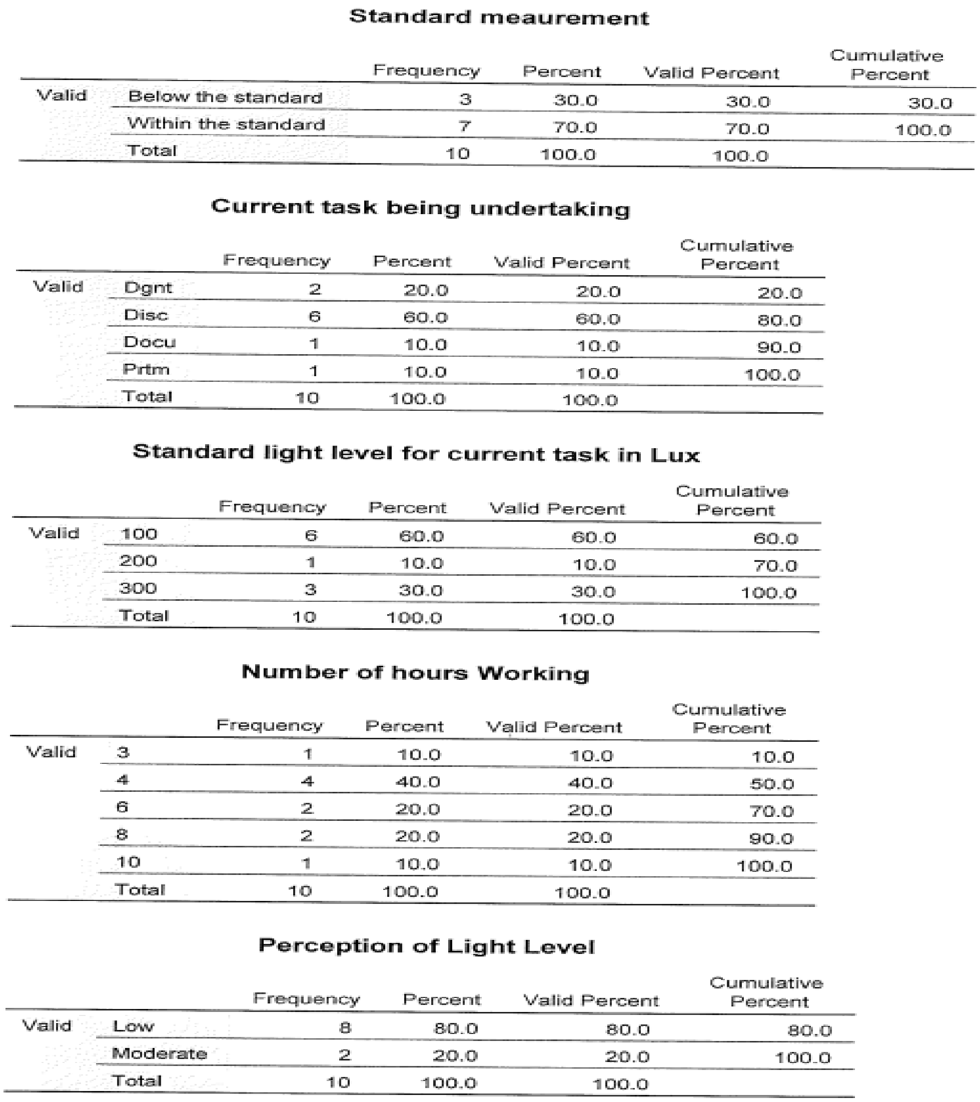
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Doctor	10	100.0	100.0	100.0

Daylight Factor in %

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below standard 2.5	5	50.0	50.0	50.0
	Below standard 2.5	2	20.0	20.0	70.0
	Below standard 2.5	1	10.0	10.0	80.0
	Below standard 2.5	1	10.0	10.0	90.0
	Below standard 2.5	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Meet standard or do not meet

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Met the standard	7	70.0	70.0	70.0
	Do not meet the standard	3	30.0	30.0	100.0
	Total	10	100.0	100.0	



Standard meaurement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below the standard	3	30.0	30.0	30.0
	Within the standard	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

Current task being undertaking

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Dgnt	2	20.0	20.0	20.0
	Disc	6	60.0	60.0	80.0
	Docu	1	10.0	10.0	90.0
	Prtm	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Standard light level for current task in Lux

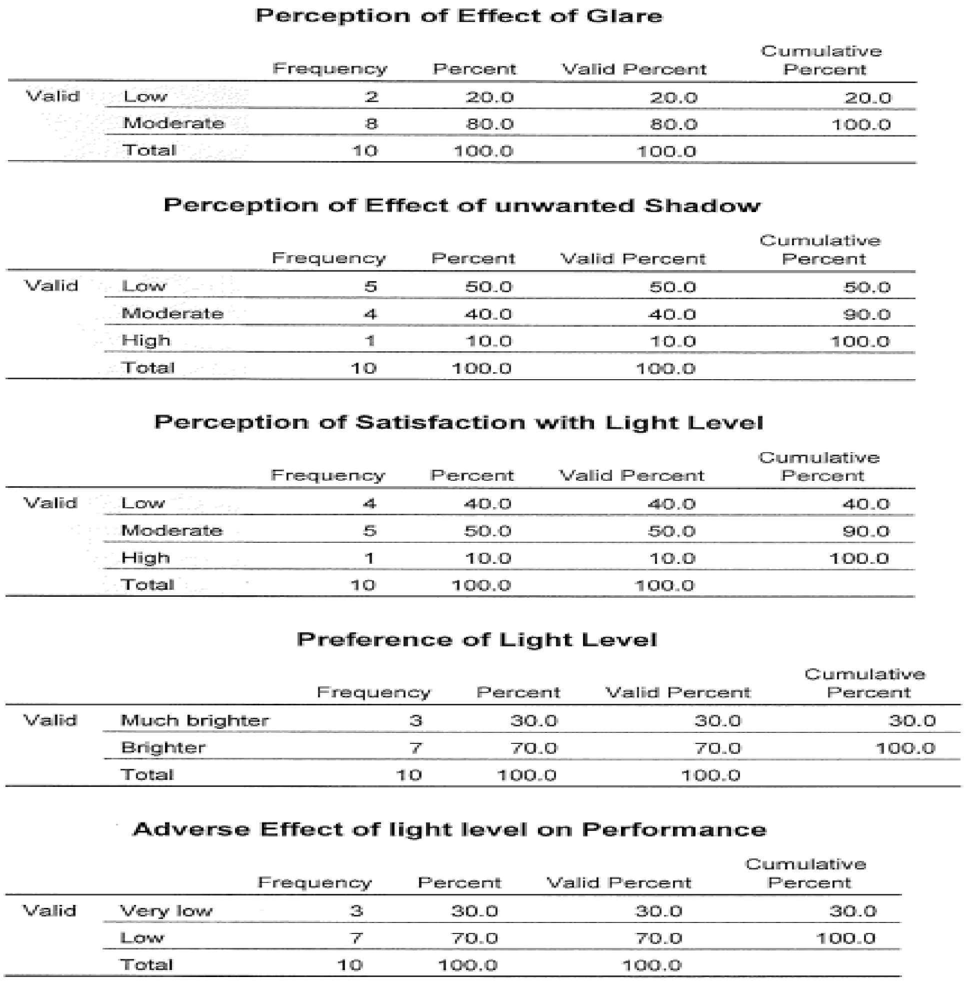
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	100	6	60.0	60.0	60.0
	200	1	10.0	10.0	70.0
	300	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

Number of hours Working

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	10.0	10.0	10.0
	4	4	40.0	40.0	50.0
	6	2	20.0	20.0	70.0
	8	2	20.0	20.0	90.0
	10	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Perception of Light Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	8	80.0	80.0	80.0
	Moderate	2	20.0	20.0	100.0
	Total	10	100.0	100.0	



Perception of Effect of Glare

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	2	20.0	20.0	20.0
	Moderate	8	80.0	80.0	100.0
	Total	10	100.0	100.0	

Perception of Effect of unwanted Shadow

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	5	50.0	50.0	50.0
	Moderate	4	40.0	40.0	90.0
	High	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Perception of Satisfaction with Light Level

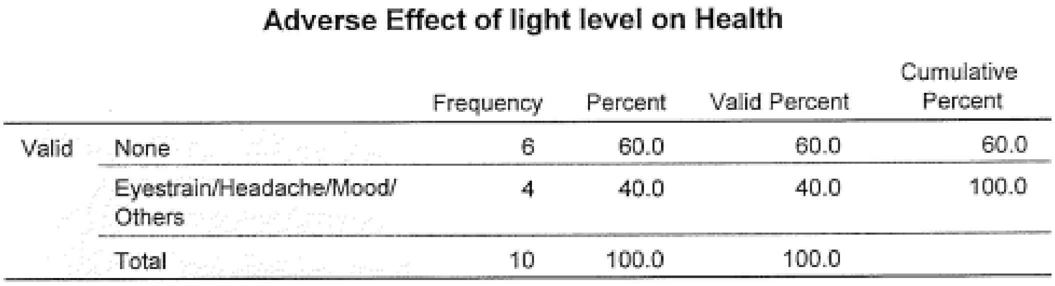
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	4	40.0	40.0	40.0
	Moderate	5	50.0	50.0	90.0
	High	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

Preference of Light Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Much brighter	3	30.0	30.0	30.0
	Brighter	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

Adverse Effect of light level on Performance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low	3	30.0	30.0	30.0
	Low	7	70.0	70.0	100.0
	Total	10	100.0	100.0	



Adverse Effect of light level on Health

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	6	60.0	60.0	60.0
	Eyestrain/Headache/Mood/ Others	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

Descriptives

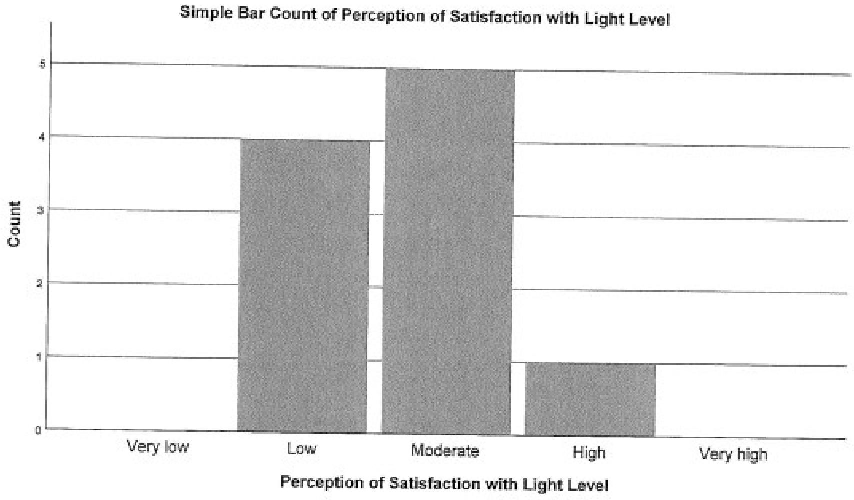
			Statistic	Std. Error
Average Illuminance in Lux	Mean		141.3900	34.23737
	95% Confidence Interval for Mean	Lower Bound	63.9397	
		Upper Bound	218.8403	
	5% Trimmed Mean		135.3111	
	Median		98.4000	
	Variance		11721.977	
	Std. Deviation		108.26808	
	Minimum		41.00	
	Maximum		351.20	
	Range		310.20	
	Interquartile Range		151.65	
	Skewness		1.339	.687
	Kurtosis		.479	1.334

Explore

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Average Illuminance in Lux	10	100.0%	0	0.0%	10	100.0%
L: External Illuminance in Lux	10	100.0%	0	0.0%	10	100.0%

GGraph



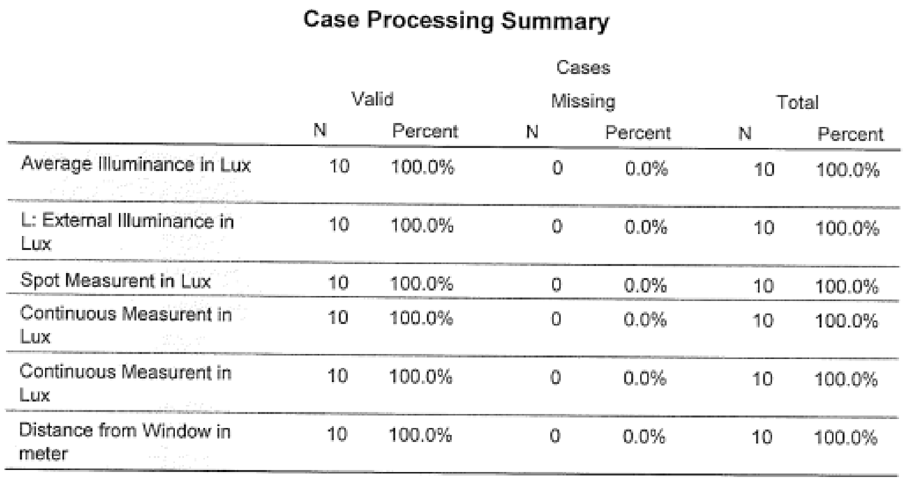
Explore

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Average Illuminance in Lux	10	100.0%	0	0.0%	10	100.0%

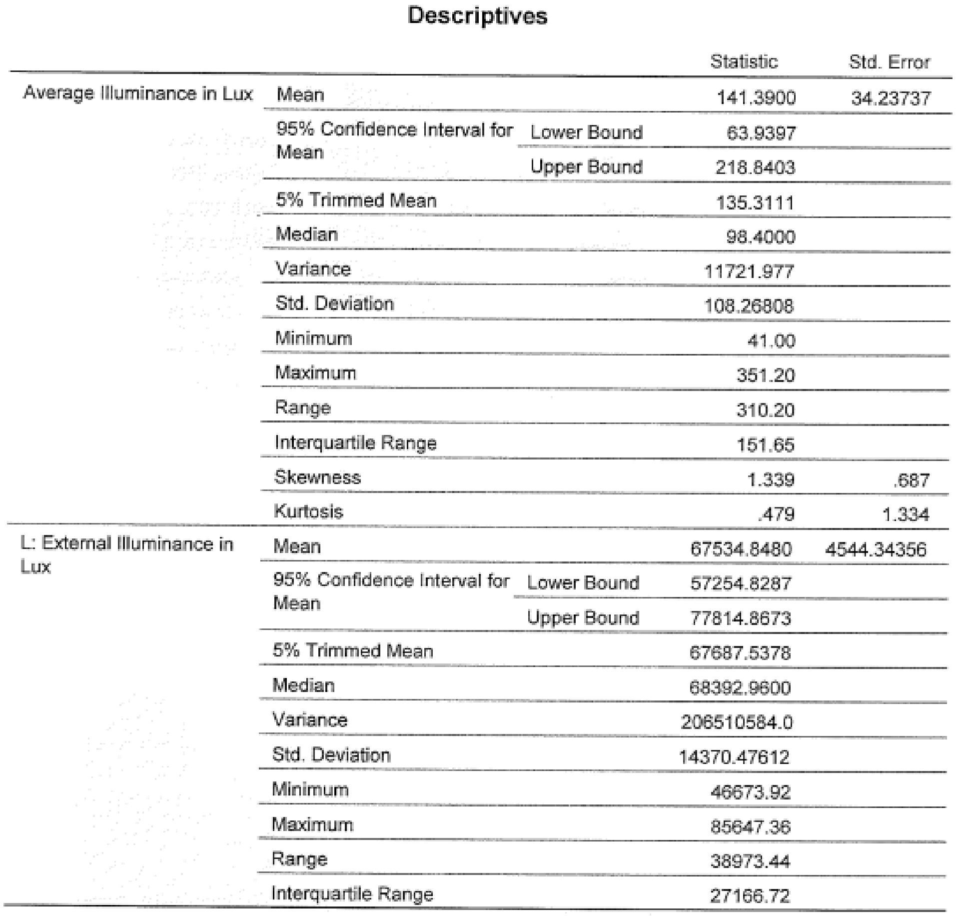
Descriptives

			Statistic	Std. Error
Average Illuminance in Lux	Mean		141.3900	34.23737
	95% Confidence Interval for Mean	Lower Bound	63.9397	
		Upper Bound	218.8403	
	5% Trimmed Mean		135.3111	
	Median		98.4000	
	Variance		11721.977	
	Std. Deviation		108.26808	
	Minimum		41.00	
	Maximum		351.20	
	Range		310.20	
	Interquartile Range		151.65	
	Skewness		1.339	.687
	Kurtosis		.479	1.334
L: External Illuminance in Lux	Mean		67534.8480	4544.34356
	95% Confidence Interval for Mean	Lower Bound	57254.8287	
		Upper Bound	77814.8673	
	5% Trimmed Mean		67687.5378	
	Median		68392.9600	
	Variance		206510584.0	
	Std. Deviation		14370.47612	
	Minimum		46673.92	
	Maximum		85647.36	
	Range		38973.44	
	Interquartile Range		27166.72	
	Skewness		-.182	.687
	Kurtosis		-1.464	1.334



Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Average Illuminance in Lux	10	100.0%	0	0.0%	10	100.0%
L: External Illuminance in Lux	10	100.0%	0	0.0%	10	100.0%
Spot Measurent in Lux	10	100.0%	0	0.0%	10	100.0%
Continuous Measurent in Lux	10	100.0%	0	0.0%	10	100.0%
Continuous Measurent in Lux	10	100.0%	0	0.0%	10	100.0%
Distance from Window in meter	10	100.0%	0	0.0%	10	100.0%



Descriptives

			Statistic	Std. Error
Average Illuminance in Lux	Mean		141.3900	34.23737
	95% Confidence Interval for Mean	Lower Bound	63.9397	
		Upper Bound	218.8403	
	5% Trimmed Mean		135.3111	
	Median		98.4000	
	Variance		11721.977	
	Std. Deviation		108.26808	
	Minimum		41.00	
	Maximum		351.20	
	Range		310.20	
	Interquartile Range		151.65	
	Skewness		1.339	.687
	Kurtosis		.479	1.334
L: External Illuminance in Lux	Mean		67534.8480	4544.34356
	95% Confidence Interval for Mean	Lower Bound	57254.8287	
		Upper Bound	77814.8673	
	5% Trimmed Mean		67687.5378	
	Median		68392.9600	
	Variance		206510584.0	
	Std. Deviation		14370.47612	
	Minimum		46673.92	
	Maximum		85647.36	
	Range		38973.44	
	Interquartile Range		27166.72	

Descriptives

			Statistic	Std. Error
	Skewness		-.182	.687
	Kurtosis		-1.464	1.334
Spot Measurent in Lux	Mean		111.680	27.6703
	95% Confidence Interval for Mean	Lower Bound	49.085	
		Upper Bound	174.275	
	5% Trimmed Mean		106.806	
	Median		75.300	
	Variance		7656.440	
	Std. Deviation		87.5011	
	Minimum		30.9	
	Maximum		280.2	
	Range		249.3	
	Interquartile Range		156.1	
	Skewness		1.120	.687
	Kurtosis		-.268	1.334
Continuous Measurent in Lux	Mean		198.474	56.6842
	95% Confidence Interval for Mean	Lower Bound	70.245	
		Upper Bound	326.703	
	5% Trimmed Mean		189.226	
	Median		107.600	
	Variance		32131.029	
	Std. Deviation		179.2513	
	Minimum		1.5	
	Maximum		561.9	
	Range		560.4	
	Interquartile Range		242.2	
	Skewness		1.110	.687
	Kurtosis		.373	1.334
Continuous Measurent in Lux	Mean		29.010	9.8464
	95% Confidence Interval for Mean	Lower Bound	6.736	
		Upper Bound	51.284	
	5% Trimmed Mean		26.533	
	Median		27.350	
	Variance		969.512	
	Std. Deviation		31.1370	
	Minimum		.0	
	Maximum		102.6	
	Range		102.6	

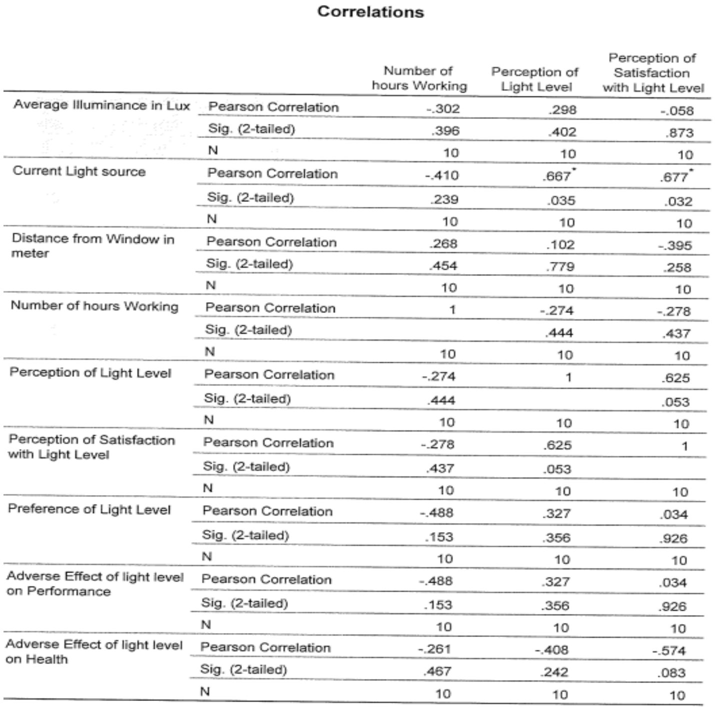
Descriptives

			Statistic	Std. Error
	Interquartile Range		39.7	
	Skewness		1.527	.687
	Kurtosis		3.029	1.334
Distance from Window in meter	Mean		2.5390	.43494
	95% Confidence Interval for Mean	Lower Bound	1.5551	
		Upper Bound	3.5229	
	5% Trimmed Mean		2.5033	
	Median		2.2500	
	Variance		1.892	
	Std. Deviation		1.37539	
	Minimum		1.02	
	Maximum		4.70	
	Range		3.68	
	Interquartile Range		2.60	
	Skewness		.414	.687
	Kurtosis		-1.497	1.334

Correlations

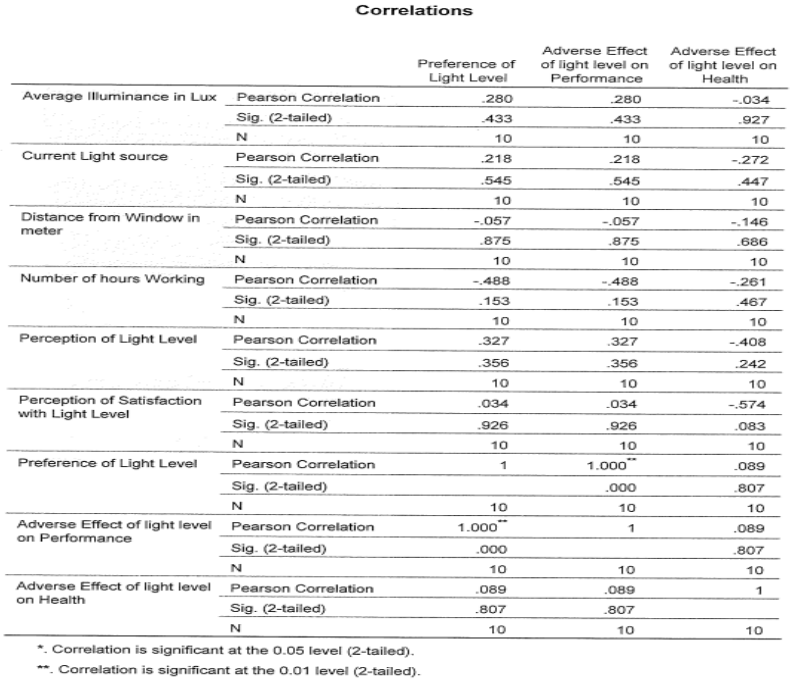
Correlations

		Average Illuminance in Lux	Current Light source	Distance from Window in meter
Average Illuminance in Lux	Pearson Correlation	1	-.165	.019
	Sig. (2-tailed)		.650	.958
	N	10	10	10
Current Light source	Pearson Correlation	-.165	1	-.317
	Sig. (2-tailed)	.650		.373
	N	10	10	10
Distance from Window in meter	Pearson Correlation	.019	-.317	1
	Sig. (2-tailed)	.958	.373	
	N	10	10	10
Number of hours Working	Pearson Correlation	-.302	-.410	.268
	Sig. (2-tailed)	.396	.239	.454
	N	10	10	10
Perception of Light Level	Pearson Correlation	.298	.667*	.102
	Sig. (2-tailed)	.402	.035	.779
	N	10	10	10
Perception of Satisfaction with Light Level	Pearson Correlation	-.058	.677*	-.395
	Sig. (2-tailed)	.873	.032	.258
	N	10	10	10
Preference of Light Level	Pearson Correlation	.280	.218	-.057
	Sig. (2-tailed)	.433	.545	.875
	N	10	10	10
Adverse Effect of light level on Performance	Pearson Correlation	.280	.218	-.057
	Sig. (2-tailed)	.433	.545	.875
	N	10	10	10
Adverse Effect of light level on Health	Pearson Correlation	-.034	-.272	-.146
	Sig. (2-tailed)	.927	.447	.686
	N	10	10	10



Correlations

		Number of hours Working	Perception of Light Level	Perception of Satisfaction with Light Level
Average Illuminance in Lux	Pearson Correlation	-.302	.298	-.058
	Sig. (2-tailed)	.396	.402	.873
	N	10	10	10
Current Light source	Pearson Correlation	-.410	.667*	.677*
	Sig. (2-tailed)	.239	.035	.032
	N	10	10	10
Distance from Window in meter	Pearson Correlation	.268	.102	-.395
	Sig. (2-tailed)	.454	.779	.258
	N	10	10	10
Number of hours Working	Pearson Correlation	1	-.274	-.278
	Sig. (2-tailed)		.444	.437
	N	10	10	10
Perception of Light Level	Pearson Correlation	-.274	1	.625
	Sig. (2-tailed)	.444		.053
	N	10	10	10
Perception of Satisfaction with Light Level	Pearson Correlation	-.278	.625	1
	Sig. (2-tailed)	.437	.053	
	N	10	10	10
Preference of Light Level	Pearson Correlation	-.488	.327	.034
	Sig. (2-tailed)	.153	.356	.926
	N	10	10	10
Adverse Effect of light level on Performance	Pearson Correlation	-.488	.327	.034
	Sig. (2-tailed)	.153	.356	.926
	N	10	10	10
Adverse Effect of light level on Health	Pearson Correlation	-.261	-.408	-.574
	Sig. (2-tailed)	.467	.242	.083
	N	10	10	10



Correlations

		Preference of Light Level	Adverse Effect of light level on Performance	Adverse Effect of light level on Health
Average Illuminance in Lux	Pearson Correlation	.280	.280	-.034
	Sig. (2-tailed)	.433	.433	.927
	N	10	10	10
Current Light source	Pearson Correlation	.218	.218	-.272
	Sig. (2-tailed)	.545	.545	.447
	N	10	10	10
Distance from Window in meter	Pearson Correlation	-.057	-.057	-.146
	Sig. (2-tailed)	.875	.875	.686
	N	10	10	10
Number of hours Working	Pearson Correlation	-.488	-.488	-.261
	Sig. (2-tailed)	.153	.153	.467
	N	10	10	10
Perception of Light Level	Pearson Correlation	.327	.327	-.408
	Sig. (2-tailed)	.356	.356	.242
	N	10	10	10
Perception of Satisfaction with Light Level	Pearson Correlation	.034	.034	-.574
	Sig. (2-tailed)	.926	.926	.083
	N	10	10	10
Preference of Light Level	Pearson Correlation	1	1.000**	.089
	Sig. (2-tailed)		.000	.807
	N	10	10	10
Adverse Effect of light level on Performance	Pearson Correlation	1.000**	1	.089
	Sig. (2-tailed)	.000		.807
	N	10	10	10
Adverse Effect of light level on Health	Pearson Correlation	.089	.089	1
	Sig. (2-tailed)	.807	.807	
	N	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 40: Examples of Analysed Quantitative Data Samples.

Appendix C

Key Photos from Study Environment

The following are photos from Study locations in the healthcare environment about which physical measurements and participants subjective responses were centred.

Figure 41: Akinbami A. (2022) Fieldnote: Study Environment Photos, Capturing the Building Approach, Adjacent Structures, and the Data Logger's Rooftop Placement.

Figure 42: Akinbami A. (2022) Fieldnote: Surgical department Study Environment Emphasising the Nearby Building (5m away) with Varying Degrees of Obstruction to Natural Light Observed throughout the Day.

Figure 43: Akinbami A. (2022) Fieldnote: Postnatal Study Environment, Highlighting the Variations in Natural Light throughout the Day.

Figure 44: Akinbami A. (2022) Fieldnote: Paediatric Study Environment, Demonstrating the Data Logger's Placement and the Impact of Natural Light's Shadow .

Figure 45: Akinbami A. (2022) Fieldnote: Obstetrics Study Environment, Illustrating the Entry of Natural Light, Data Logger's Placement, and the Contribution of Artificial Lighting.

Figure 46: Akinbami A. (2022) Fieldnote: Study Environment, Capturing Illuminance Level Measurement with a Handheld Lux Meter on a Tripod, and Simultaneous Personnel Responses.

Figure 47: Akinbami A. (2022) Fieldnote: GOPD study Environment, including Images of Lux Meter, Personnel Engaged in Various Activities and Individuals Completing Questionnaire.