The investigation of façade fenestration for daylighting levels and experienced atmosphere in design studios under overcast sky

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Submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

Mackintosh School of Architecture
Glasgow School of Art – University of Glasgow
March 2021

Mackintosh rose

Abstract

Daylight, as a design theme, is fundamental in architecture for creating a sustainable and healthy living environment. It is key to providing a congenial atmosphere, which can manipulate the way that interior space is perceived and experienced. However, due to the high cloud coverage, synonymous with dark and gloomy sky conditions in overcast locations like Scotland, decisions on façade fenestration design and the subsequent use of artificial lighting are mostly geared towards providing sufficient interior illuminance, without addressing the crucial influence of façade fenestration on daylighting and occupants' attitudes towards the aesthetic and emotional domains of atmosphere.

From this perspective, this study investigates the relationship between façade fenestration, daylight levels and the experienced atmosphere under overcast sky conditions within various façade windows and spatial typologies of design studios. Three Scottish cities, Glasgow, Edinburgh and Aberdeen, were carefully chosen as research vehicles for this investigation. The thesis attempts to deal with two research questions: How does façade fenestration design affect the daylight levels in different studios typologies under overcast sky conditions? And what is the impact of façade fenestration and the resultant daylight levels on the experienced atmosphere?

A longitudinal research design was adopted for this study. Therefore, the research methodology is largely experimental, and thus empirical in nature. It involves quantitative data measurements, namely façade fenestration, daylighting levels and distribution inside the design studios. These 'objective' data sets are then supplemented by a closed-ended questionnaire to measure user attitudes toward façade fenestration, daylighting and atmospheric ambiance inside the studios. The objective data sets were correlated with the subjective ones to compute and determine the 'strength' of the relationships between variables.

The results revealed that studios with a window-to-floor area ratio of over 20%, yielded well-illuminance levels, considered to be between 500-750 lux, except for zones under the mezzanine level, where illuminance registered less than 200 lux. Furthermore, the results unexpectedly revealed that spaciousness, furniture arrangements and proximity were the stimuli contributing most to the experienced atmosphere inside the studios. However, a weak association was identified between the characteristics of façade fenestration, daylight attributes and atmospheric factors. Consequently, one could argue that the objective factors could be considered poor predictors for the subjective well-being of occupants. The outcome of this thesis presents an important contribution to the understanding of the relationship between façade fenestration, daylighting and experienced atmosphere inside design studios, both from numerical and subjective perspectives.

Keywords: Façade fenestration, daylight levels, experienced atmosphere, studio typology

Acknowledgements

This work could not have been completed without the guidance, support and assistance of many people who have offered their time and knowledge to the creation of this study.

I would like to thank my mother from the bottom of my heart; she has pushed me to follow through with my higher education and has supported me unconditionally throughout times of joy and hardship. Thanks go also to my father who has supported me emotionally, particularly during the COVID-19 pandemic. Thank you also to my siblings and grandparents for believing in me and providing endless support.

My greatest appreciation and gratitude go to my supervisor Dr. Raid Hanna for opening my mind to endless possibilities, raising my spirit, fuelling my confidence, directing me through wide expanse of knowledge, supporting me through difficulties and giving me space and time to question, especially regarding, light equipment, data collection and statistics. Without his assistance, guidance, encouragement and empathy, this work could not have reached its rightful conclusion.

My thanks extend to Professor Tim Sharp for advice and support. Big thanks to Dr. Grainne McGill and Janice Foster for helping with all the practical work and for all the advice given to achieve smooth data collection! Special thanks go to the University of Jordan for providing funding for a full year of study and offering endless support to finish my work successfully. To the research office at GSA and to Dr. Thea Stevens. Thanks to Dr. Khawla Maayah and Dr. Hamed Al Kateeb for providing advice about weather conditions and statistics. To the Met office for providing weather data from different weather stations across U.K.

To my PhD colleagues in the Architecture department, Maryam Siddiq and Alejandro Moreno for their PhD tips and tricks and later for statistics help, Farrah Jahangeer for advice on methodology and data collection, Kristopher Yuan Sung for encouraging me to have a life amidst it all and Sean Kinnear for listening to my endless stories and rising my confidence level. To my PhD colleagues in the Design department, Sondos Rawas and Ziwei Wang for their endless support and beautiful friendship and the rest of the PhD community at GSA for their distance support throughout the pandemic.

Thanks to the collaborators from different institutions, The Scott Sutherland School of Architecture and Built Environment (Robert Gordon University): Professor David McClean, Dr. Amar Bennadji, Dr. Huda Salman, Dr. Jonathan Scott and Dr. Mansur Hamma, and from the estates, David Williams and Lukasz Wozniak. To The Edinburgh Napier University: Paul Kerlaff and Alan Curtis.

My appreciation to Jens Christoffersen from VELUX Group, Copenhagen for answering my numerous questions regarding daylight and for his endless support. Professor David Morgan from Portland State University for statistics advices. Dr. Ingrid Vogels from Eindhoven University of Technology for checking the questionnaire and giving helpful comments. Dr. Paul Littlefair from Building Research Establishment (BRE) for the artificial lighting extraction advice.

To the GSA community, my gratitude goes to the Estates department, Bell Fraser, Barrie Stewart, and Douglas Mckechnie. Alice Andrews from Student Support and to the head of the Design departments and the studios' tutors: Barbara Ridley, Craig Whitte, Stuart Bailey, Patrick Macklin, Dave Loder, Anna Gordon and Dr. Donna Leishman. Thanks to Ross Finnie from the technical services and to the IT department.

Finally, sincere thanks go to the 320 students from Glasgow, Edinburgh and Aberdeen for completing the questionnaire and providing such helpful comments. It was my pleasure to meet each one of you, answer your curious questions and talk about your projects. I hope that I helped or inspired you in one way or another. And finally, thanks go to my editor I. Stirling for assisting with my writing over the past four years.

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Chapter 1

Introduction

1.1 **Research context**

Façade fenestrations are responsible for providing views, daylight and fresh air from outside to the inside of a building; with a carefully designed and placed fenestration, a considerable reduction in the use of artificial light can be achieved. However, in places such as Scotland, a shortage of daylight hours for most of the year, due to a thick cloud coverage being the dominant type of sky, Necessities that designs incorporate a strong façade fenestration system. Furthermore, as buildings, daylight and people are closely linked, their relationship has long been recognised and studied, specifically with regards to how daylight and electric light can impact an occupant's mood, attention and behaviour (Bellia, Pedace, & Barbato, 2013). This will be the reason so to why few researchers were found in the literature, examining the crucial influences of façade fenestration and daylighting on occupants' attitudes toward the aesthetic and emotional domains of atmosphere. In this respect, this study investigates the effect of façade fenestrations on daylight levels and experienced atmosphere under an overcast sky within various architectural typologies of design studios in three Scottish cities: Glasgow, Edinburgh and Aberdeen.

This study deals with the subjective perspective along with the objective one, and so the idea of daylight has been demonstrated from theoretical, aesthetic and phenomenological viewpoints along with the scientific one. This allows for the highlighting of its opposing side, darkness, particularly within the geographical and climatic contexts. Accordingly, the elements of illumination and darkness within the domain of architecture possess qualities that impact our perception and sensation. These qualities were referred and extended to be known as atmosphere. The theory of atmosphere as a contemporary one has been explained from phenomenological and ontological perspectives, which highlight its operation within the built environment by daylight as one of its environmental generators.

In addition, the study interprets the concept of the creative space as a theory and typology in the built environment, because of its vital role in determining the most suitable façade fenestration that will secure a certain level of daylight and so generate the preferred atmosphere. Whereas, daylighting design decisions such as the designer's ability to place windows in a thoughtful position and have them of a suitable size will impact the quantity and the quality of daylight inside buildings and how deep it penetrates within the interior of buildings. However, the fenestration design can also be affected by many circumstances, such as economic, climatic, technological, political, theoretical, aesthetic and regulatory factors.

To sum up, the research context of this study assumes a theoretical rationale for the three main variables: façade fenestration, daylight levels and experienced atmosphere within the context of creative spaces in higher education under an overcast sky. These variables will be paired with empirical data collection, measurement of daylight levels and user attitudes toward façade fenestration, daylight quantity and various factors of atmospheric experience.

1.1.1 **Motivation and study objectives**

The motivation for conducting the study came from the author's personal experience of moving from a hot, dry and sunny climate to cold, humid and cloudy one. This contrast in climates prompted an interest in investigating the opportunities that cloudy weather could offer. This interest manifested in actual research when the author had an opportunity to be involved in a building tour of the interior of the Glasgow School of Art's (GSA) Mackintosh Building. Observing the patterns of light and shadow as they intersected within the building's spacious studios and ambiguous corridors made the author consider the intimate relations between physical and spatial qualities. Accordingly, the study's objectives are as follows:

- Investigate the influence of façade fenestration design on daylighting levels inside studios. Assess the 'what-if-scenario' of hypothetical changes within façade fenestration: if a change in X (a single parameter in façade fenestration) will produce a marked change in Y (daylight levels).

- Highlight the importance of façade fenestration and daylighting in design, which can contribute to the experienced atmosphere of studio space in overcast weather.

1.1.2 **Research questions**

The following research questions are addressed in this study:

- *How does façade fenestration design affect the daylight levels in different studios typologies under overcast sky conditions?*

- *What is the impact of façade fenestration and the resultant daylight level on the experienced atmosphere?*

1.2 **Thesis structure**

The thesis starts with an introduction that demonstrates research context, objectives and motivation for conducting the study, as presented in chapter 1. It also explains the current research gap and the significant contribution that this study subsequently offers (Figure 1-1). Chapter 2 discusses the theoretical framework of daylight in terms of its phenomenological dimension and physical aspects. Façade fenestration is discussed too, followed by an empirical investigation related to daylight calculation methods and daylight performance. Chapter 3 covers the theory of atmosphere as a contemporary phenomenon in the built environment in line with phenomenological and ontological perspectives. This is followed by a study of the relationship between atmosphere and daylight and lastly a demonstration of the quantitative treatment of façade fenestration and daylight on atmosphere.

Chapter 4 looks into the theory of creative space within a theoretical framework and provides an insight into the history of daylight in educational buildings and creative workspaces. The chapter ends by using the Mackintosh Building as a representative case for the synthesis of space, light and shadow within the Scottish context. Chapter 5 presents the research design and methodology, the process of determining the case studies and the sample size.

The procedure for collecting the objective and subjective data is discussed, along with the findings and alternations from pilot studies. Chapters 6 and 7 explain the daylight analysis in the two phases (Glasgow-Edinburgh and Glasgow-Aberdeen) in which vertical and horizontal daylight levels were analysed. In addition to this, the daylight factors were evaluated based on the current design guidelines for lighting. Chapters 8 and 9 explain the analysis of the students' subjective judgments regarding façade fenestration, daylight and experienced atmosphere in the studios. Chapter 10 presents conclusions, highlights areas of uncertainty and defines areas for further research related to façade fenestration, daylight and atmosphere in creative spaces.

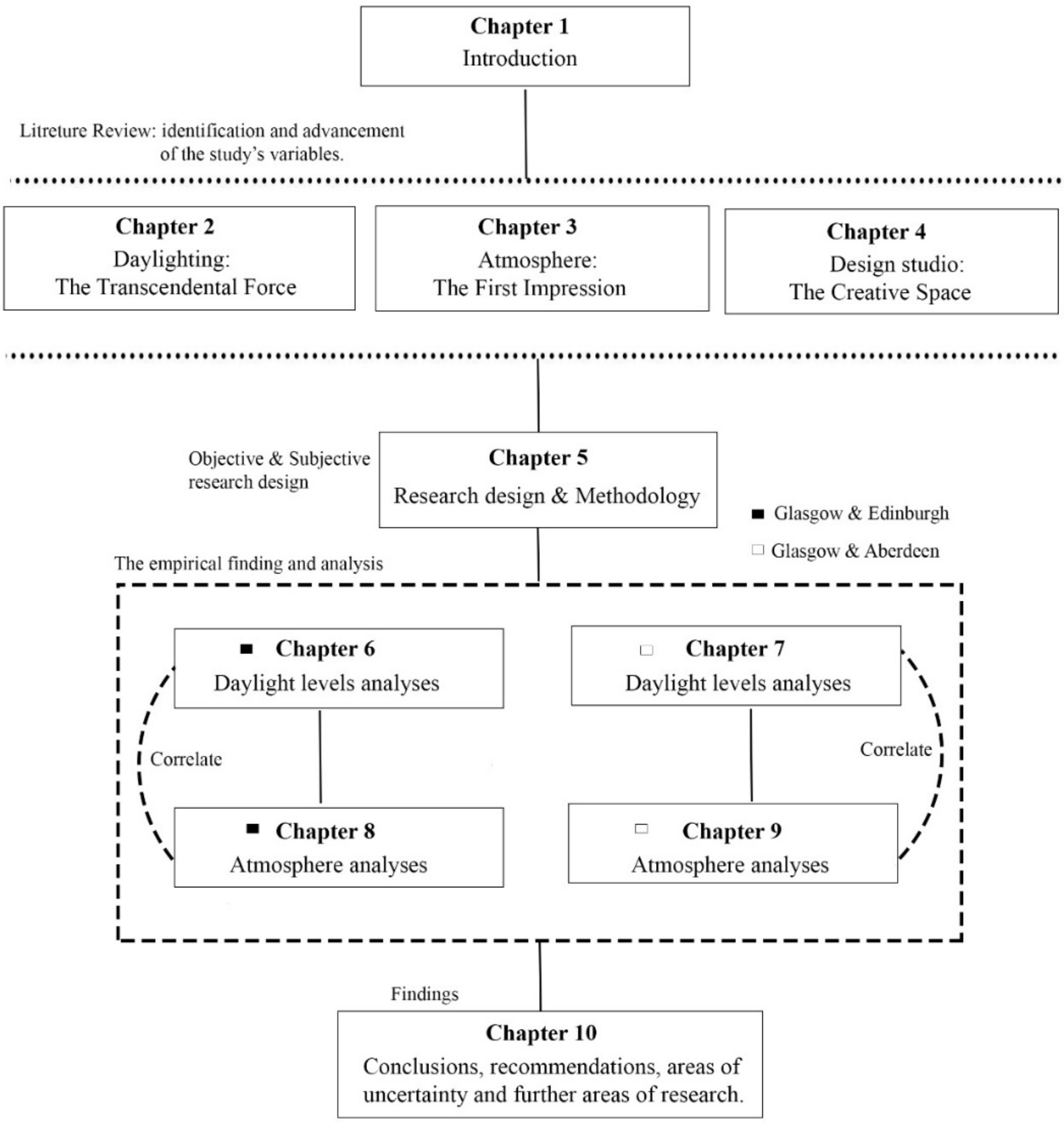


Figure 1-1 Thesis structure

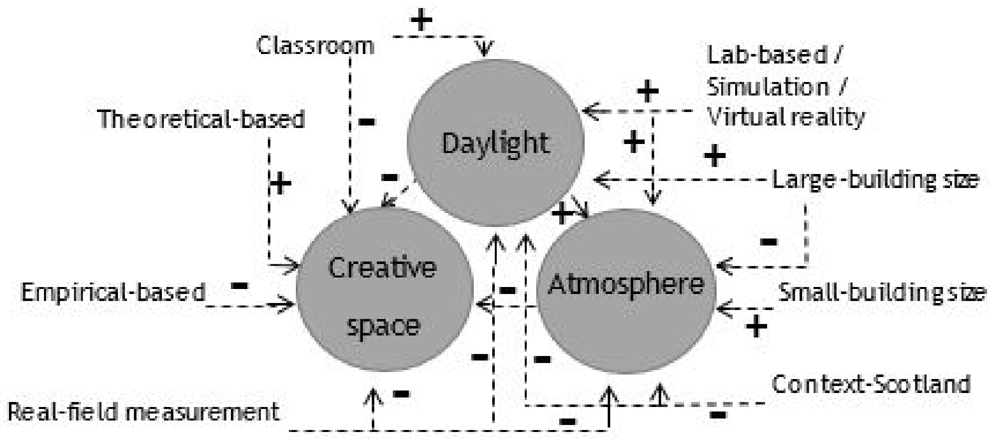
1.3 **Research gap**

Through conducting a systematic review of previous relevant literature, several significant gaps have been identified (Figure 1-2). Firstly, the quantitative aspects of daylight have been widely debated with regards to which empirical tool would be adequate and sufficiently rigorous to investigate daylight as a highly changeable parameter within the built environment. Most of the previous studies have relied on simulation-based metrics which consider time and cost efficiency, such as Zomorodian & Tahsildoost's (2019) study and lab-based environments such as in Chen's (2014) thesis. However, both tools still require results to be verified by field measurements to crosscheck the accuracy of simulation models against measure data and determine the distribution of interior daylight. As such, evaluate daylight under realistic sky conditions in a field study could be an alternative approach to predicting daylight using comprehensive simulation methods and models. In addition, the literature review revealed a major contextual gap when it comes to evaluating the objective aspects of daylighting in different contexts, such as in Scotland. In fact, the last empirical study evaluating daylight in a creative space was by Hanna (2002) in the Glasgow School of Art (GSA) building.

Secondly, atmosphere as a contemporary theory has been examined within theoretical debates by many philosophers, such as Böhme (2017) and Griffero (2014). Within the architectural practice, the importance of the interplay between light and shadow was notably addressed in the work of Zumthor (2006) and Tado Ando (Schielke, 2019). From a research perspective, while the theory of atmosphere has been investigated using different methodologies, such as virtual reality (VR) (Chamilothori et al., 2018), rendered images (Kemp, Gemelli and Shiratuddin's, 2016) and questionnaire (Vogels, 2008), the theory still faces two considerable research gaps. The first gap is concerned with the research context, in that most studies depend on a lab-environment where the settings are designed and controlled for research rather than a real-field environment with a natural setting. The second gap relates to the size of sample as, although some studies were oriented to a real-field setting, the size of case study is considering small in which the factor of generalizing the findings is missing, such as in Tantanatewin and Inkarojrit (2016) study conducted in a bank and Kemp, Gemelli and Shiratuddin's (2016) study conducted in a living room.

Thirdly, as the study is conducted within architecture and design studios, it is crucial to look into the theory of creative space as it has been extended from a theoretical base to operational implication through what is known in architecture practice the ‘typology’. However, the spatial qualities and design framework of creative space remain under development, as has been highlighted within previous literature, such as that of Thoring et al. (2019, p. 22) who argued that the physical environment that facilitates the process of creativity and innovation, specifically the design workspace, has not been investigated in detail yet. As such, there is an incentive to develop the theory of creative space from a theoretical perspective to an empirical one, whereby holistic understandings of physical spatial design and environmental factors are vital.

Within this in mind, the typology of creative space in the learning environment is not yet fully established, nor is there a satisfactory classification system that is robust enough to define the optimum façade fenestration and the required daylight; within qualitative and quantitative aspects. Moreover, through the literature review, it was noted that most recent research regarding the subjective (students’ affective impressions) and objective criteria (daylight measurements) was oriented toward university classrooms. Examples include studies such as Korsavi et al. (2016), Castilla et al. (2017) and Ricciardi & Buratti (2018). Therefore, it is clear that a holistic approach towards daylighting design and the experienced atmosphere in creative spaces within the learning environment and from end-users’ perspectives is missing. In conclusion, the main gaps that concern this study are summarized as follows: investigating daylight levels and the experienced atmosphere in a real-field environment and within presentative creative spaces in Scotland. These parameters need to be associated in order to establish an empirical and measured relationship that would take the theory of atmosphere and the theory of creative space to a more advanced level.



(+) research exists, (-) research gaps

Figure 1-2 Identifying the research gaps

1.4 Significance and contributions

The significance of the study comes from the notion of it being an intensive systematic investigation of the many objective and subjective parameters associated with facade fenestration, daylighting and the experience atmosphere. The correlation of the different parts of the parameters in scientific depth has contributed to the current knowledge within theoretical, methodological, and empirical relevancies as follows:

1.4.1 Theoretical relevance

Theory and research have been in a dialectic relationship; however, theory development relies on research, and research relies on theory (Fawcett, 1992). This study is based on the theory of experienced atmosphere as a contemporary phenomenon in the built environment; light is considered to be one of the generators. Through field measurement, the theory was evaluated in a natural setting and by its occupants, which has added a significant empirical depth to the theory of atmosphere. Similarly, the study has presented a new understanding about the nature of daylight and experienced atmosphere in various typologies, which has contributed to the theory of creative space.

1.4.2 **Methodological relevance**

The methodological contribution of the study is based on the rational process in determining the three case studies in three different cities, which by and large shared a similar weather profile, design typology and physical characteristics. For the data collection, based on the longitudinal research design, the study variables (objective and subjective) were investigated roughly at the same time. In terms of analysis, the objective data was analysed by various measures of central tendencies, such as the mean, median and standard deviation, in addition to t-test and analysis of variance (ANOVA). Meanwhile, the subjective data was analysed by the Kruskal-Wallis H test, Wilcoxon Signed-Rank test and factor analysis to describe the variables and determine the shared variance between them. A Spearman's correlation analysis between the objective and subjective data was then conducted.

1.4.3 **Empirical relevance**

The findings derived from this study are dependent on the empirical investigation and measurement of objective and subjective data in a natural setting. Accordingly, evaluating the daylight levels in a study-field context through field measurement has added more rigour, confidence and adequacy to relate the findings to the area of practice in the built environment. As explained in the chapters related to the daylight analysis, the design guidelines for daylight in creative spaces are notably missing; in turn, the study had to rely on guidelines that were designed for art rooms and classrooms. Therefore, the crucial contribution in understanding the daylight nature in creative spaces from a numerical perspective as well as from subjective judgments will provide deep insight into how to implement further design guidelines for securing an advanced façade fenestration and daylighting system in design studios.

Chapter 2

Daylight: The transcendental force

2.1 **Introduction**

This chapter aims to illustrate the subject of daylight from its philosophical and theoretical perspectives supported by up-to-date academic research and scholarships. In this study, the daylight levels have been measured and quantified in consideration with the scientific aspects of daylight, with some of its physical and technical specifications covered through the chapter.

The daylight-focused literature in the architectural field has been shaped by many philosophers and researchers from various theoretical and scientific perspectives. Their contributions are oriented in two major domains: the first one takes the role of daylight in shaping a building within its surrounding environment, where the main concern of studies is on daylight performance and energy consumption. The second domain considers the role of daylight in connecting buildings with their occupants, where studies on human health (physical and psychological) and human performance (visual and task productivity) are the most common subjects covered.

However, with all the complexity, benefits and opportunities that the daylight field could offer, this chapter will focus on the daylight performance based on quantitative aspects, such as daylight level and daylight factor, in order to relate both to the following chapter: the experienced atmosphere. This study had a major consideration from the Society of Light and Lighting (SLL) Code by Raynham et al. (2012) as it presents wide recommendations about aspects of daylight in practice: quality and quantity. Moreover, Lighting Guide10: Daylighting- a guide for designers (2014) and the British Standards (British Standards Institution et al., 2019) were taken into account while shaping this study, in which the process of designing a well-lit building has been defined.

The chapter is divided into three sections; the first one presents some of the key theoretical concepts proposed by early pioneers in the daylighting field along with physical aspects of daylight, such as the daylight factor. The second section presents the façade-window configurations, considering the building's envelopment which represents the theoretical, structural, and aesthetic aspects of architecture. The third section examines some of the up-to-date empirical investigations that have appeared in previous years. The chapter's discussion detects considerable gaps in the reviewed literature which this study could address.

2.2 Theoretical framework

'*Everything is ruled by lightning*' Heraclitus (Virilio, 2007, p. 49)

Light is the composition of silence, bright and dark parts. (Laganier, 2011, p. 39). It produces space, orientation (Blumenberg, 1993, p. 31) and action at a distance (Merleau-Ponty, 1993, p. 138). Light is a signal of information, a message, a channel and a noise, in which each case impacts differently according to the role it plays (Cubitt, 2013, p. 310). The philosopher, mathematician, astronomer and optician Ibn al-Haytham (1989) reimagined the theory of light in his influential work, *Optics*. Meanwhile, Galileo opened a range of new arguments and observations in his materialistic theory of light by examining light as a material and linking natural philosophy with scientific investigation: 'light was not God but a body' (Zajonc, 1995, p. 79). Newton, likewise, based his understanding of light on corpuscular theory (particle theory). However, this idea was later dismissed by Christiaan Huygens, who supported his claims by using the wave theory, summing up that light behaves similarly to waves and can interfere with other lights. Meanwhile, Plummer (1987, p. 9) thoughts cantered about connecting light with matter in explaining the experience of senses. The exchange that occurred between light and matter of things, make energy turns into materialized and matter becomes energized.

For Le Corbusier, light is the key, as it illuminates shapes that have an emotional power. He said: 'As you can imagine, I use light freely; light for me is the fundamental basis of architecture. I compose with light' (Steane, 2011, p. 9). Likewise, for Kahn who made this attempt: 'I can't define a space really as a space, unless I have natural light … natural light gives mood to space by nuances of light in the time of day and the season of the year as it enters and modifies the space'(Kahn, 1961). As such, light is the motive and mobilizing force, because it stimulates us, where the sense of light could be enhanced by our observations to our surroundings (Plummer, 1987, p. 13).

However, light as an architectural quality is almost missing. This might be due to the nature of light, in which it's highly embodiment within other qualities of architecture, such as texture and colour. Zumthor said: "arguably we have forgotten how to experience it as a quality in its own right" (Boal, 2012). Zajonc (1995,8) has similar view in presenting light, referring to it as an 'invisible thing'. He sought to understand light by pausing a question: "What is the nature of this invisible thing called light whose presence calls everything into view - excepting itself?" (Zajonc, 1995, p. 7). His stressing point comes from the fact that light touches all parts of our existence and revealing some of itself in each encounter. Likewise, Lawrence (2021) noted that the advances in the built architecture often depend on 'solving pragmatic functional problems' than evolving other design attributes, such as heating, ventilation and lighting.

Baker & Steemers (2002, p. 4) argued that 'light in architecture is not of singular concern that can be isolated from other design concerns, but relates to a rich integrated web of interdependent aesthetic and functional criteria'. The authors also propose that scientific measurements can be used to predict illuminance on a working plane (lux), but can say little about the emotional content of the luminous environment (Baker & Steemers, 2002, p. 22). Hence, designing lighting requires more than ensuring minimum levels of illuminance; rather, it involves visualisation in three dimensions to understand the relationships between occupants, tasks, and light sources (Tregenza & Loe, 1998, p. 73).

On the other hand, Steemers & Steane (2004) demonstrated adaptability over a building's lifetime, focusing on its two terms: the short-term, which relates to interactions between users and the building, and the longer-term, which is concerned with building adaptation in response to changes in conditions, such as due to climate change. In this regard, Steemers & Steane (2004, p. 161) connected natural light with the concept of diversity in the visual environment by categorising the experienced temporal and spatial diversity into three different kinds of movements:

- Lighting-induced movement (space moves with the viewer)
- Solar movement in relation to the building's apertures
- The secularity of surface finishes and the movement of reflections

Meanwhile, Katerina Parpairi raised the question of how the building envelope controls daylight and reveals the building's form with its dynamic character. However, the development of a mathematical approach during the Enlightenment led to the separating of aesthetic features from function (Steemers & Steane, 2004, p. 180). Parpairi also emphasised that the perception of daylight is a personal process, and propose studying the observer and the response to the environment as the best way to understand this process (Steemers & Steane, 2004, p. 182). A series of non-quantifiable parameters, described as architectural and personal, have been suggested to explore the daylight aspects that affect a user's perception, including: view out, adaptation, diversity, and control (Steemers & Steane, 2004, p. 192). From a different perspective, light has a vital role on people's state of health, especially the circadian system. Foster & Kreitzman (2014, p. 600) explored how light regulates the circadian rhythms and synchronises the body clock. There is an urgent need to explore this subject further, as changes in circadian rhythms affect our physiology, behaviour, mood, and cognitive abilities.

2.2.1 **Physical aspects of daylight**

It is essential to introduce some of the physical concepts, terms and ideas concerning daylight that are employed throughout this study. The source of daylight primarily comes from the sky, which has infinite source points of light. In physics, light is considered the electromagnetic radiation within a certain portion of the electromagnetic spectrum between 380 and 780 nm. The performance of seeing happens within this region of the electromagnetic spectrum, as visual photoreceptors in the human eye absorb energy within this range (Boyce, 2014, p. 3). Hopkinson et al. (1966) describe this as the visual manifestation of radiant energy set between certain wavelengths related to human sensation.

In terms of being a visual concept, subjective brightness is an attribute of visual perception according to which an area appears to emit more or less light.

Meanwhile, Luminance (physical brightness) is the quantity of light received at the eye, and the luminance unit is the foot-candle. That light may come from a primary source of light, such as the sun or a fluorescent lamp, or from a secondary source of light, such as a reflective white surface where its brightness is a result of reflected light coming from a primary source of light. Illuminance is the diffusion of light flux over a surface and the illuminance unit is the Lux (lumen per square foot [lm/ft^2] or the foot-candle [f.c]: which is usually estimated that [1 lm/ft^2] = 10.76 lux). The luminous intensity is an object's property to emit light in a certain direction and measured in candles. The reflectance is the reflected light flux that falls on a surface and changes its direction towards the observer, giving the surface its luminance. Each surface has its own reflecting power which gives different sensations of brightness, thus affecting how we perceive the surroundings. This is usually presented as a percentage. As such, the brightness of the reflective surface (Luminance) depends on the reflecting characteristics of the surface and the illumination that spreads over a surface. Figure 2-1 shows the metrics for lighting and daylighting.

Illumination = Luminance/Reflectance (Hopkinson et al., 1966, p. 334).

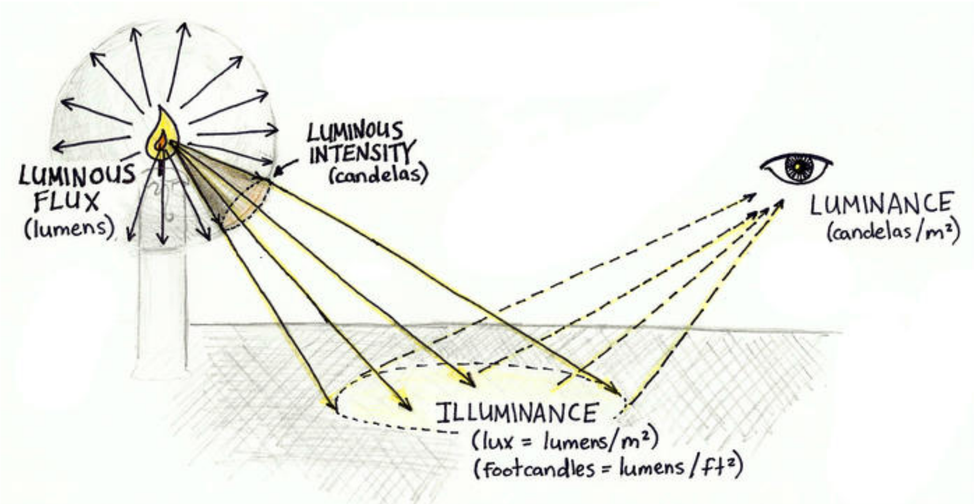


Figure 2-1 Metrics for lighting (AUTODESK, 2018).

2.2.1.1 **Daylight factor**

Measuring the quantity of daylight inside buildings can be accomplished through various methods, such as mathematical formulae, tables, graphs, scale models, software programs or devices like protractors, plotting webs and meters. Yet, evaluating the performance of daylight is highly dependent on the climate of a region. In humid climates, such as the UK and north-west Europe, the cloud coverage tends to be changeable during the day and the daylight reaching a point inside a building is varies with the sky conditions. In contrast, in a sunny dry climate, where the sky is blue and the sunlight is almost constant, the specification of daylight is easier (Hopkinson et al., p. 2).

Therefore, the variability of daylight and the performance of buildings under an overcast sky is often characterised by the daylight factor. It is considered an indicator to predict and specify the overall appearance of a room. The concept of the daylight factor is presented as the ratio of the interior illumination to the available illumination from the unobstructed outdoor sky. Whereas, daylight at a point is the daylight that directly hits the point from the outdoor sky and the reflection from the internal and external surfaces. The daylight factor then is: 'a measure of the total daylight illumination reaching a point in the interior of a building and includes the direct daylight from the sky, any light reflected into the room through the window from external obstructions, and also the light which, having once entered the room, is reflected and inter reflected at the surfaces of the room before it reaches the reference point' (Hopkinson et al., 1966, p. 69). Once again, to get a more precise calculation of the total interior daylight, the daylight factor takes two forms: the daylight factor at a point and the average daylight factor (DF_{avg}) over a surface (Tregenza & Wilson, p.134, 2011).

$$DF = \text{(Internal illuminance from daylight)} / \text{(External illuminance from an unobstructed sky)} \times 100\%$$

The advantages of the daylight factor take two forms. First is constancy, whereby the daylight factor remains constant because of associated changes between the exterior daylight and interior illumination. Second is the concept of visual adaptation, whereby the room brightness not only depends on the actual luminance of what we are looking at, but also the brightness for the entire surrounding area. Therefore, an individual's visual appreciation of a room will not change radically as the eye will adapt to the changes slowly. Based on the previous explanation, Hopkinson et al. (1966, p.17) argue that the daylight factor will provide a ‘convenient arithmetic measure’ for the daylighting in an interior space and a greater degree than the illumination level in a certain point for representing the subjective effect.

2.2.1.2 **Distribution of daylight**

Daylight calculations are concerned with the average daylight level on a reference plan or at a given reference point, yet to evaluate the variations of the penetrated daylight inside a room, reference points at specific locations in the room must be presented. The location of the reference points on the reference plane depends on the precision required for the daylight distribution survey in a room. It is therefore possible to locate some reference points in less well-lit parts of a room at a certain height above the floor to ensure that the minimum daylight factor demanded by building regulations is met. The reference plan could be horizontal like a table, meaning that the height would depend upon the nature of the task, or it could be vertical like a wall. However, in a large open-plan area, the average daylight level over a horizontal plane would be more practical to measure the distribution of daylight throughout the room (Hopkinson et al., 1966, p.81).

The penetrated daylight received inside a room depends on the sky luminance, cloud coverage, outside obstructions, size and position of windows. On the other hand, the design of decorations, i.e. colour of interior surfaces and partitions inside a room determine the reflection of daylight inside. The window design and interior decorations are controllable, but the sky luminance is not. To work with natural light simultaneously with geographical considerations is a fundamental step that has been considered by architects, urban planners and designers since the earliest times. For example, the Egyptian Imhotep, in his architecture that drew links between the sun and medicine (Hobday, 1999, p. 130), had an innovative use of light in temple design. It came from a deep understanding of the harsh climate of the desert landscape and the effects of sunlight in creating a three-dimensional formalisation inside the built space, revealing the contrast between light and shadow. The Roman Empire adopted the Passive Solar orientation for its cities and designed their architecture of windows and baths based on the solar availability (Ring, 1996, p. 717). Marcus Vitruvius, who wrote his famous *Ten Books on Architecture*, put recommendations on a building's orientation and solar design. He presented a technique to well secure the natural light inside buildings, which involved placing a window in the part of building where a clear view of the sky would be available (Vitruvius, 1999, p. 82). In modern times, plenty of noted architectural pioneers, such as Tadao Ando, Louis I. Kahn and Le Corbusier, have designed sophisticated buildings through a careful understanding of the site conditions and daylight availability. Tadao Ando, for example, is known for his complex choreography of light and shadow patterns in his abstract architecture, seen in the Church of the Light and Koshino House.

From the above factors, it is clear that many conditions should be considered along with a conscious analysis before calculating the daylight inside a room. In a northern European context, cloudy conditions have a significant effect on the daylight distribution inside the built environment, which is explained further in the daylight analysis. However, façade design also plays a vital role in controlling the penetrated daylight inside a room, in that it should be responsive and sufficient to climatic conditions.

2.3 **Facade**

'Façade' is a new term coined in Europe around the 18th century. Before that, it was known specifically as the thin outer layer or surface of a solid mass. Later, the classical features of façade dominated in Europe and were controlled by the traditional codes and concepts of orderliness, composition, facility, orientation, profile, embellishment, signification, and rigidity. Later on, due to technological development mainly in the 20th century and the effects of economic and political forces in material assemblages, facade as a notion became more advanced with a high-performance concept of 'bigger glass, the curtain wall, silicone air conditioning' rather than classical symbolism (Koolhaas et al., 2014, 703). In the architectural field, the term was originally quoted from the French meaning of 'face' comparable to ' visage'. As such, in 1656, façade was considered to be a representation of a building's exterior and, according to the Oxford Dictionary, was defined as both: 'The principal front of a building, that faces on to a street or open space' and 'A deceptive outward appearance' (Oxford, 2010).

Façade has become known as the building envelopment that represents the theoretical, structural, and aesthetic aspects of architecture, along with climatic, technological, economic and political factors. In recent years, the contemporary discipline has concentrated more on the construction innovation of facade, in terms of its material embodiment and aperture's design, rather than the superficial representation of it. Stephan Trüby argued that the focus on the façade has decreased since the 19th century, explaining that either the architectural profession has become more concerned about the architectural competitions, or that professions have depended on façade engineers to do the task according to their expertise (Koolhaas et al., 2014). Meanwhile, Oechslin expresses that a façade is not just an architectural form, but is a mixture of circumstances that combines building regulations and architectural aesthetic principles. He explains that in the beginning of the façade fabrication, architects were looking at it as a combination of elements rather than a whole concept. As such, the façade was a result of inductive implications, rather than deductive ones. Its decorative elements, such as columns, capitals and other components, were the base upon which to design and build the façade, rather than its holistic meaning. (Koolhaas et al., 2014, 736).

In this context, one of the most crucial parts of a facade is the window, which is linked with the daylight performance through its size, disposition and glazing materials, with an integrated scheme to provide a view outside. In general, it has been designed to be related to the visual and functional requirements that are needed inside the building. The investigation of façade windows is covered in the following section.

2.3.1 **Façade windows**

The window is an opening on the side of a building, which allows air and light to transfer in and out. It helps to connect the building's occupant with the outside environment, providing physiological and visual rest, allowing occupants to experience changes in time and weather. Before glass was introduced as a material, windows were left open without any covering or were roughly covered with oil paper or marble to reduce heat loss (Phillips, 2004, 15). The main function of a window is to permit light to penetrate inside and provide a view of the outside. Other needs such as ventilation and protection from exterior conditions like noise and weather conditions are also crucial considerations for a window's functionality. The size of window has a major impact too, as a satisfactory light amount with good distribution has a greater effect than penetrated big light quantity. Limitations can include the loss of internal heat, excessive heat gain, noise problems and cost considerations. From this point, the importance of daylighting design stems from the ability to place windows in a careful position and have them a size that lets enough light penetrate inside. These requirements must best serve the quantity and distribution needs for the interior space. The window may have to provide a view in some cases, taking into account the possible problems that may occur, such as excessive light or heat (Hopkinson et al., 1966, p. 16). However, Steane (2011, p. 10) argued that since reinforced concrete and steel were introduced in building construction in the beginning of the twentieth century, the appearance of a wall was dramatically changed and windows lost their depth. Accordingly, the relationship between interior and exterior is becoming questionable in terms of how windows frame the exterior view and how much light they admit.

2.3.1.1 **Weather consideration**

Weather considerations are believed to be a crucial parameter in determining the window's features which, in turn, determines the quantity of penetrated daylight. In the current study, the overcast sky is the uniform type of sky in Scotland, whereby clouds cover at least 80% of the sky dome, and the nature of luminous distribution is about three times brighter at the zenith than at the horizon (Ander, 2003, 5). Scotland’s climatic sensitivity has been observed and recorded since 1659 through using diaries and notebooks, such as the diary of Andrew Hay, who daily recorded the weather for the summer, autumn and winter of 1659 (Schove & Reynolds, 1973). Based on his records, most of his weather observations in Scotland were: ‘rain all day’, ‘gray day’, ‘gray cloudie day’, ‘A fair windie day’, ‘A pretty fair day’ and ‘A seasonable fair day’.

Similarly, the Met Office illustrates the main features of the climate of Scotland, stating that the number of hours of bright sunshine is controlled by the length of day and by cloudiness. In general, December is the dullest month and May or June are the sunniest, whereby the sunshine duration decreases with increasing latitude and distance from the coast. In the western and eastern regions of Scotland, industrial pollution and smoke haze can also reduce sunshine amounts, yet the decline in heavy industry, like in the Clyde valley, has resulted in an increase in sunshine duration, especially in the winter months (Met Office, 2016).

With this in mind, Daroda (2011) argued that the architect has to incorporate environmental aspects from the outset by employing an organised approach to designs to suit specific locations and climate parameters. To achieve a practical and effective design, the architect must first assess the climate of the area by using metrological stations to get the required climate data. Secondly, the data must be analysed based on the user comfort criteria (summer and winter comfort zones) and appropriate design strategies prepared with climate considerations. Finally, the strategies must be combined with other design steps, such as concept, economical and aesthetical considerations, to reduce the negative impact of the environment and sustain the ecosystem.

In this context, environmental-responsive architecture takes the occupant's thermal and visual comfort into consideration with little or no reliance on non-renewable energy sources (Yannas, 2003). One of the exceptional intelligent buildings that has adapted climate-responsive behaviour in response to an advanced techno-centric design approach and poetic response is The Arab World Institute (Jean Nouvel's Institut du Monde Arabe) in Paris (Holstov, Farmer, & Bridgens, 2017). The Southern façade of the building reflects the traditional patterns of Arab geometry (Mashrabiyas) in industrial and ornamental elaborations, whereby the sophisticated photoelectric cells and mobile apertures control the penetrated natural light based on the solar gain and occupant comfort. Meanwhile, the Northern façade is made of aluminium and glass for a more penetrated diffused natural light (Cateloy, 2020). Accordingly, responsive architecture manipulates the design of building components to adapt to the changes in the surrounding environment as well as the needs of people (Meagher, 2015).

One example of an advanced component for the dynamic control of transmitted solar radiation for all weathers is smart windows (Chowdhary & Sikdar, 2021). Smart windows have influenced design and architecture by making intelligent buildings in relation to their ambience (Granqvist et al., 1998), as well as controlling the building's energy efficiency by modulating light transmittance dynamically (Ke et al., 2019). The technology used in smart windows, such as thermotropic, photochromic, electrochromic and liquid crystals technologies, allows the occupant to control the light or darken it in response to direct sunlight (Bonsor, 2020). However, smart windows are considered costlier than regular glass, particularly for large windows. Both the installation and maintenances costs can be high due to smart windows not being common (Mario, 2020).

The major design elements that should be controlled to suit the climatic and geographic conditions of the place are: the shape of the building, fenestration (size, positioning and orientation), building fabric (insulation and thermal storage), solar control (shading and surface finishes) and ventilation (Sarkar, 2011). Some considerations were suggested to make the overcast locations environmentally responsive, particularly for light in classroom environments in U.K (Barrett et al., 2015, p. 18). Firstly, the glazing area and glazing orientation are crucial, in that large windows are preferred for high levels of natural light while taking consideration of orientation to avoid glare from direct sunbeams. Secondly, artificial lighting with good quality and sufficient quantity is needed to supplement the natural light when daylight fades. Thirdly, glare control, such as blinds and external shading, is needed to control light levels. Finally, attention must be given to the deep classrooms, where light levels can deteriorate between the area close to the window and the back of the room.

Different daylighting system designs can be implemented in buildings to improve the daylight performance. Light collectors, both passive (fixed in a certain position) and active (constantly tracking the source of light), are considered some of daylight transport system for overcast conditions (Obradovic & Matusiak, 2019). Rooflights or skylights can provide a higher level of useful daylight, especially if the rooflight-to-floor area ratio is between 0.15 and 0.20 (Wong, 2017), and reflecting mirrors can also be used to reflect and redirect light for high-rise buildings (Kotani, Narasaki, Sato, & Yamanaka, 2003).

2.3.1.2 **Orientation**

The orientation of the window walls is an important parameter to consider in daylighting design. Müeller (2014, p. 237) noted that: 'east-west oriented streets with equatorial and polar-side window walls are preferable in many situations'. Meanwhile, skylights orientated horizontally are considered to be most efficient for daylighting, because they face the full sky's hemisphere of 180°, receiving relatively high luminance from its zenith. So, the skylight window area needs only be 20% of the floor area for a daylight factor of 5%, compared to 50–60% for vertical openings in roofs or walls. Although the skylight is considered efficient for providing daylight, windows at eye level are also crucial for providing an adequate view, which a skylight cannot offer.

R2A Architects (2017) in Switzerland have demonstrated that each climate has a different composition of direct and diffused light as well as different cloud coverage. As such, daylighting strategies vary with site locations and climates. They stated that: 'There is no direct sunlight on the polar-side wall (north-facing wall in the northern hemisphere and south-facing wall in the southern hemisphere) of a building from the autumnal equinox to the spring equinox in parts of the globe north of the Tropic of Cancer and in part of the globe south of the Tropic of Capricorn'. Therefore, houses were designed with minimal windows on the polar side but larger windows on the equatorial-side (south-facing wall in the northern hemisphere and north-facing wall in the southern hemisphere). The architects' argument was based on the notion that the: 'Equatorial-side windows receive at least some direct sunlight on any sunny day of the year (except in tropical latitudes in summertime), so they are effective at daylighting areas of the house adjacent to the windows'. However, light tends to be highly directional in mid-winter, leading to it casting shadows. In different types of buildings, such as educational ones, an uncomfortable glare will be the main issue caused by direct sunlight.

A summary report by (Barrett et al., 2015) gave some advice for designing smart classrooms for UK latitudes. First, a large window is recommending in North-facing, which has uniform daylight throughout the day and year. In contrary, large window should be avoided in South-facing and if it's applied, external shading should be provided to control the penetration of direct sunlight, which cause glare discomfort. Classroom in East and West-facing receive abundant daylight with low risk of glare. Likewise, Version et al. (2013, p. 21) stated that a window at every orientation could provide useful daylight; however, each orientation provides different results as follows:

- North: High-quality consistent daylight with minimal heat gains, but thermal loss during heating conditions and associated comfort problems. Shading possibly needed only for early morning and late afternoon.

- South: Good access to strong illumination (the original source), although it varies throughout the day. Shading is 'easy'.

- East and West: Shading is difficult. Shading is critical for comfort on both sides and heat gain too, especially on the west.

Furthermore, obstructions can impact on the daylight availability. A report by Version et al. (2013) suggested an estimation for the obstruction factor (OF) by sketching the window elevation and shade from objects seen from this viewpoint, such as trees and buildings, from desk height and 3.3m from and cantered to a window. The obstruction factors will be as follows (Figure 2-2): OF=1, view < 50% obstructed. OF= 0.85, view ≥ 50% obstructed. OF= 0.65, view ≥ 70% obstructed. OF= 0.40, view ≥ 90% obstructed.

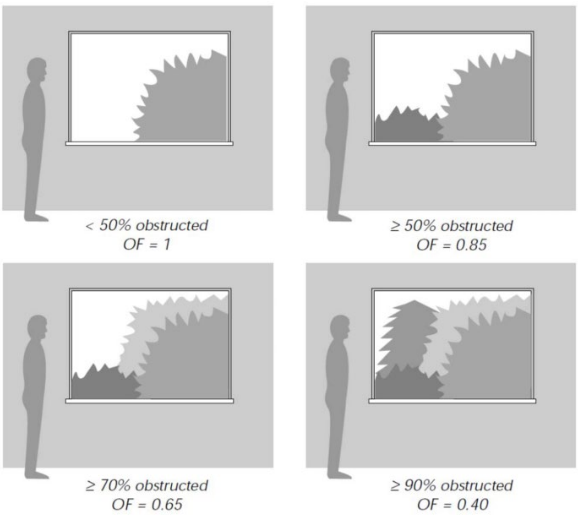


Figure 2-2 Estimating the obstruction factor (Version et al., 2013).

2.3.1.3 **Window-to-wall area ratio**

The window-to-wall area ratio also has a significant effect on daylight performance, in that it shows the acceptable exploitation of natural light and glare risk. Goia et al. (2013) evaluate the impact of window-to-wall area ratio (WWR) on daylight availability for an office in Montreal (latitude 45°). The analysis reveals that 30% WWR for the south façade provides the space with 500 lux on the work plan for 76% of the working time in a year. However, increasing window size by more than 30% does not significantly increase the useful daylight inside, in which the daylighting saturation region should be considered for glass ratio in a South-facing façade. Similarly, the West-facing façade of 40% WWR provides 70% daylight availability and the East-facing façade provides stabilized daylight levels for over 50% of WWR. Meanwhile, the North-facing façade provides stable daylight availability with 50% WWR.

In a different study, Goia (2016) investigates the optimal WWR values in four different climates across Europe: Oslo, Frankfurt, Rome and Athens. The focus was on Oslo (latitude 59°) as it presents the closest weather conditions to Scotland; the study explained that the cold season is the main concern for building design. Using Daylight Autonomy (DA) and Useful Daylight Illuminance (UDI) metrics to assess the natural light for different orientations, the study reveals that the four orientations present similar daylight behaviour conditions for different values of WWR. Still, the south-facing façade shows a risk of discomfort glare. The daylight autonomy values significantly increase in the range of 0.20-0.35 of WWR. In terms of passive solar and heating energy, the south-facing façade shows a significantly different behaviour trend from other orientations and the north, west and east-facing facades present similar trends. In conclusion, the ideal values were found in a relatively narrow range (0.30 <WWR< 0.45). Only south-oriented facades in very cold or very warm climates require WWR values outside this range. The results correspond to the Goia et al. (2013) study results in Montreal except for interpretation related to the South-facing façade.

2.3.1.4 **Room dimensions**

From a different perspective, room dimensions have a significant effect on the daylight distribution inside, where the level of daylight decreases with an increased distance from the window. Therefore, high windows were considered an efficient treatment for more direct daylight distributions. A suggested ratio of 1:2 for the height of the window to the depth of the room from the window would approach the optimum daylight distribution and allow greater penetration (Hopkinson et al., 1966, p.435). Similarly, Version et al. (2013, p. 17) noted that the practical depth of daylighting zone is 1.5 to 2 times the window head height (Figure 2-3) and argued that strip windows provide more uniform daylight than the punched windows, as the breaks between windows may create a contrast of light and dark areas (Figure 2-4). Moreover, the authors suggested that the horizontal shapes of the windows will provide more even light distributions than the vertical windows, the latter being more likely to create contrast between light and dark, even though they provide deeper penetration. With regards to WWR, 30% is the recommended practice for high-performance glazing.

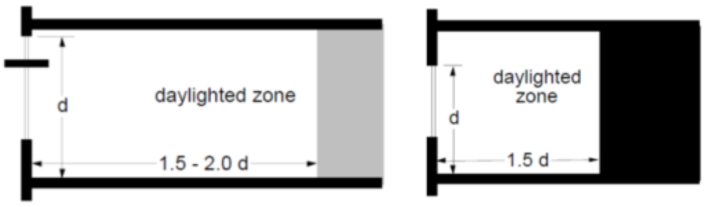


Figure 2-3 Daylight penetration (rule-of-thumb). Right: standard window. Left: window with reflective light shelf (Version et al., 2013, p. 17)

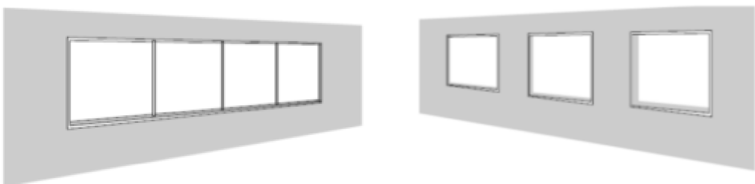


Figure 2-4 Strip windows vs punched windows (Version et al., 2013, p. 18)

On the other hand, Müeller (2014, p. 238) recommends the following room depth for adequate daylighting under overcast sky conditions and a secured daylight factor of 1–2% (Figure 2-5): Room depth = 2.5 x window height above desktop for one window wall. Room depth = 5 x window height above desktop for windows on two opposite walls. Finally, researchers have introduced several rules of thumb (Table 2-1), which have covered the window-to-wall area ratio, window-to-floor area ratio and daylight factor. However, it can be concluded that there is no comprehensive rule of thumb that considers the crucial parameters that could affect the nature of penetrated daylight, such as orientation, room height and windowsill height

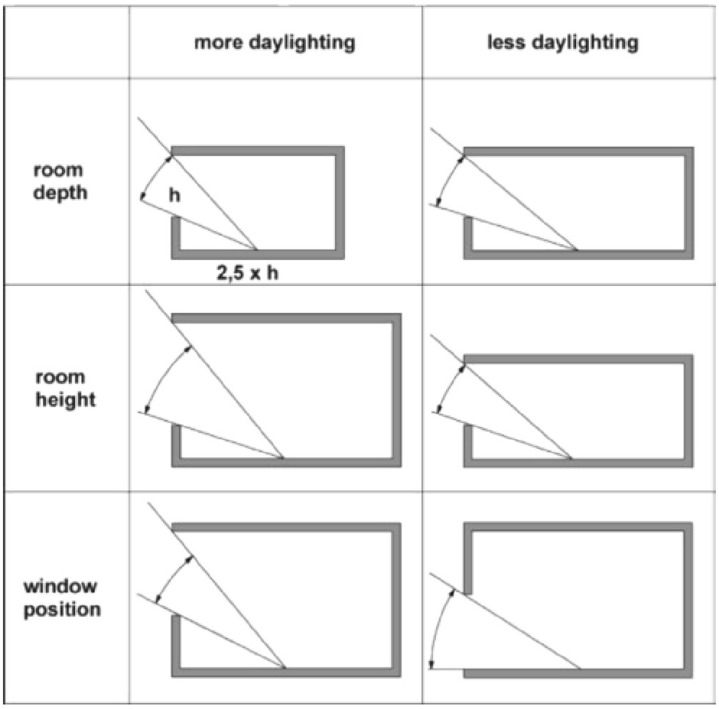


Figure 2-5 Room and window design (h: window height above desktop) (Müeller, 2014).

Aim	Year	Country	Reference	Building type	Rule of thumb	Orientation	Room Height
Maintained illuminance Em on the reference surface							
Artificial lighting	2012	U.K	The SLL code for lighting	Educational building	Recommended maintained illuminance Em¯ on the reference surface to be 300 lux for classrooms, 750 lux for art rooms in art schools, 750 lux for the technical drawing-room, and 500 lux for the teaching workshop	-	-
Window Area to Floor Area Ratio (W/F) %							
Functional purposes	1874	U.K	Architect ER Robson	School	20% ratio	-	-
	20th century	Germany	Price, 1914	School	17% to 25% ratio	-	-
	1966	-	Hopkinson et al. (1966)	-	20% ratio	-	-
Window Area to Wall Area Ratio (W/W) %							
User satisfaction	1972	U.K	The Illuminating Engineering Society	-	20 - 30% ratio	-	-
User satisfaction	1970	U.K	Ne'eman & Hopkinson, (1970)	Educational (Architectural School) and research building	25%- 35%	-	-

	1981		Boyce (1981)	-	15%	-	-
	1999	Hong Kong	Li et al (1999) (Danny H. W. Lit, 1999, p. 215)	Residential	25 - 30%, in which mean value is 27.4%.	-	-
energy conservation	2002	U.K	Energy and Environment in Architecture: A Technical Design Guide. (Nick Baker, 2002, p. 31)	Nondomestic sector small buildings	Increase in heating energy with glazing ratio area heating and lighting energy show almost no increase with glazing area	North-facing glazing South-facing glazing	-
Plan Depth							
	2002	U.K	Energy and Environment in Architecture: A Technical Design Guide. (Baker et al., 2002, p. 44)	Non-domestic sector small buildings	-If a plan is greater than 12m deep, the inner central zones (beyond 6m from either side) will need to be permanently artificially lit. -The intermediate zone between 3m and 6m will be daylit for fewer hours than the outer zone. -A double-height space will allow useful penetration up to 12m.	-	3m Window height close to wall

Daylight Factor							
	2002	U.K	Energy and Environment in Architecture: A Technical Design Guide. (Baker, Nick; Steemers, 2002, p. 44)	-	Increasing the glazing area above 40% of wall area will increase the minimum DF, and low uniformity ratio.	-	3m
	1966	U.K	Hopkinson (Hopkinson, Petherbridge, & Longmore, 1966)	-	The minimum daylight factor is equal to one-tenth of the window to floor area ratio (restricted to rectangular side-lit rooms, up to 5:3 proportions with windows in the long side and without internal and external obstructions).	-	-

Table 2-1 Rules of thumb for the daylight context

2.4 Daylight calculation methods

There are various methods employed to measure daylight, such as surveys (Kim et al., 2014), the use of light metres (Hanna, 2002; Konis, 2013; Bellia et al., 2014; Matour et al., 2017), and computerised methods that rely on software programmes (Chi et al., 2018; Mayah & Hanna, 2019; Ahmad et al., 2020; Queiroz et al., 2020; Kent et al., 2020; Ma'bdeh & Matar, 2020). In addition, HDR imaging technology and techniques are used to capture and analyse the luminance distributions in spaces (Bellia et al., 2015; Chamilothori, 2019; Mardaljevic et al., 2020). This section presents some of the arguments regarding the different methods and techniques used to measure daylight inside buildings.

A study by Tregenza (2017) examined the daylight coefficient and the uncertainty in daylight illuminance calculations. He argued that daylight illuminance is sensitive to changes in the sky and building design; in fact, most studies are concerned about the error in the simulation programme rather than the uncertainty in the daylight modelling process. Hence, daylight should be treated in terms of probability, given its unpredictable nature, especially in climates known for unstable sky conditions and luminance distribution. Buildings change during their lifetimes due to the weathering of materials and the deposition of air-borne pollutions, both of which are significant factors that bring uncertainty to daylight calculations. In the short term, changes in furniture layout, use of blinds, curtains, and decoration of surfaces are also relevant.

In another study, Tregenza & Mardaljevic (2018) reviewed the codes, guidelines, regulations, and standards on daylighting design criteria. The paper argued that there is a lack of consistency between countries in adopting daylight regulations, standards, and metrics. Some regulations are based on the illuminance level as an absolute value, while others require the daylight factor be calculated as a percentage value. In addition, Tregenza noted that there is a practical difference between mandatory standards, which are concerned with the minimum acceptable level of illuminance, and the codes and guides created by professional organisations to describe good practice. Thus, the characteristics required for any standard should be as follows:

- They should be able to provide beneficial and clear outcomes;
- Conformities must be few, related to the purpose, testable in a realistic time, and at a reasonable cost;
- There should be consistency in results when reproduced or repeated by all relevant parties. In terms of metrics, illuminance levels in buildings should be measured after construction, furnishing and decoration processes are complete, and when the buildings are in actual use.

2.4.1 Daylight metrics

Daylighting design principles, methods, and performance were critically reviewed by Wong (2017), who assessed the strengths and weaknesses of different calculation methods and daylighting systems. The study indicates that the daylight factor (DF) can be predicted using a scale model with artificial sky, computer simulation programmes, or field measurements within a real building. Although the daylight factor excludes the effect of orientation and direct sunlight, it remains a widely used parameter in assessing and representing the daylight illuminance in a building. Wong identifies about 50 methods used to determine interior illuminance in studies, experiments, and procedures.

Similarly, Alshaibani's study (2016) found that the most widely used method for predicting daylight illuminance is the average daylight factor (DF_{avg}). A study by Li et al. (2014) proposed an approach for calculating the average daylight factor for a room under overcast and non-overcast skies. However, the author argued that the original average daylight factor method is not sufficiently accurate to predict the variations of illuminance as the position of the sun undergoes dynamic changes under a non-overcast sky. The authors evaluated the proposed method by comparing it with results obtained from a lighting simulation programme (Radiance); the average daylight factor data predicted by the proposed method was found to be in good agreement with the simulated programme results. The study recommended that the accuracy of the proposed method be checked with more reliable surface reflectance and diffused sky data.

Mardaljevic (2013) examined the current daylight evaluation practices and suggested ways to improve on the recent attempts in advanced daylight evaluation. Regarding the daylight factor (DF), the author noted that design guides link the DF, measured as a percentage, with absolute illuminance level, measured in lux. Hence, relative DF does not necessarily constitute a rigorous representation of the actual illuminance level. In addition, it is assumed that overcast skies only exhibit uniform brightness across the sky dome, and so have constant luminance. However, it has been revealed that overcast skies exhibit a relative gradation luminance, from the darker horizon to the brighter zenith; the zenith is often three times greater in luminance than the horizon for most overcast skies.

Furthermore, Mardaljevic proposed that the average daylight factor should not be based on mean measurements. Instead, the median would serve as a more robust indicator of a single quantity of daylight performance to characterise a daylit space, as it removes the effect of outliers when representing the distribution of DF. Some measurement points are significantly different from other points due to the variability among the measurement points. For example, in spaces with a vertical opening on one wall only, the DF value close to the window is significantly higher than at the back of the studio, which in turn affects the average DF value, which is sensitive to the proximity of the sensor grid to the opening. Lighting Guide 5 (LG5), therefore, recommends a perimeter zone be set between sensor points and the opening. With regard to daylight simulation programmes, it has been argued that the sky models (sky luminance patterns) used by the generator programmes are not based on local meteorological conditions, but instead rely on the location of the place, latitude, longitude, and sun position (time of day, year, and solar radiation).

From a different perspective, Reinhart et al. (2006) encouraged the use of dynamic daylight performance measures for sustainable building design. These metrics focus on the site-specific and dynamic interactions between a building, its occupants, and the surrounding environment, including the climate, on an annual basis. The current quantitative performance metrics used to implement daylighting in a building are daylight factor, view to the outside, and avoidance of direct sunlight. However, the authors argued that optimising the daylight/glazing factor and view to the outside does not necessarily lead to enhanced daylighting design. This is due to the many limitations associated with the daylight factor metric, as it does not consider season, time of day, variable sky conditions, direct solar ingress, building orientation, or location. Hence, the daylight factor cannot detect whether a glare problem will occur; nor can it help to develop glare prevention strategies for different façade orientations. The same issues are associated with the view to the outside as its benefits are dependent on the type of view and affected by the movable shading devices often used where there are glare issues.

In order to prevent direct sunlight while also making daylight factor predictions in parallel (combined approach), building orientation and latitude are considered; however, no consideration is made of the actual climate in which the building is located, the type of building, and the occupants' requirements. Furthermore, there are practical limitations associated with shading devices. The combined approach only considers static shading, such as lightshelves, as the performance of dynamic shading devices such as venetian blinds are difficult to measure.

On the other hand, dynamic daylight performance metrics that use three-dimensional CAD software as well as a daylight simulation model are based on time series of illuminances or luminance within a building. They consider the quantity and seasonal variations of daylight for a particular building site. The most well-known simulation software is the Radiance-based daylighting package, which includes metrics such as daylight autonomy (DA), continuous daylight autonomy (DA con), and useful daylight index (UDI). While these metrics have become alternatives to the daylight factor metric, they do not necessarily provide holistic predictions of good daylighting, because the absolute benchmark levels are still missing. The results show that different performance metrics lead to different mean rating results in different façade layouts, orientations, shade controls, and illuminance requirements. As a result, a metrics-based approach to daylighting still presents certain limitations.

To predict the internal illuminance per hour for a full year period, Mardaljevic (2000) described a procedure that depends on sky and sun conditions obtained from meteorological time-series data. The typically adopted procedure, as noted in the paper, starts with using climate data, including global and diffuse irradiance from weather tape or TRYs (Test Reference Years). The irradiance data is converted into illuminance values using a luminous efficacy model. Then, a distribution of sky luminance is created using a sky model to calculate internal illuminance. Finally, the requirements of artificial lighting are determined using a lighting control algorithm. However, as this procedure is considered to be time consuming, even with multi-processor workstations, the daylight coefficient approach is more efficient in computing long-term daylighting performance in buildings.

A new paradigm, known as useful daylight illuminance (UDI), was introduced by Nabil & Mardaljevic (2005) to assess daylight in buildings and provide an alternative approach to the daylight factor (DF). UDI uses absolute illuminance values predicted on an annual time-series under real sky conditions generated from standard meteorological datasets. The illuminance values are within the range of 100 to 2000 lux based on occupants' preferences and behaviour reports in daylit offices with shading devices. A further examination of the UDL metric is presented in (Azza Nabil & Mardaljevic, 2006) study. The UDI metric is designed to evaluate and interpret the daylight illuminance levels from climate-based analyses that present hourly levels of daylight illuminance levels under realistic, time-varying sky and sun conditions for a period of a full year.

Meanwhile, other approaches like the standard daylight factor evaluate illuminance as a percentage, which, it is argued, is inappropriate for representing realistic daylit conditions. This is the case with the Daylight Autonomy metric (DA), which indicates the percentage of time (annual daytime hours) that daylight levels are above a specified target illuminance (illuminance threshold) within a physical space or building. This metric can be used to help determine how long an occupant can work without the need for artificial lighting. However, the authors argued that DA cannot be used to measure daylight illuminance levels below the targeted threshold. It also cannot measure the amount by which threshold illuminance has been exceeded in any given instant. Hence, the UDI paradigm reduces the size of the illuminance time-series data when presenting daylight illuminance. It also provides information about the potential for unwanted solar gain and occupant discomfort due to excessive daylight levels. The UDI scheme proposes three ranges of hourly daylight illuminance levels over a year at each of the calculation points as follows:

1- within the range defined as useful (i.e. 100–2000 lx)
2- below the useful range (i.e. less than 100 lx)
3- above the useful range (i.e. greater than 2000 lx)

The authors stated that these ranges are useful levels of illumination for an informative metric. If the illuminance levels are below the minimum range, the visual perceptions will likely not occur. On the other hand, visual and/or thermal discomfort will occur if the illuminance levels are above the maximum range. To examine the UDI paradigm in greater detail, the authors compared it with two other daylight assessment techniques: daylight factor (DF) and daylight autonomy (DA). For this comparison, a simple 3D model of a four-storey open-plan building with a central light-well was constructed using Radiance. The results show that DF and DA present similar distributions overall, whereas UDI presents inverse patterns. Nevertheless, the authors argued that UDI constitutes a more informative and comprehensive form of daylight assessment. It provides more insights into the dynamics of daylight illumination in terms of spatial and temporal aspects by considering a range of illuminations related to human comfort factors, rather than merely considering a single threshold value, as is the case with DA. Further research was recommended to better understand the high illuminance levels presented in UDI so as to assess its suitability as an indicator for low usage of electric lighting. There is also the need to determine the implications for cooling requirements.

Brembilla & Mardaljevic (2019) reviewed five climate-based daylight modelling (CBDM) techniques and metrics based on the Radiance engine and compare them with a benchmark CBDM method. The authors argued that this is the first systematic study that compares multiple metrics used in CBDM simulation, as these metrics and techniques are rarely assessed against each other, even though they have been developed for more than two decades. The modelled spaces in this study are four existing school classrooms and the examined simulation techniques are the 4-component method, DAYSIM, the 2-phase method, the 3-phase method, and the 5-phase method. The evaluation is based on an inter-model comparison, combined with sensitivity analysis, given that the performance evaluations are highly sensitive to the choice of CBDM software, the initial model configuration, and user assumptions. The findings show that metrics that consider both direct and inter-reflected light are more robust. The representation of direct sunlight is significantly different between CBDM techniques; metrics based on horizontal direct sunlight are sensitive to the type of simulation method. The orientation and sky discretisation scheme were also found to affect some metrics, while the spacing of virtual sensor grid and time-step interpolation have no effect on the metrics and techniques.

In another study, Brembilla et al. (2019) compared Radiance-based simulation techniques for performing Climate-Based Daylight Modelling (CBDM) to simulate Complex Fenestration Systems (CFSs). The study was conducted on a modelled classroom with three different shading systems: diffuse venetian blinds, specular venetian blinds, and perforated solar screens. The three shading systems were simulated using five simulation techniques: the 4-component method (4CM), DAYSIM, the 2-phase method (2PH), the 3-phase method (3PH), and the 5-phase method (5PH). The results show that the CBDM Radiance-based methods are extremely varied in reproducing the effect of direct sunlight onto and through fenestration and shading systems. The main study limitation is that it lacks a reliable validation measurement dataset, such as sky luminance distribution and direct normal illuminance, for the various scenarios to compare them against the simulated values. Moreover, the validation procedures in each case were different and so present different levels of rigour. Therefore, further work is needed on the validation of CBDM techniques in simulating façades containing CFSs. Also, further research is recommended to enhance the understanding of the relationship between simulation and reality by considering data measured in real spaces and relating them to the CBDM techniques.

Mardaljevic (2004) examined the assumptions made in validation studies for lighting simulation programmes. The validity of the assumptions was tested using luminance-mapped measurements of real skies. However, as the paper argued, in the simulation model, it is difficult to present with high levels of certainty the actual occurring conditions. As the setting of the building used for the validation study is unlikely to be identical to the actual conditions, the scenario will be imprecise and incomplete. For example, moderate imprecision in measuring the effects of surface texture on reflectivity can lead to uncertainty in illuminance and daylight factor results. The assumption of CIE overcast conditions based on a limited range in global horizontal illuminance was found to be unreliable. The representation of urban buildings in lighting simulation programmes presents many issues, such as glazing and surface articulation, which can affect reflectivity.

Therefore, as the paper noted, the validation tests should be repeated to check for consistency. To determine the programme's accuracy, a critical comparison of the validation methodologies should be made, as well as comparisons of the two scenarios to detect any fundamental qualitative differences between the settings that may cause conflicting findings. It is proposed that the Radiance programme, which has been validated based on the benchmark BRE-IDMP study, has high predictive accuracy in heavily obscured urban settings. The BRE-IDMP is a controlled scenario of a full-size office space under real sky and sun conditions with similar settings of urban buildings. However, new validation studies are recommended, especially in urban settings.

Finally, Ayoub (2019) made a chronological review of daylight predictions and calculation methods over the past 100 years. The study was conducted to remove the ambiguity surrounding unfamiliar terms and technicalities in order to guide architects' use of suitable daylight tools in building design. Furthermore, the paper illustrates the need to increase architects' awareness of daylighting simulation programmes before employing them in practice. The study proposes several evaluation criteria, such as usability (user-friendliness, cost), accuracy (functionality, validation), interoperability (adaptability with design phases), and exchangeability (integration with other programmes).

2.4.2 **Field measurements vs simulation**

Many studies rely on field measurements to validate daylight calculations generated using software programmes (Galasiu & Atif, 2002; Mardaljevic & Mphil, 2004; Reinhart & Andersen, 2006; Bian & Ma, 2017). However, it has been found that using software programmes presents certain issues, as explained in a study by Yu et al. (2014). The quantitative analysis of this study, which included field measurements in selected rooms, was conducted in the University of Nottingham's Engineering and Science Learning Centre in the UK. The aim was to calculate the daylight factor and validate the results with the DF result of the RELUX artificial lighting simulation programme. When comparing the results of the two methods, a difference was found: the simulation programme registered a higher value than the field measurements. However, the authors argued that the deviation between the two methods (around 20%) is within the accepted range. The study reports the difference as follows:

- The simulation programme did not consider the thickness of the building façade, which led to a higher result in the simulated values of the DF near the window compared to the measured ones at the same location inside the building.

- The effect of the surface reflectance on the surrounding buildings, external ground reflectance, and external shading devices may not be the same as the reality.

- The simulation programme used a standard CIE overcast sky, but, during field measurements, the sky was completely overcast.

- Measuring equipment error may affect the DF value.

Based on the above, it can be concluded that computer-based simulation programmes offer both a cost-effective solution and accurate predictions for daylighting calculations. However, the simulation programmes must be validated by experimental and field measurement work, which makes the programmes applicable only to the initial stage of building design or prior to conducting real field measurements. With this in mind, although real field measurements are considered a challenging and expensive prospect (Tregenza & Mardaljevic, 2018), they can still be considered more accurate and reliable, as they provide more rigorous results for longer periods of measurements (Wong, 2017).

Furthermore, it was found that the software programmes do not rely on local meteorological conditions and that the type of sky (sky luminance distribution) still poses problems in decision-making (i.e. standard overcast sky vs standard sky or uniform sky). Furthermore, Tregenza (2017) considered future conditions, such as the deposition of dirt on glaze openings, which is a determining factor affecting daylight quantity. He also addressed issues such as the use to which a room will be put, and future furnishing, decoration, and outside obstructions, such as trees and buildings, all of which can obstruct daylight. The author further explained the sources of uncertainty in daylight quantities, arguing that buildings change significantly during their lifetimes. These long-term changes include the weathering of materials, the deposition of air-borne pollution, and significant effects caused by cleaning and maintenance. Meanwhile, short-term changes are dependent on user behaviour, such as choices of furniture layout, decorations, and the use of blinds and curtains.

2.5 Evaluation of daylight in educational building

The importance of daylight in the indoor built environment has been highlighted by many researchers to securing an adequate daylight inside spaces. In this section, the review will be limited to the current findings, theoretical and methodological contributions that relate to the objective aspect of daylight within the educational building domain.

Hopkinson et al. (1966) rule suggests that if a window area to floor area ratio is approximately 20–25%, the daylight factor obtained will not be less than 2%. This rule of thumb has also been applied to educational buildings (classrooms) in the U.K by the architect E.R. Robson (Wu & Ng, 2003) and has been examined in different latitudes as in Lukman et al.'s (2010) study. However, the study concludes by using daylighting simulation programs that latitude angle which confirmed that has a crucial role in the applicability of window area to floor area ratio rule of thumb. For different geographical latitudes, such as temperate areas, this rule of thumb will secure different average illumination levels, which may lead to brighter conditions than required. ~~As such~~, the study argues that to obtain an average illuminance of no less than 500lux under an overcast sky, the latitude angle should not exceed 40°, and to be valid in temperate areas, the room's windows must be facing away from direct sun.

A study by Hanna (2002) investigated the daylight performance in the Glasgow School of Art (GSA) building in Scotland for an environmental appraisal of the historic buildings project. The study conducted the field measurements using light data loggers over the summer and winter in a studio facing north, as well as using questionnaires that covered areas of acoustics, lighting, thermal comfort, ventilation and the importance of living inside a historical building. The data was analysed using a statistical test to find correlations between users' overall impressions of the building and environmental variables. The study results revealed that students were satisfied with the luminous environment, although daylight levels were relatively low in winter and too high in summer.

Similarly, a study by Barrett, Zhang, et al. (2015) examined 153 classrooms within 27 selected schools in the United Kingdom. The data collection consisted of a detailed survey for each selected classroom and school, measuring architectural elements such as the room dimensions and zone layouts. In addition, field measurements were conducted to assess the environmental conditions, such as light, temperature, humidity, CO2 levels and acoustics. A questionnaire-based interview was carried out with teachers to investigate their experiences throughout the entire year.

The study results revealed that the physical characteristics of schools' impact significantly on their occupants and provided recommendations for design parameters that should be considered, most importantly those related to the factor of light. The study noted that natural daylighting must be supplemented by good quality and quantity of electrical lighting for when the daylight fades. High glazing areas are optimal, yet must be moderated to avoid glare from direct sunlight. Glare control factors, such as blinds and external shading, are functionally effective in controlling light levels. In terms of the window orientation, the study demonstrated that a very large south-east glazing ratio is considered poor, while a large east-facing glazing ratio is considered good. Also, a small north-facing glazing ratio is considered poor, while a small south-facing glazing ratio is considered good. In conclusion, large windows orientated without direct sunlight (E, W, NE, NW and N) had better results than those receiving direct sunlight (S, SE and SW).

From a different context, few studies have been carried out using different methodologies in the evaluation of daylight performance. Michael & Heracleous

(2017) investigated the performance of natural light within educational schools in Cyprus; a total of 114 educational buildings for secondary education all over Cyprus were studied. The study used multiple evaluation criteria, including both qualitative and quantitative elements. These included a questionnaire-based survey (of 400 students) alongside static and dynamic simulations to investigate the performance of the natural light and assess the visual component. Field measurements were taken on one day during the summer solstice to verify the simulation. The study argued that this holistic approach could be used to evaluate other areas of a similar climate, such as areas of southern Europe and illustrated the importance of orientation when dealing with lighting contrast, like glare.

Similarly, Zomorodian & Tahsildoost (2019) evaluated daylight performance (both dynamic and static daylight) and visual comfort through using a longitudinal subjective survey (842 total responses) and simulation-based metrics (Rhinoceros 3D & DIVA) in four classrooms in two LEED™ silver certified buildings in Texas, USA over the course of a year. The study methodology consisted of five stages: selecting case studies based upon pre-determined criteria, determining and calculating the daylight and glare metrics using a simulation programme, conducting a subjective survey to assess the students' perceptions of the investigated visual environment, undergoing statistical analysis and finally correlating and rating the study’s metrics.

According to the LEED static daylight metrics, spaces with an average DF of lower than 2% are considered ‘not adequately lit’, while a DF between 2 and 5 is classed ‘adequately lit’, and a DF over 5 is considered ‘well lit’. The study indicated that because of the high cost and time-consuming process of field daylight data collection, researchers rely on simulation results to analyse daylight availability and glare. However, surface reflectance was measured using two Lux meters, i.e., one facing towards the surface and the other facing away from the surface. The survey was carried out in February, May, September and December 2016 during class hours to demonstrate different months, days and sky conditions. Likert's seven step spectrum was used to rank the students' visual comfort, covering issues such as daylight availability on the desk, degree of glare when viewing the windows, daylight distribution in the classrooms, problematic glare occurrence, and satisfaction with overall visual comfort. The results indicated a high correlation between students' perceptions and dynamic daylight metrics. The main limitation however was that it was carried out in just one type of space, climate and location (classroom, Texas-USA). As such, the study recommends applying the research in other areas and with different window configurations.

From the data given above, it can be concluded that although real field-measurements can be considered more accurate and reliable in evaluating daylight levels, there is limited research that adequately considered it, especially in big projects such as in high educational buildings. Researchers tend to use real field measurements to validate the simulation results only, as it is considered costly and time-consuming. Accordingly, a major research gap has been detected in evaluating daylight levels in educational buildings based on real-field measurements as well as in overcast locations.

2.6 Discussion

The literature review for this chapter addresses the investigation of daylight from theoretical and empirical scholars. The physical perspective of daylight involves calculations of illuminance levels and daylight factor was demonstrated in order to assess the objective aspects that are more desirable and acceptable when articulating scientific judgments towards the nature of daylight. Therefore, comprehensive methods and tools have emerged to complete daylight calculations, such as field measurements using light meters and software programmes using computer simulations that still require verification of results by field measurements. Although daylight studies have covered a wide range of theoretical and practical investigations, there has been no integration between these two aspects in order to determine a holistic realisation for the daylighting inquiry.

The needs to secure sufficient daylight throughout a building requires careful design work, considering elements such as orientation. Version et al. (2013) and Barrett et al. (2015) found that the North-facing window provides consistent and uniform daylight with minimal heat gain, while the South-facing window provides strong illumination because of direct sunlight, which causes glare and excessive heat gain if it's not controlled by external or internal shading. Meanwhile, the East and West-facing window receive abundant daylight with a low risk of glare. In respect of window-to-wall area ratio (W/W%), most of the literature, such as the Illuminating Engineering Society (IES, 1972), Ne'eman & Hopkinson (1970) recommended the range between 20-35%. Similarly, window-to-floor area ratio (W/F %) was recommended to be within the range of 17-20%, as explained in Hopkinson (1966) and Robson (1874) studies. However, the recommendations were based only on the user satisfaction and did not consider the orientation nor the room dimension.

There have been many studies on the objective aspects of daylighting in different contexts, such as in the United States (Fang & Cho, 2019), China (Cheng et al., 2018), the Republic of Korea (Boafo et al., 2019), Turkey (Ashrafian & Moazzen, 2019), Iran (Bakmohammadi & Noorzai, 2020), Argentina (Boutet, Hernández and Jacobo, 2019), Chile (Moreno & Labarca, 2015), Jordan (Freewan & Al Dalala, 2020), Lebanon (Omar et al., 2018) and Europe (Chinazzo et al., 2020). However, this study identifies a major contextual gap in that there have been limited empirical studies conducted in the U.K (Scotland, in particular) that take daylight aspects into consideration. Furthermore, studies recommend that to best evaluate the daylight performances of climate regions and orientations; numerous methodologies must be employed to achieve a comprehensive prediction. However, researchers tend to use simulation in evaluating daylight levels and considering to use real field measurements in a small scale to validate the simulation results only. Based on the mentioned gaps, more investigations focusing on real-field measurements as well as in overcast locations were needed.

Chapter 3

Atmosphere: The first impression

3.7 **Introduction**

This chapter sought to give some insight into the new paradigm of atmosphere as a phenomenological subject in architecture. The fundamental aim is to understand the circulation between atmosphere, façade fenestration and daylight, and their applicability in the built environment within pedagogical and experimental contexts. As atmosphere considers a contemporary theory and a prominent topic that adds a poetic dimension to space, its applicability to translate the aesthetic tendencies into sensible patterns of thoughts was aimed to adapt into further investigations, in which basics concepts and assumptions from philosophers and architectural thinkers have been underlined.

Daylight, as one of atmospheric generators, can evoke impression, emotions and sensations. It has a metaphysical connotation with the experienced atmosphere, yet, the rational attitude for both of them have not been dominated in the discourse of interior architecture. The challenge of this chapter is to highlight the benefits and opportunities that daylight can offer, not only in that they are responsible for making things visible, but also in terms of their hidden phenomenological effects on the occupant's experience. Within this, it has been argued in different scholarships that optimizing the daylight attributes will enhance the experienced atmosphere inside spaces.

Although different measurement methods, such as simulation, have been adapted to quantify the effect of façade openings and daylight on humans' impressions and understanding of experienced atmosphere, field daylight measurements had to be conducted only to test the simulation's reliability in analysing the daylight attributes. Consequently, crucial insight from literature is recommended as a means to investigate the subjective responses to the relationship between façade fenestration, daylight and experienced atmosphere in a real environment, rather a visualised area or lab room. This recommendation stems from the fact that a significant difference between real and visualised rooms has been found in some studies, and other factors may impact the investigation, such as outside view and furniture arrangements.

The chapter is divided into four sections; the first one covers the theoretical interpretations of atmosphere by various authors within phenomenological, ontological and aesthetical perspectives. Section 2 covers the relationship between atmosphere and daylight and their role in the built environment. Section 3 presents the latest studies related to the scope of measuring atmosphere in different contexts. Finally, the last section summarizes and discusses the scope of the current review.

3.8 **Theoretical framework of Atmosphere**

The term "atmosphere" originally appeared in the eighteenth century as part of the meteorological field. It's been clarified as an invisible ocean, a layer of gases surrounding our planet and acts as a gigantic filter, keeping out the harmful ultraviolet radiation from living things on Earth (National geographic, 2020). In the dynamic science, atmosphere is a system depends on the motions driven by the sun's radiation upon the air and water' (Gill, 1982, p. 15). It is divided into different segments, in which its radiative heat leads to density differences that in return causes motion (Gill, 1982, p. 36).

In the built environment, atmosphere was employed to metaphorically describe moods, in which it is known as "tuned space": something spatial and emotional (Böhme, 2017, p. 2). However, Vogels (2008, p. 26) argued that atmosphere differs from emotion and mood in the sense that it is a more stable and less complicated concept; it is not: 'an affective state, but...is the experience of the surrounding in relation to ourselves'. Therefore, despite the fact that emotion and mood each being affective phenomena, they remain distinct from each other. Emotion can be defined as the: 'bodily sensations or feelings that typically manifest themselves to us through bodily agitations or disturbances, and we refer to it by terms such as fear, joy and nostalgia', while mood is the: 'mental response that often causes emotions, and typically lasts longer than emotions' (Deonna & Teroni, 2012, p. 4).

'*when a building manages to move me*...such a beautiful, natural presence, things that move me every single time' (Zumthor, 2006, p. 10).

According to Stewart (2011, p. 449), atmosphere can be considered: 'the collective saturation of the senses' which move in and through bodies, spaces, rhythm and tempo to pull textures and density. Likewise, in his book, *Atmosphere*, Zumthor described atmosphere as possessing an "architectural quality" which he likened to the sensation and confessed it as a first impression: 'I enter a building, see a room, and – in the fraction of a second - have this feeling about it' (Zumthor, 2006, p. 12). While Griffero (2014), in his book Atmospheres: Aesthetics of Emotional Spaces expresses that: "atmosphere" can be either a neutrally descriptive expression (the atmosphere can be harmonious or suspicious), or implicitly (and positively) axiological, in the sense that by exclaiming 'what an atmosphere!'. He argues: 'atmosphere can, paradoxically, be everything and nothing' (Griffero, 2014, p. 5). With this in mind, the next section goes on to discuss the phenomenological and ontological manifestations of atmosphere, in terms of experiencing it from the first-person point of view to its reality of existence.

3.8.1 **Phenomenological and ontological manifestations of atmosphere**

Phenomenology is 'a form of philosophy that attempts to give a direct description of first-person experience' (Casey, 2001, p. 683). It is the study of essences (Schmidt, 1985, p. 35) that focuses on sensual experience, rather than experience by thought or intuition. Ponty defined Phenomenology as the 'universal reflection investigation, not only on thought, but on lived experience'(Merleau-Ponty, 2002, p. 15), in which it is defined 'as a pure act of constituting consciousness' (Schmidt, 1985, p. 41). This intangible relational phenomenon translates to atmosphere. According to Griffero (2014, p. 5), atmosphere is: 'a qualitative-sentimental *prius*, spatially poured out of our sensible encounter with the world' which exists as 'something that is chronologically at the start and objectively at the peak of the hierarchy'.

However, from an ontological perspective, atmospheres vary in intensity and have different arrangements of objects, humans, nonhuman creatures and technologies that characterized by changing and multiplicity (Edensor, 2017, p. 140). These elements are important because: 'they have qualities, rhythms, forces, relations, and movements' which add varying intensities to the capacity of atmosphere (Stewart, 2011, p. 445). On the other hand, atmospheres should not be considered as beings or things, due to them not existing without a subject feeling them: 'they do not exist as entities which remain identical over time; nevertheless, even after a temporal interruption, they can be recognized as the same, through their character' (Böhme, 2017, p. 30). Duff (2010) claimed that: 'affective atmospheres capture the emotional feel of a place, as well as the store of action-potential, the dispositions and agencies, potentially enactable in that place' (Duff, 2010, p. 881).

Edensor (2017, p. 140) added more conflict on the nature of atmospheric manifestation by argues that atmospheres are also affected by many other factors, such as personal experience, shared knowledge of local, national, or global events, or by prior circumstances related to place and event. Meanwhile, Böhme (2017) developed the concept of quasi-things in his book *Quasi-Things: The Paradigm of Atmospheres*, where he claimed that quasi-things maintain their own ontological category and do not exist in our conventional sense, like events or substances. Instead, they hold a power over us and our frame of mind. Böhme argued that atmosphere is responsible for suggestive moods due to the vagueness of its nature (International Ambiances Network, 2017).

From the previous interpretations of atmosphere, it seems quite sensible that they added a powerful clarification of its existence. However, the absence of inclusion, cooperation and intellectual intuition between the two manifestations; phenomenological and ontological of atmosphere, cause a mislaid in the holistic understanding for a new critical theory. It is not surprizing to reach to this conclusion as phenomenology and structuralism have been in paradoxical discourses within Philosophy and architectural field (Haddad, 2010, p. 2). By this, I would argue that all meaningful contributions to the concept of atmosphere could be considered as personal opinions rather an objective one, in which the "logic of reflection" (Sedgwick, 2002, p. 9) must be articulate to reach an acceptable manifestation of atmosphere as a holistic concept in the built environment. A better clarification could be reached, if more insight put into how can we perceive the atmosphere? A subject articulated in the section below.

3.8.2 **Atmospheric perception**

The Italian philosopher, Griffero (2014), argued that atmospheric perception exists emotionally and holistically in our world. He discussed atmospheric perception as follows: 'perceiving an atmosphere means grasping a feeling in the surrounding space, definitively the most important thing for men, implied by any subsequent clarification, both sensible and cognitive' (Griffero, 2014, p. 15). The argument confirmed by Zumthor (2006), who proposed that atmosphere is perceived: 'through our emotional sensibility - a form of perception that works incredibly quickly, and which we humans evidently need to help us survive'.

While the German philosopher, Schmitz, explained atmospheric perception through his theory concerning the felt body, corporeal sensation, and corporeal dynamics – subsequently called Schmitz' theory. Schmitz (2011) argued that the personal subject can be divided into two fundamental spheres: the material body and the immaterial soul. In contrast with physics and geography, Schmitz' interpretation of space is a: 'pre-dimensional surfaceless realm, manifest to each of us in an undistorted corporeal experience rather than being a locational measurable space'. Schmitz argued that the felt body itself is a surfaceless space or: '...more precisely an assemblage of many such spaces'. Consequently, the felt body can be defined as a feeling body that presents: 'an absolute location of subjective orientation and opens the dimension of a pre-dimensional, surfaceless space' (Schmitz, 2011, p. 244). Thus, the only way to perceive an atmosphere is by the "felt body" (Leib) rather than the material body (Körper) (Michels, 2015, p. 256). As Griffero (2014, 16) noted 'perceiving atmosphere mostly means being touched by them in the felt-body', therefore, its mode of existence and a manifest to the conscious subject in particular kinds of corporeal feeling.

Schmitz goes on to argue that emotions neither exist nor emerge from an individual's consciousness, but instead are: 'atmospheres poured out spatially which move the felt (not the material) body' (Schmitz, 2011, p. 247). In this way, atmosphere is taking surfaceless space around the conscious subject and then dynamically engaging with the felt body. As emotions are merely half-entities that rely on being experienced by a person, their existence may easily be interrupted (Michels, 2015, p. 256). They depend largely on one's personal affective history, meaning that: ‘they are only accessible to the person through their individual perspective shaped by personal experience’ (Schmitz, 2011, p. 256). It useful to return here to Griffero (2014) who noted that “the eye can certainly touch” and keenly articulates that our felt atmosphere within a particular place results from our bilateral perception of our co-perceived (kin-aesthetically, syn-aesthetically, pre-categorically) corporeal situation, and how our feelings and evaluations occur in that place rather than within an absolute metaphor. Thus, atmospheres are not metaphors, but are instead feelings and quasi-things spread out into space. The atmosphere, therefore exists in between the place that spread a qualitative mood (the object), on the other hand, the person who feels and participates in this mood (the subject) or as Schmitz called, the felt body (Griffero, 2014, p. 121). This claim is confirmed by Böhme's opinions (2017), for he defined atmosphere as the: ‘powers poured out into the lived space we inhabit’ (International Ambiances Network, 2017). He goes on to suggest that it: ‘is what relates objective factors and constellations of the environment with my bodily feeling in that environment’ (Böhme, 2017, p. 5). He insisted that atmosphere is intermediate phenomena, one belonging neither to the individual person nor the outside world but invariably diffusing between them. As such, atmosphere spreads between the subjective and objective realms.

‘atmosphere is what is in between, what mediates the two side’.
(Böhme, 2017, p. 5).

However, Schmitz would disagree, claiming instead that atmospheres do not exist without a subject experiencing them: ‘to talk about atmospheres, you must characterize them by the way they affect you’ (Böhme, 2017, p. 6). He argued that perceiving atmospheres indicates on experiencing phenomena (Griffero, 2014, p. 124). A concept confirmed by Vogels (2008), who explained atmosphere as: ‘the experience of the surrounding environment in relation to ourselves, which takes place through the perception of external elements and internal sensations’ (Vogels, 2008, p. 25). She argued that atmosphere is not a particular feeling rather, it contains the potency of changing people’s affective state. Therefore, from their points of view, atmospheres should not be considered as beings or things, due to them not existing without a subject feeling them: ‘they do not exist as entities which remain identical over time; nevertheless, even after a temporal interruption, they can be recognized as the same, through their character' (Böhme, 2017, p. 30). Accordingly, Michels (2015) addressed an important issue in questioning how we approach atmospheres. He considerd whether we should investigate the spatial and material qualities of a place, or if we should concentrate on how the place has been experienced by its inhabitant. Michels proposed that the best approach to research atmosphere is a third option: in between the human and non-human components (Michels, 2015, p. 255).

It is important to mention that the aesthetic theory has its roots from ecological aesthetics and sensory cognition discourses. As such, Böhme (2017, p.1) considered atmosphere as being the prime sense of the aesthetic and a theory of sensory perception. He argued that the feeling we sense in a particular place is evidence of the aesthetic qualities of it, and their aesthetic factors are just as important as natural factors in terms of affecting human beings in their environment. Consequently, the elements of the environment impact the human beings and so have a critical value in producing an impression on human feeling. Zumthor (2006, p. 6) also considered atmosphere to be an aesthetic category. Meanwhile for Griffero & Tedeschini (p.2, 2019), atmosphere and aesthetics are considered a plural perspective, in which atmosphere has taken out from the conception of focusing on human emotions to be an effective quality of space. This realization that atmosphere can relates to objective factors (environment) with the subjective feeling in that environment means that atmosphere 'is what is in between', in which the phenomenon of atmosphere can be approached by two different sides: the perception aesthetic and the production aesthetics (Böhme, 2017, p. 2). Figure 3-1 presents the conceptual framework, which encompasses key theoretical concepts of atmosphere.

As noted above, it could be seen that Phenomenology is not enough to interpret how we approach atmosphere. Yet, a more empirical consciousness is crucial to recognize its existence. This empirical subjective knowledge is called psychology or more specifically, cognitive psychology; a subjective assessment focused on people's perspective toward their place. The bounded domains of Phenomenology and Psychology are found in what Merleau-Ponty call "chiasmus", a concept that added ontological explanation to the phenomenology of perception. (Schmidt, 1985, p. 30). Meanwhile, Edmund Husserl would call that parallel domains as “Phenomenological psychology” or “rationalism” (Merleau-Ponty, 2002, p. 6). However, it cannot be taken as granted, as an objective measurement is needed to reach to a holistic investigation as previous arguments explained above. Within this, a new knowledge is known to link between two sides, called Psychophysics, a branch of psychology that deals with the relationships between physical stimuli and sensory responses. Psychophysical studies are designed to establish functional relationships between a physical stimulus (e.g., radiant energy, temperature, sugar content) and a subjective reaction (e.g., brightness, thermal comfort, sweetness) (Houser and Tiller, 2003, p. 183).

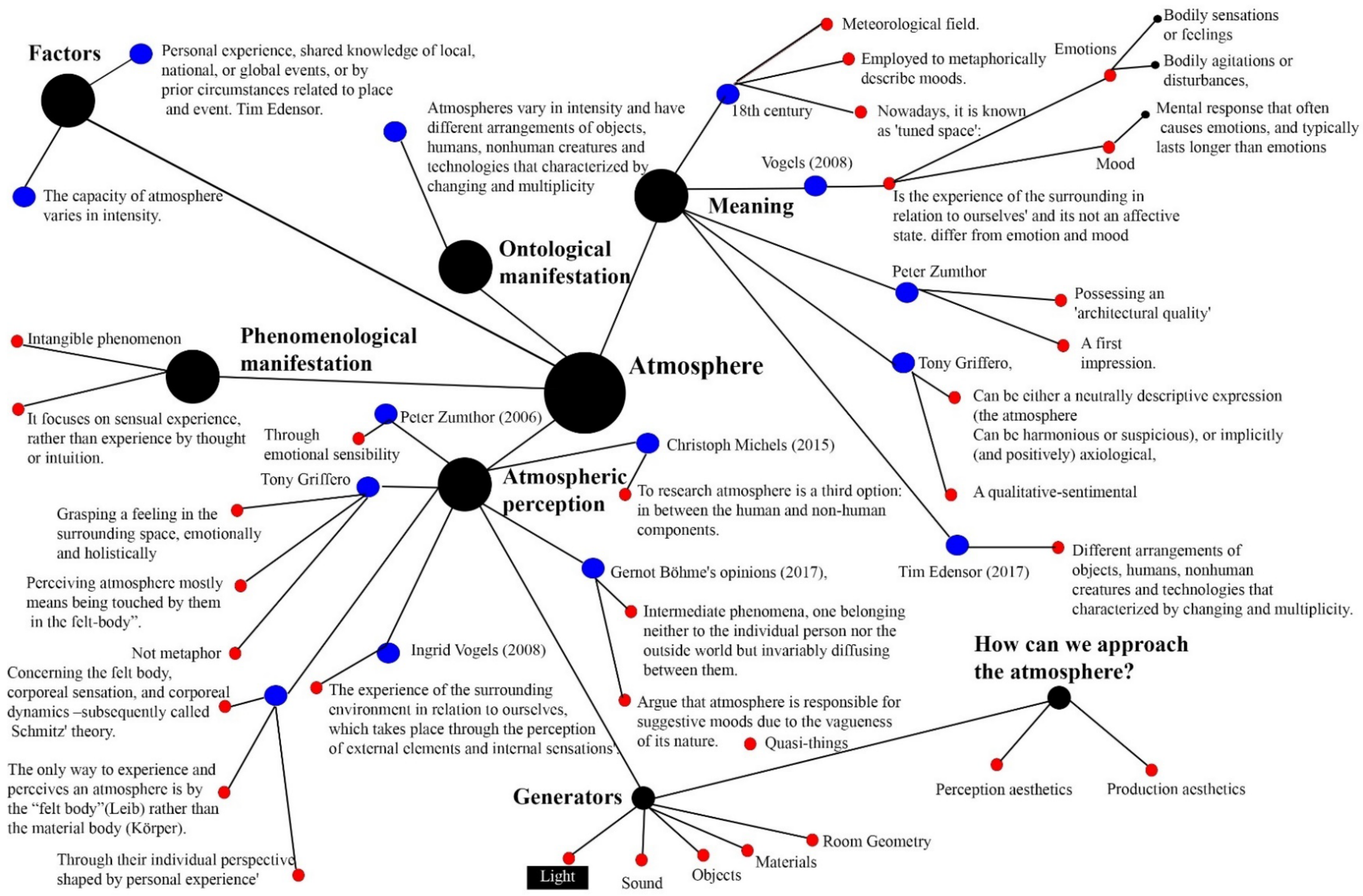


Figure 3-1 Conceptual framework of the key theoretical concepts of atmosphere

3.8.3 **Researcher interpretation**

Atmosphere, within its phenomenological, ontological, and aesthetic dimensions, still requires an operational interpretation derived from the experienced space. Tuckmen's (1972) operational definition is something identified by making a stable observation of an object or phenomenon, rather than based on any conceptual, hypothetical, or abstract criteria or synonymous form. The operational definition has three main types: type A is concerned with the process or operations that cause the state; type B focuses on the dynamic properties that allow the state or object to operate; and type C concerns the static properties (Tuckmen, 1972, p. 58). The process by which atmosphere can be operationalised from its abstract form to observable characteristics is presented in the bubble diagram below. Figure 3-2 presents the three types of operational definition of atmosphere based on the researcher's observations.

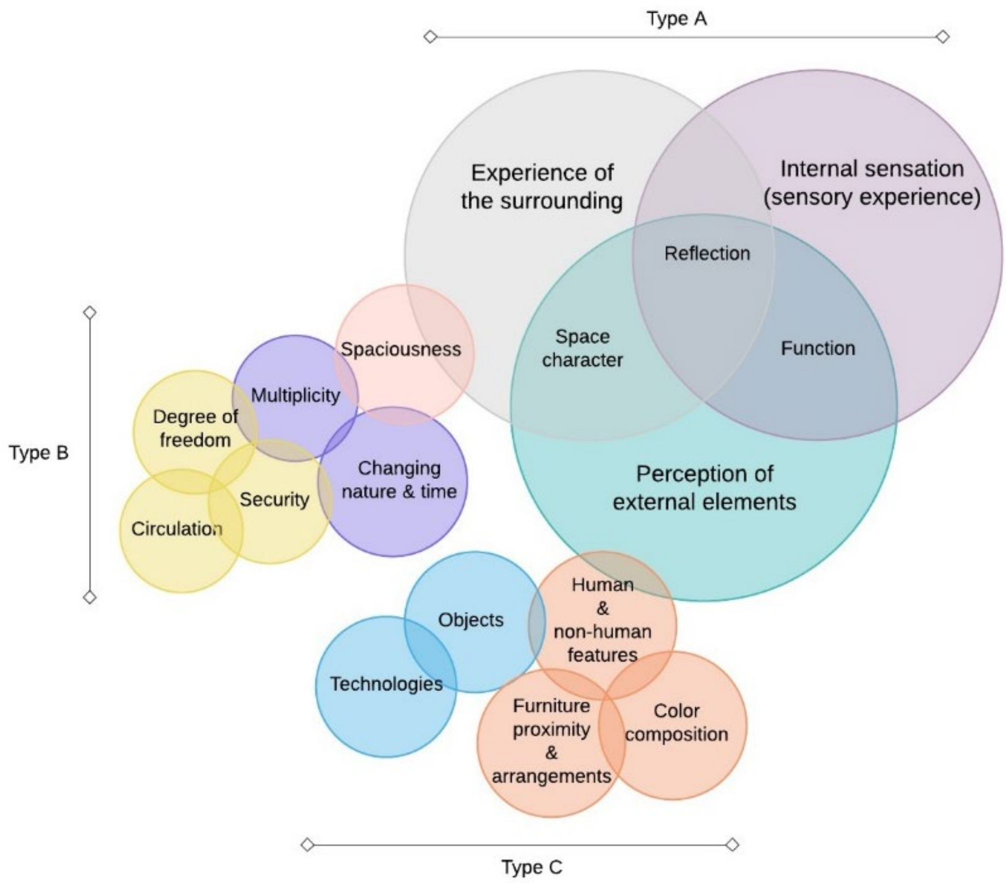


Figure 3-2 Three types of operational definition of atmosphere

Based on the conventional definition of atmosphere, it is the first impression one has when entering a space. It is an invisible field of phenomenological factors diffused within the place that spreads a qualitative mood (the object); and the person who feels the atmosphere and participates in this mood (the subject). Nevertheless, in this thesis, I will attempt to interpret atmosphere as a physical phenomenon - something magnetic. If I feel something, then it exists; and if it exists, then it has an ontological dimension - it is a physical. But, why is it an invisible field?

After around four years of reading, observing, and experimenting in relation to the subject of atmosphere, I experienced a major shift in my thoughts about the phenomenon. The first concept I worked on was related to the “spirit of place”, or what (Norberg-Schulz, 1980) terms “Genius Loci”. The investigation, which began during my master’s study, was carried out in the Templeton building on Glasgow Green. The mysterious and spiritual concept of the “spirit of place” was materialised in the building by its previous events (it had originally been built as a carpet factory) and its magnificent façade, considered a praiseworthy design for an exotic building. Figure 3-3 presents an analysis of the Templeton building, Glasgow.

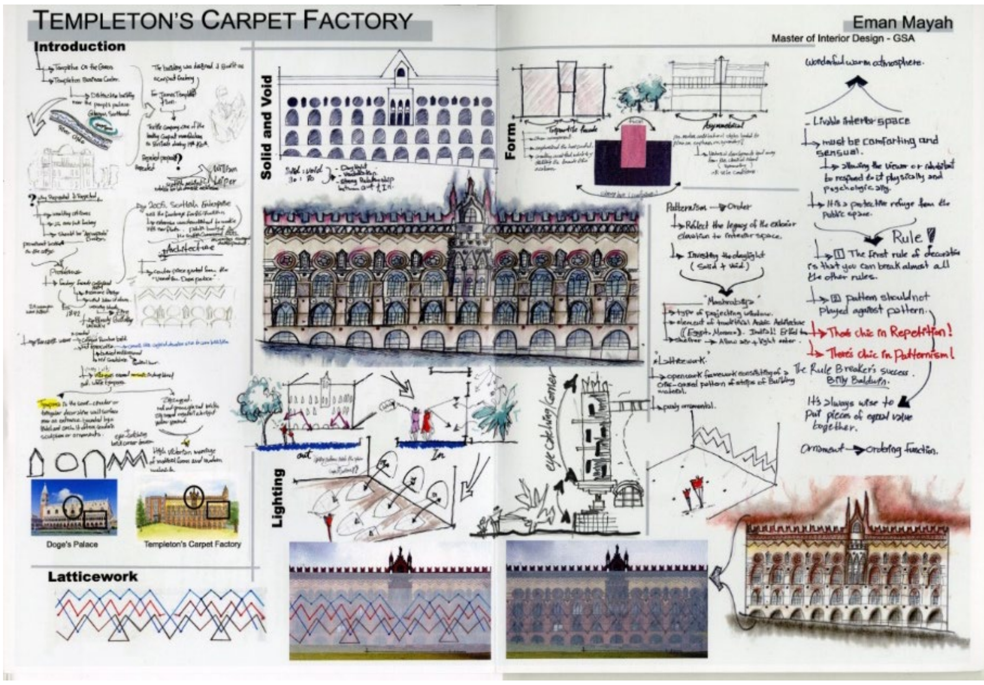


Figure 3-3 Analysis of Templeton building.

It has been argued that the magic of space can be found if a building's code is defined as follows: 'A code allow[s] space not only to be read, but also to be constructed' (Lefebvre, 1991, p. 7). Here, the building's code is embodied in its design; its materials, colours, and forms are all significant components that engage smoothly with one another to fabricate a special design language, or, in other words, a character. 'There can be no thought, no reflection, without language. And no language without material underpinning - without the senses' (Lefebvre, 1991, p. 402).

The Templeton building's "bonnie" character relies on the aesthetic expression of its three-dimensional masses and vernacular colours, which reflect human civilisation and the strength of society. Nevertheless, and most importantly, the building has an auric field, an enigmatic phenomenon whereby a person is incorporated into the "experience of space". The aura is the unseen "spiritual" energy field that surrounds all living and non-living things; however, some people who suffer from migraines can see and recognise the aura. With this in mind, spiritual science connects with the science of energy dynamics to describe the light, sound, frequency, and, most importantly, electromagnetic energy.

Thus, the auric system consists of the invisible electromagnetic fields that surround us. Starting from the Earth's geomagnetic field, which extends from the magnetic minerals and rocks to our bodies, which have their own internal magnetic fields generated by electrical activity in the excitable cells and nerve impulses. The aura extends to 1-1.5 m around the healthy body. Our thoughts and emotions are also linked to this invisible energy, in the form of our physical, mental, emotional, and spiritual energies.

Since the aura extends from inside everything, I would argue here that atmosphere is not the in-between phenomena, or diffuse between subject and object. Rather, as Alexander posits, 'it is a process through which the order of a building or a town grows out directly from the inner nature of the people, and the animals, and plants, and matter which are in it' (Alexander, 1979, p. 7). Hence, atmosphere is a process by which new collections of auras are fabricated via the collisions of electromagnetic fields in a space. It is an operation that creates an invisible physical stimulus sphere, which acts as the fifth spatial dimension of space (besides width, height, length, and time). It is a momentary process controlled by time, in which peoples' and objects' presence in a space, past events, and future expectations exert forces on each other to create different frequencies of the magnetic field, ultimately generating a system.

3.9 **Atmosphere and light**

Light considers an intangible building material in the built environment. It has various functional, aesthetical and psychological benefits, which makes it a crucial element in the design of building environment. The striking importance of light in our life is not merely because of its ability to represent the change of time and lit spaces, but also for its intangible ability to form our environment. It has been suggested that light affects mood, attention, performances and impacts the synchronisation of the biological clock (Bellia et al., 2013), as such, awareness has increased of the non-visual effects of light that can be received by the human eye (Andersen et al., 2012, p. 37). With this in mind, how can the daylight contributes to the atmosphere?

Böhme (2017) proposed a crucial insight regarding the study of light from the phenomenological approach rather than a physical fact. He argued, the brilliance, the flickering, the glow and shadow are all related to the "sense of the eye" (Böhme, 2017, p. 205). The phenomenological manifestation emerged because light is not something tangible, its nature is primarily the "brightness" as it's the basic experience of light. Brightness is a phenomenon that belongs to light, but with transcendental meaning 'It turns sight into a real capability in the first place, and enables visible things to be seen in reality' (Böhme, 2017, p. 206). Likewise, in his book *Light and Emotions*, Laganier (2011) explaind that brightness: '...refers to the subjective perception of two "objective" physical characteristics: the intensity and the amount of light' (Laganier, 2011, p. 15). Brightness, then is used to increase the understanding of a space and create a sense of hierarchy.

Böhme (2017) described the space that light creates as a “clear space”, which its illuminate quality gives a distinctive advantage and essential emotional experience; security and freedom. Security is based on the distance that applied on everything, and that distance led to the freedom of movement (Böhme, 2017, p. 207). Yet, it's not necessarily to perceive the source of light in order to experience the clear space, as its phenomenological nature is linked to the experience of brightness and shadow.

To let light manifest its own voice within all the surrounded qualities, the key is to know how to experience it. Zumthor (2006) proposed some questions to best understand the experience of light, beginning with how and where the light falls, the shadow locations and whether the surface property is dull, sparkles or has its own depth. To answer, he proposed two concepts: the first, to: ‘plan the building as a pure mass of shadow then, afterwards, to put in light as if you were hollowing out the darkness, as if the light were a new mass seeping in’ (Zumthor, 2006, p. 58). The second concept was to choose materials based on how well they reflect and match other qualities together accordingly: ‘...to go about lighting materials and surfaces systematically and to look at the way they reflect the light’ (Zumthor, 2006, p. 58).

However, it is important to mention that more light does not necessarily mean better light. Ramos (2015) noted that it is a mistake to believe that increased quantity equals increased quality. Ramos used the term “light pollution” to reference the lack of scientific approach when using artificial light (Ramos, 2015, p. 173). However, this issue also can be reflected to natural light in which too much penetrated light would cause what is known of glare.

3.9.1 **Light and darkness**

Initially, the concept of light belonged to a dualistic conception of the world (Blumenberg, 1993, p. 32); clarity and shadow. Shadow is the great unknown (Garnermann, 2017) that involves darkness, and both are exist in relation to light. Edensor (2017) argued that our experience of light is often a subconscious one, suggesting that it: ‘...takes place in the unremarkable settings of everyday realms and as part of the quotidian routines in which we are entangles’ (Edensor, 2017,

p. 27). Edensor goes on to say that the perception of gloomy and luminous spaces can be considered an: ‘existential dimension of living in the world, of the experience of place and time’ (Edensor, 2017, p. vii).

Although the quality of luminosity and murkiness (in terms of patterns and rhythms) affects how people sense, perceive and understand a place, other factors like time, season, and weather also contribute to our experience of light. Moreover, Edensor demonstrates that the intensity of light, the depth of darkness, and the qualities of the surfaces (reflect, deflect, absorb) contribute fundamentally to our experience. Accordingly, both light and darkness possess qualities that impact our perception and sensation of the world. They are ubiquitous and have different effects on places (Edensor, 2017, p. ix). Light and darkness like day and night, have poetic power that make a space alive by optical adventure and tremors (Plummer, 1987, p. 75). They are: ‘like fire and earth, fundamental primordial principles’ (Blumenberg, 1993, p. 32).

‘A respect for darkness is a key tenet’ (Art in the open, 2004).

It is crucial to understand the concept of darkness in order to realise the meaning and experience of light. Blumenberg (1993) noted that light does not necessarily have to exist in contrast with darkness – a concept which he clarifies by introducing the concept of being and non-being, truth and appearance, from a dualism reliance on their opposite. ‘Being does not exist because it is not-Being (since not-Being would then be necessary for its Being), and light is not essentially the opposite of darkness; rather, in the essence of light, darkness is destroyed and overcome’ (Blumenberg, 1993, p. 33). Although Plummer confirmed that light and darkness have powers to make spaces alive as noted above, he contradicts later by expressing that “Exhilarative light” will raise the spirit, while “grim light” will bring them down (Plummer, 1987, p. 139). For Louis Kahn, he argued that there will be no space with dark, a space cannot be defined unless it has a natural light that evoked moods by changing time during the day and seasons during the year.

‘I would say all spaces need natural light . . . all spaces worthy of being called a space need natural light. Artificial light is only a single little moment in light . . . and natural light is the full of the moon and it just makes a difference’ (Kahn, 1961, p. 14).

It is not surprising to have this negative image about darkness as a polar opposite to the light in which certain concepts such as danger, fear, fall and collapse have always been related to it. In contrast, Tadao Ando argued that the spatial reverberations and the subtle patterns created by light and shade would be forgotten if darkness lost its significance (Dal Co et al., 1997, p. 458). An approach is well known in the traditional Japanese architecture, where the powerful relationship between light and darkness is highly presented. The quality (beauty) should come from the reality of life, and the variations of shadow against the light shadows are the base of beauty in the Japanese room (Jun'ichirō, 1977, p. 18).

Within this, I argue that a holistic approach of light and atmosphere can be reached by understanding how the light behaves and interacts within objects inside space. The degrees of brightness to darkness and darkness to brightness within the context of architecture, in particular, geographical context, would help to understand its ability to generate a particular language of atmosphere inside spaces. By this, no more ambiguity, yet a particular appearance would be formulated, a subject has its own dimensions known as the character of space.

3.9.2 **Daylighting and interior character**

Daylight has a powerful ability to change forms and spaces through the interplay between light and shadow. The appearance and the character of the interior space are highly linked with the daylight by the modelling effect. Francesca Bettridge, a lighting designer from the USA, explained that light does not merely provoke an emotional reaction, it also affects the way people appear in a space: ‘that’s then evokes the emotions’ (Laganier, 2011, p. 214). As one of the daylight accomplishments is its “intensification of time” (Plummer, 1987, p. 141), we associate time with daylight changes, such as blue light for morning and golden light for the evening. In our contemporary world, various designers and pioneers in architecture have been working to secure daylight within buildings for functional and aesthetic reasons. It's become as a prestigious way to represent the magnificent of the building. Yet, the considerations of cost that would be needed for a good lighting design, make it a need to compromise between what is perfect and what is cost affordable (Hopkinson et al., 1966, p. 2).

'Great buildings that move the spirit have always been rare. In every case they are unique, poetic, products of the heart' (Platt, 2013: p. 8).

For Louis Kahn, light provides a character to space with the consciousness of its possibilities (Kahn, 1961, p. 14). In addition, it is been argued that the character of space is related to four factors; the space geometry, the source of light; in terms of intensity, direction and colour, surfaces properties, and human factors, such as visual perception and movement (Gill, 2006, p. 24). However, I argue to add one more factor, which is the building geographical location, where light attributes in different locations are highly affected by the generated character.

Norberg-Schulz (1980) noted that every place has its own light, which tells us how and where we are in that particular place. With his popular phrase "Let there be light!", he continued to express that light and things belong together; where light appears, there is a place as mood and thing, thing and mood. He argued that the investigation of illumination is not the ultimate way to study light, but rather that light, things and places must be understood in their joint relationship. Norberg-Schulz concluded his argument by returning to the phenomenology of light, things and places, which are derived from the notion of sky and earth, where the sky is the original source of light and earth is its manifestation (Plummer, 1987, p. 5).

Peter Andres, a lighting designer based in Germany, described how he created a lighting design that would create the right atmosphere to give people a sense of well-being. The location is in Germany, so the weather is rainy and cloudy most of the time, such as in Scotland. He explained that the correct design for light comes from considering the local weather conditions, in which the design he created was based on a transition from a diffused light, to slightly more direct light, to absolute direct light. He argues that the combination of diffused and direct light makes people appear healthier and consequently behave friendlier. As he demonstrated: ‘It’s all about the temperature of light’ (Laganier, 2011, p. 204). This concept dictates that colour is always associated with light, and cannot be separated because of its nature. Ramos (2015) argued that in order to investigate light within a context, it is necessary to understand how the colour of light works, and to consider the colour of objects which absorb or reflect the components of fallen light (Ramos, 2015, p. 15).

Similarly, Schielke (2019) stated that windows, luminaires and lighting patterns in space embody signs that consequently enhance the quality of lighting and impact on generating an identity for the space. As such, lighting as a sign is highly implemented in retail environment and urban design as an architectural expression and a communicating message with people, in which it could offer a medium for visual communication, psychological effects and aesthetic narrative in architectural context.

From above, light is not only considered from a scientific angle; its aesthetic and phenomenological manifestations also play important roles in our lives. Its influential abilities in architectural spaces can be maintained through understanding its nature, behaviour and conditions, then introducing other architectural forces around, such as function and beauty in a holistic integration.

The previous thoughts about modelling effect (time), space geometry, source of light, surface properties, colour, window, human factors, things, and places are all linked with the interior character. However, a character is not only about the qualities and features that identify and distinguish a place. It’s a message of proportion, association and integration of interior elements. Therefore, a character can be expressed by “theming” the interior to evoke a certain meaning and feeling. With emphasising on daylighting, it has a distinctive manner with the interior character through its source, direction, depth, colour, and intensity. Figure 3-4 presents the conceptual framework, which serves as a classification system for the key theoretical studies of light.

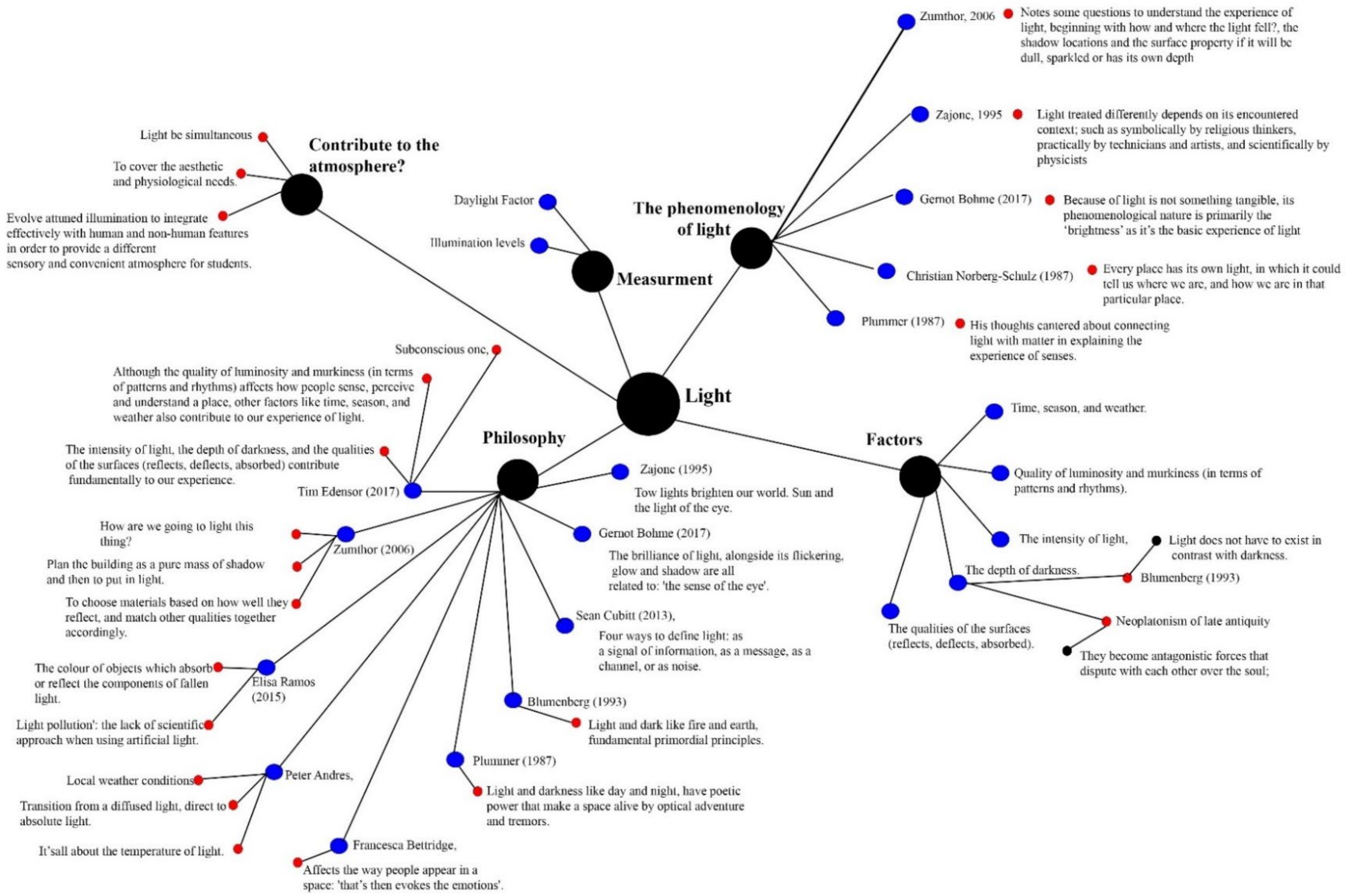


Figure 3-4 Conceptual framework for the key theoretical studies of daylight

3.10 **Quantitative treatment of façade fenestration and daylight on atmosphere**

Based on the Empiricism theory of Francis Bacon, knowledge must come from sensory experience that based on evidence rather than on intuition. As experiment is tentative, probabilistic and subject to falsification, the scientific methods of the following studies are guided by the experiment and validated measurements tools.

3.10.1 **Virtual reality**

Various studies have addressed the role of daylight each from their own perspective. In the subject of virtual reality, many researchers have chosen this method, as daylight experiment in a real-life context is complex in its nature and expensive in resources. Chamilothori et al. (2018) presented a novel projection technology, a virtual reality (VR) as an empirical tool for investigating the perceptual effects of daylight and subjective experiments by comparing the subjective evaluations of a real space and its representation in virtual reality, using a VR headset and a questionnaire. The findings demonstrated that both techniques, real vs virtual, have close matching in terms of how they were perceived. However, the virtual work should be perceptually realistic and tricky to be distinguished from the reality (Loomis et al., 1999).

A thesis by Chamilothori (2019) investigated the effects of façade and daylight patterns on human responses by using virtual reality (VR) as an experimental tool along with rating scales. The impact of façade geometry, sky type and spatial context on the participants' subjective responses was examined in different countries: Switzerland and Greece. The thesis concluded that both the façade and daylight patterns consistently impacted the spatial experience (pleasant, interesting, exciting, calming and complex) and the spatial attributes, such as brightness, spaciousness and satisfaction with the view in the space. Moreover, the study found no differences between the participants' responses in the two investigated contexts, making it possible to generalize across latitudes in

Europe. The thesis recommended that experiments should be conducted in a real environment with real-world settings to test the robustness and generalisability of the perceptual effects of façades, as presented in the thesis. Furthermore, more studies are essential to examine the impact of different façade attributes, such as ratio, depth and material of façade, on human responses.

In another study, Chamilothori et al. (2019) investigated the impact of façade geometry and sunlight patterns on occupants' subjective perceptions (how pleasant, interesting, and exciting the space was perceived) and physiological responses (heart rate and skin conductance) through virtual reality. Three façade configurations with an equal opening ratio (irregular distribution of openings, regular distributions of openings and venetian blinds) were applied with different space scenarios (social and working contexts) to an interior space with a clear sky and direct sun penetration. The study concluded with the significant influence of façade and sunlight geometry on subjective and physiological responses within both context scenarios. However, it argued that the use of VR method limits the luminance range, which in return cannot detect the discomfort, and because of the limited exposure time period for each façade variation, the generalizability of results is restricted. In addition, as the study asked participants to imagine the use of space, the effect of spatial contexts, such as variations of furniture or activities, are lower in virtual reality than in the actual room. As such, the study recommended further research, where occupants can spend more amount of time in evaluating the façade variation.

In a similar piece of work, Moscoso et al. (2020) examined the effect of three different window sizes, two context scenarios (socialising and working) and three different sky types (overcast sky and clear skies with either a high or low sun angle) on the perception of both a small and a large space at high latitudes via virtual reality. The study concluded that window size significantly affects perceptual impressions, whereby the large window size caused more positive evaluations of how pleasant, interesting, exciting, bright, complex, and spacious the space was perceived. However, the study argued that the use of virtual reality controls the presented visual stimuli, restricting the luminance range of the investigated spaces, limiting the exposure time to the presented scenes and leading to the evaluation being based on a fixed position in the space. Therefore, the study recommended that further studies be conducted in real environments to investigate the perceptual effects of the different studied factors, as well as comparing the studied variables to other demographic groups and in different latitudes.

3.10.2 Questionnaire

Castilla et al. (2017) investigated students' affective responses, within a university classroom, to determine the most appropriate design elements to produce a certain affective response. The study used the semantic differential method to implement the investigation, which comprised the following factors: functionality and layout, cosy and pleasant, concentration and comfort, modern design, daylight and outward facing, and finally the artificial lighting. The study concluded that changing the classroom layout to improve functionality and enhance the cosy-pleasant atmosphere were the main two aspects necessary to improve the classroom environment.

In another study (Castilla et al., 2018a), the affective impressions of university students, in terms of luminous environment and different carried tasks, were analysed using subjective evaluation scales and the semantic differential method (SD). The data was then analysed using factor analysis and Spearman's correlation coefficient to identify the luminous environment according to the activities or tasks performed inside the classroom. The study identified the affective structure of students in relation to the classroom's luminous environment: surprising-amazing; clear-efficient; cheerful-colourful; uniform; intense- brilliant and warm-cosy. Finally, the findings show that the luminous environment should produce different types of sensation to adapt to the different teaching tasks, such as writing-reading, reflecting-discussing and paying attention tasks need to be in different luminous environments.

In further study, Castilla et al. (2018b) evaluated students' opinions of artificial lighting using subjective assessment over a period of four years. A questionnaire was prepared to capture the students' first true impressions within six expressions: attractive, efficient, cutting-edge technology, stimulating, comfortable and cosy. Likewise, Ricciardi & Buratti (2018) investigated the thermal, acoustic and lighting conditions with university classrooms using subjective and objective measurements, in which the combination between them provide a complete investigation for classrooms environmental quality.

In Vogels' (2008) study, a method was presented to quantify the perceived atmosphere using the questionnaire method within different kinds of environment, mainly shops and restaurants. The study proved the robustness and sensibility of the questionnaire in terms of quantifying atmospheric perception. Vogels' designed questionnaire was used in Chen's (2014) thesis to quantify the atmosphere and field light measurements conducted in real laboratory space and a visualised room. The thesis questioned how the perceived atmosphere is affected in both a real and virtual environment. The results demonstrated minimal effects of daylight on the perceived atmosphere from the northern side. Therefore, it was recommended that the effect of sunlight from the southern side on light attributes and perceived atmosphere should also be investigated. With regards to the difference between the real and visualised rooms, the study found significant differences in their atmospheres.

3.10.3 **Mixed methods**

Bellia et al. (2015) developed two methods to investigate the luminous environment: the HDR imaging technique and the measurement of light's characteristics at users' eye levels in field measurements. The paper illustrated an innovative measurement system to investigate the light quality in an educational environment by using HDR imaging technology. The study justified its importance by indicating that most of the educational buildings in the study area (Italy, in this study) did not comply with the given lighting standards, making it necessary to investigate their current situation. Therefore, a comprehensive lighting analysis was needed to evaluate the non-visual effects of light. The study argued that to analyse the light's characteristics, it should be conducted at the users' eye level to best evaluate the non-visual effects of light. As field measurements could be “tricky”, it was decided that a new “fast” measurement method was required on several visual tasks at the same time.

In another study, Bellia et al. (2013) analysed the impact of daylight and electric light on occupants in a university classroom, using field measurements to record the outdoor and indoor illuminance on horizontal surfaces and vertical illuminance at eye level, and how they impacted on the human circadian system. The study concluded that the internal and external surfaces had a major impact on the results, recommending that further studies use different reflectance.

A thesis by Moscoso (2016) explored the effect of different window sizes on the aesthetic quality of a student room under overcast sky conditions (Norway), and the effect of the daylighting system on the aesthetic quality of a single small office under both an overcast sky and clear sky conditions. The thesis used the mixed methods approach as a research strategy, in which 3D stereoscopic images of environments and questions related to the aesthetic attributes (such as pleasantness and excitement) were used. The results confirmed the significant impact of window size and daylighting design on the aesthetic impression of a small room, as well as concluding that photometric measurements are not always perfect predictors for judging the used aesthetics attributes. The thesis made some recommendations for further research: the stereoscopic images that were used do not match the measured luminance in the real rooms; therefore, matching the real luminance of the room with the stereoscopic images is recommended. Moreover, a wider range of window sizes is recommended as the thesis dealt with only three different window sizes and two types of daylighting system.

Likewise, a thesis by Sawyer (2019) investigated the effect of façade design geometry on daylight ingress and distribution, using the simulation method (HDR renderings of office environments) and Conceptual Content Cognitive Mapping for the perceptual assessment of light qualities. The thesis concluded by illuminating the strong connection that people have with natural light in spaces and recommended that further research be conducted into the relationship between spatial daylight measurements and subjective visual impressions and preferences. Moreover, more investigations into different types of spaces and brightness levels in a real environment are required.

Within different context, Kemp et al.'s (2016) study assessed the positive or negative responses to six rendered images of an interior living room space based on the factors of clarity, spaciousness, relaxation, privacy, pleasantness, and order, using the semantic differential scales method. The study compared artificial lighting with natural lighting to determine whether men or women responded differently to changes within an interior living room space. The study's findings implied that there was no strong preference towards either natural or artificial light, and that the most positive overall ratings appeared to be for space with the artificial light set to a high level of brightness and the space with natural light set in the morning. The key limitation of this study was that the space was coloured neutrally to not influence impressions, yet this led some subjects to evaluate the space negatively based solely on the colour scheme. Moreover, the subjects mentioned that their impressions were also affected by the room's layout and furniture arrangements, which were also not considered in the study's variables. Variation of colour temperature was also not included due to the difficulty of controlling it and the layout of slides had affected the judgment. The study recommended repeating the study with an older age group (over 25 years), different interior spaces, combining artificial and natural lighting and using life-sized mock-up spaces.

From a different method's perspective, Flynn et al.'s (1973) study represented some findings concerned with the effects of environmental lighting on a user's impressions and behaviour. The focus of this study was to explain how several methods, such as factor analysis, multidimensional scaling, observation and mapping, could be used to anticipate lighting quality decisions through assessing six artificial lighting arrangements. The rating scales were obtained from Osgood et al.'s (1957) book, which presents the development of an objective measure of meaning, as well as the logic and evaluation of semantic differentiation. The study concluded that evolving psychological procedures for rating and mapping the behaviour would be useful to understand the function of light for human beings.

In another study by Hendrick et al. (1977), the aim was to determine if the results from a previous study by Flynn et al. (1973) could be replicated by using slides (two-dimensional) instead of the real spaces (three-dimensional). The study concluded that the slides method could be used as a substitute for the real space if factor analysis was the mode of analysis. However, the results from the multidimensional scaling method made clear that this mode of analysis cannot be relied upon in terms of using slides as a substitute for the real space, as it gives a different kind of information.

In Amundadottir et al.'s (2017) paper, an approach was proposed for the assessment of daylight performance in buildings in Germany as a means to predict the non-visual health potential, perceptual visual interest, and gaze behaviour at the eye level of an occupant through assessing the indoor environment in terms of space, time and sky conditions in 3D rendering models across a range of view directions. The paper developed a quantitative model based on a survey that considered the subjective ratings of visual interest in daylight renderings. The survey was constructed on the ranking of nine rendered architectural spaces under three sunny sky conditions, and using the seven-point semantic differential scales. The paper argued that through using a 360° view range rendering instead of 2D rendering with a fixed view direction, could assess the effects of view direction on visual interest predictions. The study presented some recommendations for further studies; data collection for a real-world condition is recommended for the non-visual direct response model as the study had collected the data based on laboratory settings. Besides, the study mentioned that some limitations would occur when generalising the findings for different populations, as age and gender may affect the responses to the light.

Zomorodian & Tahsildoost (2019) evaluated the daylight performance and visual comfort of college classrooms, based upon the human subjective response. The study used a longitudinal subjective survey along with simulation-based metrics to investigate the selected environment. The study recommended applying the described methods in different locations and using different window configurations in order to find the most appropriate daylighting and glare metrics with high global acceptability. Furthermore, it was determined that more insight into the cultural and climatic factors was needed.

In another study, Korsavi et al. (2016) aimed to test the visual comfort (in terms of students' impressions) in daylit and non-daylit areas of classrooms using field measurements, questionnaires and simulation metrics. Overall, the study concluded that the students' impressions towards the daylight availability were either neutral or more optimistic than the simulation results. The study recommended many crucial points; most importantly was that, in order to optimise the simulation results, more insight into orientation, window configurations, furniture arrangements and classroom dimensions should be considered. Furthermore, regions, space, view configurations, users' behaviours and expectations should be taken into account in future daylighting analysis.

Seuntiens & Vogels' (2008) study investigated the different lighting characteristics and designs needed to create certain atmospheres and then assessed their relationship in the context of a living room. The results from the questionnaire revealed that different atmospheres had been discriminated by different lighting characteristics. Following a similar aim, Stokkermans et al.'s (2017) study examined the relationship between perceived brightness and uniformity with the perceived atmosphere. The investigation was carried out using computer-generated visualisations of space with several light conditions along with an administered questionnaire. The results showed that a second-order polynomial was considered an accurate function to describe the perceived atmosphere in relation to the light perceptual attributes (brightness and uniformity).

In another study, Stokkermans et al. (2017) compared three methodologies in studying the influence of electric light and daylight on the atmospheric perception of a space. The study methods relied on computer visualisation and a questionnaire, similar to previous studies. The investigated methodologies were: a rating scale with blocked presentation of daylight conditions, a rating scale with a random presentation of daylight conditions, and a paired comparison. The results highlighted variations in effect size between the three types of methodologies, with the overall conclusion being that daylight has a more limited role than artificial lighting, and atmosphere perception in the case when daylight is controlled with no available view outside. Since the study was conducted in an empty space, it is recommended that the investigation is repeated within a furnished space.

Apparently, the concept of atmosphere has been investigated from the perspective of façade fenestration as it determines the relationship between daylight and the experienced atmosphere in the built environment. However, most of the conducted research to date has argued the need for further studies in real environments. And it is indeed the case that, by investigating the experienced atmosphere within real situations, participants can sense the physical presence of the space. Böhme (2017) argued that the physical nature of things could be represented by perspectives, but their spatiality cannot, as sensing physical presence involves spatial geometry, movement and physical distance from things. As such, a sense of "whereness" is more specific, decisive and integrating: 'this participation is an affective tendency by which our mood is attuned to the nature of a space, to its atmosphere' (Böhme, 2017, p. 138).

Furthermore, investigating the effect of light on people's impression and experience is becoming urgently needed. Yet, the subject has its limitations, which are worth to highlight as follows: Firstly, the aesthetics qualities have always been related to artificial lightings, in which most of the research has been directed to the artificial sources more than the natural ones. Secondly, it's rare to talk about feelings in the scientific discourse (Griffero & Tedeschini, 2019, p. 77), in which senses have been rejected to formulate a source of truth, hence test the reality. However, atmosphere as a phenomenological concept has been developed to become a reliable subject for scientific testing by using methods like semantic differential scale and Factor analysis, which were presented in this section. Thirdly, it is not guaranteed to secure the favourer impression of space, hence the required atmosphere. Chamilothori et al. (2018, p. 203) argued that there is no absolute method nor a rule to get to know the effect of daylight on human's experience unless the building is built and used in real life.

3.11 **Discussion**

This chapter aims to demonstrate the relationship between façade fenestration, daylight and experienced atmosphere in the built environment. Through evaluating various theories and concepts, it is found that the manifestation of atmosphere relies on different perspectives, most importantly phenomenology and aesthetic domains. The ultimate conclusion is that atmosphere can be approached from the viewpoint of perception aesthetics (the person who feels and participates in this mood - the subject) or production aesthetics (the place that spread a qualitative mood - the object). In this manner, it can be claimed that: 'atmospheres are quasi-objective or something existing intersubjectively that can be produced and contributed by different aspects, particularly by light and sound, but also by objects, materials and geometry of a room' (Böhme, 2017, p. 6).

To consider the atmosphere from the daylight perspective, I argue that in overcast locations, where gloomy conditions are dominating the sky during most of the year, darkness could be considered a curial attribute of light to generate such an atmospheric experience. Hence, the lighting coverage must be simultaneous with darkness aspects - not merely in the reconfiguration of spaces to meet modern standards and cover functional tasks, but also in terms of aesthetic and physiological needs. The obligation is to evolve attuned illumination and darkness to integrate effectively with human and physical features in order to provide a different sensory and convenient atmosphere for occupants.

In terms of quantitative treatment, although field measurements were considered "tricky" and costly for conducting daylight analysis, most studies have recommended to conduct the investigation in a real-life environment, where other factors may have an effect on the experienced atmosphere, such as the outside view, spaciousness and furniture arrangements. This emphasized what the theoretical inputs confirmed about the nature of atmosphere, which exists in between the subjective and objective components, or in other words, the produced aesthetics and perceived aesthetics. In terms of the simulation work as an alternative option for presenting the real environment, studies conclude that it cannot be considered reliable nor rigorous unless it is being assessed and compared with on-site field measurements, especially if it used for daylight analysis. Accordingly, the questionnaire method, in particular the semantic differential scale (SD), was found the most rigorous and valid method to evaluate the humans' affective impression toward their environment.

The main gaps of knowledge were identified as contextual, methodological and time-wise gaps. Therefore, the study was conducted in Scotland, where a very limited number of studies, almost none, were found in the literature which aimed to investigate the effect of façade fenestration and daylight on experienced atmosphere. Moreover, recent studies were conducted in different types of places, such as retail and educational buildings, in particular classrooms; however, no research is found to have investigated the design studio environments in relation to both daylighting and atmosphere. Consequently, this study attempted to evaluate the students' impression toward the façade fenestration, daylight and experienced atmosphere in design studios as creative places. For methodological and time-wise concerns, the recent studies reviewed have recommended that daylight should be analyzed in a real place and over a lengthy period of time, followed by a survey of occupants' attitudes. Additionally, the use of simulation programs to predict daylight should be crosschecked with in-situ measurements of daylight in real buildings under existing sky conditions. Any measurement of occupants' subjective attitudes based on simulated scenarios or in a laboratory has to be confirmed by field studies in real buildings. From this perspective, the study adopted the aforementioned recommendations and conducted daylight measurements in real studio spaces and for prolonged periods of time, as well as conducting a systematic survey of attitudes through questionnaires that were administered to students occupying those spaces.

Chapter 4

Design studio: The creative space

4.1 Introduction

This chapter demonstrates the phenomenon of creative space from both theoretical and historical perspectives. It aims to show the overlap between the theory of creativity and the built environment, with an intention to highlight the need to develop a typology for creative spaces in higher education. Consequently, an empirical investigation of the occupants' needs and the daylighting effect inside creative spaces is needed, from both qualitative and quantitative perspectives. However, due to the clear typology of creative space still being under development, as a result of it requiring further description and identification by its occupants, the daylighting design of creative spaces faces uncertainty. Students' activities and tasks need to be considered in the first place in order to come up with a holistic or 'typical' approach to implementing the aspects of daylight, thus manifesting in atmosphere. Thoring (2019, p. 49) argued that the interplay between workspace needs, management styles and technological development required careful consideration when designing a creative space. Additionally, social, economic, political and climatic factors along with educational theories, are all fundamental factors within the designing stage.

The chapter consists of five sections. It begins by presenting the theoretical base of the creative space in line with the need for typology. Secondly, it presents a review of creative workspace development. Thirdly, daylighting in educational buildings and creative workspaces is discussed from a historical perspective with an emphasis on social, economic and political factors along with educational theories that have shaped the current daylighting system in educational buildings. Fourthly, the chapter focuses on an outstanding Victorian Art School-Glasgow School of Art in Scotland, where the created poetic relationship between light and dark in creative spaces (studios) was masterly designed, thoughtfully conceived and technically executed by Charles Rennie Mackintosh. Finally, the chapter puts forth a discussion explaining gaps of knowledge regarding the creative space in learning environment.

4.2 Theoretical framework

The creative space can be defined as the physical structure and surrounding elements that are designed to support the process of creative work or facilitate innovation or creative projects. It covers many activities, including educational, corporate and innovative ones, and consists of two parts: creative and space (Thoring, Desmet, & Badke-Schaub, 2019). Amabile (1996, p. 249) stated in her discussions that the ‘the physical environment that is engineered to be cognitively and perceptually stimulating can enhance creativity’. Amabile added that the holistic understanding of the creative space is frequently ignored and suggested the need to develop social psychology of creativity as a theory and as an experimental investigation. This notion is raised because there is considerable evidence to suggest that social-psychological factors have an important role in the productivity and creativity of individuals, such as evaluations, competition, reward and time.

Many studies have investigated the role of workplace design in contributing to creativity, innovation and occupants’ experience, such as a survey conducted in a UK office (Gensler, 2016) which concluded that open-plan workplaces are considered to support individual and group work on the condition that workers have a range of spaces. With regards to educational spaces, where there is an increased interest in forming a creative learning environment (Thoring, Mueller, Desmet, & Badke-Schaub, 2020), a study by Klein (1975) examined the effects of two different classroom environments (open vs structured) on children’s creative abilities in terms of high and low levels of anxiety. The results revealed that children with low levels of anxiety in an open classroom were more creative than children with the same level of anxiety in a structured classroom. Meanwhile, children with low anxiety in a structured classroom were not significantly more creative than children with high anxiety in the same classroom.

From another perspective, the theory of creative space has been investigated by a number of researchers based on the spatial design that impacts on creativity. For example, a thesis by Thoring (2019) demonstrated the practical importance of workspace design and decisions about spatial elements and configurations on different levels. The study stressed that a design could increase or decrease the comfort, productivity and efficiency of employees (internal effects), while also affecting the image of the organisation to customers or the media (external effects). However, Thoring (2019) argued that there is a lack of holistic understanding and theoretical relevance regarding the relationship between spatial design decisions and creative work (Figure 4-1). A study by Kohlert & Cooper (2017) discussed the design concepts, factors and guidelines that should be considered in the creative space to stimulate original thinking and shape creativity, such as physical comfort (safety, accessibility and hygiene), functional comfort (the degree that environment supports users' tasks) and psychological comfort (feeling of belonging and ownership). Furthermore, the researchers stated that the creative space contributes mechanical knowledge to art and literature and that, consequently, the concept of environmental psychology can be highlighted as a vital concept exploring experiences in the physical world that impact on human thoughts, behaviours and objects within that place.

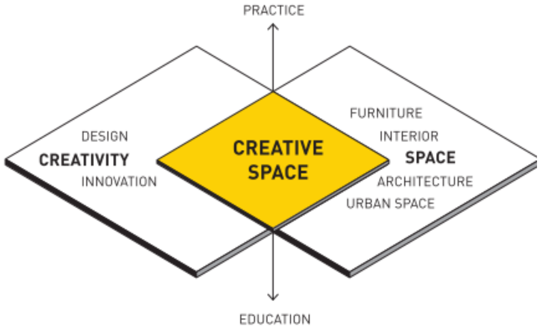


Figure 4-1 Intersection of creativity and the built environment. (Thoring, 2019, p. 23)

The positive-design initiatives focused attention on the positive psychology that comes from optimising desirable experiences based on positive mindsets (P. M. A. Desmet & Pohlmeyer, 2013). They illustrated that design can enable, stimulate and inspire engagement in meaningful activities, hence contributing to the happiness of individuals. Accordingly, the positive-design initiatives proposed a framework that combined three key cornerstones where each can stimulate the subjective well-being: design for pleasure, design for personal significance and design for virtue. Within this framework, designers are required to develop an approach to how their designs will bring positive effects, stimulating people to achieve their personal goals and supporting them to express good moral behaviour. However, in order to study the impact of existing designs on subjective well-being, they stressed on the importance of validated assessment tools and empirical evidences. Similarly, Hassenzahl & Diefenbach (2012) stated that any positive experience stems from "psychological need fulfilment", which is the basis for shaping any meaningful experience and guiding the design decisions. They developed a narrative approach that involves many momentary experiences to form ‘holistic user experience narrations’ that depends on the needs and, in turn, on types of activities.

Arguably the most important work on psychological need comes from psychologist Abraham Maslow who created Maslow's hierarchy of needs, a theory of psychological health based on the simple question: ‘What motivates humans?’. The theory proposed that human activity and behaviour are motivated by all innate needs, both physiological (security, social esteem and self-actualization needs) or psychological (competence, relatedness, popularity, stimulation and security needs). Some people, such as Desmet & Fokkinga (2020) argued that these needs do not require to be organised in a hierarchy and addressed in a certain order. Others criticized for the absence of empirical evidences and the operationalization of the entire concepts. Yet, regardless, Maslow’s theory still proposes a clear overview of the fundamental needs that contribute to the wellbeing of occupants within a space. This is known as ‘typology’.

The definition and essential component of typology are each demonstrated in Desmet & Fokkinga's (2020) paper. Typology as theory describes a phenomenon, presenting dimensions or characteristics. It not only reduces complexity and categorises tangible and intangible objects into a shared type, but also collects fundamental needs, such as the cognitive and aesthetic that fulfil the positive experience of being human, offering insight to designers on what people really need. For Collier et al. (2012), typology is an organised system of types, an analytic tool in the social sciences that forms, redefines and creates categories for classification and measurement.

From this perspective, the relationship between the theory of creative space, spatial characteristics and configurations of place are mapped within the dimension of typology. A number of researchers have looked into the development of creative space typologies, such as Thoring et al.(2017), who conducted eight semi-structured interviews with experts from the fields of design education, architecture and interior, product and furniture design. The results revealed a variety of inspirational propositions relating to the influence of the spatial environment on creativity in design educational context, such as visual stimuli, open view, playful experimental atmosphere, surprising space and social interaction. With regards to research from Meinel et al. (2017), the identified categories and characteristics relating to the physical work environment can be grouped into three aspects:

- Office elements (intangible: sound, colour, light, temperature and smell; tangible: furniture, plants, window/view, equipment, decoration and materials).

- Spatial layout (privacy, flexibility, office layout and size and complexity).

- Space types (relaxing, disengaged, doodle and unusual/fun space).

Meanwhile, Paoli & Ropo (2017) described the five thematic categories that contribute to the characterising of creative workspaces in Northern Europe using qualitative research (grounded theory): home, symbolism and memory, sports and play, past and future technologies and nature. These inherent characteristics in the spatial design of the creative workspaces are supposed to provide the necessary aesthetic features that can flourish within the creative space. The 'home' theme evokes a cosy feeling, which in turn reflects a peaceful and trusting environment that the creative space needs. For example, design a kitchen table to serve as a place for meetings or for eating together and the use of warm colours and lamps create a feeling of warmth and hominess. The 'symbolism and memory' theme evokes a bond and connection between the space and distinctive culture presented by decorative elements, such as Swiss cable cars and chalets used as rooms built on national symbolism, which in turn spreads the aura and symbolism throughout the space. The 'sports and play' theme evokes energy for creative work and presents youth and playfulness. The 'past and future technologies' theme evokes imagination and a nostalgic appeal for creative work. Finally, the 'nature' theme evokes relaxation and psychological restoration.

Organisational creativity can "flourish" by using different aesthetic features and various material tools in different kinds of spaces, as mentioned earlier. Nevertheless, the paper stated a variety of different arguments as follows. The current spatial elements and design ideas in creative spaces are based on the 'stereotyped models of creativity' more than on empirical research. Moreover, it is advised that the user of the space should be involved in the planning and designing of the workspace so as to achieve a more balanced and contextual approach. Paoli & Ropo (2017) recommended further empirical investigations for this field of research as they proposed four balanced paths in designing the creative workspaces: balancing between the individual versus open space; balancing planned versus spontaneous creativity; balancing the need for designed creative workspaces with the tools for creativity, and balancing the need for users' participation and external design expertise.

Similarly, a study by Luippold et al. (2012) identified five different types of space within the work environment of a German design school using a qualitative approach: the solitary space for personal withdrawal, the team space for group work, the thinker space to experiment and build stuff, the presentation space to present the work and the transition space, such as cafes and hallways. Although all types of spaces provide specific functions to support the workflow of creativity, the paper found that one function could be allocated in different types of spaces and one space could be designed for several functions.

Thoring et al. (2020), examined spaces that are related to creativity and innovation, separating them into six categories identified as follows. First, individual workspaces include personal space, focus space, incubation space, and reflection space. Next, collaborative workspaces that include team and meeting spaces. Third, making spaces involve experimentation spaces, analysis spaces, verification spaces, and workshop spaces. Fourth, presenting spaces that involve lecture and exhibition spaces. Further, preparation spaces that relate to the work process, such as research and exploration spaces. The final category is break spaces where people can talk, relax and transit between spaces; these include intermission and disengaged space. In that context, the paper ordered the requirements of a creative space from large to small scale to answer the raised question of 'how exactly should a creative space be designed in order to facilitate creativity and innovation?'. The large scale relates to the geographic location (city centre, neighbours, mobility, field access), where the change of workspace during the break is beneficial to provide an opportunity for a temporary creative retreat.

Architectural structures (spaciousness, proximity, open views, decorations, greenery and mobility), can be conducive to creativity. The small scale is concerned with interior styles (furniture and equipment) and interior aspects (natural and artificial light, colours, materials, positive sound, positive smell, indoor climate and atmosphere).

In Radziunaite's (2016) thesis, the creative workspace is a composition of tangible visual and phonic elements, architectural surfaces and structural frames and movable divisions, furniture and technological appliances which are all shaped by inter-human relationships. The thesis demonstrated that the level of awareness of environmental factors is now on par with technological development, such as Indoor Environmental Quality (IEQ) and Sick Building Syndrome (SBS). Through conducting interviews with researchers, designers and users, the thesis found that users relate concepts of openness, daylight, furniture, zoning and playfulness to definitions of creative workspace. Users mainly describe the creative workspace as ‘the different work modes that require to visualise data for more efficient communication and high level of mobility to change work environments depending on the work modes or types’ (Radziunaite's, 2016, p. 42). Meanwhile, designers prioritised concepts of openness, flexibility, zoning and interactions for special arrangements, geographical location, view, daylight, air, natural elements, acoustics and furniture for the design component. Designers mainly describe the creative workspace as ‘is the need to transition through different work modes in order to complete complex tasks’ (Radziunaite's, 2016, p. 40). The thesis articulated the need to recognise ‘zoning’ that accommodates different kinds of settings and moods by breaking up the open environment into different areas so that occupants can decide on the appropriate space to get work done. When focusing on the field of lighting, the thesis argued that the light strategy should vary depending on the zone that it is used in. As such, daylight and task light (artificial light) would be considered the optimum lighting strategy, whereby occupants can control, personalise and adjust the sources of light (amount and directions) based on the needs of creative work.

4.3 History of the creative workspace

Figure 4-2 A Taylorism Inspired Office

As modern educational studios contain characteristics and features similar to workspaces, this section of the study is opting to review the creative workspace development. The concept of "Taylorism" was introduced to workspaces in the United States during the 20th century and was developed by the industrial engineer Frederick Winslow Taylor, who implemented the 'scientific management style' to improve labour productivity and economic efficiency (Figure 4-2). The concept comprises analysis, synthesis, rationality, logic, standardisation, empiricism and work ethic principles. Stoller (2015) demonstrated that Taylor's principles are embedded in the policies and practices of the American contemporary school system as a part of the social efficiency movement. Taylor's perspective focused on the "task" whereby the system will function well within 'rigid, definable and quantifiable ends'; similarly, the educational practices reformed around a specific 'learning outcome' through a 'definable set of skills, attitudes and traits'.

Due to this, the office design based on Taylor's concept was characterised by large halls and desks arranged in rows. However, the architect Frank Lloyd Wright later launched the concept of an open-plan office environment in 1939 that prioritised atmospheric aspects with a good ventilation system and indirect light to best secure ambience within the workspace. Following on from this, the scientific management style was criticised because of pressure and standardised work conditions, so defining a new design concept known as 'cubicles' (Thoring, 2019, p. 43). Before implementing the cubicles concept, new non-hierarchical office environments were introduced in 1950s, known as 'office landscapes' (German: Bürolandschaft) in Germany (Figure 4-3 and Figure 4-4). The main idea of this concept was to implement a flexible open-plan office, irregular arrangement of furniture in free groupings and introduce a lot of light, similar to the landscape reality (Thoring, 2019, p. 45). However, many complaints were raised regarding the working conditions in open-plan office environments, specifically relating to the noise, uncomfortable indoor temperature and health problems (Jahangeer, 2015, p. 50).

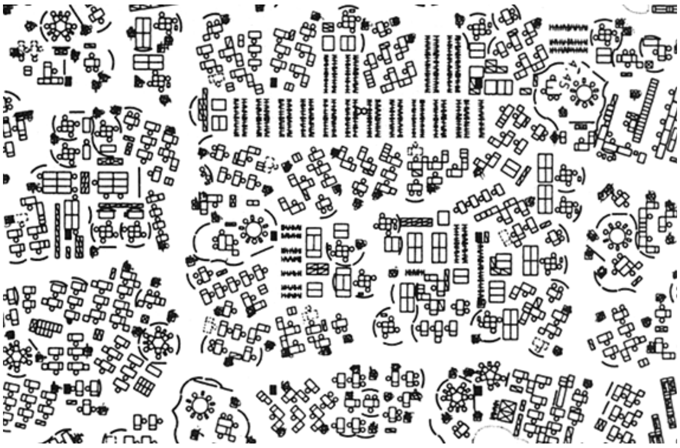


Figure 4-3 Buero Landschaft (office landscape) layout of the 1950s (Bürolandschaft). (kohlstedt, 2017)

Figure 4-4 An example of a Burolandschraft workplace. (K2 space, n.d.)

In the late 1960s, research began to solve the issues associated with open-plan offices, such as noise and privacy issues, by developing appropriate furniture and equipment. This research was known as 'action office' and was designed by Robert Propst and Jack Kelley within the Herman Miller Research Corporation. The action office (Figure 4-5) is characterised by portable partitioned walls, desks and furniture that are each arranged based on individual workers' needs. With the increased number of female workers entering into male-dominated workplaces in the 1960s, major

Figure 4-5 Action office. (Propst & Kelley, 2020)

changes were implemented to secure a greater level of privacy. As such, the office design shifted from 'action office' to 'cubicle farm' in the 1980s (Figure 4-6), whereby a three-sided vertical division defended the individual's space (K2 space, n.d.).

Figure 4-6 The cubicle farm. (K2 space, n.d.)

Following the previous design developments for workspaces, advanced technology, and the need for more flexible and mobile spaces led to the emergence of a new office design known as 'hot desking' (Figure 4-7). This type of design became associated with funkier, more colourful furniture as well as the introduction of screens and cables. Here, rather than there being allocated spaces for occupants, the individuals could instead choose to use any available space.

Figure 4-7 The modern workplace. (K2 space, n.d.)

4.4 Educational buildings from a historical perspective

The development of educational buildings began in the nineteenth century and continues today. In the 1890s, introducing new progressive teaching methods led to important changes in the designing and planning of schools. Due to there being universal compulsory education, the Elementary Education act established 'school boards' in the 1870s, making children's school attendance mandatory between the ages of five and thirteen. Children's full attendance was then taken seriously after the fees were cancelled in large part of elementary schools in 1891. As a result, large classrooms became an urgent necessity in order to accommodate a large number of students and the teaching staff was also increased to accommodate these changes. School rooms were increased along the central school corridor, which became a hall used for general activities, known as the 'central-hall plan' used until the outbreak of the First World War (Seaborne, 1971, 25).

Although the central hall design addressed many issues through it being a 'focal point' that added a sense of community, the acoustics in the hall tended to cause noise annoyance. The high ceiling produced an echo which affected the adjacent classrooms due to the separating walls being made partially from glass. Another crucial point to be solved was the ventilation design. Many of the windows were located too high, making them difficult to reach and open, and the unplanned window design made the room gloomy for most of the time. Meanwhile, the bottom windows had an issue of letting in dust from the road (Seaborne, 1971, 32). As a result, the central-hall design posed many difficulties in the important aspects of ventilation, lighting and insulation. Moreover, from a health perspective, the design of the central hall had several hindrances in terms of providing proper lighting and ventilation, as only one side of the classrooms was connected to the outside environment. Thus, cross-ventilation could not be achieved through this type of design, which led to brainstorming new designs that would address these new health concerns.

During the interwar period, multiple architectural developments were emerging along with other changes in society and in educational ideas and practice. By the end of the nineteenth century, the pressure from universal compulsory education had lessened, ending the demand for large school buildings. A veranda school or open-air school is a new concept that would achieve the required cross-ventilation, which emerged as a result of First World War conditions causing unhealthy environments stemming from industrialisation and urbanisation. The open-air school concept is based on separating classrooms from the central hall, but arranges them in rows with folding glass doors rather than sidewalls, to let the airflow between classrooms during the summer. In the winter, the airflow would then be secured by designing clerestory windows at the top of the verandas when the doors were closed (Seaborne, 1971, 36). For this design, the school buildings were oriented towards the south so as to be exposed to fresh air and direct sunlight (Wu & Ng, 2003).

Despite there being various advantages to this type of design in terms of health benefits, its main criticism came from new educational theories that led to general changes in teaching attitude. As mentioned above, the veranda design was based on separating classes for cross-ventilation, which made an argument of destroying the educational unity and architectural form as a whole. Moreover, the function of the central hall remained crucial from an educational perspective in terms of using it as a general space for musical works and physical exercises. Another factor was the climatic issue related to the veranda design; in that it was difficult to adjust due to the UK's climate. As a result, the open veranda had to be closed to prevent the classrooms from becoming cold and instead, it was used as an ordinary corridor (Seaborne, 1971, p. 38).

Robson (1874), articulated his recommendations for daylighting in the UK's schools and the western world. He showed that the external appearance of schools, or what we now refer to as the façade, was a reflection of learning ambition, social improvement and educational aspirations. Therefore, as the relationship between students and school buildings became more explicit, the principles of modern architecture expanded to become a universal language in the mid-twentieth century, advocating for large windows for daylight, fresh air, and functional spaces based on open planning and new materials. Robson argued that the best light source for classrooms came from the north, whereby the light is cooler and steadier than the south, which would often produce glare in summer weather. Furthermore, he suggested a ratio of about 20% glazing area to floor area in the classroom (Wu & Ng, 2003).

During the interwar period, new educational theories began to emerge regarding the designing of classrooms. The concept of 'class-teaching' was coined by 'progressives' who were calling for a new education policy that favoured an informal teaching method characterised by individual and group work, making the presence of the teacher less important. So, new educational tools meant new design and arrangements within a classroom. Therefore, instead of providing fixed seats with heavy desks, tables and chairs were designed to be easier to move around for group work (Seaborne, 1971, p. 39). From the mid-nineteenth century, ideas about air quality, hygiene and light levels appeared regarding educational spaces, which were later formulated more deeply as creating environmental controlled spaces that shifted from teacher-centred spaces to student-centred spaces. As such, changes in school design were based on both architectural modes and pedagogy, where new designs were a reflection of social shifts occurring in the late nineteenth century into the twentieth century. Consequently, architects started to adapt the concepts of a healthy environment for educational buildings by working on schools' façades and expanding their windows, alongside considering the principles of passive ventilation system, which changed the appearance and placement of educational buildings (Darian-Smith & Willis, 2017).

In the Second World War, major improvements were applied to school designs, such as considerably enlarging some of the Gothic windows and providing' upright shafts' in every room for better ventilation and easier access to open the windows. Furthermore, innovative construction technology and the use of steel frames increased the possibility for large glazing areas for windows and partitions in schools. Yet, these large windows caused glare and uncomfortable overheating in the summer and so the concept of permanent supplementary artificial lighting of interiors (PSALI) was implemented in school designs. In addition to this, new educational theories argued that the windows distracted students' focus and the oil crisis in the 1970s promotes windowless school, especially in the USA. Based on that, the incorporation of fluorescent lighting and an air-conditioning system allowed for an adaptation of small windows to improve energy efficiency and control the glare issue. Following this change, researchers found that over-usage of artificial environments could be potentially psychologically harmful to students. As such, a passive solar school design was introduced, which focused on penetrative daylight and visual performance (Wu & Ng, 2003).

4.5 Case study _ Daylight in the creative space

Daylight in creative spaces contributes significantly to spatial experience by providing a poetic dimension and a unique expression of the relationship between art, culture and surrounding environmental qualities. This advantage of light was greatly implemented in Victorian art schools in the UK, such as those in Manchester, Birmingham and the current case study, the Glasgow School of Art building, which has been referred to as the foundation of the modern movement. The following section covers the daylighting design scheme that was implemented in the Mackintosh Building, as the light was integral to Mackintosh's design. His philosophy of designing from the inside out led to an endless series of surprises, with his decision to create a constantly changing series of counterpoints - rough against smooth, high against low, black against white and gloom against light - impacting upon the overall experience of space (Jones, 1990, p. 96).

4.5.1 The Mackintosh Building

'*Great buildings that move the spirit have always been rare. In every case they are unique, poetic, products of the heart'* (Platt, 2013: p. 8).

The Glasgow School of Art, designed by Charles Rennie Mackintosh, is a critical example of the synthesis of space, light and shadow within the Scottish context (Stewart, 2007, p. 27). The building reflects the relationship between science, art, design and the manufacturing industry (Cairns, 1992, p. 65). It was the first art school that placed electric light fittings in studios and installed a mechanical heating and ventilation system to provide clean tempered air inside the building (Lawrence, 2021). It represents an evolution of the Victorian art school model that synthesises the functional requirements of light and air (Lawrence, 2014a). The intellectual interplay between these characteristics brings about a unique appearance with a sensual elegance, while the careful daylighting design marrying brightness and darkness reflects the sensibility of the geographical and cultural context. As such, a dramatic interior space is created from the two components of light and darkness. The building plan is simple in composition, adopting the E-shaped plan (Figure 4-8) to allow daylight to penetrate the central spaces on the upper levels. Meanwhile, using roof lights on the lower levels (the studios located below the Renfrew Street level) within the recesses to provide natural light. Spaces are organised along the east-west axis of the site, with studios primarily distributed along the north side, huge north-light windows and a central corridor to connect spaces together (Cairns, 1992). Meanwhile, the windows in the south side are deeply recessed to produce a high level of natural light while restricting the direct sunlight (Figure 4-9).

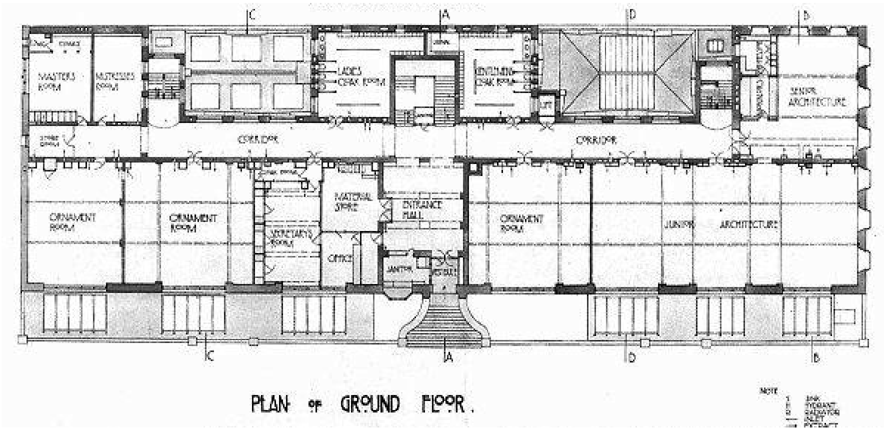


Figure 4-8 Ground floor plan, Glasgow School of Art. (GreatBuildings, n.d.)

Figure 4-9 Right: South elevation of Glasgow School of Art. Left: North elevation of Glasgow School of Art by Charles Rennie Mackintosh, at Glasgow, Scotland, 1897 to 1909. (Marshall, 2014)

Mackintosh's building presents an intrinsic symbolic meaning, an atmospheric experience and a spatial richness by manipulating the environmental qualities of the building using light, ventilation and warming or cooling qualities. These interior environmental qualities are shaped in a manner similar to the physical fabric of the building so as to form spiritual, aesthetic and physical qualities. The levels of illumination within the Glasgow School of Art have been argued to far exceed the lighting guidance, as the daylight factor (DF) registered 12% on the horizontal working plan at the front of the north-facing studio on the first floor (Figure 4-10). In comparison, the daylight factor never fell below 4% in the back of the studio because of the inclined window above (Lawrence, 2014a, p. 106). However, during the time of the build, Glasgow was experiencing considerable smoke in the sky, meaning that light was obstructed by the smoke pollution (Lawrence, 2014a, p. 107). It is crucial to mention that these calculated measurements were taken by Lawrence (2014a, p. 125) in February 2009 (between 12:30-13:00). Therefore, the readings were affected from minor obstructions by the Foulis Building and Newbery Tower on the north side of Renfrew Street, where these buildings were obstructing light from the horizon rather than from the brighter azimuth.

Figure 4-10 Interior of a studio, first floor, Glasgow School of Art. (Lawrence, 2014a)

The corridors, however, are designed differently- so creating a complementary contrast. The small windows, arranged in a symmetrical composition, are a manifestation of an aggregation of symmetries to allow for a noticeable poetic effect. Mackintosh's design has transformed a functional building into a distinctive landmark through his incorporation of sensual elegance, thus forming a: 'significant testimony of his integrity of mind and spirit' (Jones, 1990: p. 41). A distinctive feature is Mackintosh's integration of light and shadow in a dramatic and theatrical way. By pairing light and dark, a mysterious and expressive atmosphere is formed, alongside a presentation of the phenomenology of the aesthetic qualities of lighting. Mackintosh wanted the school to be a perfect base for the learning and practicing of arts. As such, he was fully aware of the importance of sensual and aesthetic aspects to stimulate students and provide an extraordinary, unique atmosphere for them – evident in his interesting juxtaposition of light and darkness.

With this in mind, the major difference between the Macintosh buildings' studios and the investigated studios in this study is the acceptance of darkness that emerges from the nature of overcast locations. As the weather in Scotland is unpredictable and very changeable, other qualities, such as darkness and artificial light are crucially important considerations in designing a certain atmosphere. Mackintosh took benefit of the vital possibilities that darkness can offer and connected it with the two sources of light; natural and artificial to create a dramatic experience that supports the learning and practicing of art. The experienced atmosphere that was created in the Mackintosh Building not only presented by the power of Victorian art school in contribution to the evolution of art pedagogy and reinforces the national culture, but also it created from the interplay between light and darkness. Therefore, the aesthetic and physical qualities were mainly based on the environmental factors that reinforced the atmospheric narrative during the day and throughout the year.

4.6 **Discussion**

The creative space as a collaborative hub holds intellectual and personal qualities. It is a place to generate ideas and brainstorm, as well as to find creative solutions to problems. The concept of creative space has a considerable theoretical base, in that it provides new possibilities and a better understanding of using spatial design and configurations to impact on creativity and innovation. As such, it is widely implemented in business and, more recently, in educational institutions. Creative learning environments are constantly adapting to new typologies and new façade designs. For the most part, they adhere to research findings that are based on other educational environments, such as classrooms in schools and colleges or offices in workplaces. However, the context of creative space in a learning environment (studio) has its own character and related spatial qualities, whereby it needs further empirical investigation and deep insight in order to improve its function for the learning process and creative working. Likewise, Meinel et al. (2017) suggested to develop appropriate measurement constructs to conduct further empirical and conceptual studies on creative workspaces, and Thoring et al. (2020) recommended a holistic understanding based on empirical evidence and theoretical underpinning of the impact of spatial design on the creative workspace.

The noted literature on the spatial design of creative space focused attention on proposing frameworks based on physical, functional and psychological comfort (Kohlert & Cooper, 2017). Positive psychology that based on positive mindsets (P. M. A. Desmet & Pohlmeyer, 2013) and psychological need fulfilment (Hassenzahl & Diefenbach, 2012) that depends on human activity and behaviour (Maslow's hierarchy of needs). However, the research field of creative space in learning environment is struggling to determine its own terminology, structure and knowledge as well as a spatial design framework to secure functional and psychological comfort, as well as the visual and aesthetic qualities that would support the design thinking and creative working.

With this in mind, there are few valid or comprehensive existing studies that present potential typologies for creative space, despite investigations having been conducted in varying levels of space quality. Thoring et al. (2018) argue that the most recent literature has revealed no comprehensive nor satisfactory typology for creative spaces. It is likely that this stems from the multi-faceted style of creative spaces, where design education in theory and practice are conducted simultaneously. This sees practical activities, such as drawing and model-making, co-exist with theoretical activities, like tutorials and presentations. Thoring et al. (2017) developed theoretical propositions about the influence of physical environments on creativity in design educational contexts. Yet, the paper argued that the presented work is considered as a starting point for further research as some aspects, such as visual stimuli and playful experimental atmosphere have no supporting or contradicting literature and some design aspects that gained positive influence on creativity impacted on another aspect negatively. Furthermore, the paper gained insights from experts only and did not include students' perspectives, which also emphasized by Paoli & Ropo (2017) on the importance of involving the end-users in planning and designing the workplace. This was noted in designing the school buildings, where architects had involved suggestions and recommendations from schools' headmistresses and teachers in the major experimentation that shaped the learning classrooms (Seaborne, 1971).

In terms of daylight in creative spaces, it was found that social, cultural, political, climatic, economic factors and educational theories have progressed in terms of implementing the daylighting system, subsequently changing the physical manifestation of façade configuration. As different tasks and activities are happening in different patterns at the same time and within the same area of studio, the ability to control the light sources to adjust to the creative work is desired. In that respect, this study argues that the combination of daylight and artificial light is so far may consider the optimum strategy in studios. However, this is considered to be a sensitive aspect that must be examined at the early stages of design. Studios are typically operating for around 10-15 hours a day, which makes it critical for the architect to decide either to create an attractive functional studio or to secure other design criteria, such as energy efficiency.

Chapter 5

Research design and Methodology

5.1 **Introduction**

This chapter presents the methodology used to investigate the impact of façade fenestration on both daylight levels and experienced atmosphere on design studio space, under overcast sky conditions. It offers a systematic attempt to answer the study's questions and the formulated hypothesis. It has been clarified that in overcast locations, such as Scotland, a shortage of daylight with dark and gloomy conditions (especially in winter) necessitates a strong building design that ensures the creation of well-lit and attractive spaces. From a climatic perspective, daylight and experienced atmosphere are changeable, varying from time to time and from one season to another. Similarly, when considering a contemporary design studio space, many factors related to occupants, furniture, interior layout and functions would also be changeable and so affect relationships. Consequently, this study has adopted the longitudinal quantitative research design, in which cause-and-effect relationships would be suggested throughout.

Within this investigation, the fieldwork has been conducted within design and architecture schools in an attempt to understand how façade fenestration affects the daylight and experienced atmosphere from both conceptual and operational levels. As such, by testing the applied theories (the theory of creative space and the theory of atmosphere), fundamental patterns would be generalised across space and time. The identification of the chosen variables was partially derived from the conclusion of the author's master degree research project 'Let the Light In', which highlighted the importance of examining façade fenestration as an element of significance in the relationship between daylight and experienced atmosphere.

The field measurements consisted of an analysis of different scenarios of façade fenestration for the selected studios in three main cities in Scotland; the analysis comprised photographs and analytical drawings. The collection of objective data regarding daylight levels and their distribution was achieved by locating data loggers in the studios to measure light, temperature and humidity. Subjective attitudes were measured by means of a questionnaire where students were asked about their attitudes toward daylight and the experienced atmosphere from their seating positions.

The research methodology that has been used is largely experimental, and thus empirical in nature, in that the involvement of objective data along with subjective data will add more precise measurements and aid our understanding of real conditions inside the design studios. The data gathered both from measurements and from the questionnaires has been analysed statistically using SPSS (Statistical Package for the Social Sciences), whereby various design parameters and orientations (i.e. north facades vs south) were correlated with levels of daylighting. Significance levels, in terms of statistical probability, were computed and levels of statistical variance between design parameters were calculated. This use of statistics and the engagement with statistical probability (P) will add an intellectual dimension to the thesis and facilitate accuracy in data mining in the search for hidden patterns and relationships.

The chapter starts with an illustration of the research questions and hypothesis, the research design and the procedure for the sample design, followed by the sampling strategy for case studies. The collection processes of objective data (daylight measurements and weather considerations) and subjective data (attitude measurement via questionnaire) were carried out according to a timeline. They were proceeded by a pilot study highlighted technical issues and ambiguity in some of the questions' semantics; both issues were dealt in the study.

5.2 Research Questions & Hypothesis

From the literature review, it can be concluded that previous studies investigated the relationship between daylight and experienced atmosphere either theoretically or in a laboratory-based environment. Means that phenomena were investigated either conceptually, away from practicality, or within an artificial environment where variables are controlled. In this case, low realism may affect the ecological validity and impact the participant's insight. For example, theoretically, Edensor (2017) has previously explained the effects of daylighting on our perception of space and how the quality of light can contribute to atmosphere. In another study, Edensor (2015) found that light and darkness can be strong tools within the production of atmosphere. Meanwhile, a study by Ramos (2015) suggested that light as phenomena is to be an intangible material that can improve our built environment and quality of life, while a thesis by Chen (2014) concluded that daylight contributes to atmosphere perception in reality and within visualized lab environments.

In terms of the impact of daylighting levels in creative spaces, it is crucial to highlight the empirical investigation conducted by Hanna (2002), which appraises the environmental efficiency of daylighting, acoustics and thermal comfort within Scotland's historic Glasgow School of Art (GSA). The study was the first systematic research with a clear methodology developed specifically for environmental appraisal, where the measured environmental parameters inside studios are comparable in size to those measured for daylighting in the Reid building, one of the case studies chosen by this thesis. However, this research is aiming to conduct the investigation in contemporary creative spaces (architecture and design studios) in three cities in Scotland, where there is currently a lack of research in this area. Thoring (2019) argued that there is a lack in the holistic understanding and theoretical relevance of the relationship between spatial design decisions and creative work.

Changes in façade configurations have been influenced by daylighting levels, an element strongly linked with the aesthetics of façade design (Saridar & Elkadi, 2002). Lim (2012) and Dubois (2001) argued that modifications in building façade design, such as window glazing and shading devices, considerably improve indoor daylighting quality. Despite that, Ünver et al. (2003) has suggested that facade direction, obstruction and transparency ratios are the main parameters necessary for daylight illumination. Zomorodian & Tahsildoost (2019) recommended evaluating the daylight performance and visual comfort in the educational environment using different window configurations in different locations. Ricciardi & Buratti (2018), who investigated the thermal, acoustic and lighting conditions with university classrooms using subjective and objective measurements, would like to go further by combining and correlated the subjective factors with the objective experimental results. Accordingly, it is noted that the investigation of facade fenestrations, daylight levels and experienced atmosphere are highly recommended parameters to be examined in different contexts, different façade configurations and in creative spaces, such as design studios, where its typology and spatial design are still under development. The following research questions are tackled by this study:

- *How does façade fenestration design affect the daylight levels in different studios typologies under overcast sky conditions?*

- *What is the experienced atmosphere that would result from that effect?*

Various rules of thumbs have had a vital impact in shaping the design of façade fenestration and daylight levels for a long time now, such as that articulated by Robson (1894) and Hopkinson (1963) about window area to floor area ratio to be 20%. Rule of thumb about window area to window wall ratio by the illuminating engineering society (1972) and Ne'eman & Hopkinson (1970) to be 20-30% and 25%-35%, respectively. The Society of light and lighting (2014) recommended daylight levels for educational environment, i.e. art rooms, to be within the range of 500-750 lux and daylight factor to be > 2%. From this perspective, the study addresses the following hypothesis and relationships between variables after previous work-fields, theory observations and various rules of thumbs:

Hypothesis 1:

'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.'

Hypothesis 2:

'The characteristics of facade fenestration (window-to-floor area ratio, window-to-wall area ratio, window area, windowsill height) are strongly associated with the experienced atmosphere'

5.2.1 Identifying and labelling variables and relationships

The choice of the following variables and relationships is to test the suggested hypotheses and answer the research questions. Table 5-1 and Table 5-2 list the independent and dependent variable in each hypothesis. Certain variables are highly qualified as moderator variables in that they may produce differing impacts on the dependent variables, because the relation between the independent variable and dependent variable changes across levels of the moderator variable (Stadtlander, 2014). Their interaction would likely affect the study's interpretation of the mentioned theory. The study's variables are identified and labelled as follows (Figure 5-1):

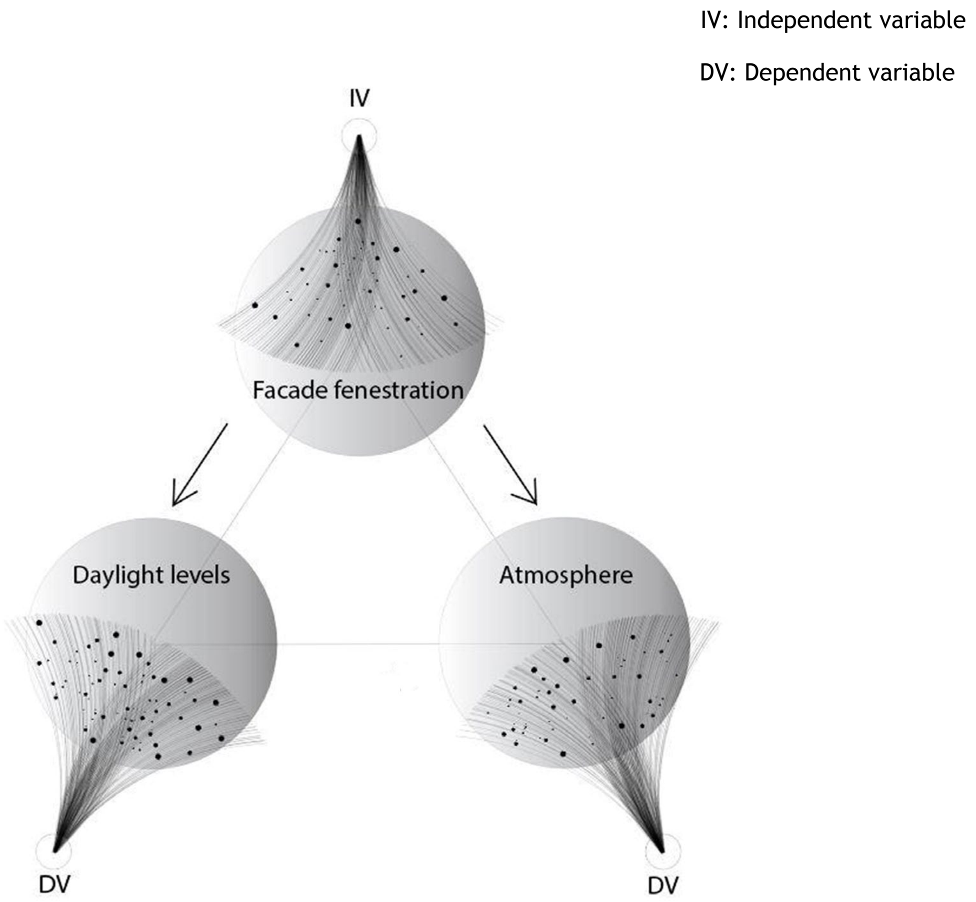


Figure 5-1 Identifying and labelling variables

(IV: is a variable that the researcher studies as a possible cause of something else. DV: a variable that is potentially caused or influenced by the independent variable-that 'something else' just mentioned (Leedy Paul D. et al., 2019, p. 46).

For the first relationship (façade fenestration-daylighting levels):

Variable	Identify
Independent variable 1	Façade fenestration (dimensions and arrangement)
Dependent variable 1	Daylight levels
Moderator variable	Distance from the window, obstructions, sun altitude, time of day, season.
Control variable	Glass materials, city's cloud coverage and studio's orientation.

Table 5-1 Variables related to the first relationship (façade fenestration-daylighting levels).

For the second relationship (façade fenestration-experienced atmosphere):

Variable	Identify
Independent variable 1	Façade fenestration (dimensions and arrangement).
Dependent variable 2	Experienced atmosphere
Moderator variables	Daylight, view, obstructions, eye view
Control variable	The age of a building, studio's orientation, Students' level of education, age, and nationality.

Table 5-2 Variables related to the second relationship (façade fenestration-experienced atmosphere

5.3 Research design

This research deals with three crucial components in the design of the studio: façade fenestration in terms of openness, daylight in terms of its scientific values, and atmosphere in terms of its mysterious and sensible vigour. After defining the research questions, hypotheses, the empirical approach was deemed appropriate to follow and a quantitative research method is adapted to conduct the study.

Due to the fact that the factors of time, change and continuity are present in this research, and appreciating that the assessment of change over time is essential in social sciences, a longitudinal research design was found the most convenient tactic to examine ongoing dynamic relationships through collecting repeated measures from the same unit of observation (Ployhart & Vandenberg, 2010; Chan 1998). From this perspective, “latent trajectories” can be estimated because the temporal dimension of data (i.e. time) is collected from the same units on multiple occasions (Gayle & Lambert, 2018); this been clarified by Bollen & Curran (2006) as a process that is not observed directly, but either by using repeated measures over time and an across cases. On the contrary, a cross-sectional research approach is not a sufficient means by which to examine, measure or control change over time because it requires completion by a single respondent at a single point in time (Singer & Willett, 2003, p. 3). Moreover, in terms of threats to validity, the cross-sectional approach has a higher bias threat due to the use of a single source (Rindfleisch et al., 2008, p. 276).

In terms of the frequency and timing of repeated measures, different seasons and the period of a year were covered in this research. As such, to provide enough repeated observations in order to account for changes in daylight levels, prevent bias within a measurement occasion and avoid having time lags between them, the measurement occasions were designed to cover two weeks in each month. Every phase of the investigation received a week of measurements per month (Phase 1: Glasgow and Edinburgh. Phase 2: Glasgow and Aberdeen); more details are presented in the research procedure section. The measurement procedures for each investigated variable is presented in Table 5-3.

Variable	Measurement Procedure
Façade fenestration	Its characteristics could be measured either by using the architectural drawings for it and/or by field measurements.
Daylight levels	Field measurements
Experienced atmosphere	Phenomenology research measured by questionnaire and observation.

Table 5-3 Measurement procedure

- The longitudinal research design has two forms: descriptive longitudinal research that aims to explain how a phenomenon changes over time, and a description of only the form of change over time, e.g. linear or nonlinear. Meanwhile, explanatory longitudinal research aims to recognize the cause of the change and how the change articulates using substantive variables (Ployhart & Vandenberg, 2010, p. 99).

The research consists of three main parts of data gathering (Figure 5-2):

1. The first relates to the case study research analysis for the selected studios, which would relate to the investigated theory and establish the “replication logic” in terms of generalizability and external validity (see section 5.4.1.1).

2. Objective data measurements for the daylight levels from the real field using specific equipment – more details are described in the research procedure section (see section 5.5.1).

3. Subjective data measurements for the occupant's experience inside their studio. As the research concerns in a multi relationship where an aspect of phenomenology (atmosphere) is presented along with the scientific one (façade fenestration & daylight levels), it is necessary to investigate the user’s opinion in order to secure the internal validity (see Section 5.5.4).

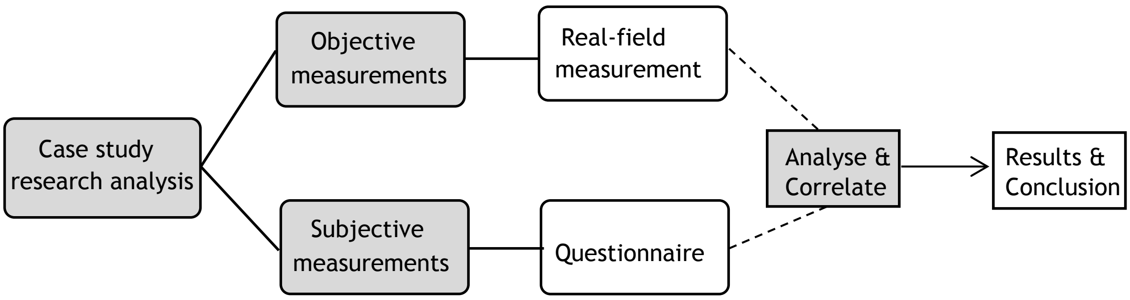


Figure 5-2 Three main parts of data collection

5.4 Research sample

The research design devises a strategy to test the predicted hypothesis and clarified the relationship between a complex set of real-world variables in real-time circumstances, where they cannot be manipulated for practical reasons. It is crucial to highlight that atmosphere has drawn the attention of many researchers recently, especially in terms of light being considered an atmospheric generator, as discussed in the literature review. Yet, previous studies into the built environment have three main limitations. Firstly, many researchers have conducted atmospheric experiments in a light lab environment, such as Knez (1995), Vogels (2008), Smolders & de Kort (2012), Stokkermans et al. (2015), Stokkermans et al. (2017), and Smolders & de Kort (2017), and or have done so in a virtual lab as in a study by Chen (2018) rather than in a real-world environment. Secondly, the complexity of investigated buildings is relevant. Although some studies conducted light and atmosphere investigations in a real-field setting, the size of the environment (experimental context) was considered small and less complex. These studies included that of Seuntiens et al. (2008), who examined the relationship between light characteristics and atmosphere in a living room.

Veitch and Newsham (2010) studied the relationship between person and building characteristics with regards to the perceived environmental conditions in an office environment. A long-term behavioural study by Begemann et al. (1997) who studied the relationship between lighting conditions and human physiology also in an office environment. Ciani (2010) examined the relationship between lighting and customer experience in a restaurant environment. Finally, the work of Kalinauskaite et al. (2018) which studied the impact of socio-physical context on psychological behaviour within a nightlife space. The third limitation is in the research method deployed; the last time that longitudinal approach was used as a research method in Scotland was that of Hanna (2002) when he conducted a systematic environmental appraisal for the Glasgow School of Art building.

As shown by the examples discussed above, conducting light-atmosphere measurements in a real environment that carries greater scientific weight than laboratory studies and often deals with a raft of complex issues on the field is urgently needed. However, this type of investigations is needed if greater objectivity from measurements under real conditions is an important research aim. It presents a scientific base for highly exploratory research to investigate the relationship between daylight and atmosphere and extend the atmosphere theory as a contemporary phenomenon from a conceptualized reality to a more reliable and operational state. By addressing the gaps in the literature's existing research, this study highlights a potential contribution in improving knowledge and practice.

The criteria for choosing architecture and design schools as the real creative environment within which to conduct the proposed research are justified as follows: from a personal perspective, the researcher has their own experiences and observations regarding the theory of atmosphere during study in a design studio at the Glasgow School of Art. From a historical perspective, architects and designers have been working since the nineteenth century to develop an optimum physical environment for learning and creative work in terms of offering appealing aesthetic features within primary, secondary and higher education in order to meet the functional, psychological and physiological needs of learners. However, a limited number of research dealing with those crucial components in contemporary buildings meant that this empirical research would play a key role in contributing to the knowledge by addressing important gaps.

5.4.1 **Case study selection**

At the beginning of the research, the plan was to choose one case study that was to be critically and methodologically applicable, allowing for issues highlighted regarding fenestration, daylight and atmosphere to be investigated in depth. However, it was recommended that multiple case studies are most viable for increasing the methodological rigour (Shakir, 2002, p. 191). Yin (2018) defined a case study as a research method, clarifying that 'an empirical method (that) investigates a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident' (Yin, 2018, p. 15). However, Groat & Wang (2002) suggested that deleting the word "contemporary" and adding the word "setting" would be more applicable to architectural research in terms of adding depth to the historical and contemporary settings. From this perspective, after multiple site visits to the institutions which have architecture and design studios in Scotland (Figure 5-3), the research identified the potential samples of case studies from five main cities in Scotland as follows:

- **Edinburgh**: University of Edinburgh (Edinburgh College of Art), Heriot-Watt University, Edinburgh College, Edinburgh Napier University.

- **Glasgow**: Glasgow School of Art, Strathclyde University, City of Glasgow College.
- **Dundee**: University of Dundee (Duncan of Jordanstone College of Art and Design).
- **Aberdeen**: Robert Gordon University (The Scott Sutherland School of Architecture and Built Environment).
- **Inverness**: University of the Highlands and Islands (Inverness College). The potential cases were classified according to the level of education they offer, the age/architectural style of the building and the orientation of the studio (Table 5-4, Table 5-5, and Table 5-6).

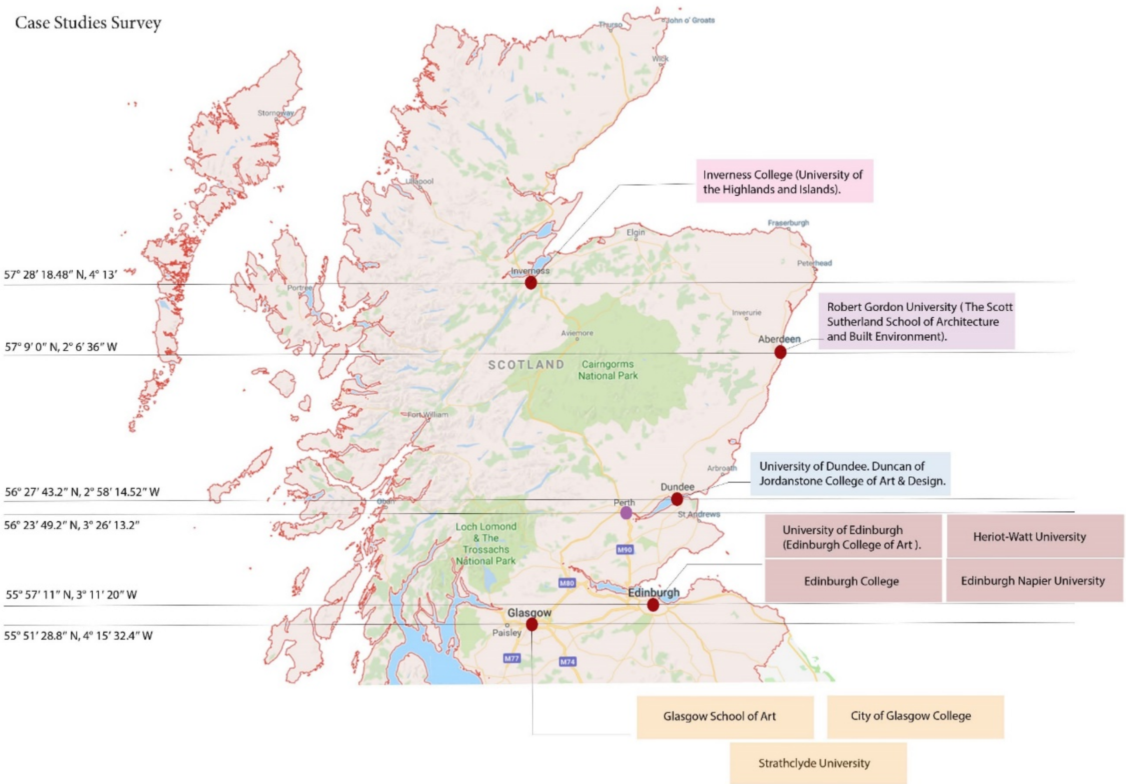


Figure 5-3 Architecture and design institutions in Scotland

Study system	
University	**Further Education**
Glasgow School of Art	Inverness College (University of the Highlands and Islands)
Strathclyde University	Edinburgh College
University of Edinburgh (Edinburgh College of Art)	City of Glasgow College
Heriot-Watt University	
University of Dundee (Duncan of Jordanstone College of Art & Design).	
Robert Gordon University (The Scott Sutherland School of Architecture and Built Environment)	
Edinburgh Napier University (Merchiston Campus)	

Table 5-4 Study system classification

Built-time	
Contemporary	**Modern**
Reid Building, Glasgow School of Art, 2014	Bourdon Building, Mackintosh School of Architecture, GSA, 1845
Evolution House, Edinburgh College of Art, 2006	Strathclyde University, 1912
The Scott Sutherland School, Robert Gordon University, 2015	Hunter Building, Edinburgh University, 1970
Inverness College, University of the Highlands and Islands (Further Education), 2015	Heriot-Watt University, 1969
City of Glasgow College (Further Education), 2016	Duncan of Jordanstone College of Art and Design, University of Dundee, 1888
Edinburgh College (Further Education) 2012	
Edinburgh Napier University (the studios built in the 1970’s, and renovated with the mezzanine in 2017)	

Table 5-5 Built-time classification

Façade Orientation			
North Elevation	**South Elevation**	**West Elevation**	**East Elevation**
Glasgow School of Art (The Reid building)	Glasgow School of Art (The Reid building)	Inverness College (University of the Highlands and Islands)	Glasgow School of Art (Bourdon building)
Heriot-Watt University	Robert Gordon University (The Scott Sutherland School of Architecture and Built Environment)	Glasgow School of Art (Haldene building)	Edinburgh College of Art, Evolution House)
(Edinburgh College of Art, Evolution House)	Edinburgh College of Art, Hunter building)		
City of Glasgow College			
Edinburgh Napier University			

Table 5-6 Orientation classification

According to the research questions, flexibility, information-richness and practical considerations, the selection of case studies was based on choosing studios at the university level, contemporary style and North vs South façade orientation to obtain generalization and validation purposes as justified below.

5.4.1.1 **Sampling strategy**

To identify the two types of validity in research, Tuckman (1972) clarified that a study achieves internal validity, 'if the outcome of the study is a function of the program or approach being tested rather than the result of other causes not systematically dealt with in the study'. Meanwhile, it obtains an external validity, 'if the results obtained would apply in the real world to other similar programs and approaches' (Tuckman, 1972, p. 4).

Accordingly, the criteria for the sampling was based on many factors; first, external validity was the main issue. Coyne (1997) and Kuzel (1999) suggested that appropriateness and adequacy are the main concepts necessary to guide the selection. Adequacy relates to the number of cases that is sufficient to conduct the proposed research, while Shakir (2002) clarified that appropriateness is related to fit the purpose of research and the phenomenon of inquiry. Patton (2002) defined purposeful sampling as the logic based on selecting information-rich cases that illuminate the questions under study for insight and depth of understanding instead of empirical generalisation (Patton, 2002, p. 230). Shakir (2002) demonstrated that there is no specific number in case studies research, yet to achieve in-depth information, a smaller number of cases is required to keep the focus on information richness rather than generalisation and prediction (Shakir, 2002, p. 194).

However, Yin (2018, p. 57) suggested a “replication logic” strategy to determine the satisfactory number of chosen case studies and securing external validity. He clarified the replication logic as a strategy in selecting multiple cases. The priority is to reflect some theoretical interest, replicate the same manner and predict the same findings (literal replication) in multiple experiments or taking a different direction in predict contrasting findings under anticipatable reasons (theoretical replication). In term of the number of cases, Shakir (2002) clarified that this is a decision to be made by the researcher in which the degree of certainty and information saturation would affect the decision; however, Yin (2018, p. 61) suggested the initial numbers to be 6-8 cases for theoretical replication and 3-4 for literal replication. Furthermore, the number of replications depends on the certainty of results ($p<.05$ or $p<.01$) and the strength of rival explanations.

Second is the internal validation. The achievement for internal validity was based on selecting homogeneous groups by controlling the extraneous variables, such as level of education and building built-time (Reynolds et al., 2003, p. 84). Based on the case studies survey and replication justification, the chosen cases are located in three different cities; Glasgow, Edinburgh and Aberdeen, where two replication directions were adopted to secure the required information (Figure 5-4). First, literal replication between cases that shared similar typology and settings. Second, theoretical replication for different settings of case studies and the expectation to achieve different results (Shakir, 2002, p. 192).

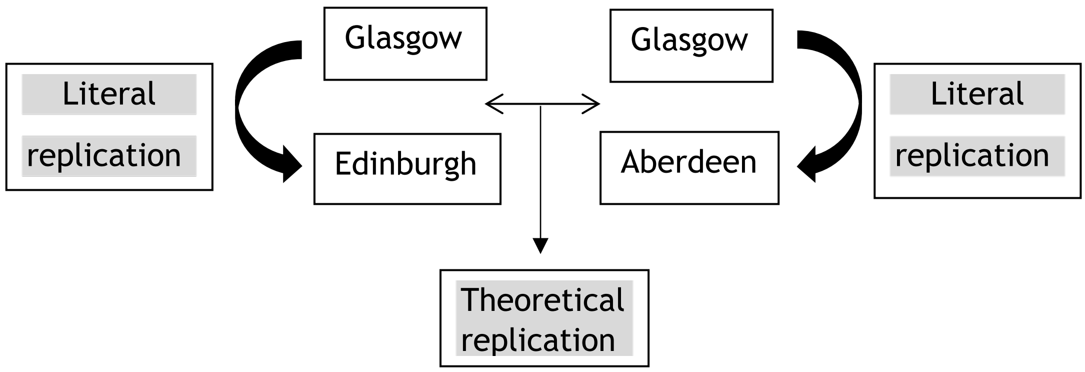


Figure 5-4 Literal replication vs theoretical replication

5.5 The Procedure

The research procedure was conducted in three main contemporary buildings in three different cities across Scotland: The Reid Building in Glasgow, Edinburgh Napier in Edinburgh and The Scott Sutherland Building in Aberdeen. Fourteen studios were investigated and measured in total, with these mainly intended for Design and Architecture study courses. As previously justified, the three selected cases were considered to have the potential to encompass answers to the research questions, guarding against threats to the internal. The three buildings have different design layouts and arrangements, yet with many similarities in terms of façade orientation, furniture arrangements and colour choices. As there is no specific layout and typology for Design and Architecture studios as creative spaces in general, conducting correlation research in the actual field was challenging.

The study has attempted to test its hypotheses mainly in two phases depending on the shared factors between the cases, in which each phase takes a week in the month. Façade orientation was considered as a control variable, where it is highly qualified to alter and affect the examined daylight situation, the interpretation of results and, most importantly, the internal validity. Thus, the procedure was mainly segmented into two different phases, with orientation (North vs South) being the shared factor in each stage (Figure 5-5). Despite the fact that the measurement procedure was conducted in three different cities, the study findings are highly likely to be generalizable in Scotland as the chosen cites have similar weather data, a close latitude, and the timeframe of the measurements was very close in all cities due to them being conducted in the same month. This is described in the weather considerations research (see section 5.5.3).

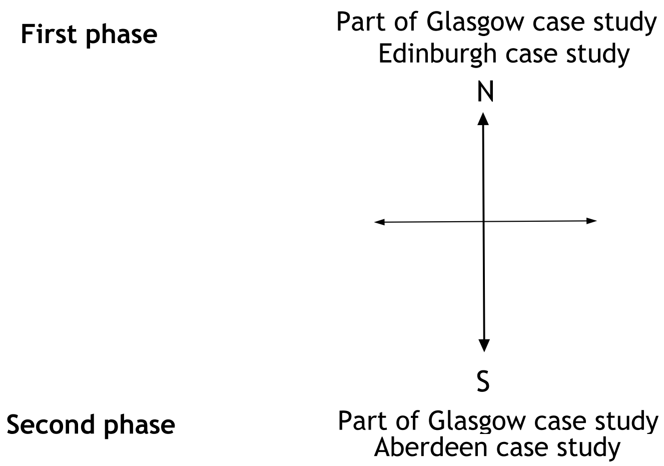


Figure 5-5 Façade orientation for each stage.

For a comprehensive analysis of the selected research design and thorough handling of the multiple relationships, the study collected the data and recorded the measurements without manipulating the study variables. The measurements were conducted over a nine-month period register daylight variation over time. The data collection procedure was in two stages:

The first stage was designed as a snapshot into the studios' space, i.e. a walk-through appraisal. The aim was to measure the variables and serve the first and second relationships in the study, whereby façade fenestration can be correlated with the daylight levels and experienced atmosphere. First, objective data collection for the light intensity (light levels) was conducted inside studios at certain points, mainly using data loggers. Second, the subjective data collection consisting of a general questionnaire was given to a random sample of students in order to gather students' judgements and experiences inside their studios.

The first phase was conducted in studios in both the Reid Building in Glasgow and in the Edinburgh Napier in Edinburgh, and took a week of every month. The two buildings share a certain unique type of studio design and layout (double-volume open plan floor with mezzanine floor above), meaning that it was crucial to study how both their interior layouts and façade fenestrations could affect the daylight levels and, consequently, the students' experiences inside. The studios were orientated towards the Northern façade, with similar furniture colours and designs and the students inside carrying out similar tasks. However, the studios were located on different floor levels, leading to differing considerations of obstructions and window height. The advantage of this phase was that the findings could be generalised as the two cases more or less experience the same overcast sky conditions and have the same orientation.

The second phase of measurement was conducted in the Reid Building in Glasgow, and the Scott Sutherland Building in Aberdeen, two buildings which possess the same layout and design (open plan studio), and the targeted studios also have the same orientation, both are facing south. However, their differences lie in their roofs, in that there is a skylight (roof window) on the Southside of the Reid Building studios so as to allow more daylight inside. The four studios in the Reid Building are adjacent and open to each other. Regarding the Scott Sutherland Building in Aberdeen, there are two large open plan studios on both the second and fourth floors; however, the study focused on the fourth-floor studio, as its floor level height is closer to that of the one in the Reid Building.

5.5.1 **Objective data collection**

This study is concerned with the effects of façade fenestration on the daylight levels and experienced atmosphere inside studios under overcast sky conditions. In order to sufficiently address the research questions, two methods were employed. The first method relied on objective measurements, and was conducted for nine months from February 2019 to November 2019 in order to record the daylight levels that penetrated the studios. The timeline is presented in Appendix A. 1.

The daylight levels were recorded using the UbiBot ® WS1 sensor (Figure 5-6) for measuring environmental conditions, in which the ambient light sensor has ±2% precision and a range from 0.01 to 83K lux. Meanwhile, the temperature has ±0.3℃ precision and a range from -20℃ to 60℃ (-4℉ to 140℉) and humidity has ±3%RH precision and 10% to 90% range. In addition, the study used a HOBO MX 2200 waterproof data logger for measuring the daylight levels on the buildings' roofs under an unobstructed sky along with the UbiBot meter, just in case water should leak inside the waterproof bag of UbiBot meter (Figure 5-7). The HOBO data logger has ±10% accuracy with a range spanning from 0 to 167.731 lux.

Figure 5-6 UbiBot meter inside waterproof bag (left) to measure daylight levels on buildings' roofs under unobstructed sky & UbiBot meter (right) to measure daylight levels inside studios

Figure 5-7 UbiBot meter inside waterproof bag (left) & HOBO meter (right) for measuring light levels on buildings' roofs under unobstructed sky

5.5.1.1 **Pilot study**

A pilot study was carried out in the Glasgow studios from the period of 27-Jan to 9-Feb, 2019 to test the proposed quantitative method of collecting objective measurements. This stage was crucial to preventing any fatal flaws that could affect the measurement process (Lowe, 2019), as recording daylight levels are highly dependent on the time of day and the season. As such, multiple light meters were tested in order to establish their adequacy and flexibility in measuring the light levels inside studios (Figure 5-8). The tested meters are UbiBot ® WS1, HOBO MX 2200 and Extech SDL 400: Light meter/data logger that has ±4%rdg accuracy with a lux range reaching 100l lux.

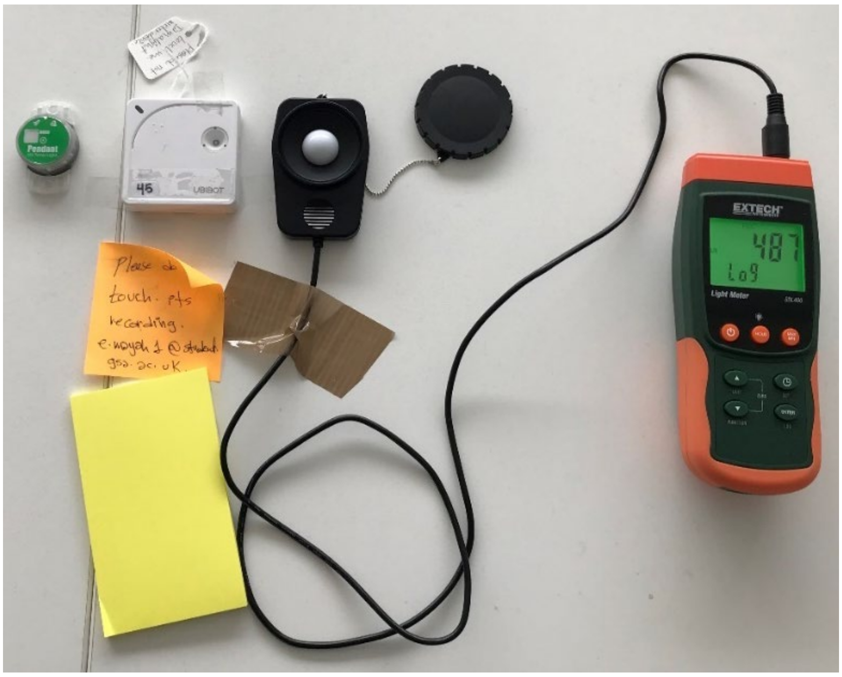


Figure 5-8 **Testing various light meters during the pilot study**

After testing various light meters, the following issues were raised:

- For the Extech meter, a tutor and some students argued that the body of the meter was quite big and consequently took up excessive space on the student's desk (Figure 5-9). This is due to its design, whereby the light lens is detached from the main body and connected to it through a wire. In addition to its bulky size, some students were not comfortable with its bold colour. Additionally, the researcher noted that the Extech meter was heavier and less flexible to locate on a vertical wall to measure the illuminance levels on vertical walls around the studio. A final problem with the meter was that the process of retrieving the light levels data was through the SD card inside the body of the meter, which was a time-consuming process.

- With regards to the UbiBot meter, it weighed less and was more flexible to locate on the vertical wall, and the tutors and students were more comfortable with its small size and white colour. However, because its colour was similar to the colour of the students' desks, some students did not notice it and accidentally covered it with papers and drawing sheets (Figure 5-10). Therefore, the researcher tended to position some notes next to the meter while it was recording so that the students would notice it and not obstruct it (Figure 5-11 and Figure 5-12). Another advantage of the UbiBot meter is that the data it collects can be transferred directly to a cloud- based platform through a Wi-Fi connection, meaning that access and monitoring data was easier and more practical. On a rainy day, one of the meters which had been placed near a window was damaged by leaking rainwater; consequently, all meters that were placed near to windows were kept inside transparent plastic bags to prevent water penetration (Figure 5-13). A calibration with or without the plastic bag's effect on light levels was done to the data obtained from these meters.

Figure 5-9 Difference between UbiBot meter vs Extech meter in terms of size and colour

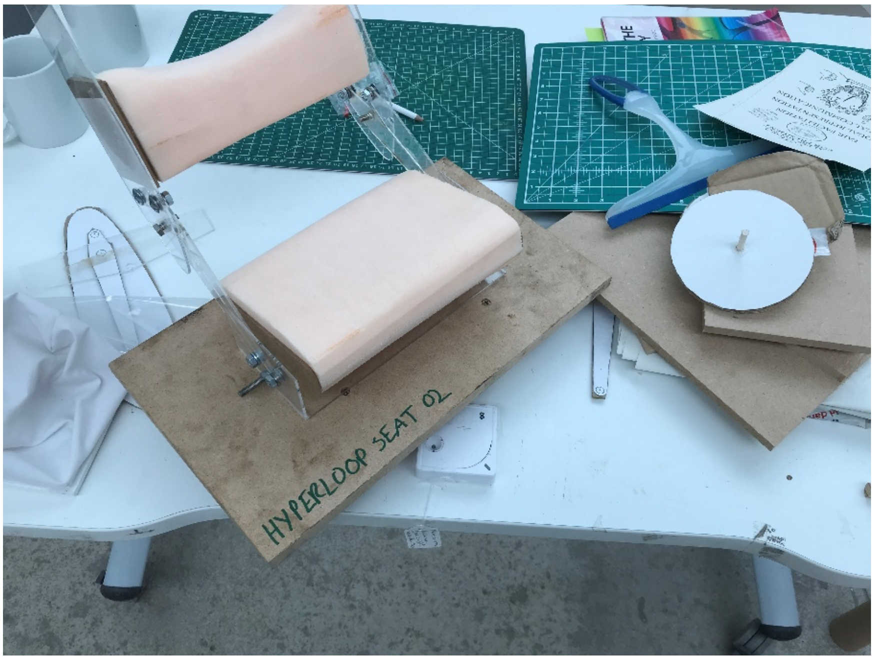


Figure 5-10 Meter was accidentally covered by student's model

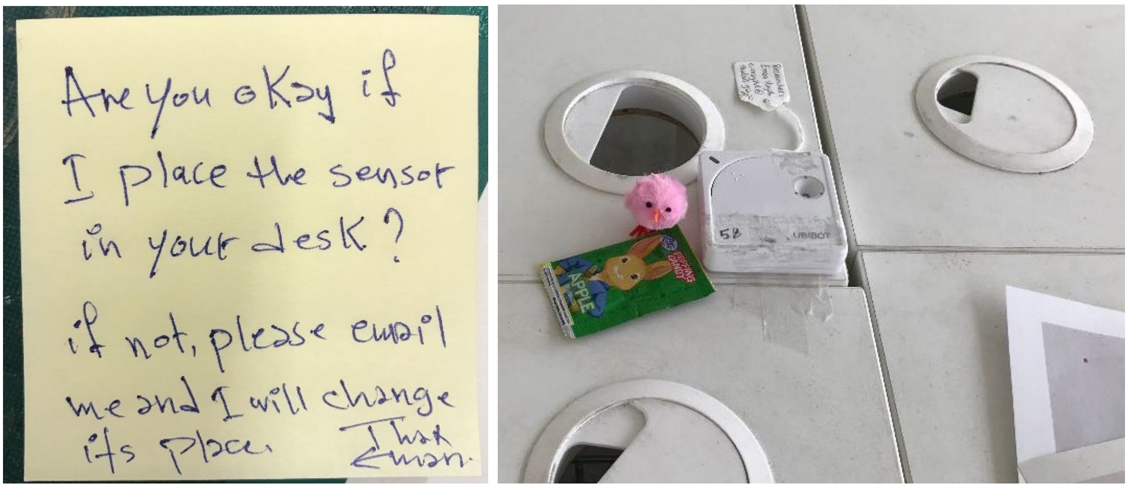


Figure 5-11 Example of note asking for the students' consent for keeping the light meters on their desks (left) and sometimes some catchy bright colour objects were placed close to the meter so it will be noticed by students.

Figure 5-12 Light meters with note so students notice it was placed on their desk

Figure 5-13 The damaged meter due to rainwater leak (left) & an example of one of the meters being kept inside a plastic bag for protection against rainwater leakage from the window (right).

- The HOBO meter meanwhile has a waterproof body and a very lightweight compared with the other meters, and the data retrieval process is via Bluetooth. However, it was quite challenging to access and monitor the data automatically as the phone must be placed in close proximity to the meter every time to transfer the data. In addition, changing the battery was not flexible enough for the nature of the current study.

From the perspective of daylight level readings, a Pearson correlation test was conducted for data collected on 9-Feb-2019 from the UbiBot and Hobo meters which were located in the Glasgow building's roof under an unobstructed sky. Table 5-7 show a high correlation between the measurements recorded from the two types of meters (N= 168, r= .879, P<0.01) and the results in (Table 5-8) shows a statistical description for the two meters.

		UbiBot	Hobo
UBibot	Pearson Correlation	1	.879**
	Sig. (2-tailed)		.000
	N	168	168

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5-7 Pearson correlation

		UbiBot meter	Hobo meter
N	Valid	168	168
	Missing	0	0
Mean		3945.9914	3772.3904
Median		2166.8751	2024.3088
Std. Deviation		4430.40803	4448.83929
Range		16198.95	16419.75
Minimum		.01	.00
Maximum		16198.96	16419.75

Table 5-8 Statistics information

Furthermore, a paired t-test was conducted to check if the mean of the meters' readings was significantly different; the results in (Table 5-9) showed a non-significant difference (P >0.05) between the two-meter means (N = 168, p = .304). Consequently, the results highlight the close accuracy of the two meters in measuring daylight levels, so validating their usage within the investigation.

		Mean	Std. dv	Std. Error Mean	95% Confidence Interval of the Difference		t	df	.Sig
					Lower	Upper			
Pair 1	UbiBot meter Hobo meter	173.60	2182.65	168.39	-158.85	506.05	1.03	167	.304

Table 5-9 Paired sample T- test between UbiBot and Hobo.

5.5.2 **Artificial extraction**

The daylight measurements recorded inside the studios were affected by the presence of artificial lights during working days only. This limitation was very difficult to control for as the investigation was carried out in real-life settings, where artificial lights were needed to support daylight for conducting functional tasks. Unlike spectrophotometers, the light meters (data loggers) used in this investigation could not differentiate between the wavelength functions of daylight and artificial light. Therefore, an extraction process was applied to the recorded data to exclude the effect of artificial lighting. The light meters located inside the studios kept recording for the full day, including both day and night time; hence, the contribution of artificial lighting could be extracted.

Dr. Paul Littlefair, the principle lighting consultant at the Building Research Establishment (BRE), shared with me the results from his PhD study in 1984 entitled “Daylight design and energy conservation”: *My results showed that daylight levels indoors were not generally proportional to daylight outdoors. Even under fully overcast skies there was a 25% standard deviation in the ratio. Whenever skies depart from being overcast, which they do around 80% of the time in the UK, the ratios vary a lot more depending on sunshine, bright cloud and the orientation of the room. One way to separate out the artificial lighting is by measuring it at night at each point, and keeping a log of when it was switched on. However, if the lights were dimmed some of the time that would not be possible*. Likewise, Jens Christoffersen, a senior researcher in the Daylight, Energy and Indoor Climate group (DEIC) at VELUX, noted:

Daylight during daytime = Daytime measurements - Nighttime measurements

Accordingly, the process for extracting the artificial light was based on the registered value at night time. Some of the artificial lights have maximum and medium values, while others have one value only. Figure 5-14, Figure 5-15, and Figure 5-16 present examples of total illuminance levels registered all day, artificial contributions after extraction, and daylight contribution after artificial abstraction inside studios. Table 5-10, Table 5-11, and Table 5-12 present the numerical measurements registered by Meter 66 in studio GNC (Glasgow), Meter

60 in studio E1 (Edinburgh), and Meter 42 in studio A1 (Aberdeen), respectively for total illuminance levels for the full day, artificial only, and daylight only. Since the artificial light has an on/off control system with no dimming, it was noted that the maximum artificial level registered by Meter 66 in studio GNC (Glasgow) was around 668 lux, while the artificial contribution was noted as 600 lux for the maximum level registered by Meter 60 in studio E1 (Edinburgh). Meanwhile, the artificial contributions at night registered by Meter 42 in studio A1 (Aberdeen) were around 676 lux for the maximum level and 391 lux for the medium level or turned off.

Date/	Total illuminance levels	Artificial light only	Daylight only
2019-04-08T08:03:31+01:00	14.73	0.00	14.73
2019-04-08T08:08:31+01:00	13.31	0.00	13.31
2019-04-08T08:13:31+01:00	12.47	0.00	12.47
2019-04-08T08:18:31+01:00	10.61	0.00	10.61
2019-04-08T08:23:31+01:00	11.09	0.00	11.09
2019-04-08T08:28:31+01:00	16.76	0.00	16.76
2019-04-08T08:33:31+01:00	23.52	0.00	23.52
2019-04-08T08:38:31+01:00	19.25	0.00	19.25
2019-04-08T08:43:31+01:00	27.02	0.00	27.02
2019-04-08T08:48:31+01:00	28.99	0.00	28.99
2019-04-08T08:53:31+01:00	28.89	0.00	28.89
2019-04-08T08:58:31+01:00	29.32	0.00	29.32
2019-04-08T09:03:31+01:00	32.47	0.00	32.47
2019-04-08T09:08:31+01:00	36.01	0.00	36.01
2019-04-08T09:13:31+01:00	34.74	0.00	34.74
2019-04-08T09:18:31+01:00	36.61	0.00	36.61
2019-04-08T09:23:31+01:00	38.61	0.00	38.61
2019-04-08T09:28:31+01:00	42.56	0.00	42.56
2019-04-08T09:33:31+01:00	46.8	0.00	46.80
2019-04-08T09:38:31+01:00	55.78	0.00	55.78
2019-04-08T09:43:31+01:00	54.86	0.00	54.86
2019-04-08T09:48:31+01:00	55.82	0.00	55.82
2019-04-08T09:53:31+01:00	55.6	0.00	55.60
2019-04-08T09:58:31+01:00	50.36	0.00	50.36
2019-04-08T10:03:31+01:00	47	0.00	47.00
2019-04-08T10:08:31+01:00	46.22	0.00	46.22
2019-04-08T10:13:31+01:00	51.92	0.00	51.92
2019-04-08T10:18:31+01:00	55.72	0.00	55.72
2019-04-08T10:23:31+01:00	53.7	0.00	53.70
2019-04-08T10:28:31+01:00	16.83	0.00	16.83
2019-04-08T10:33:31+01:00	30.24	0.00	30.24
2019-04-08T10:38:31+01:00	44.5	0.00	44.50
2019-04-08T10:43:31+01:00	69.98	0.00	69.98
2019-04-08T10:48:31+01:00	68.82	0.00	68.82
2019-04-08T10:53:31+01:00	61.12	0.00	61.12

2019-04-08T10:58:31+01:00	52.24	0.00	52.24
2019-04-08T11:03:31+01:00	79.2	0.00	79.20
2019-04-08T11:08:31+01:00	91.4	0.00	91.40
2019-04-08T11:13:31+01:00	89.44	0.00	89.44
2019-04-08T11:18:31+01:00	83.72	0.00	83.72
2019-04-08T11:23:31+01:00	89.84	0.00	89.84
2019-04-08T11:28:31+01:00	89.48	0.00	89.48
2019-04-08T11:33:31+01:00	84.88	0.00	84.88
2019-04-08T11:38:31+01:00	77.18	0.00	77.18
2019-04-08T11:43:31+01:00	92.04	0.00	92.04
2019-04-08T11:48:31+01:00	88.24	0.00	88.24
2019-04-08T11:53:31+01:00	76.22	0.00	76.22
2019-04-08T11:58:31+01:00	79.5	0.00	79.50
2019-04-08T12:03:31+01:00	83.08	0.00	83.08
2019-04-08T12:08:31+01:00	71.24	0.00	71.24
2019-04-08T12:13:31+01:00	80.6	0.00	80.60
2019-04-08T12:18:31+01:00	94.32	0.00	94.32
2019-04-08T12:23:31+01:00	87.24	0.00	87.24
2019-04-08T12:28:31+01:00	87.56	0.00	87.56
2019-04-08T12:33:31+01:00	80.06	0.00	80.06
2019-04-08T12:38:31+01:00	76.64	0.00	76.64
2019-04-08T12:43:31+01:00	59.32	0.00	59.32
2019-04-08T12:48:31+01:00	48.78	0.00	48.78
2019-04-08T12:53:31+01:00	66.28	0.00	66.28
2019-04-08T12:58:31+01:00	62.06	0.00	62.06
2019-04-08T13:03:31+01:00	58.12	0.00	58.12
2019-04-08T13:08:31+01:00	60.22	0.00	60.22
2019-04-08T13:13:31+01:00	55.58	0.00	55.58
2019-04-08T13:18:31+01:00	55.58	0.00	55.58
2019-04-08T13:23:31+01:00	48.48	0.00	48.48
2019-04-08T13:28:31+01:00	72.2	0.00	72.20
2019-04-08T13:33:31+01:00	68.68	0.00	68.68
2019-04-08T13:38:31+01:00	58.14	0.00	58.14
2019-04-08T13:43:31+01:00	52.22	0.00	52.22
2019-04-08T13:48:31+01:00	59.88	0.00	59.88
2019-04-08T13:53:31+01:00	45	0.00	45.00
2019-04-08T13:58:31+01:00	51.7	0.00	51.70
2019-04-08T14:03:31+01:00	56.2	0.00	56.20
2019-04-08T14:08:31+01:00	42.5	0.00	42.50
2019-04-08T14:13:31+01:00	50.32	0.00	50.32
2019-04-08T14:18:31+01:00	46.92	0.00	46.92
2019-04-08T14:23:31+01:00	48.82	0.00	48.82
2019-04-08T14:28:31+01:00	53.58	0.00	53.58
2019-04-08T14:33:31+01:00	59.26	0.00	59.26
2019-04-08T14:38:31+01:00	41.4	0.00	41.40
2019-04-08T14:43:31+01:00	44.76	0.00	44.76
2019-04-08T14:48:31+01:00	48.56	0.00	48.56
2019-04-08T14:53:31+01:00	46.48	0.00	46.48
2019-04-08T14:58:31+01:00	41.28	0.00	41.28
2019-04-08T15:03:31+01:00	47.16	0.00	47.16
2019-04-08T15:08:31+01:00	45.4	0.00	45.40
2019-04-08T15:13:31+01:00	35.72	0.00	35.72

2019-04-08T15:18:31+01:00	44.36	0.00	44.36
2019-04-08T15:23:31+01:00	44.14	0.00	44.14
2019-04-08T15:28:31+01:00	44.06	0.00	44.06
2019-04-08T15:33:31+01:00	44.06	0.00	44.06
2019-04-08T15:38:31+01:00	613.28	0.00	44.00
2019-04-08T15:43:31+01:00	784.32	668.00	116.32
2019-04-08T15:48:31+01:00	775.04	668.00	107.04
2019-04-08T15:53:31+01:00	787.84	668.00	119.84
2019-04-08T15:58:31+01:00	779.84	668.00	111.84
2019-04-08T16:03:31+01:00	765.76	668.00	97.76
2019-04-08T16:08:31+01:00	752	668.00	84.00
2019-04-08T16:13:31+01:00	740.8	668.00	72.80
2019-04-08T16:18:31+01:00	732.48	668.00	64.48
2019-04-08T16:23:31+01:00	727.36	668.00	59.36
2019-04-08T16:28:31+01:00	723.2	668.00	55.20
2019-04-08T16:33:31+01:00	719.04	668.00	51.04
2019-04-08T16:38:31+01:00	714.24	668.00	46.24
2019-04-08T16:43:31+01:00	711.04	668.00	43.04
2019-04-08T16:48:31+01:00	708.16	668.00	40.16
2019-04-08T16:53:31+01:00	705.6	668.00	37.60
2019-04-08T16:58:31+01:00	702.72	668.00	34.72
2019-04-08T17:03:31+01:00	701.12	668.00	33.12
2019-04-08T17:08:31+01:00	699.52	668.00	31.52
2019-04-08T17:13:31+01:00	699.2	668.00	31.20
2019-04-08T17:18:31+01:00	697.6	668.00	29.60
2019-04-08T17:23:31+01:00	696.96	668.00	28.96
2019-04-08T17:28:31+01:00	696.32	668.00	28.32
2019-04-08T17:33:31+01:00	695.68	668.00	27.68
2019-04-08T17:38:31+01:00	694.72	668.00	26.72
2019-04-08T17:43:31+01:00	694.08	668.00	26.08
2019-04-08T17:48:31+01:00	693.76	668.00	25.76
2019-04-08T17:53:31+01:00	693.44	668.00	25.44
2019-04-08T17:58:31+01:00	692.8	668.00	24.80
2019-04-08T18:03:31+01:00	691.84	668.00	23.84
2019-04-08T18:08:31+01:00	690.88	668.00	22.88
2019-04-08T18:13:31+01:00	689.92	668.00	21.92
2019-04-08T18:18:31+01:00	689.28	668.00	21.28
2019-04-08T18:23:31+01:00	688.32	668.00	20.32
2019-04-08T18:28:31+01:00	687.68	668.00	19.68
2019-04-08T18:33:31+01:00	686.4	668.00	18.40
2019-04-08T18:38:31+01:00	684.16	668.00	16.16
2019-04-08T18:43:31+01:00	601.44	585.44	16.00
2019-04-08T18:48:31+01:00	681.6	668.00	13.60
2019-04-08T18:53:31+01:00	680.32	668.00	12.32
2019-04-08T18:58:31+01:00	679.04	668.00	11.04
2019-04-08T19:03:31+01:00	678.08	668.00	10.08
2019-04-08T19:08:31+01:00	677.44	668.00	9.44
2019-04-08T19:13:31+01:00	677.44	668.00	9.44
2019-04-08T19:18:31+01:00	677.12	668.00	9.12
2019-04-08T19:23:31+01:00	676.8	668.00	8.80
2019-04-08T19:28:31+01:00	675.84	668.00	7.84
2019-04-08T19:33:31+01:00	675.2	668.00	7.20

2019-04-08T19:38:31+01:00	673.6	668.00	5.60
2019-04-08T19:43:31+01:00	672	668.00	4.00
2019-04-08T19:48:31+01:00	671.36	668.00	3.36
2019-04-08T19:53:31+01:00	670.72	668.00	2.72
2019-04-08T19:58:31+01:00	670.08	668.00	2.08
2019-04-08T20:03:31+01:00	669.44	668.00	1.44
2019-04-08T20:08:31+01:00	669.12	668.00	1.12
2019-04-08T20:13:31+01:00	669.12	668.00	1.12
2019-04-08T20:18:31+01:00	668.48	668.00	0.48
2019-04-08T20:23:31+01:00	668.48	668.00	0.48
2019-04-08T20:28:31+01:00	668.16	668.00	0.16
2019-04-08T20:33:31+01:00	668.16	668.00	0.16
2019-04-08T20:38:31+01:00	668.48	668.00	0.48
2019-04-08T20:43:31+01:00	668.48	668.00	0.48
2019-04-08T20:48:31+01:00	668.48	668.00	0.48
2019-04-08T20:53:31+01:00	668.8	668.00	0.80
2019-04-08T20:58:31+01:00	669.12	669.12	0.00
2019-04-08T21:03:31+01:00	3.75	0.00	0.00
2019-04-08T21:08:31+01:00	3.75	0.00	0.00
2019-04-08T21:13:31+01:00	3.75	0.00	0.00
2019-04-08T21:18:31+01:00	3.77	0.00	0.00
2019-04-08T21:23:31+01:00	3.76	0.00	0.00
2019-04-08T21:28:31+01:00	3.76	0.00	0.00
2019-04-08T21:33:31+01:00	3.75	0.00	0.00
2019-04-08T21:38:31+01:00	3.78	0.00	0.00
2019-04-08T21:43:31+01:00	3.78	0.00	0.00
2019-04-08T21:48:31+01:00	3.79	0.00	0.00
2019-04-08T21:53:31+01:00	3.78	0.00	0.00
2019-04-08T21:58:31+01:00	1.18	0.00	0.00
2019-04-08T22:03:31+01:00	1.18	0.00	0.00

Table 5-10 The numerical measurements registered by Meter 66 in studio GNC (Glasgow) for total illuminance levels for the full day, artificial only, and daylight only in April.

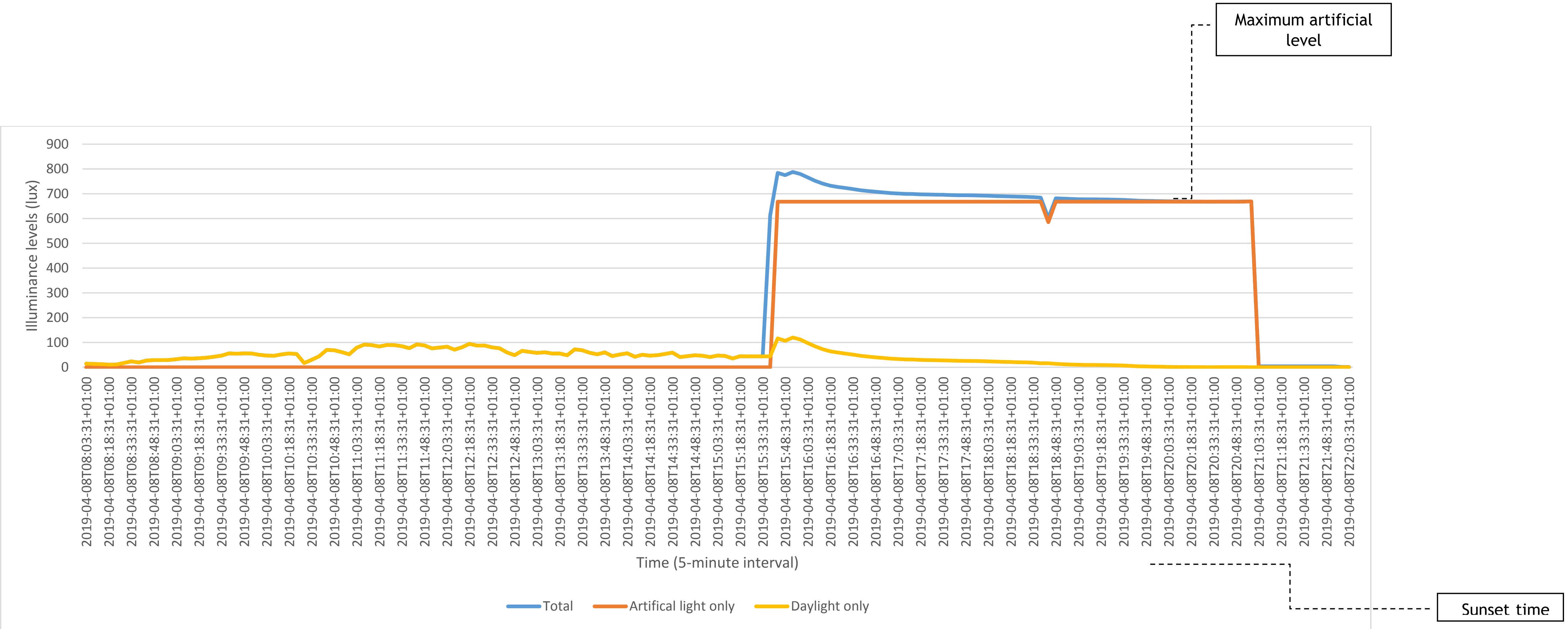


Figure 5-14 Illuminance levels registered by Meter 66 in studio GNC (Glasgow) in April for the total measurements vs artificial only after extraction vs daylight only after abstracting the artificial

Date/	Total illuminance levels	Artificial only	Daylight only
2019-04-09T08:02:19+01:00	175.60	0.00	175.60
2019-04-09T08:07:19+01:00	820.48	600.00	220.48
2019-04-09T08:12:19+01:00	811.84	600.00	211.84
2019-04-09T08:17:19+01:00	806.08	600.00	206.08
2019-04-09T08:22:19+01:00	807.36	600.00	207.36
2019-04-09T08:27:19+01:00	808.32	600.00	208.32
2019-04-09T08:32:19+01:00	811.52	600.00	211.52
2019-04-09T08:37:19+01:00	815.36	600.00	215.36
2019-04-09T08:42:19+01:00	818.56	600.00	218.56
2019-04-09T08:47:19+01:00	822.40	600.00	222.40
2019-04-09T08:52:19+01:00	824.64	600.00	224.64
2019-04-09T08:57:19+01:00	219.60	0.00	219.60
2019-04-09T09:02:19+01:00	226.72	0.00	226.72
2019-04-09T09:07:19+01:00	250.00	0.00	250.00
2019-04-09T09:12:19+01:00	262.88	0.00	262.88
2019-04-09T09:17:19+01:00	261.84	0.00	261.84
2019-04-09T09:22:19+01:00	279.68	0.00	279.68
2019-04-09T09:27:19+01:00	302.08	0.00	302.08
2019-04-09T09:32:19+01:00	322.08	0.00	322.08
2019-04-09T09:37:19+01:00	422.08	0.00	422.08
2019-04-09T09:42:19+01:00	387.36	0.00	387.36
2019-04-09T09:47:19+01:00	442.72	0.00	442.72
2019-04-09T09:52:19+01:00	413.76	0.00	413.76
2019-04-09T09:57:19+01:00	364.64	0.00	364.64
2019-04-09T10:02:19+01:00	419.20	0.00	419.20
2019-04-09T10:07:19+01:00	401.60	0.00	401.60
2019-04-09T10:12:19+01:00	432.64	0.00	432.64
2019-04-09T10:17:19+01:00	417.44	0.00	417.44
2019-04-09T10:22:19+01:00	391.36	0.00	391.36
2019-04-09T10:27:19+01:00	403.20	0.00	403.20
2019-04-09T10:32:19+01:00	371.52	0.00	371.52
2019-04-09T10:37:19+01:00	294.48	0.00	294.48
2019-04-09T10:42:19+01:00	300.64	0.00	300.64
2019-04-09T10:47:19+01:00	393.28	0.00	393.28
2019-04-09T10:52:19+01:00	372.00	0.00	372.00
2019-04-09T10:57:19+01:00	350.88	0.00	350.88
2019-04-09T11:02:19+01:00	368.48	0.00	368.48
2019-04-09T11:07:19+01:00	338.72	0.00	338.72
2019-04-09T11:12:19+01:00	386.56	0.00	386.56
2019-04-09T11:17:19+01:00	367.52	0.00	367.52
2019-04-09T11:22:19+01:00	287.92	0.00	287.92
2019-04-09T11:27:19+01:00	374.40	0.00	374.40
2019-04-09T11:32:19+01:00	841.92	600.00	241.92
2019-04-09T11:37:19+01:00	800.00	600.00	200.00

2019-04-09T11:42:19+01:00	806.08	600.00	206.08
2019-04-09T11:47:19+01:00	857.60	600.00	257.60
2019-04-09T11:52:19+01:00	784.32	600.00	184.32
2019-04-09T11:57:19+01:00	809.28	600.00	209.28
2019-04-09T12:02:19+01:00	779.20	600.00	179.20
2019-04-09T12:07:19+01:00	742.40	600.00	142.40
2019-04-09T12:12:19+01:00	866.24	600.00	266.24
2019-04-09T12:17:19+01:00	818.56	600.00	218.56
2019-04-09T12:22:19+01:00	872.00	600.00	272.00
2019-04-09T12:27:19+01:00	821.44	600.00	221.44
2019-04-09T12:32:19+01:00	899.52	600.00	299.52
2019-04-09T12:37:19+01:00	789.44	600.00	189.44
2019-04-09T12:42:19+01:00	813.44	600.00	213.44
2019-04-09T12:47:19+01:00	931.52	600.00	331.52
2019-04-09T12:52:19+01:00	898.88	600.00	298.88
2019-04-09T12:57:19+01:00	860.80	600.00	260.80
2019-04-09T13:02:19+01:00	985.28	600.00	385.28
2019-04-09T13:07:19+01:00	836.16	600.00	236.16
2019-04-09T13:12:19+01:00	897.60	600.00	297.60
2019-04-09T13:17:19+01:00	876.48	600.00	276.48
2019-04-09T13:22:19+01:00	805.44	600.00	205.44
2019-04-09T13:27:19+01:00	808.96	600.00	208.96
2019-04-09T13:32:19+01:00	858.24	600.00	258.24
2019-04-09T13:37:19+01:00	861.12	600.00	261.12
2019-04-09T13:42:19+01:00	841.28	600.00	241.28
2019-04-09T13:47:19+01:00	903.68	600.00	303.68
2019-04-09T13:52:19+01:00	889.92	600.00	289.92
2019-04-09T13:57:19+01:00	844.48	600.00	244.48
2019-04-09T14:02:19+01:00	856.64	600.00	256.64
2019-04-09T14:07:19+01:00	797.44	600.00	197.44
2019-04-09T14:12:19+01:00	857.28	600.00	257.28
2019-04-09T14:17:19+01:00	931.52	600.00	331.52
2019-04-09T14:22:19+01:00	775.36	600.00	175.36
2019-04-09T14:27:19+01:00	837.12	600.00	237.12
2019-04-09T14:32:19+01:00	896.64	600.00	296.64
2019-04-09T14:37:19+01:00	890.24	600.00	290.24
2019-04-09T14:42:19+01:00	917.76	600.00	317.76
2019-04-09T14:47:19+01:00	904.00	600.00	304.00
2019-04-09T14:52:19+01:00	866.24	600.00	266.24
2019-04-09T14:57:19+01:00	897.28	600.00	297.28
2019-04-09T15:02:19+01:00	807.68	600.00	207.68
2019-04-09T15:07:19+01:00	830.40	600.00	230.40
2019-04-09T15:12:19+01:00	863.36	600.00	263.36
2019-04-09T15:17:19+01:00	816.64	600.00	216.64
2019-04-09T15:22:19+01:00	879.36	600.00	279.36
2019-04-09T15:27:19+01:00	884.80	600.00	284.80

2019-04-09T15:32:19+01:00	851.52	600.00	251.52
2019-04-09T15:37:19+01:00	882.88	600.00	282.88
2019-04-09T15:42:19+01:00	811.84	600.00	211.84
2019-04-09T15:47:19+01:00	761.60	600.00	161.60
2019-04-09T15:52:19+01:00	857.92	600.00	257.92
2019-04-09T15:57:19+01:00	865.92	600.00	265.92
2019-04-09T16:02:19+01:00	879.36	600.00	279.36
2019-04-09T16:07:19+01:00	808.00	600.00	208.00
2019-04-09T16:12:19+01:00	836.80	600.00	236.80
2019-04-09T16:17:19+01:00	870.08	600.00	270.08
2019-04-09T16:22:19+01:00	871.04	600.00	271.04
2019-04-09T16:27:19+01:00	871.36	600.00	271.36
2019-04-09T16:32:19+01:00	862.72	600.00	262.72
2019-04-09T16:37:19+01:00	879.68	600.00	279.68
2019-04-09T16:42:19+01:00	847.04	600.00	247.04
2019-04-09T16:47:19+01:00	862.08	600.00	262.08
2019-04-09T16:52:19+01:00	886.40	600.00	286.40
2019-04-09T16:57:19+01:00	909.44	600.00	309.44
2019-04-09T17:02:19+01:00	946.56	600.00	346.56
2019-04-09T17:07:19+01:00	1075.52	600.00	475.52
2019-04-09T17:12:19+01:00	1087.68	600.00	487.68
2019-04-09T17:17:19+01:00	1077.76	600.00	477.76
2019-04-09T17:22:19+01:00	1087.68	600.00	487.68
2019-04-09T17:27:19+01:00	1129.28	600.00	529.28
2019-04-09T17:32:19+01:00	831.04	600.00	231.04
2019-04-09T17:37:19+01:00	843.20	600.00	243.20
2019-04-09T17:42:19+01:00	1171.20	600.00	571.20
2019-04-09T17:47:19+01:00	1195.20	600.00	595.20
2019-04-09T17:52:19+01:00	1156.16	600.00	556.16
2019-04-09T17:57:19+01:00	853.12	600.00	253.12
2019-04-09T18:02:19+01:00	911.36	600.00	311.36
2019-04-09T18:07:19+01:00	1187.52	600.00	587.52
2019-04-09T18:12:19+01:00	979.84	600.00	379.84
2019-04-09T18:17:19+01:00	862.08	600.00	262.08
2019-04-09T18:22:19+01:00	1159.68	600.00	559.68
2019-04-09T18:27:19+01:00	1133.44	600.00	533.44
2019-04-09T18:32:19+01:00	1008.32	600.00	408.32
2019-04-09T18:37:19+01:00	1114.88	600.00	514.88
2019-04-09T18:42:19+01:00	1078.72	600.00	478.72
2019-04-09T18:47:19+01:00	1049.92	600.00	449.92
2019-04-09T18:52:19+01:00	1037.44	600.00	437.44
2019-04-09T18:57:19+01:00	965.12	600.00	365.12
2019-04-09T19:02:19+01:00	822.40	600.00	222.40
2019-04-09T19:07:19+01:00	953.92	600.00	353.92
2019-04-09T19:12:19+01:00	802.24	600.00	202.24
2019-04-09T19:17:19+01:00	737.60	600.00	137.60

2019-04-09T19:22:19+01:00	712.96	600.00	112.96
2019-04-09T19:27:19+01:00	696.96	600.00	96.96
2019-04-09T19:32:19+01:00	679.68	600.00	79.68
2019-04-09T19:37:19+01:00	672.00	600.00	72.00
2019-04-09T19:42:19+01:00	659.20	600.00	59.20
2019-04-09T19:47:19+01:00	647.04	600.00	47.04
2019-04-09T19:52:19+01:00	636.48	600.00	36.48
2019-04-09T19:57:19+01:00	627.36	600.00	27.36
2019-04-09T20:02:19+01:00	618.56	600.00	18.56
2019-04-09T20:07:19+01:00	612.64	600.00	12.64
2019-04-09T20:12:19+01:00	608.00	600.00	8.00
2019-04-09T20:17:19+01:00	604.64	600.00	4.64
2019-04-09T20:22:19+01:00	603.20	600.00	3.20
2019-04-09T20:27:19+01:00	601.92	600.00	1.92
2019-04-09T20:32:19+01:00	600.64	600.00	0.64
2019-04-09T20:37:19+01:00	600.64	600.00	0.64
2019-04-09T20:42:19+01:00	600.32	600.00	0.32
2019-04-09T20:47:19+01:00	600.00	600.00	0.00
2019-04-09T20:52:19+01:00	600.80	600.80	0.00
2019-04-09T20:57:19+01:00	601.28	601.28	0.00
2019-04-09T21:02:19+01:00	602.72	602.72	0.00
2019-04-09T21:07:19+01:00	602.88	602.88	0.00
2019-04-09T21:12:19+01:00	602.72	602.72	0.00
2019-04-09T21:17:19+01:00	602.88	602.88	0.00
2019-04-09T21:22:19+01:00	0.02	0.02	0.00
2019-04-09T21:27:19+01:00	0.02	0.02	0.00
2019-04-09T21:32:19+01:00	0.02	0.02	0.00
2019-04-09T21:37:19+01:00	0.02	0.02	0.00
2019-04-09T21:42:19+01:00	0.02	0.02	0.00
2019-04-09T21:47:19+01:00	0.02	0.02	0.00
2019-04-09T21:52:19+01:00	0.02	0.02	0.00
2019-04-09T21:57:19+01:00	0.03	0.03	0.00
2019-04-09T22:02:19+01:00	0.02	0.02	0.00

Table 5-11 The numerical measurements registered by Meter 60 in studio E1 (Edinburgh) for total illuminance levels for the full day, artificial only, and daylight only in April.

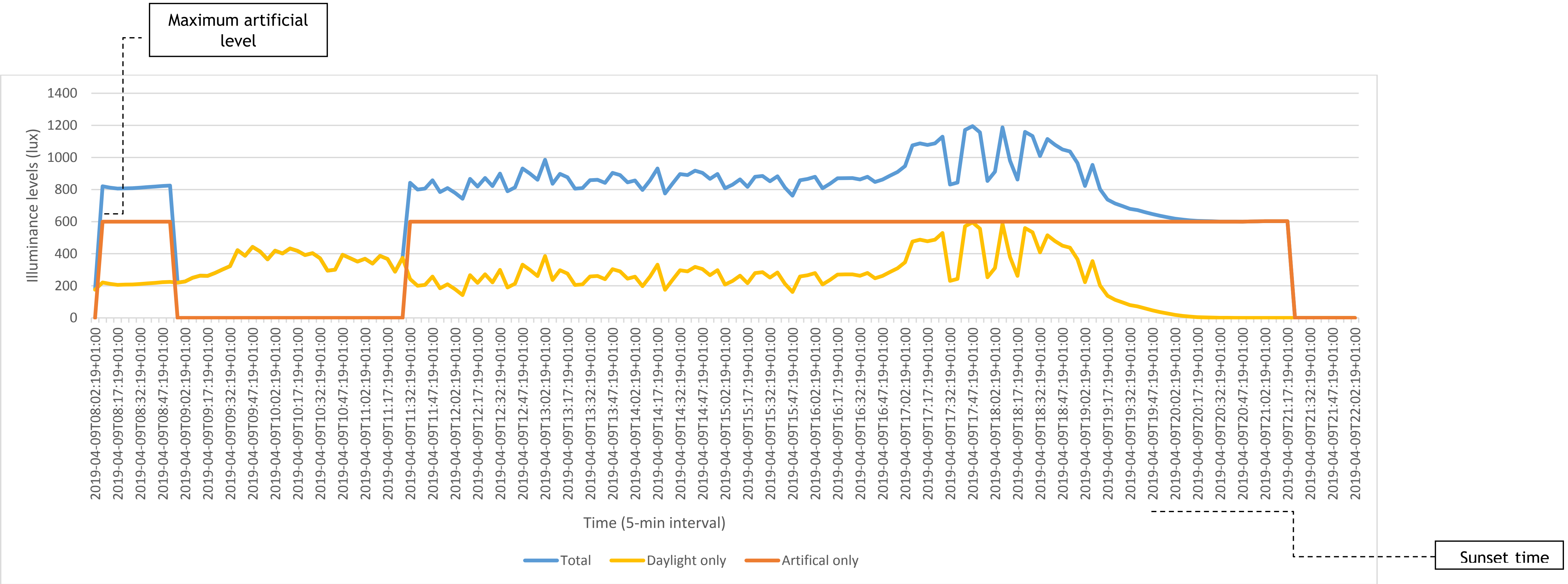


Figure 5-15 Illuminance levels registered by Meter 60 in studio E1 (Edinburgh) in April for the total measurements vs artificial only after extraction vs daylight only after abstracting the artificial

Date/	Total illuminance levels	Artificial only	Daylight only
2019-04-02T08:01:03+01:00	682.24	676.00	6.24
2019-04-02T08:06:03+01:00	681.60	676.00	5.60
2019-04-02T08:11:03+01:00	681.28	676.00	5.28
2019-04-02T08:16:03+01:00	680.96	676.00	4.96
2019-04-02T08:21:03+01:00	681.60	676.00	5.60
2019-04-02T08:26:03+01:00	681.60	676.00	5.60
2019-04-02T08:31:03+01:00	681.92	676.00	5.92
2019-04-02T08:36:03+01:00	683.84	676.00	7.84
2019-04-02T08:41:03+01:00	400.16	391.00	9.16
2019-04-02T08:46:03+01:00	684.48	676.00	8.48
2019-04-02T08:51:03+01:00	685.12	676.00	9.12
2019-04-02T08:56:03+01:00	686.08	676.00	10.08
2019-04-02T09:01:03+01:00	687.04	676.00	11.04
2019-04-02T09:06:03+01:00	686.72	676.00	10.72
2019-04-02T09:11:03+01:00	402.08	391.00	11.08
2019-04-02T09:16:03+01:00	403.84	391.00	12.84
2019-04-02T09:21:03+01:00	405.44	391.00	14.44
2019-04-02T09:26:03+01:00	406.40	391.00	15.40
2019-04-02T09:31:03+01:00	690.56	676.00	14.56
2019-04-02T09:36:03+01:00	690.24	676.00	14.24
2019-04-02T09:41:03+01:00	690.24	676.00	14.24
2019-04-02T09:46:03+01:00	689.92	676.00	13.92
2019-04-02T09:51:03+01:00	691.20	676.00	15.20
2019-04-02T09:56:03+01:00	692.16	676.00	16.16
2019-04-02T10:01:03+01:00	693.44	676.00	17.44
2019-04-02T10:06:03+01:00	695.68	676.00	19.68
2019-04-02T10:11:03+01:00	696.00	676.00	20.00
2019-04-02T10:16:03+01:00	741.12	676.00	65.12
2019-04-02T10:21:03+01:00	742.40	676.00	66.40
2019-04-02T10:26:03+01:00	745.92	676.00	69.92
2019-04-02T10:31:03+01:00	745.92	676.00	69.92
2019-04-02T10:36:03+01:00	753.92	676.00	77.92
2019-04-02T10:41:03+01:00	752.96	676.00	76.96
2019-04-02T10:46:03+01:00	756.16	676.00	80.16
2019-04-02T10:51:03+01:00	758.08	676.00	82.08
2019-04-02T10:56:03+01:00	480.16	391.00	89.16
2019-04-02T11:01:03+01:00	483.20	391.00	92.20
2019-04-02T11:06:03+01:00	483.68	391.00	92.68
2019-04-02T11:11:03+01:00	482.08	391.00	91.08
2019-04-02T11:16:03+01:00	480.32	391.00	89.32
2019-04-02T11:21:03+01:00	767.68	676.00	91.68
2019-04-02T11:26:03+01:00	770.56	676.00	94.56
2019-04-02T11:31:03+01:00	772.80	676.00	96.80

2019-04-02T11:36:03+01:00	772.48	676.00	96.48
2019-04-02T11:41:03+01:00	491.52	391.00	100.52
2019-04-02T11:46:03+01:00	490.24	391.00	99.24
2019-04-02T11:51:03+01:00	484.96	391.00	93.96
2019-04-02T11:56:03+01:00	484.00	391.00	93.00
2019-04-02T12:01:03+01:00	486.24	391.00	95.24
2019-04-02T12:06:03+01:00	492.16	391.00	101.16
2019-04-02T12:11:03+01:00	779.20	676.00	103.20
2019-04-02T12:16:03+01:00	789.12	676.00	113.12
2019-04-02T12:21:03+01:00	790.72	676.00	114.72
2019-04-02T12:26:03+01:00	782.08	676.00	106.08
2019-04-02T12:31:03+01:00	539.84	391.00	148.84
2019-04-02T12:36:03+01:00	806.40	676.00	130.40
2019-04-02T12:41:03+01:00	768.00	676.00	92.00
2019-04-02T12:46:03+01:00	822.72	676.00	146.72
2019-04-02T12:51:03+01:00	802.24	676.00	126.24
2019-04-02T12:56:03+01:00	851.20	676.00	175.20
2019-04-02T13:01:03+01:00	837.44	676.00	161.44
2019-04-02T13:06:03+01:00	799.68	676.00	123.68
2019-04-02T13:11:03+01:00	775.36	676.00	99.36
2019-04-02T13:16:03+01:00	795.84	676.00	119.84
2019-04-02T13:21:03+01:00	536.96	391.00	145.96
2019-04-02T13:26:03+01:00	589.92	391.00	198.92
2019-04-02T13:31:03+01:00	544.64	391.00	153.64
2019-04-02T13:36:03+01:00	559.36	391.00	168.36
2019-04-02T13:41:03+01:00	883.20	676.00	207.20
2019-04-02T13:46:03+01:00	879.68	676.00	203.68
2019-04-02T13:51:03+01:00	891.52	676.00	215.52
2019-04-02T13:56:03+01:00	877.44	676.00	201.44
2019-04-02T14:01:03+01:00	888.32	676.00	212.32
2019-04-02T14:06:03+01:00	862.08	676.00	186.08
2019-04-02T14:11:03+01:00	869.76	676.00	193.76
2019-04-02T14:16:03+01:00	807.04	676.00	131.04
2019-04-02T14:21:03+01:00	775.36	676.00	99.36
2019-04-02T14:26:03+01:00	482.56	391.00	91.56
2019-04-02T14:31:03+01:00	517.44	391.00	126.44
2019-04-02T14:36:03+01:00	546.72	391.00	155.72
2019-04-02T14:41:03+01:00	840.96	676.00	164.96
2019-04-02T14:46:03+01:00	847.68	676.00	171.68
2019-04-02T14:51:03+01:00	805.76	676.00	129.76
2019-04-02T14:56:03+01:00	759.68	676.00	83.68
2019-04-02T15:01:03+01:00	862.72	676.00	186.72
2019-04-02T15:06:03+01:00	863.36	676.00	187.36
2019-04-02T15:11:03+01:00	828.80	676.00	152.80
2019-04-02T15:16:03+01:00	780.80	676.00	104.80
2019-04-02T15:21:03+01:00	781.76	676.00	105.76

2019-04-02T15:26:03+01:00	774.40	676.00	98.40
2019-04-02T15:31:03+01:00	779.52	676.00	103.52
2019-04-02T15:36:03+01:00	792.96	676.00	116.96
2019-04-02T15:41:03+01:00	804.16	676.00	128.16
2019-04-02T15:46:03+01:00	781.76	676.00	105.76
2019-04-02T15:51:03+01:00	744.96	676.00	68.96
2019-04-02T15:56:03+01:00	741.12	676.00	65.12
2019-04-02T16:01:03+01:00	780.16	676.00	104.16
2019-04-02T16:06:03+01:00	782.40	676.00	106.40
2019-04-02T16:11:03+01:00	771.84	676.00	95.84
2019-04-02T16:16:03+01:00	757.12	676.00	81.12
2019-04-02T16:21:03+01:00	742.40	676.00	66.40
2019-04-02T16:26:03+01:00	723.52	676.00	47.52
2019-04-02T16:31:03+01:00	732.48	676.00	56.48
2019-04-02T16:36:03+01:00	740.16	676.00	64.16
2019-04-02T16:41:03+01:00	734.40	676.00	58.40
2019-04-02T16:46:03+01:00	739.52	676.00	63.52
2019-04-02T16:51:03+01:00	743.04	676.00	67.04
2019-04-02T16:56:03+01:00	744.96	676.00	68.96
2019-04-02T17:01:03+01:00	750.72	676.00	74.72
2019-04-02T17:06:03+01:00	737.60	676.00	61.60
2019-04-02T17:11:03+01:00	724.80	676.00	48.80
2019-04-02T17:16:03+01:00	720.96	676.00	44.96
2019-04-02T17:21:03+01:00	718.08	676.00	42.08
2019-04-02T17:26:03+01:00	427.52	391.00	36.52
2019-04-02T17:31:03+01:00	423.84	391.00	32.84
2019-04-02T17:36:03+01:00	422.24	391.00	31.24
2019-04-02T17:41:03+01:00	421.92	391.00	30.92
2019-04-02T17:46:03+01:00	419.68	391.00	28.68
2019-04-02T17:51:03+01:00	417.76	391.00	26.76
2019-04-02T17:56:03+01:00	420.80	391.00	29.80
2019-04-02T18:01:03+01:00	422.56	391.00	31.56
2019-04-02T18:06:03+01:00	413.76	391.00	22.76
2019-04-02T18:11:03+01:00	415.52	391.00	24.52
2019-04-02T18:16:03+01:00	408.96	391.00	17.96
2019-04-02T18:21:03+01:00	408.48	391.00	17.48
2019-04-02T18:26:03+01:00	405.12	391.00	14.12
2019-04-02T18:31:03+01:00	405.60	391.00	14.60
2019-04-02T18:36:03+01:00	404.96	391.00	13.96
2019-04-02T18:41:03+01:00	405.12	391.00	14.12
2019-04-02T18:46:03+01:00	692.16	676.00	16.16
2019-04-02T18:51:03+01:00	689.60	676.00	13.60
2019-04-02T18:56:03+01:00	687.68	676.00	11.68
2019-04-02T19:01:03+01:00	686.08	676.00	10.08
2019-04-02T19:06:03+01:00	401.28	391.00	10.28
2019-04-02T19:11:03+01:00	12.18	0.00	12.18

2019-04-02T19:16:03+01:00	10.32	0.00	10.32
2019-04-02T19:21:03+01:00	8.85	0.00	8.85
2019-04-02T19:26:03+01:00	8.30	0.00	8.30
2019-04-02T19:31:03+01:00	7.46	0.00	7.46
2019-04-02T19:36:03+01:00	7.18	0.00	7.18
2019-04-02T19:41:03+01:00	6.59	0.00	6.59
2019-04-02T19:46:03+01:00	5.33	0.00	5.33
2019-04-02T19:51:03+01:00	4.55	0.00	4.55
2019-04-02T19:56:03+01:00	3.96	0.00	3.96
2019-04-02T20:01:03+01:00	3.69	0.00	3.69
2019-04-02T20:06:03+01:00	3.60	0.00	3.60
2019-04-02T20:11:03+01:00	3.50	0.00	3.50
2019-04-02T20:16:03+01:00	3.43	0.00	3.43
2019-04-02T20:21:03+01:00	396.64	391.00	5.64
2019-04-02T20:26:03+01:00	394.24	391.00	3.24
2019-04-02T20:31:03+01:00	392.96	391.00	1.96
2019-04-02T20:36:03+01:00	392.32	391.00	1.32
2019-04-02T20:41:03+01:00	392.00	391.00	1.00
2019-04-02T20:46:03+01:00	391.52	391.00	0.52
2019-04-02T20:51:03+01:00	391.36	391.00	0.36
2019-04-02T20:56:03+01:00	391.20	391.00	0.20
2019-04-02T21:01:03+01:00	678.08	676.00	2.08
2019-04-02T21:06:03+01:00	676.80	676.00	0.80
2019-04-02T21:11:03+01:00	676.16	676.00	0.16
2019-04-02T21:16:03+01:00	675.52	675.36	0.16
2019-04-02T21:21:03+01:00	0.99	0.00	0.00
2019-04-02T21:26:03+01:00	1.00	0.00	0.00
2019-04-02T21:31:03+01:00	0.99	0.00	0.00
2019-04-02T21:36:03+01:00	1.00	0.00	0.00
2019-04-02T21:41:03+01:00	3.48	0.00	0.00
2019-04-02T21:46:03+01:00	3.42	0.00	0.00
2019-04-02T21:51:03+01:00	3.40	0.00	0.00
2019-04-02T21:56:03+01:00	3.40	0.00	0.00
2019-04-02T22:01:03+01:00	0.99	0.00	0.00

Table 5-12 The numerical measurements registered by Meter 42 in studio A1 (Aberdeen) for total illuminance levels for the full day, artificial only, and daylight only in April.

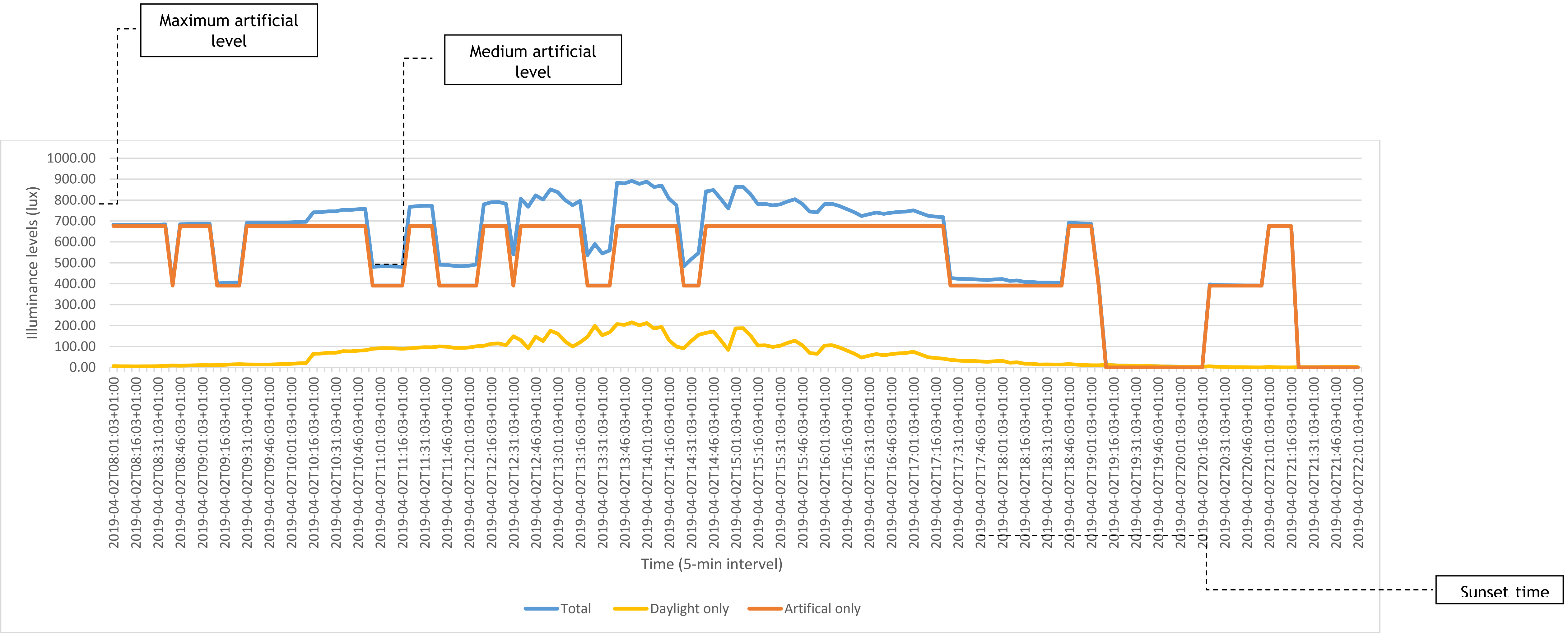


Figure 5-16 Illuminance levels registered by Meter 42 in studio A1 (Aberdeen) in April for the total measurements vs artificial only after extraction vs daylight only after abstracting the artificial.

5.5.2.1 **Waterproof bag calibration**

The light meters were placed on the roofs to measure daylight under unobstructed sky, and the light meters were placed on windowsills have been protected from rainwater by using waterproof bags (see section 5.5.1). Figure 5-17 presents the illuminance levels registered with waterproof bag vs without. The calibration process was based on the percentage of difference value over time, as follows:

$$C = \frac{X2 - X1}{X1} * 100\%$$

C = percentage of difference

X1 = initial value (light meter readings with waterproof bag)

X2 = final value (light meter readings without waterproof bag)

Ex: Average illuminance levels registered with waterproof bag = 18.32 lux

Average illuminance levels registered without waterproof bag = 17.43 lux

The percentage of difference: (17.43-18.32)/18.32 = - 4.89%

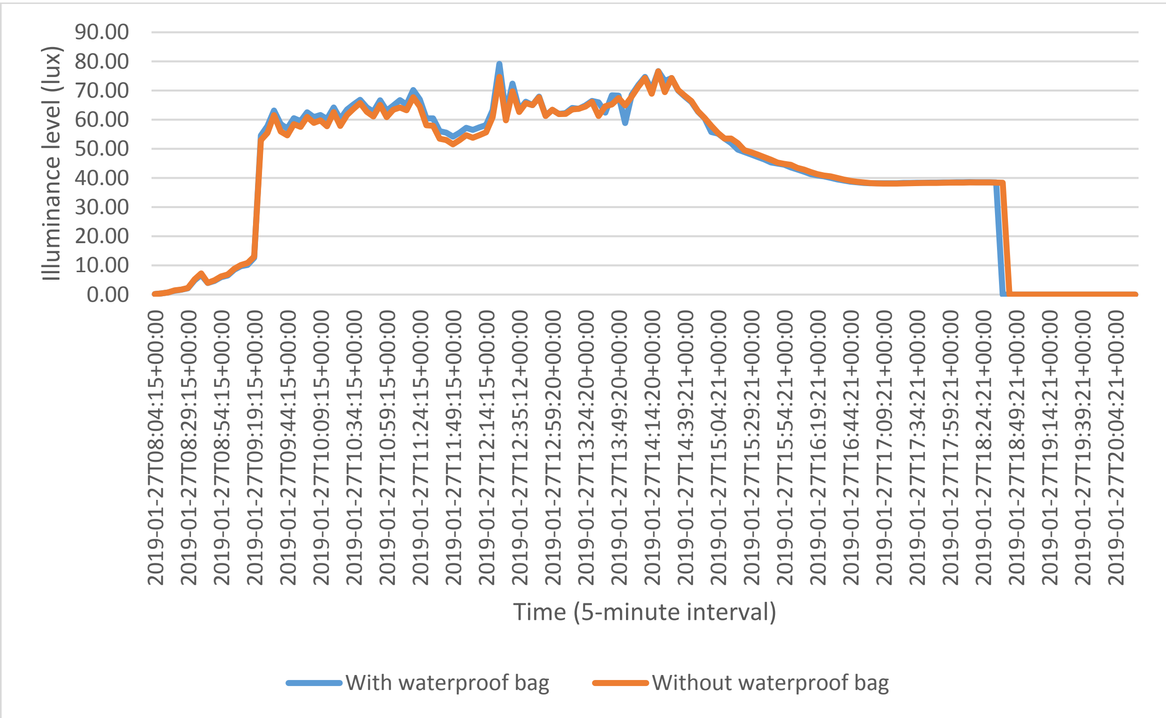


Figure 5-17 Illuminance levels registered by waterproof bag vs without.

5.5.2.2 **Vertical measuring points calibration**

To measure daylight levels on vertical walls and at eye level, calibration was conducted to find the percentage of difference for the vertical measuring points (VMPs) placed at two heights: at eye level (1.20 m) and above eye level (1.60 m). The reason for carrying out the calibration is that in some studios, it was difficult to place the light meter at eye level due to student movement; hence, the research used a vertical one placed above eye level. Figure 5-18 presents the illuminance levels registered at eye level vs above eye level for the calibration process.

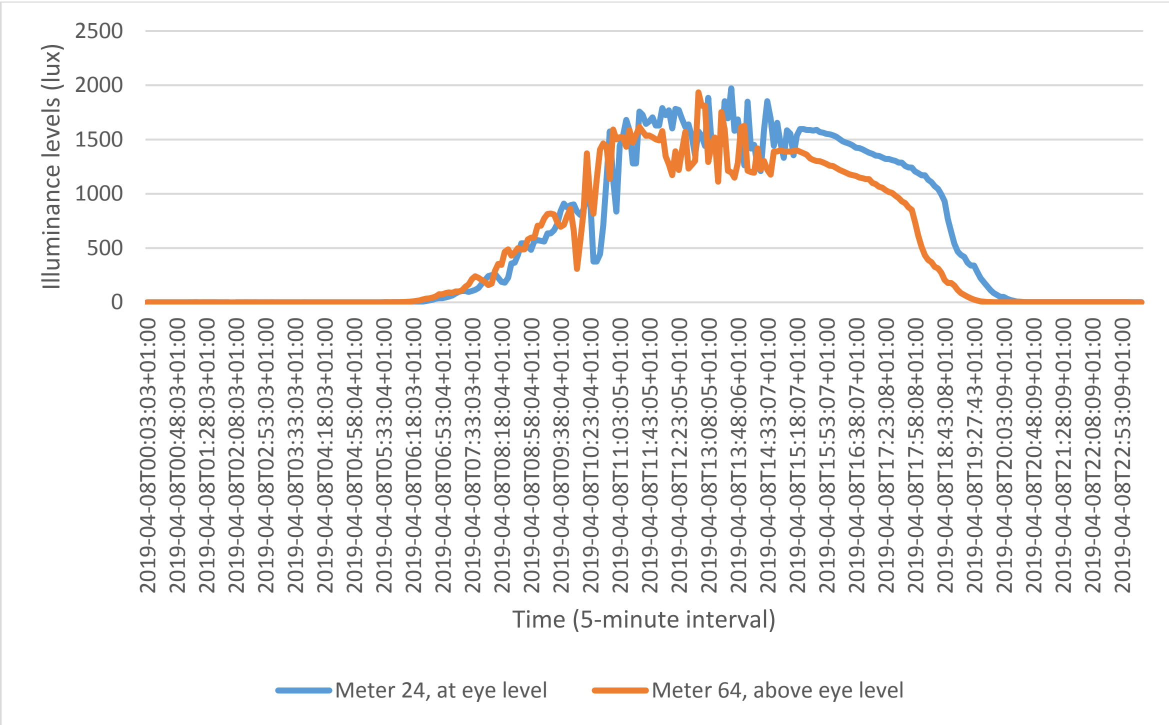


Figure 5-18 **Illuminance levels registered at eye level vs above eye level for calibration process**

The calibration was based on the percentage of difference value over time, as follows:

$$C = \frac{X2 - X1}{X1} * 100\%$$

C = percentage of difference

X1 = initial value (VMP above eye level)

X2 = final value (VMP at eye level)

Ex: Average illumiance levels registered by meter 24 at eye level = 574 lux

Average illumiance levels registered by meter 64 above eye level = 505 lux

The percentage of difference is: (574-505)/505= 13%

5.5.3 **Weather considerations**

Daylight measurements were carried out simultaneously in studios with north-orientation from Glasgow and Edinburgh, followed by simultaneous recordings in studios facing south from Glasgow and Aberdeen. As the study mainly deals with the measurement of daylight levels, the location of the case studies in terms of their geographical coordination, sun altitude, season and time were all crucial to consider. To clarify, the building latitude determines the solar elevation (altitude), solar radiation, length of daytime at different times of the day and also different seasons of the year (VELUX, 2020). Therefore, the outdoor illuminance is highly affected by the latitude of a building site. The Glasgow case study coordinates are 55.8642° N, 4.2518° W, and the Edinburgh case study coordinates are 55.9533° N, 3.1883° W. As such, when considering their latitude and longitude coordination, there is no time zone difference, meaning that both cases have similar values of sun altitude, direction and length of day throughout the year. As such, the parameters that are related to the sun's effects on daylighting performance at specific areas are roughly similar, such as sun altitude, direction, daily total sunshine and global radiation. The sun altitude, azimuth and day length for the two cities are presented in Appendix B. 1. Meanwhile, the sunrise, sunset and day length for Glasgow and Edinburgh are presented in Appendix B. 2.

The climatic conditions of a site also define the overall daylighting performance in a building. Within this research, cloud coverage (oktas), daily total sunshine and daily total global radiation (KJ/m2) were checked hourly for both cities during the research period. Using SPSS statistical programme, the hourly cloud coverage descriptive data for Glasgow and Edinburgh was compared to check if there was a notable difference between the two cities. Table 5-13 confirms that there is very little difference between Edinburgh and Glasgow's hourly total cloud coverage means, in that the hourly total cloud coverage means for Edinburgh and Glasgow are 5.56 and 5.48, respectively. For a difference in dispersion between

Edinburgh and Glasgow's cloud coverages, the standard deviations are 3.087 and 3.133, respectively. The median and minimum values are identical for both cities, registered 7 and 0, respectively, for both cities. In terms of cloud coverage frequencies, both cities have 8 oktas of cloud coverage (overcast, sky completely cloudy) as the most frequent amount of cloud coverage throughout the study period, with Edinburgh and Glasgow registering 42.8% and 43%, respectively. In comparison, the clear sky with 0 oktas of cloud coverage for Edinburgh and Glasgow registered 15.8%, 16.5%, respectively, throughout the study period. Figure 5-19 presents the frequencies of Edinburgh and Glasgow's cloud coverages. The percentage of cloud coverage as a fraction for the two cities is presented in Appendix B. 3. The cloud amount estimation as a fraction of the sky (oktas) is presented in Appendix B. 4.

Statistics	*Edinburgh cloud*	*Glasgow cloud*	*Sunshine Edinburgh*	*Sunshine Glasgow*	*Radiation_ Edinburgh*	*Radiation_ Glasgow*
Mean	5.56	5.48	3.93	4.12	10997.82	11264.93
Median	7.00	7.00	3.85	3.70	9983.50	9932.00
Mode	8	8	.00	.00	1479.00[a]	1046.00[a]
Std. Deviation	3.08	3.13	3.26	3.62	5697.43	6783.65
Minimum	0	0	.00	.00	1479.00	1046.00
Maximum	8	9	12.50	12.90	20391.00	26849.00

Table 5-13 Comparing cloud coverage means between Edinburgh and Glasgow, 2019

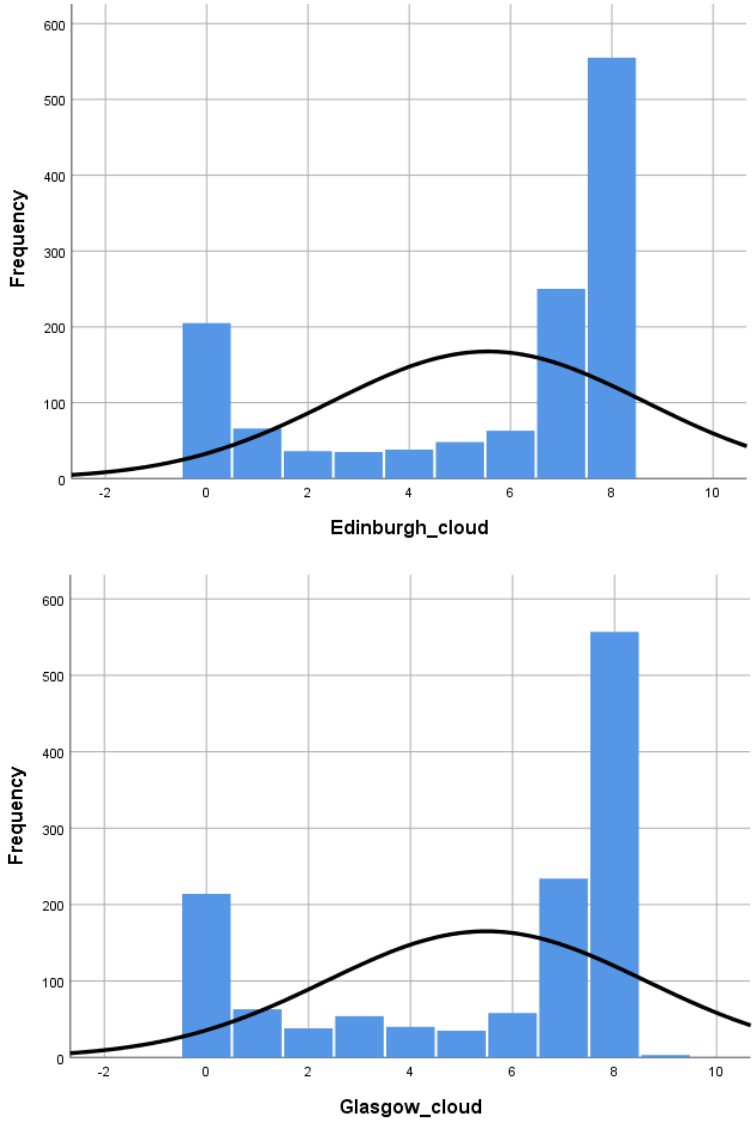


Figure 5-19 Frequencies of Glasgow and Edinburgh cloud coverage

In terms of the sunshine parameter (Table 5-13), the mean values for daily total sunshine in Edinburgh and Glasgow are 3.93 and 4.12 hours, respectively, throughout the study period, and the standard deviations for both cities are 3.26 and 3.62, respectively. The total daily means of global radiation for Edinburgh and Glasgow are 10997.82 and 11264.93 KJ/m2, respectively, while the standard deviations are 5697.43 and 6783.65, respectively, for both cities. Consequently, we can conclude that due to the means, standard deviations and frequencies of the total cloud coverage amount, the total daily sunshine and global radiation of both cities are very similar; there is not a notable difference in the climatic parameters that affect the daylighting performance between the two cities. Daily total sunshine, global radiation and cloud coverage are presented in Appendix B. 5.

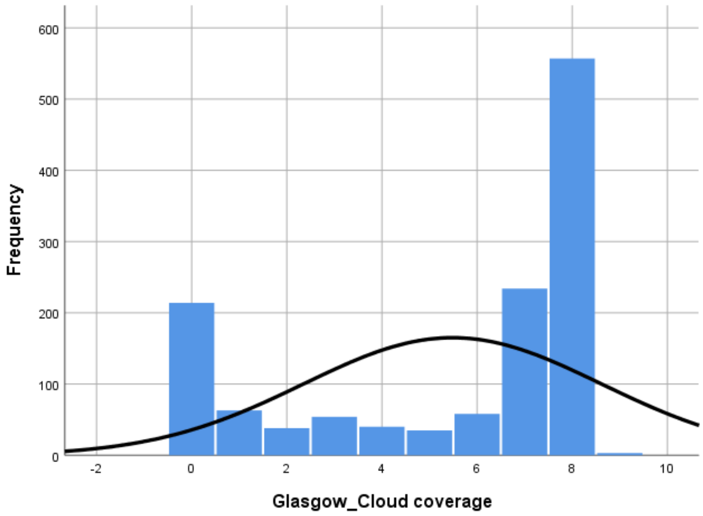
With regards to the South orientation, the Glasgow case study coordinates are 55.8642° N, 4.2518° W, while the Aberdeen case study coordinates are 57.1497° N, 2.0943° W, which means that both cities do not have any time zone difference and both cases have close values of sun altitude, direction and length of day throughout the year. Hence, the parameters that are related to the sun effects on daylighting performance at specific areas are roughly similar, such as the sun altitude, direction, daily total sunshine and global radiation. The sun altitude, azimuth and day length for the two cities are presented in Appendix C. 1. Meanwhile, the sunrise, sunset and day length for Glasgow and Aberdeen are presented in Appendix C. 2.

In terms of climatic conditions, cloud coverage (oktas), daily total sunshine and daily total global radiation (KJ/m2) were checked hourly for both cities during the research period. Using the SPSS statistical programme, the hourly cloud coverage descriptive data for Glasgow and Aberdeen was compared to check whether there is a notable difference between the two cities. Table 5-14 confirms that there is very little difference between Aberdeen and Glasgow's hourly total cloud coverage means, in which the hourly total cloud coverage means for Aberdeen and Glasgow are 5.91 and 5.48, respectively.

For a difference in dispersion between Aberdeen and Glasgow's cloud coverages, the standard deviations for Aberdeen and Glasgow are 2.90 and 3.133, respectively. The median and minimum values are identical for both cities, registered 7 and 0, respectively, for both cities. In terms of cloud coverage frequencies, both cities have 8 oktas of cloud coverage (overcast, sky completely cloudy) as the most frequent amount of cloud coverage throughout the study period, whereby Aberdeen and Glasgow registered 48.4% and 43%, respectively. In comparison, the clear sky of 0 oktas of cloud coverage for Aberdeen and Glasgow is 12.7%, 16.5%, respectively, throughout the study period. Figure 5-20 presents the frequencies of Aberdeen and Glasgow's cloud coverages. The percentage of cloud coverage as a fraction for the two cities is presented in Appendix C. 3.

Statistics	*Aberdeen cloud*	*Glasgow cloud*	*Sunshine Aberdeen*	*Sunshine Glasgow*	*Radiation_ Aberdeen*	*Radiation_ Glasgow*
Mean	5.91	5.48	3.69	4.1207	10642.27	11264.9310
Median	7.00	7.00	2.80	3.7000	10425.50	9932.0000
Mode	8.00	8.00	.00	.00	837.00[a]	1046.00[a]
Std. Deviation	2.90	3.13	3.55	3.62650	6429.75	6783.65
Minimum	0	0	.00	.00	837.00	1046.00
Maximum	9.00	9.00	11.50	12.90	27042.00	26849.00

Table 5-14 Comparing cloud coverage, sunshine and radiation means between Aberdeen and Glasgow, 2019



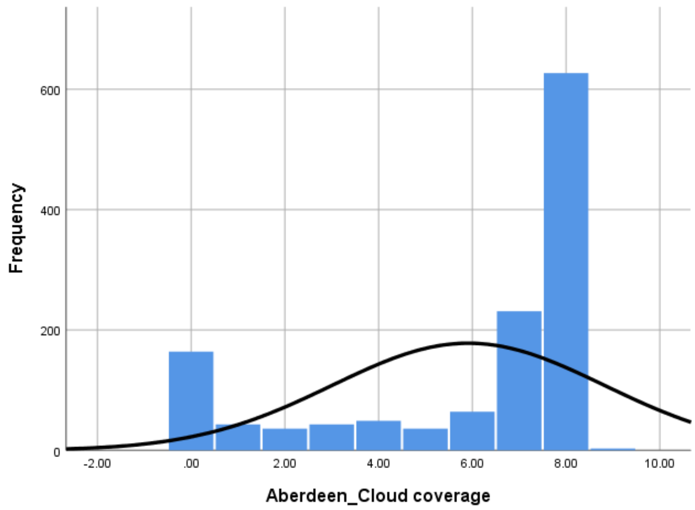


Figure 5-20 Frequencies of Glasgow and Aberdeen cloud coverage

In terms of the sunshine parameter (Table 5-14), the mean values for daily total sunshine for Aberdeen and Glasgow are 3.69 and 4.12 hours, respectively, throughout the study period, and the standard deviations for both cities are 3.55 and 3.62, respectively. The total daily means of global radiation for Aberdeen and Glasgow are 10642.27 and 11264.93 KJ/m2, respectively, while the standard deviations are 6429.75 and 6783.65, respectively, for both cities. Consequently, we can conclude that because of the means, standard deviations and frequencies of the total cloud coverage amount, the total daily sunshine and global radiation of both cities are very close; there is no notable difference in climatic parameters that would affect the daylighting performance between the two cities. Daily total sunshine, global radiation and cloud coverage are presented in Appendix C. 4.

5.5.4 **Subjective data collection**

The second data collection method was more concerned with the subjective measurements of attitudes, which aimed to evaluate from student's perspective the daylight systems that have been used in the selected case studies and investigate the specifics of student's experience inside their studios. In this research, the self-administrated questionnaire was found to be the ideal procedure for data collection of student's opinions, due to the following reasons:

1. It has been argued that sensitive information or negative events will accurately and more frequently be reported in the self-administrated model than through interviews (J. & Jr., 2002, p. 63). Therefore, in this case, the participants' comments were treated anonymously, meaning that they do not have to reveal themselves directly to the interviewer.

2. The advantage of using the questionnaire was that it was deemed an appropriate method for the production of statistics within the research. As such, the questionnaire was easier in terms of presenting questions that involved visuals and rankings.

The self-administrated questionnaire was distributed to participants as a hard copy, because students who were interested in completing the questionnaire requested for it to be a paper copy rather than an online version. Moreover, the study requested that participants complete the questionnaire while sitting inside their studios to account for their real experience. The questionnaire's format was based on the spatial analysis of the selected buildings and the review of the previous literature. As such, it was concluded that the evaluation of daylight from the perspectives of the occupants is affected by multidimensional factors, meaning that multiple evaluations were needed and have to be conducted in order to reach an ultimate evaluation. With this in mind, the questionnaire was designed in sections, which included:

Demographic information, sitting location in the studio, view evaluation in terms of its relation to the window arrangements and its contribution to the studio spatial experience, evaluation of studio's windows, daylight conditions evaluation for both winter and summer seasons in terms of the relation to the window arrangement and its importance to the studio's spatial experience, artificial light evaluation inside the studio, spaciousness evaluation and evaluation of the atmosphere in relation to the light for both winter and summer seasons. The questionnaire was designed to address part of the first question, which focused on objective measurements, and the second question, which sought data on the subjective perspective. It revolved around two themes.

- *How does façade fenestration design affect the daylight levels in different studios' typologies under overcast sky conditions?*

- *What is the experienced atmosphere that would result from that effect?*

The drafts of the designed questionnaire have been reviewed and commented on by the study's supervisors, two PhD candidates and three experts working in different contexts: one in lighting and atmospheric research, one in Qualitative Social Research and Mixed Methods, and one in psychology.

5.5.4.1 **Pilot study**

A pilot study was conducted in 3 cities during the period of 5-10 April 2019 for the designed questionnaire, in which 26 students (9 males and 17 females) from three case studies in Glasgow, Edinburgh and Aberdeen responded to the printed questionnaire. The age range of the subjects was 18 to 25 years old. Each subject evaluated their studio while sitting inside it; the subjects have some understanding of the effect of light in space based on their studies in design and architecture. The questionnaire was written to cover the main ways in which light can affect humans; the questions were either qualitative (e.g. colour appearance, visual comfort, shadow: not applicable at all...just applicable...very applicable) using scales for measuring attitudes or quantitative (e.g., quantity of daylight in terms of brightness, uniformity: very low...just right...very high). The types of questions included multiple-choice and a 7-point scale.

To test the questionnaire's inter-item reliability, the study used Cronbach's alpha test in SPSS as an index of reliability to measure the internal consistency and reliability of a set of items (Cronbach, 1951). The test results showed 0.864 correlation coefficient which represents a high level of consistency among the 178 items, in which it has removed some items with zero variance as they cannot be computed, and are instead displayed as system missing (Figure 5-21). Alpha coefficients range in value from 0 to 1 (Cortina, 1993), therefore, the test results showed a relatively high consistency and reliability in terms of their use as an instrument for subjective judgement.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.864	.777	178

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
383.19	2410.429	49.096	178

Figure 5-21 The result of Cronbach's alpha test in SPSS

5.5.4.1.1 Alternations to the questionnaire

Although the questionnaire has been validated by research and had the reliability test applied, some semantic alterations were found to be crucial and were applied to the questionnaire:

1. The most reliable approach to achieve information from a subjective perspective or rate an emotional attitude towards a topic is through using a rating scale. Vogels (2008), Flynn et.al (1973) and Küller (1972) used a semantic model to measure the way human subjects perceive an

environment. As such, within the questionnaire, questions were changed from multiple choices to rating scale questions as the latter is a more suitable method for measuring subjective judgment and is more effective for the parametric test analysis in statistics (SPSS); examples are presented in (Figure 5-22 and Figure 5-23).

44. Does your studio evoke a positively unique sense of atmosphere?
- ☐ Yes, go to Q a
- ☐ Maybe
- ☐ No, go to Q b

45. If Yes, how would you describe the atmosphere in your studio? (choose all that are relevant)
- ☐ Cozy (intimate)
- ☐ Pleasant (enjoyable)
- ☐ Appealing (attractive)
- ☐ Lively (stimulating)

46. If No, how would you describe the atmosphere in your studio? (choose all that are relevant)
- ☐ Tense (terrifying)
- ☐ Detached (business-like)
- ☐ Threating
- ☐ Formal

32. From your point of view, which of the following best describe the state of atmosphere in your studio.

	1	2	3	4	5	6	7	
Business-like	○	○	○	○	○	○	○	Cozy
Formal	○	○	○	○	○	○	○	Intimate
Dull	○	○	○	○	○	○	○	Stimulating
Terrifying	○	○	○	○	○	○	○	Pleasant

Figure 5-22 The previous format (multiple choice) on the left and the alternative format (S-D scale) on the right.

41. Do you think the Atmosphere state that you perceived in your studio is stable and not changing over time?
- ☐ Yes, go to Q 41
- ☐ Maybe
- ☐ No, go to Q 42

42. If Yes, why do you think Atmosphere state is stable? (choose all that are relevant)
- ☐ It's not varies from time to time
- ☐ It's not different from weather season to another
- ☐ It's not changing by changing any stimuli inside studio

43. If No, how the Atmosphere that you perceived in your studio is changing? (choose all that are relevant)
- ☐ It varies from time to time during the day
- ☐ It varies from weather season to another
- ☐ It's changing by changing any stimuli inside studio

26. Please tick the number that best describes how stable the atmosphere is in your studio.

	Strongly disagree						*Strongly agree*
	1	2	3	4	5	6	7
It varies from time to time during the day	○	○	○	○	○	○	○
It varies from one weather season to another	○	○	○	○	○	○	○
It's changing and causing a change in any stimuli inside studio	○	○	○	○	○	○	○

Figure 5-23 The previous format (multiple choice) on the left and the alternative format (Likert scale) on the right.

2. Some questions included an unintentional leading sentence which the research either had to delete, rephrase, or replace the question. The leading sentence could manipulate the participant, encouraging them to answer in a particular which may increase bias and yield inaccurate information; examples are presented in (Figure 5-24).

39. Does your studio evoke a positively unique sense of atmosphere?

☐ Yes, go to Q 40

☐ Maybe

☐ No, go to Q 41

43. It has been argued that light is one of the generators of the atmosphere inside space, how could natural light contribute to your studio's atmosphere? (choose all that are relevant)

☐ Brightness

☐ Color

☐ Uniformity

☐ Shadow

☐ Darkness

Figure 5-24 The word 'positively 'was considered as a leading word, and so has been deleted (above). The sentence 'It has been argued that light is one of the generators of the atmosphere inside space' was considered as a leading sentence, and so has been deleted.

3. Some of the questions regarding the semantic differential (S-D) scale were converted from two opposite S-D sentences to a Likert-scored approach (7-point scale) for an easier score, easier relevant analysis, and so as to indicate the level of agreement or disagreement. By this, the subjects may have found the scale to be more meaningful; examples are presented in (Figure 5-25).

17. Please tick the number that best describes your view point about the importance of daylight in your studio's spatial experience.

	1	2	3	4	5	6	7	
Daylight does not stimulate my visual experience in my studio	○	○	○	○	○	○	○	Daylight stimulates my visual experience in my studio
Daylight provides uncomfortable solar glare in my studio	○	○	○	○	○	○	○	Daylight provides high illuminance, color and variability in my studio
Daylight does not provide a psychological comfort to me in my studio	○	○	○	○	○	○	○	Daylight provides a psychological comfort to me in my studio
Daylight is insufficient in my studio, which impacts regarding on my productivity	○	○	○	○	○	○	○	Daylight creates a productive environment as it brings less stress and discomfort than artificial light in my studio

20. Please tick the number that best describes your view point about the importance of daylight in your studio's spatial experience.

	Not applicable at all						*Very applicable*
	1	2	3	4	5	6	7
Daylight stimulates my visual experience in my studio	○	○	○	○	○	○	○
Daylight provides high illuminance, color and variability in my studio	○	○	○	○	○	○	○
Daylight provides uncomfortable solar glare in my studio	○	○	○	○	○	○	○
Daylight provides a psychological comfort to me in my studio	○	○	○	○	○	○	○
Daylight creates a productive environment as it brings less stress and discomfort than artificial light in my studio	○	○	○	○	○	○	○
Daylight is insufficient in my studio, which impacts regarding on my productivity	○	○	○	○	○	○	○

Figure 5-25 S-D Scale (left) vs Likert- Scale (right)

The final draft of the questionnaire consisted of 31 questions, in which 11 questions used a 7-point Likert scale and represented the evaluation of the qualitative aspects of daylight (e.g., not applicable at all... just applicable...very applicable) and quantitative one (e.g., very low...just right...very high). The major content sections remained the same as in the pilot study, as they considered either independent or moderator variables: demographic information, sitting position, view, window arrangement, daylight, artificial light, spaciousness and atmosphere. Three questions were of the 7-point semantic differential scale (bipolar dimension) for describing the variables (artificial lighting, spaciousness and atmosphere), 16 multiple-choice questions enquired mainly about demographic information, 1 location question to mark/identify each student's sitting position inside the studio and a final section for additional comments that the students may want to raise, regarding either window design, daylight or the experienced atmosphere.

The type of data used to measure the variables was mainly categorical (nominal) and (interval) with some questions reflecting the ratio data. The questions were item-focused so as to achieve a specific response. Some of questions were asking about facts (e.g. age, residency), while others requested the subjects to provide their opinions. The response modes were based on the nature of variables and the statistical test that will be used to test the hypothesis. Other criteria included not having too many open-ended questions, as such control variables such as degree type and the performed tasks were excluded. Table 5-15 shows the scale type used for each variable in the study.

Variable name	Data/scale type
Demographic information	Multiple choices
Sitting position	Multiple choices
View	Multiple choices, 7-point Likert scale
Window	7-point Likert scale
Daylight	Multiple choices, 7-point Likert scale
Artificial lighting	Multiple choices, 7-point Likert scale, 7-point semantic differential scale
Spaciousness	7-point Likert scale, 7-point semantic differential scale
Atmosphere	Multiple choices, 7-point Likert scale, 7-point semantic differential scale

Table 5-15 The variables and their scale types in the study

Most of the questions were designed to allow subjects to give accurate judgments, which could be used for factorial/ multidimensional analysis and phrased in such a way to make it easier for them to evaluate their studios (Figure 5-26). Therefore, alternation in the rating scale occurred by changing some of the questions from a qualitative form to a quantitative rate: (e.g. tick the best describe) to (e.g. very low...just right...very high).

:0. In your opinion, which of the following daylight states best describe the season in your studio? (tick all that are relevant)

DAYLIGHT STATE	IN WINTER	IN SUMMER	NEITHER NOR	BOTH
ADEQUATE ILLUMINATION	○	○	○	○
TOO BRIGHT	○	○	○	○
TOO DARK	○	○	○	○
TOO MUCH SUNLIGHT	○	○	○	○
INSUFFICIENT SUNLIGHT	○	○	○	○
SHADOWS	○	○	○	○
LACK OF CONTROL	○	○	○	○

28. Please evaluate the contribution of daylight in your studio's atmosphere in the winter season?

	Very low						Very high
	1	2	3	4	5	6	7
Brightness*	○	○	○	○	○	○	○
Illumination*	○	○	○	○	○	○	○
Uniformity*	○	○	○	○	○	○	○
Room luminance*	○	○	○	○	○	○	○
Distribution of daylight	○	○	○	○	○	○	○
Color- Gray	○	○	○	○	○	○	○
Color- Yellowish	○	○	○	○	○	○	○
Shadow	○	○	○	○	○	○	○
Darkness	○	○	○	○	○	○	○
Glare from daylight	○	○	○	○	○	○	○
Visual comfort*	○	○	○	○	○	○	○
Lack of control - blinds	○	○	○	○	○	○	○

Figure 5-26 qualitative form of question (left) vs alternative to quantitative form (right)

The questions about the view and window arrangements were developed from Bell & Burt (1995, p. 20). The question about evaluating the contribution of daylight in the studio (including the option of the colour grey and the colour yellowish) was developed from the pilot study, where this point was raised by several students. In the artificial light section, some terms used in the semantic differential scale originated from Flynn et al. (1973), in which their designed rating form comprised three main categories to evaluate the user impression and satisfaction: perceptual, behavioural and overall preference categories. The most appropriate terms for the study have had to be interpreted. The same scale was used in another study by Flynn et al. (1975) in which a six-rating scale was designed to evaluate five different lighting installations in three conferences rooms (Boyce, 1981, p. 268). For the spaciousness section, the evaluation rating terms were based on the Flynn study (1973), in which he proposed five factors with which to evaluate a conference room lit by a lighting installation. The factors were: evaluation, perceptual clarity, spatial complexity, spaciousness and formality (Boyce, 1981, p. 263). Figure 5-27 shows the rating scales for the spaciousness factor. Figure 5-28 shows alternation occurred by changing the form from a qualitative to quantitative rating scale (e.g. strongly disagree...neutral...strongly agree).

	1	2	3	4	5	6	7	
Small	○	○	○	○	○	○	○	Large
Short	○	○	○	○	○	○	○	Long
Cramped	○	○	○	○	○	○	○	Spacious

Figure 5-27 The adapted rating scale for the spaciousness factor

20. What makes it appear spacious, and what it does not in your studio?

Spaciousness indicator	Tick if Yes	Tick if No
Ceiling Height		
The area of floor plan (depth)		
Furniture compactness		
Studio shape (rectangular, square, etc.)		
The studio's painting colour		
Window size and arrangement		
Overlooked view		
The amount of daylight		
Artificial light		

22. In your opinion, which of the following indicators make your studio appear spacious, or otherwise?

	Strongly disagree						*Strongly agree*
	1	2	3	4	5	6	7
Ceiling height	○	○	○	○	○	○	○
The area or depth of floor plan	○	○	○	○	○	○	○
Furniture compactness	○	○	○	○	○	○	○
Studio shape (rectangular, square,etc.)	○	○	○	○	○	○	○
The studio's walls and ceiling colour	○	○	○	○	○	○	○
Window size	○	○	○	○	○	○	○
Window arrangement	○	○	○	○	○	○	○
Overlooking view	○	○	○	○	○	○	○
The amount of daylight	○	○	○	○	○	○	○
The quality of artificial light	○	○	○	○	○	○	○

Figure 5-28 the qualitative form (left), alternative to rating scale (right)

Further alternations were done to the questions asked for descriptions of the dependent variable; atmosphere, by set of terms, in which some of the terms have been adapted from Vogels (2008), but their scale construction was changed. So, instead of one descriptive word (Likert-scale) as designed by Chen (2018), they were defined by opposed pairs (S-D), in which the construction of scale was changed from Likert-scale to S-D scale (Figure 5-29).

	Not applicable at all						**Very applicable**
Business-like	0	0	0	0	0	0	0
Cozy	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	
Business-like	○	○	○	○	○	○	○	Cozy

Figure 5-29 The type of scale used by Chen (2018) above vs *type of scale used in this study (*Changing from Likert –scale to S-D) below

The rest of the terms used originated from Küller's thesis (1972), where he hypothesised that the perception of an environment might be described in a limited number of meaningful valid dimensions (1972, p. 13). He proposed eight factors that could be given a meaningful interpretation: pleasantness, social status, enclosedness, originality, complexity, affection, unity and potency. Each factor has many dimensions of scale; however, the study excluded any terms that could have the same meaning or cause a repetition. The dimensions used to evaluate the experience of atmosphere in this study included: Complexity: Lively, Subdued. Enclosedness: Demarcated, Airy. Potency: Masculine, Feminine. Affection: Aged, Modern, New. Originality: Surprising, Ordinary. Social status: Simple, Complex.

The first page of the final draft of the questionnaire included definitions for terms that the students may need to know when filling out the questionnaire. The survey began by giving the students 'the participant's information sheet' in order to provide them with an overview of the study's aims and the survey process. Then, a 'consent form' was to be completed and signed by the surrey participants. The researcher next gave general oral instructions about the questionnaire and asked the participants to fill it while sitting in their studio. The participant information sheet is presented in Appendix D. 1, the research consent form in Appendix D. 2 and the final draft of the questionnaire is presented in Appendix D. 3.

In addition, the researcher prepared a translated draft in Chinese, which allowed the Chinese students to complete the questionnaire in 20 minutes instead of the one-hour time allocated in the English versions, as had been observed during the pilot study. The need for a translated draft came from the fact that 80% of one studio was occupied by Chinese students. The final draft of the pilot questionnaire was finished in August 2019, at which point 45 master's students responded to and completed it. The questionnaire was distributed over the summer period to master's students from Glasgow, who were the only available ones.

5.5.4.2 **Participants sampling design**

The research sample size that truly represents the population is based on the probability sampling design. The importance of securing the true sample size is concerned with the external validity of the research, in which the study's findings would be generalised for the entire population from the three case studies. Proportional Stratified Sampling was selected as the technique to proceed with the probability sampling, because each case study in the research had a different population size with various strata (Leedy Paul D. et al., 2019). In each case study, the sample was selected randomly, assuming that the sample characteristics would be close to the characteristics of the total population of each strata and every member of population has an equal chance to be selected with consideration that the population is small and its members are known as it's applied in this research. The total population size for the three case studies is 553 students, in which 415, 64, 74 are the total numbers of students for the Glasgow, Edinburgh and Aberdeen case studies, respectively (Appendix E. 1). The calculation of the sample size was based on the following equations:

$$N= (z/e)^2 (p) (1-p) \;\ldots\ldots\; (1)$$ (Tuckman, 1972, p. 205)

Where *N* is the sample size, *z* is the standard score corresponding to a given confidence level, *e* is the proportion of sampling error in a given situation, and *p* is the estimated proportion.

$$N= 1.96^2\, Q^2 / E^2 \;\ldots\ldots\; (2)$$ (Tuckman, 1972)

Q is the standard deviation (the response distribution is determined to be %50, which gives the largest sample size), *E* is the error rate which is determined to be +-%5, and the confidence level is determined to be %95, then $z= 1.96^2$.

Consequently, the total sample size is 227 students. The Proportional Stratified Sampling is determined by: (each strata/ total population size) * sample size. (Tuckman, 1972, p. 203). Then, the sample size for each case study is calculated to be: 170 students for Glasgow; around 26 students for Edinburgh; around 30 students for Aberdeen (Appendix E. 2).

5.6 **Summary**

The experimental protocol for this study is empirical in nature, in that the full daylight investigation required a systematic procedure to determine the exterior and interior daylight levels distributed on horizontal and vertical reference planes. Accordingly, a longitudinal research design was found to be the appropriate research method to repeatedly test the effects of façade fenestration design on daylight levels and experienced atmosphere, and to detect any change over a period of time. Consequently, the daylight availability in every studio was measured at five-minute intervals throughout the study period from February – November 2019. After conducting a pilot study with multiple data loggers, it was deduced that the study should deploy light meters that were considered to be small in size, light in weight, flexible to place on vertical walls and able to give access and monitor data easily. With regards to selecting case studies, various site visits were conducted to potential institutions which have architecture and design studios. The case studies' classifications were based on the level of education offered by institutions, the age/ architectural period, style and studio façade orientation to increase the validity of the study and its derived conclusions. Studios in Glasgow, Edinburgh and Aberdeen were considered the most appropriate to fit the research purpose and the phenomenon of inquiry as well as being adequate to replicate the findings (literal replication) to answer the research questions: *How does façade fenestration design affect the daylight levels in different studios' typologies under overcast sky conditions? And* What is the experienced atmosphere that would result from that effect?

The research methodology comprised three main steps. Firstly, a field-work survey was conducted to establish the physical dimensions and façade fenestration characteristics of the studios. Secondly, objective data measurements for exterior daylight levels on each building roof under unobstructed sky and interior daylight levels inside studios were carried out. Thirdly, a subjective survey (questionnaire) was designed to ask the students about the window, daylight and experienced atmosphere within their respective studios. Finally, the studied metrics were analysed and correlated to give insights to address the research questions.

Chapter 6

Analysis of daylight levels for studios orientated to the North: Glasgow & Edinburgh case studies

6.1 **Introduction**

This chapter presents the procedure and findings on conducting daylight measurements and analysis for studios orientated to the North in the two selected cities: Glasgow and Edinburgh. The investigated studios in the two cities are more or less under similar overcast sky conditions and share a similar design typology (a double-volume open plan floor with mezzanine floor above), housed similar design activities and have other similarities in terms of furniture design and colour. Many site visits and observations were required to be carried out for the selected cases prior to the actual measurements taking place. Furthermore, to guarantee that the location of the light meters would not interfere with students' activities in the studio, approved location points for the light meters were agreed by both the studios' tutors and students. This chapter is useful for providing insights to test one of the two hypotheses: ***'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.'***

The chapter is divided into two main parts (Figure 6-1): the first one presents the spatial context of the investigated studios, the studios' zone divisions and the results of the objective measurements (illuminance levels) that were registered by the vertical and horizontal measuring points. Whereas the second part presents an assessment of daylight levels, daylight factors and testing the suggested hypothesis in relation to the guidelines. The main findings are as follows: the illuminance levels registered by VMPs at students' seated eye level were statistically significant different from above eye level, due to the effect of window-to-wall area ratio and window-to-floor area ratio. Meanwhile, no statistically significant effect for the positioning of the window in the centre of the wall in the illuminance variations between the two levels.

For the illuminance levels registered by the horizontal measuring points (HMPs) in different zones, the findings revealed that zone 3 (which represented the studios at mezzanine levels) had the highest illumination levels, followed by zone 1 (double-volume open plan floor) and finally by zone 2 (the area in the double-volume studio but covered by the mezzanine above). In testing the hypothesis, the findings revealed that studios with a window-to-floor area ratio of over 20% supported the hypothesis. However, this applied only in zones that were not covered by the mezzanine floor above, with October and February being an exception.

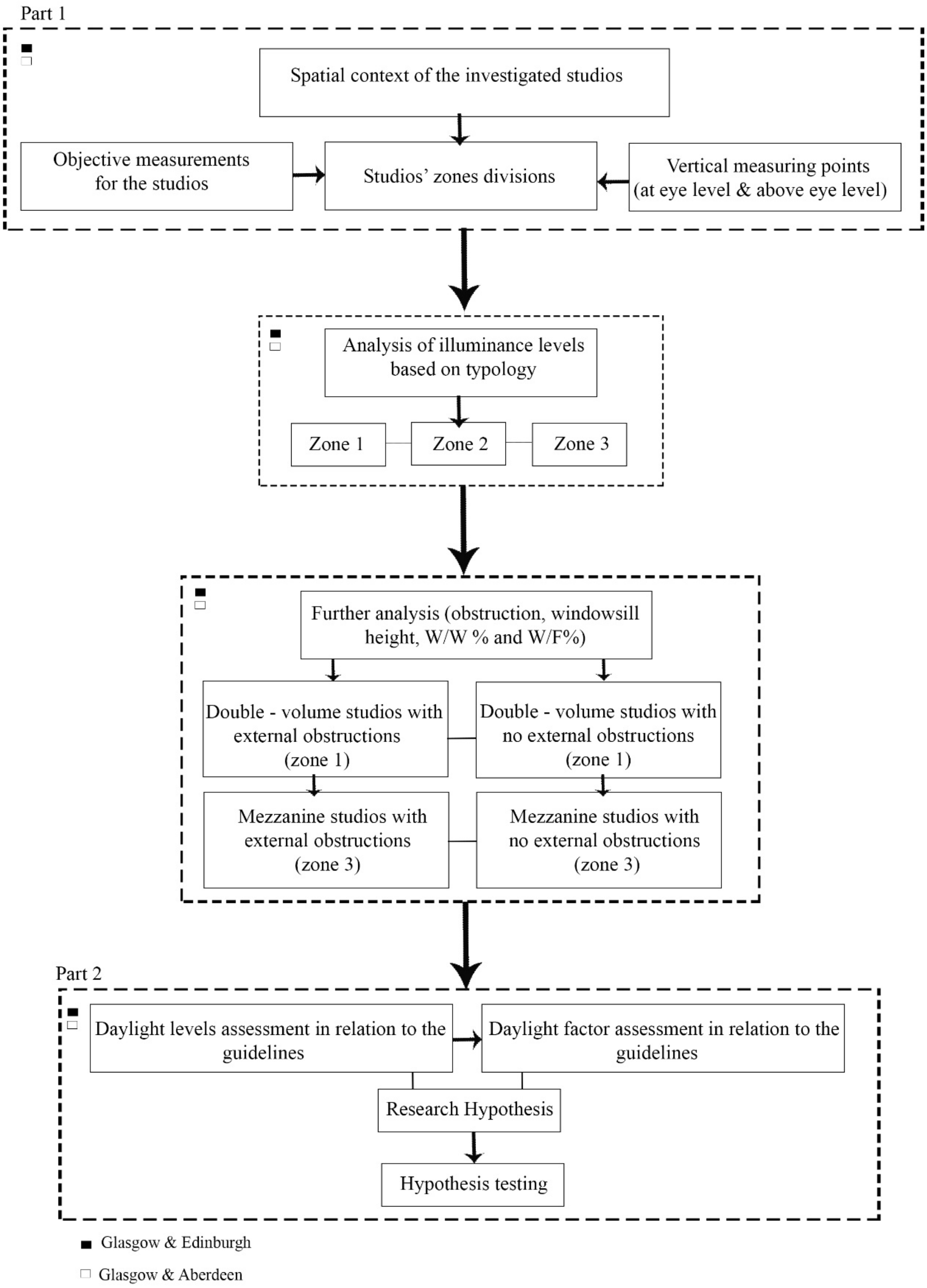


Figure 6-1 Structure diagram of the daylight levels analysis.

6.2 Spatial contextualisation of the investigated studios

Investigations were conducted in eight studios; six studios were in Glasgow (GNC, GNCm, GNIn, GNPL, GNPm, GNJm) and two were in Edinburgh (E1, Em). All the studios were orientated towards the North and have similar characteristics, a double-volume open plan studio with a mezzanine floor above, except for studio GNIn which is a double-volume open plan studio only. All studios were finished similarly, with white painted walls and ceilings, grey concrete floors (except for studio GNPm), white tables and similar glazing materials. In terms of form and function, all the studios were more or less of a similar plan shape, with drawing desks arranged perpendicularly or along the window wall. The studios' activities mainly concerned design, drawing, painting, reading, model making and digital work. Tutorials may be conducted from time to time and small sitting areas were arranged to be used for students' rest and socialising. The investigated studios have different height levels from the ground, different windowsill heights and varied outside obstructions; buildings and trees. These differences were observed and noted so as to be taken into consideration during the analysis. The studios' survey information has been included in Table 6-1. Photographs in context are presented in section 6.2.1. In Edinburgh case study, Figure 6-2 presents studio E1 and studio Em. In Glasgow case study, Figure 6-3 presents studio GNC and studio GNCm. Figure 6-4 presents studio GNPL and studio GNPm, and Figure 6-5 presents studio GNJm.

Observations about use of artificial lighting and shading in each of the studio are included in section 6.2.2. All studios in Glasgow case study have Fluorescent Batten artificial lighting type in manual switching / on-off control system (Littlefair, 1990). Meanwhile, studios in Edinburgh case study have Academy LED range artificial lighting type in manual switching / on-off control system. Table 6-2 shows information about artificial lighting (light fixture type, quantity, colour, construction, control type), and shading devices in Glasgow and Edinburgh studios. Figure 6-6 presents the types of artificial lightings. Figure 6-7, Figure 6-8, Figure 6-9, Figure 6-10, Figure 6-11, Figure 6-12, Figure 6-13, and Figure 6-14 present wide panoramic fisheye photos for Glasgow and Edinburgh studios. The used camera is DSLR: Canon 5D MkII with Sigma 8mm f/3.5 EX DG Circular Fisheye Lens.

Characteristics	Glasgow						Edinburgh	
	GNC	GNCm	GNIn	GNPL	GNPm	GNJm	E1	Em
Design type	Double- volume with mezzanine	Mezzanine floor	Double- volume open plan	Double- volume with mezzanine	Mezzanine floor	Mezzanine floor	Double- volume with mezzanine	Mezzanine floor
Studio floor level (m)	+4.375 First floor	+8.375 Second floor	+18.525 Fourth floor	+18.525 Fourth floor	+22.40 Mezzanine floor	+22.40 Mezzanine floor	+5 m	+7.5 m Mezzanine floor
Dimension (m) W*L*H	15*10*8	15*7*4	14.65*11*8	5*7*8	8*11*4	8*11*4	16*11*5	9*9*2.5
Floor Area (m^2)	146.5 m^2	102.5 m^2	161 m^2	42 m^2	88 m^2	88 m^2	288 m^2	99 m^2
Wall Area (m^2)	117 m^2	60 m^2 (window placed in entire wall)	North: 117 m^2 South: 117 m^2	56 m^2	North: 32 m^2 South: 28 m^2	North: 32 m^2 South: 20 m^2	90 m^2	22.5 m^2
Window Area (m^2)	60 m^2		North: 51 m^2 South: 51 m^2	21 m^2	North: 32 m^2 South: 28 m^2	North: 24 m^2 South: 10 m^2	6 m^2 each/ 48 m^2 for total.	1 m^2/ 4 m^2 for total
No. of windows	1	1	2	1	2	2	8	4
Window elevation	North							
Window dimension (m)	15*4 (60 m2, the window is shared with two studios)		North & South: 14.65*3.5	6*3.5	North: 8*4 South: 7*4	North: 8*3 South: 4*2.5	2*3 (48 m^2 for total)	2*0.5 (1 m^2 for total)
window sill height (m)	4	0	North & South: 4	4	North & South: 0	North: 1 South: 1.50	1	0
Window/ Floor ratio	40%	57%	32%	50%	North: 36% South: 32%	North:27% South:18%	16.6% total	4 %
Window/Wall ratio	50%	100%	North & South: 44%	50%	North & South: 100%	North: 75% South: 50%	53.3% total	18%
Obstructions (Type, Height, Distance)	Residential building, 5.5 m distance, and 22 m height.		No obstructions	No obstructions	No obstructions	No obstructions	Trees, 5m distance and 6m high. Tenement building, 16m distance and 13 m height.	Limited access to window

Table 6-1 Studios' characteristic's in Glasgow & Edinburgh.

*(windows in South wall are covered by curtains most of the time).

6.2.1 **Photographs in context (North orientated studios)**

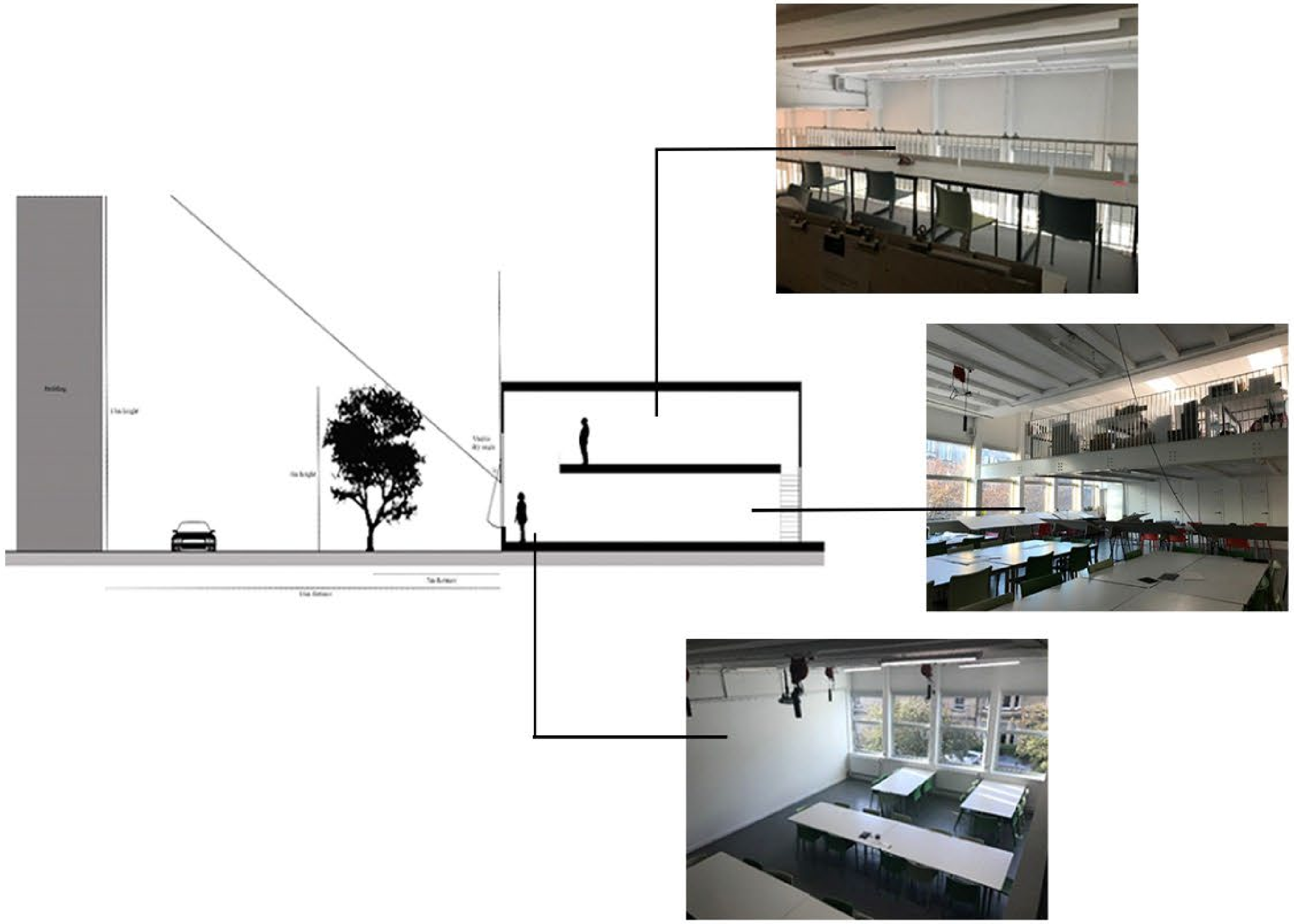


Figure 6-2 Edinburgh case study (studio E1 & mezzanine studio above Em).

Top view from Google earth.

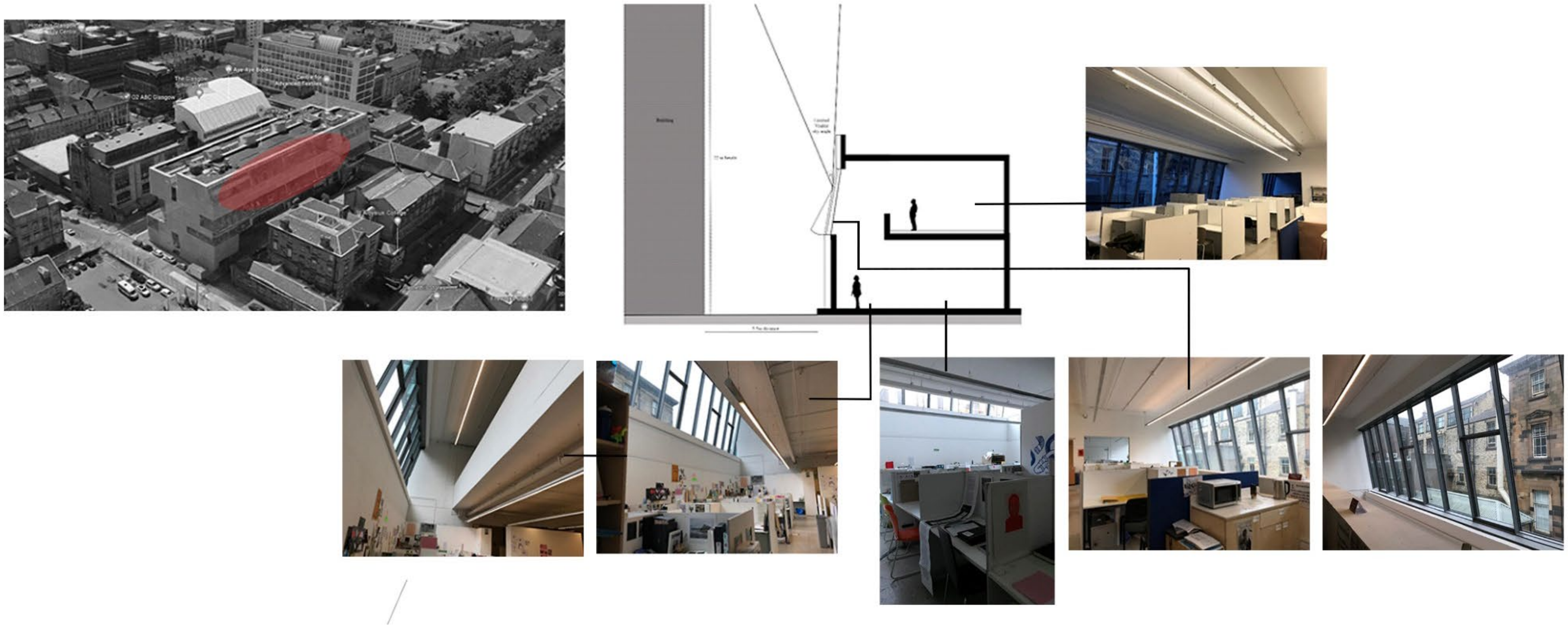


Figure 6-3 Glasgow case study (studio GNC & mezzanine studio above GNCm).

Top view from Google earth.

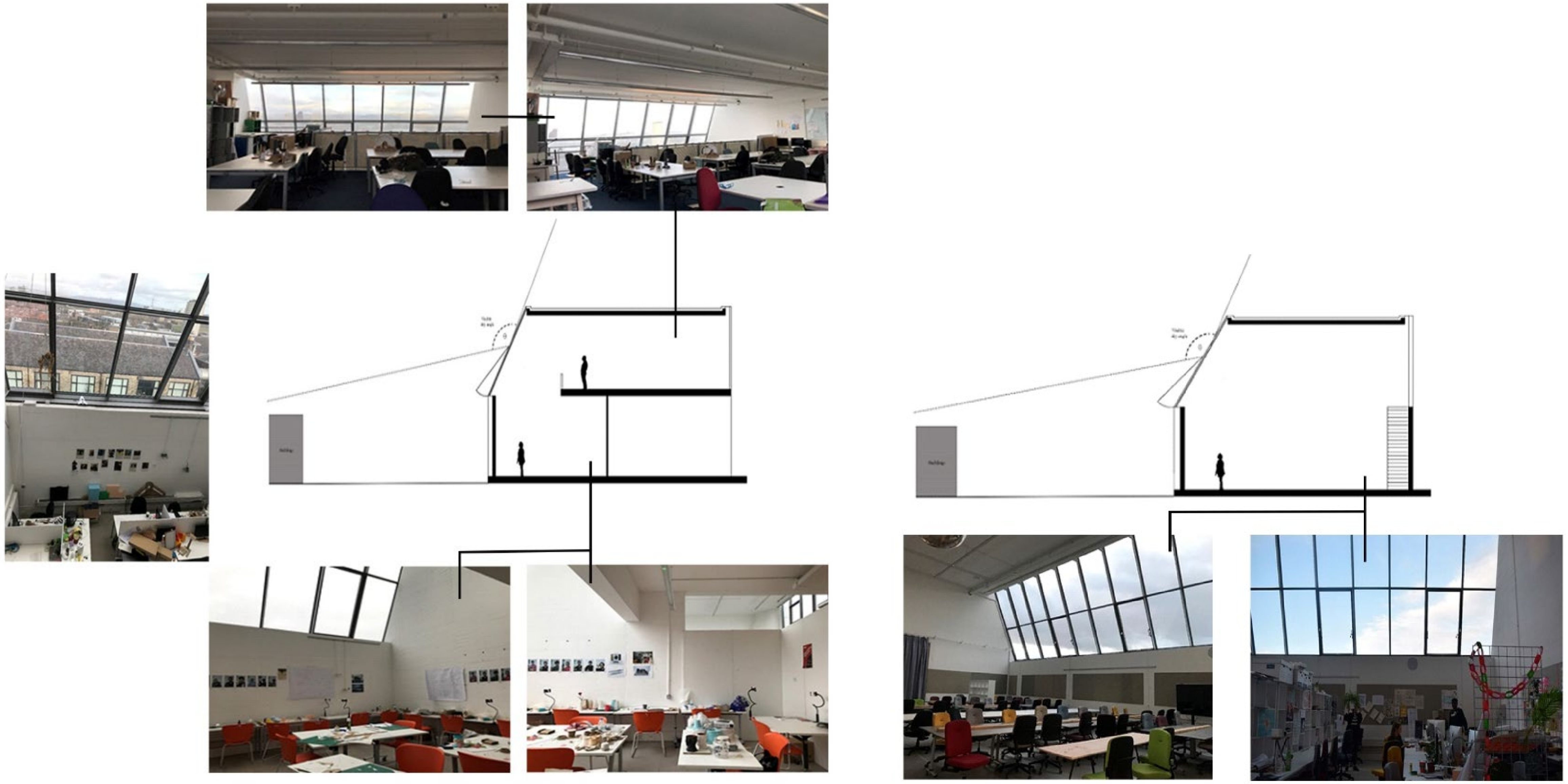


Figure 6-4 Glasgow case study, studio GNPL & mezzanine studio above GNPm (left) and studio GNIn (right).

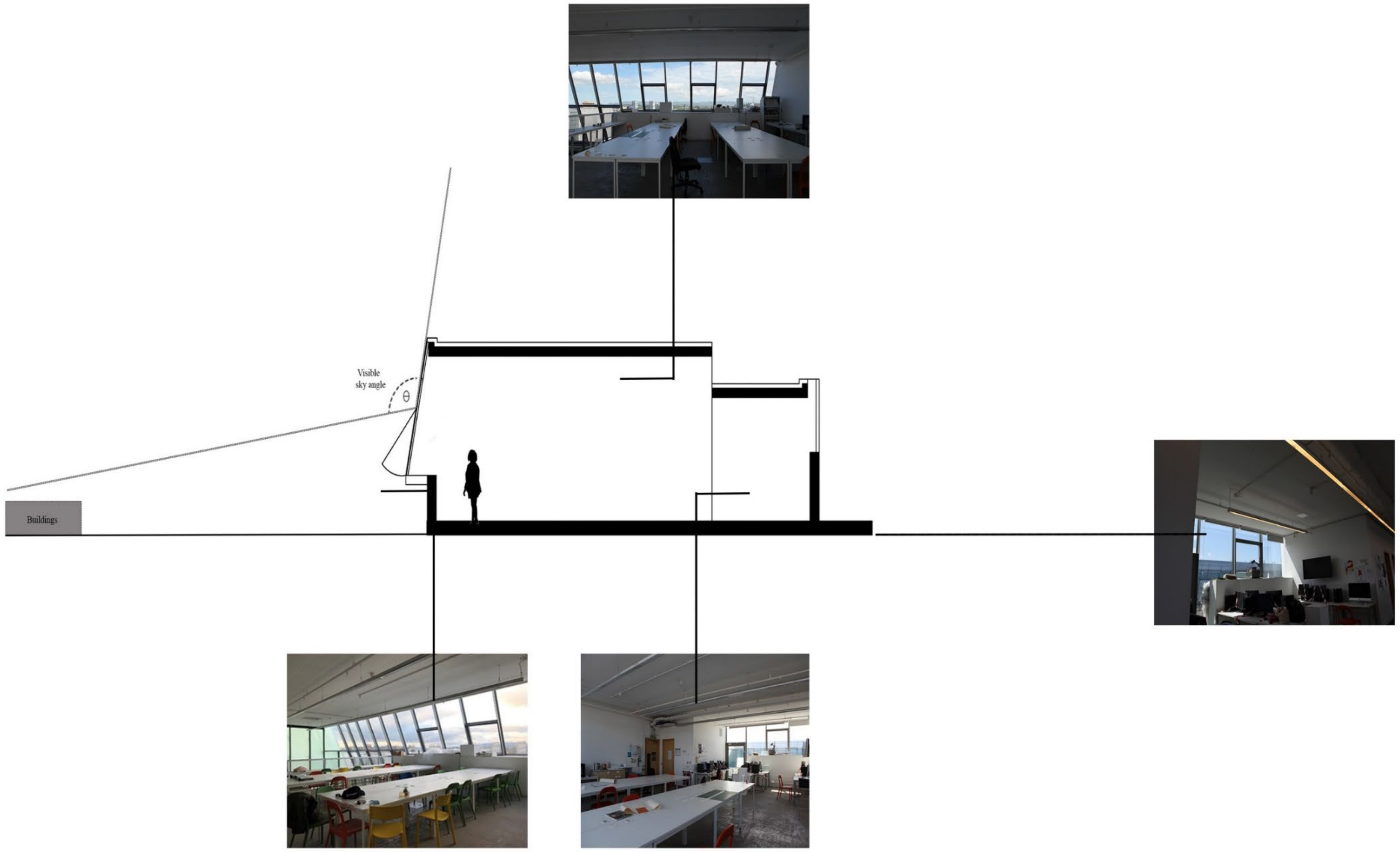


Figure 6-5 Glasgow case study, studio GNJm

6.2.2 **Artificial lighting**

Analysis factor	Studio							
	GNC	GNCm	GNIn	GNPL	GNPm	GNJm	E1	Em
Lighting fixture type	Fluorescent Batten						Academy LED range	
Quantity	4	3	4	2	4	4	12 (4 of them are under mezzanine)	4
Colour characteristics	Warm/Yellow						Cool/White	Cool/White
Construction	Suspended direct-indirect light. The ceiling is also white bright to reflect light.							Ceiling surface
Control type	- Manual switching, On-off control - The detectors are programed to time out after a duration of 15 - 20 minutes from the last detected movement within that area to switch off the artificial lightings.							
Shading devices	-No shading for windows in the Northern walls. -Windows in the Southern walls are covered by curtains most of the time.						Curtains (used only to cover windows during the data show presentations).	-

Table 6-2 Information about artificial lightings for Glasgow and Edinburgh case studies.

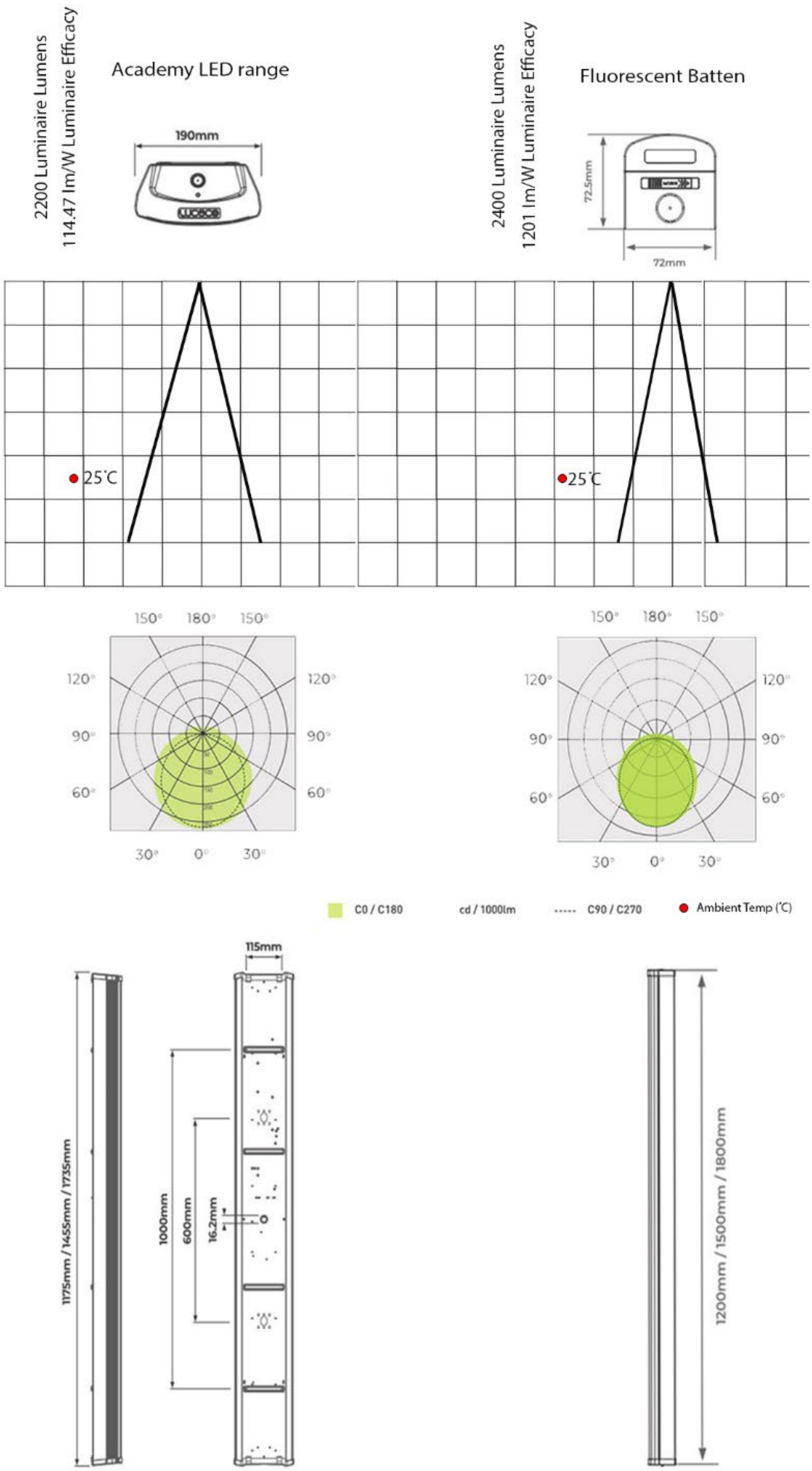


Figure 6-6 Types of artificial lightings; Academy LED range and Fluorescent Batten.

6.2.2.1 **Artificial lightings in context**

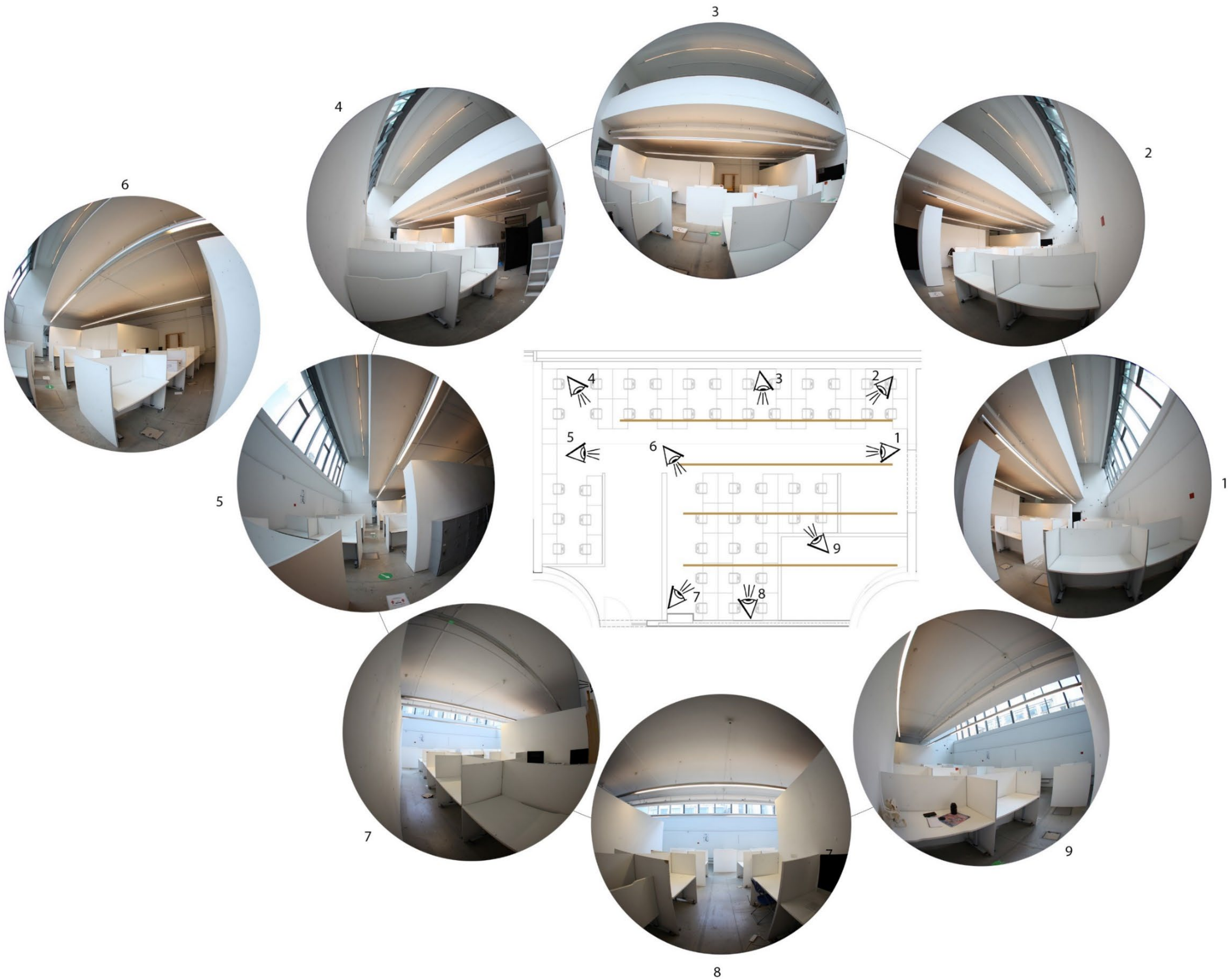


*Photo shoots 6 to 9 were taken under the mezzanine studio GNCm.**

Figure 6-7 Wide panoramic fisheye photos show artificial lightings in studio GNC, Glasgow.

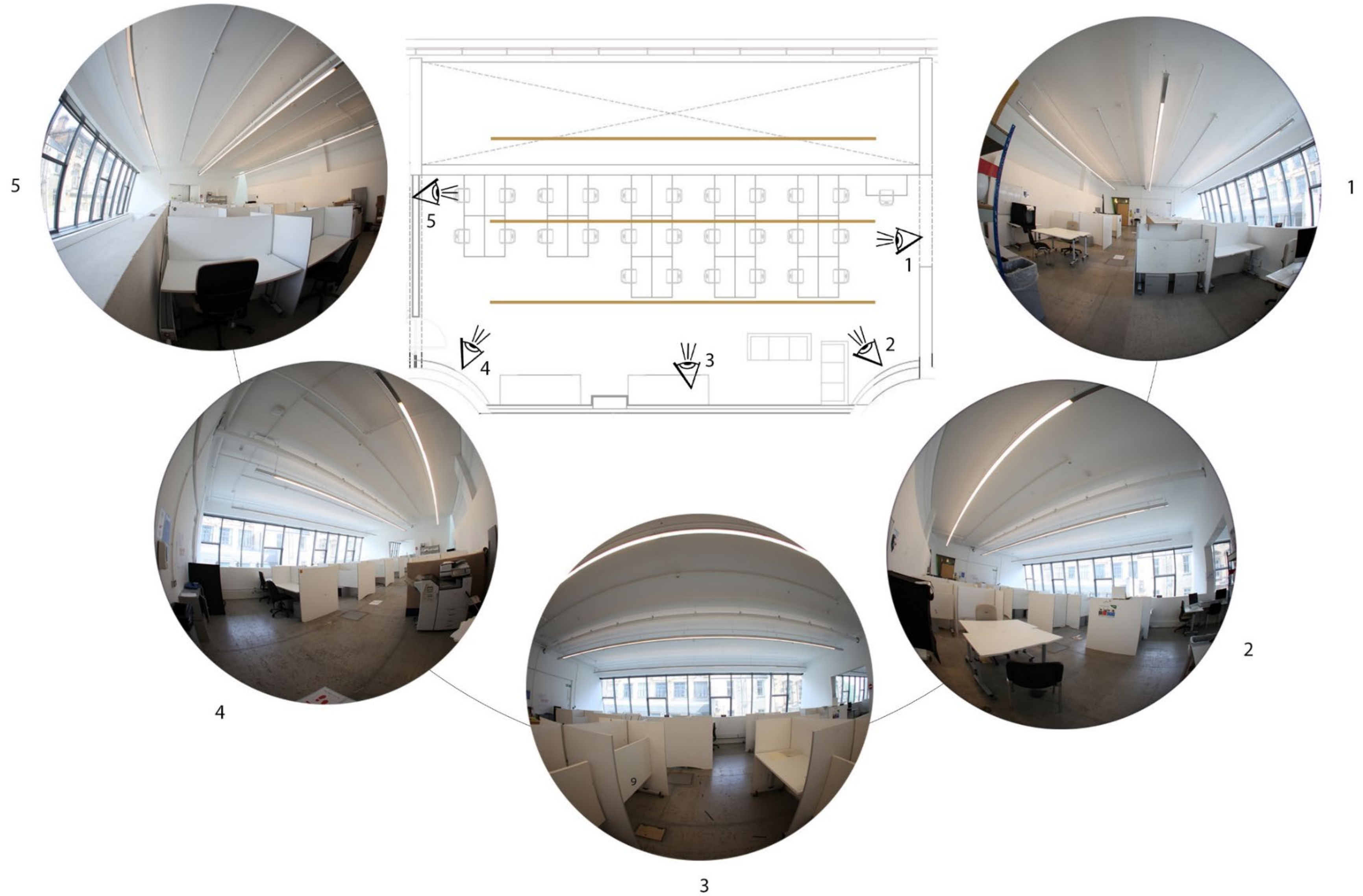


Figure 6-8 Wide panoramic fisheye photos for the mezzanine studio GNCm, Glasgow.

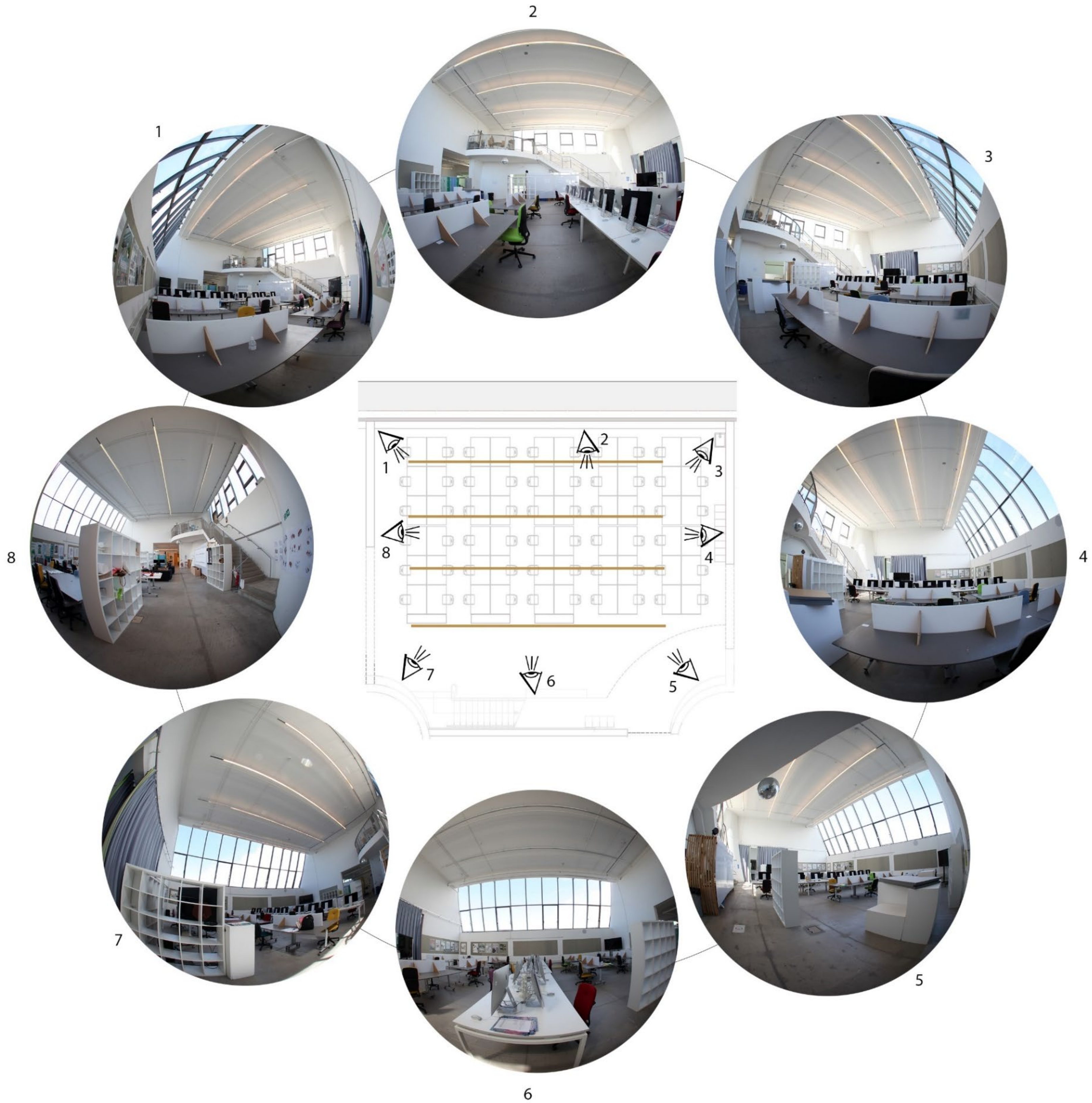


Figure 6-9 Wide panoramic fisheye photos for studio GNIn, Glasgow.

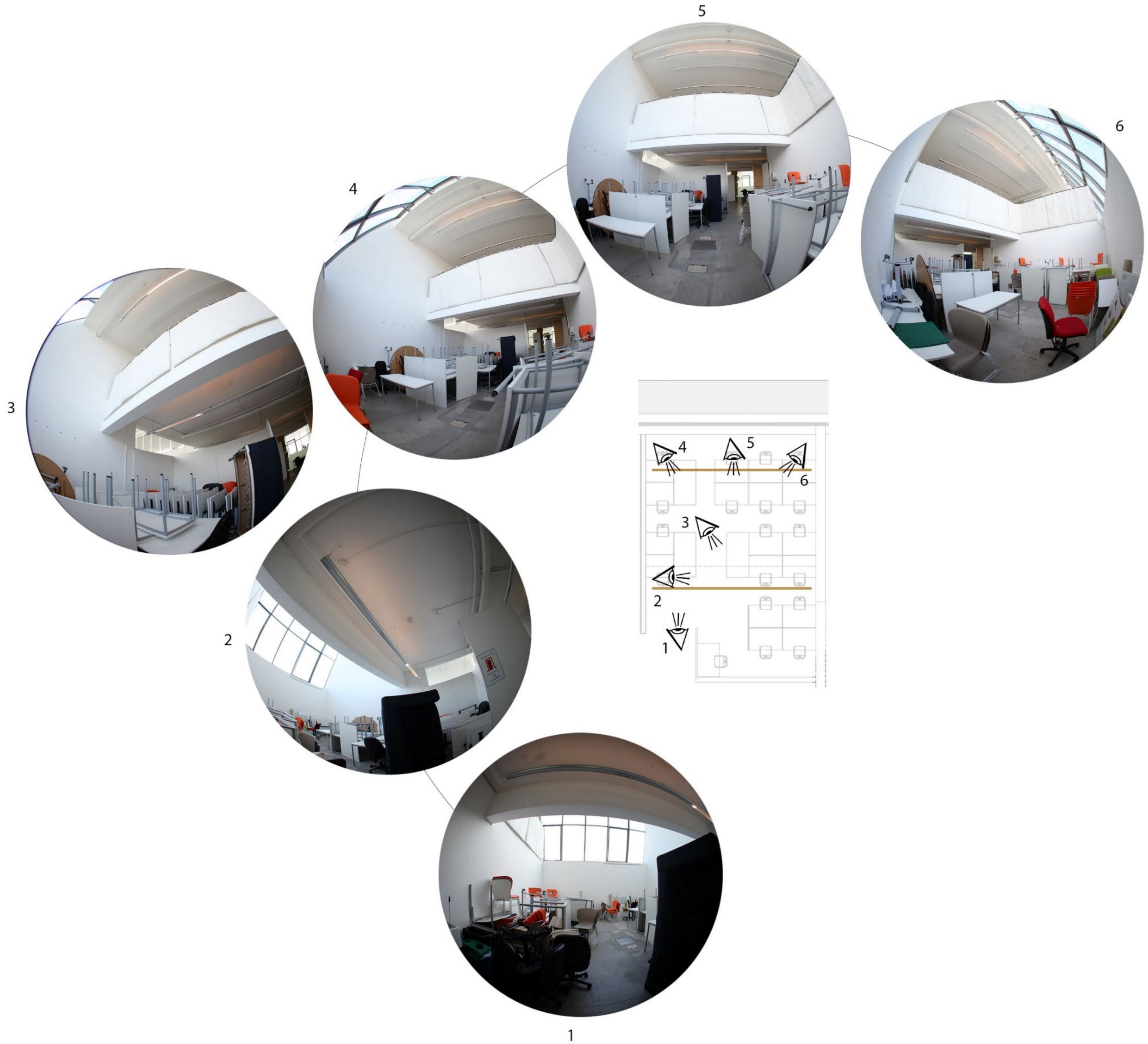


Figure 6-10 Wide panoramic fisheye photos for studio GNPL, Glasgow.

* Photo shoots 1 and 2 were taken under the mezzanine studio GNPm.

Figure 6-11 Wide panoramic fisheye photos for studio GNPm, Glasgow.

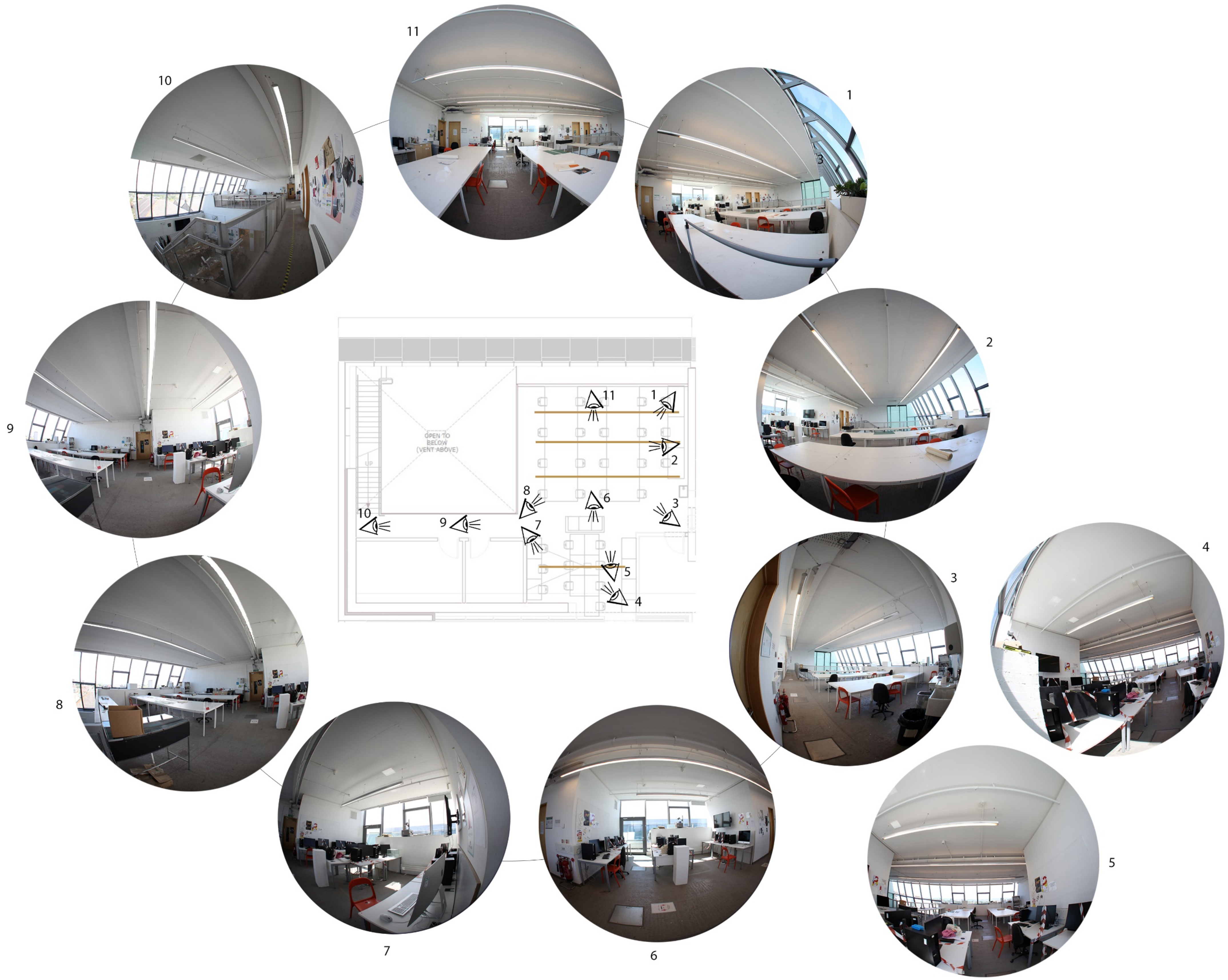


Figure 6-12 Wide panoramic fisheye photos for studio GNJm, Glasgow.

Figure 6-13 Wide panoramic fisheye photos for studio E1, Edinburgh.
***Photo shoot number 2 was taken under the mezzanine studio Em**

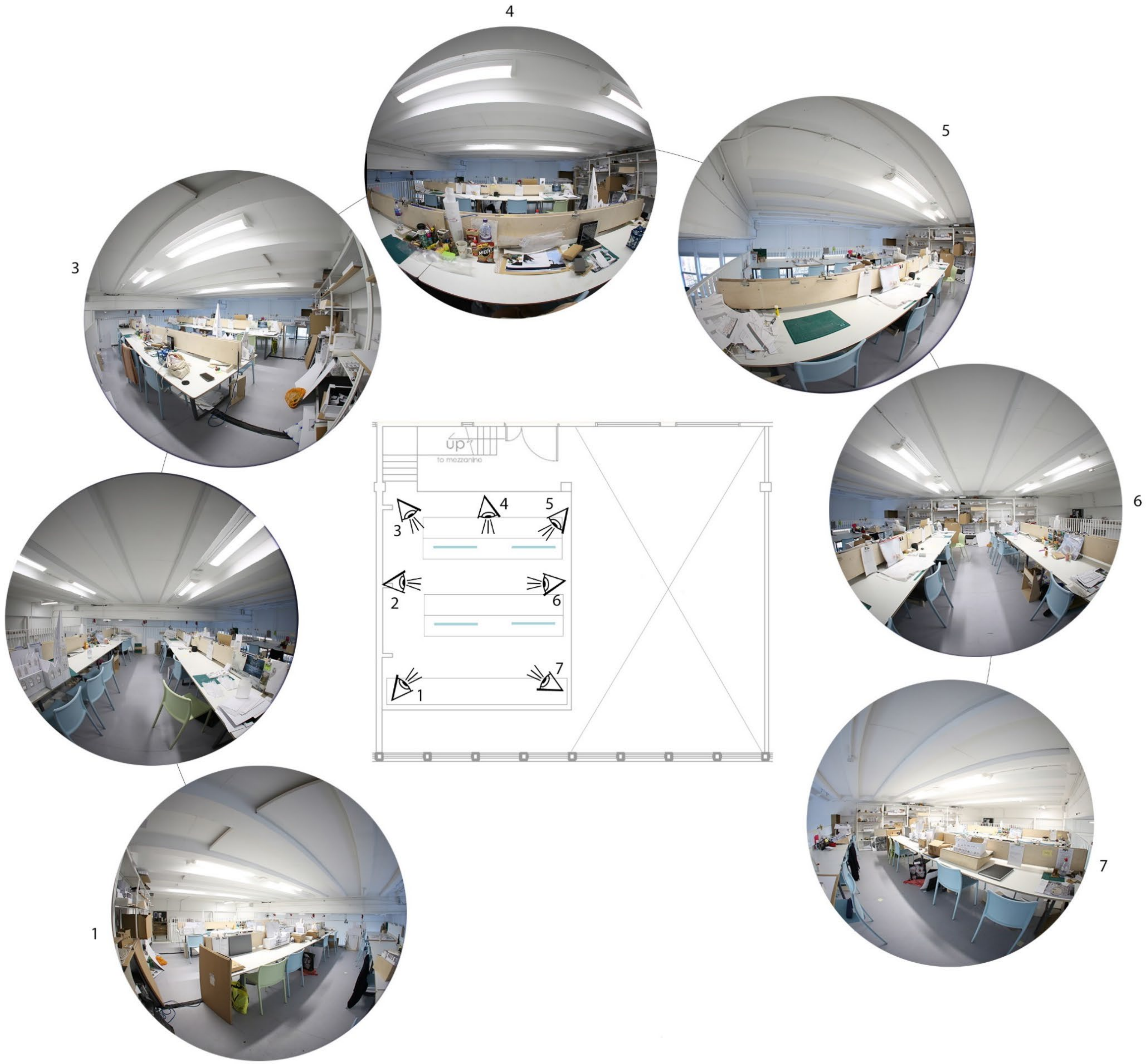


Figure 6-14 Wide panoramic fisheye photos for studio Em, Edinburgh.

6.3 **Objective measurements in North orientated studios**

The total number of light meters used for this analysis was around 94 meters, 4 of which were placed horizontally at the top of each building's roof (two on the Glasgow building's roof and another two on the Edinburgh building's roof) to measure light levels from an unobstructed sky (Figure 6-15 and Figure 6-16). Appendix B.6 presents the average illuminance levels registered under unobstructed sky (Glasgow & Edinburgh). The rest of the meters were placed inside the studios, from the window wall, to the middle, to the furthest point of each studio horizontally, and in the middle of every wall vertically. Appendix G. 1, Appendix G. 2 and Appendix G. 3 show the details of the light meters that were placed in the Glasgow and Edinburgh studios.

Figure 6-15 **Edinburgh building roof meter**

Figure 6-16 Glasgow building roof meter

The objective measurements that were recorded at each studio mainly related to the studio's physical characteristics, such as the window dimensions, and quantitative daylight measurements, including illuminance levels and the daylight factor. As weather under overcast sky tends to be varied and changeable over time (Met Office, 2016), the daylight measurements were recorded at 5-minute intervals, six days per month (from February to November, 2019). Furthermore, the daylight hours (in terms of sunrise and sunset per month) play a crucial role in determining the daylight availability inside buildings. To illustrate this, Table 6-3 reports the day length for the first recorded day per month in the Edinburgh studio, whereby the longest daylight hours' figure was registered in July with 17.30 hours of daylight. Meanwhile, January registered the shortest daylight hours figure with around 7 hours of daylight availability. However, in an overcast location, it was found that cloud coverage had a greater effect on daylight availability outside and inside buildings. For example, in Edinburgh, although the month of April had fewer daylight hours (13.00 hour) than the month of May (15.21 hour), the mean illumination levels registered were higher in April (mean illuminance levels: 28132 lux, cloud coverage: 4 oktas) than in May (mean illuminance levels: 18944 lux, cloud coverage: 7 oktas). Table 6-4 reports the mean values of cloud coverage for the period of investigation in Edinburgh.

Month	Sunrise (hour)	Sunset (hour)	Day length (hour)
1st January	08:43	15:48	7:05:19
1st February	08:07	16:45	8:37:23
1st March	07:05	17:46	10:41:14
1st April	06:44	19:50	13:05:50
1st May	05:29	20:51	15:21:17
1st June	04:35	21:46	17:10:50
1st July	04:31	22:01	17:30:03
1st August	05:16	21:20	16:04:16
1st September	06:16	20:07	13:51:32
1st October	07:14	18:48	11:34:00
1st November	07:18	16:33	9:14:18
1st December	08:18	15:44	7:25:38

Table 6-3 Day length for Edinburgh city for the 1st day of every month

Month	Mean values of cloud coverage for every day of measurements (Total of 8 a.m. to 10 p.m.)						Total cloud mean coverage value in every month
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	
February	7	7	3	7	3	2	5
March	5	3	8	4	8	8	6
April	3	2	4	8	3	6	4
May	7	7	8	7	7	8	7
June	6	4	7	7	8	4	6
July	8	5	7	7	5	5	6
August	6	3	8	5	3	8	6
September	5	2	7	4	3	4	4
October	7	5	3	8	7	8	6

Table 6-4 Mean values of cloud coverage for Edinburgh, 2019

6.3.1 **Studios' zones divisions**

The measured studios were divided into zones based on a number of parameters. Although the studios have similar design typologies (double-volume open plan studio with mezzanine studio above), the nature of the penetrating daylight in the different zones within the same studio was experienced differently. Consequently, the analysis began by dividing each studio into three zones: zone one related to the area in the double-volume open studio that is not covered by the mezzanine above, zone two related to the area in the double-volume open studio that is covered by the mezzanine above and zone three related to the mezzanine studio (Figure 6-17). Accordingly, the vertical measuring points (VMPs) and horizontal measuring points (HMPs) in each zone have been grouped for further analysis across each studio (Appendix H. 1).

The effect of façade fenestration on daylight levels has examined using varied statistical tests like One-way analysis of variance (ANOVA) to test the significant differences between two or more variables. Also, the Paired-Samples T-test has used to determine whether the mean difference between repeated measurements is statistically significant or not.

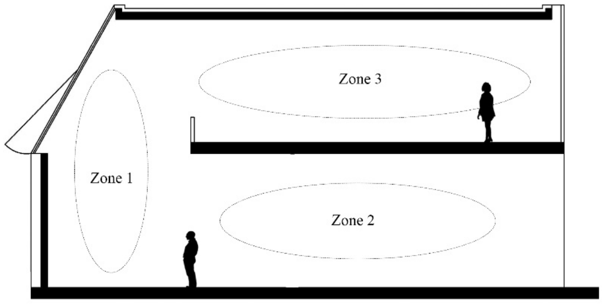


Figure 6-17 Example of studio's zones divisions

6.3.2 **Vertical measuring points (at eye level vs above eye level)**

The vertical measuring points (VMPs) were placed at two levels on the vertical walls (Figure 6-18): at the students' eye level while seated (1.20m) and above eye level (1.60m). Accordingly, several paired sample t-tests were used to determine whether the illuminance levels (lux) registered by VMPs at eye level were significantly different (*P<0.05*) from the illuminance levels registered by VMPs above eye level in each studio and throughout the measurement period. Table 6-5 reports the *p-values* for the several t-tests that were conducted in each studio. The findings revealed a non-statistically significant difference between VMPs at eye levels vs above eye level in studio Em and studio GNJm (covered zone) throughout the measurement period. This result stems from the fact that there is a limited window presence in these two studios as well as limited penetrated daylight inside. On the other hand, there was a statistically significant difference (*p<0.05*) between VMPs at eye level vs above eye level for studios GNC, GNCm, GNIn, GNPL, GNPm, GNJm and E1 for most of the measurement period. Even though the studios have a window-to-wall area ratio (W/W%) of more than 50%, the findings indicated a noticeable illuminance variation between VMPs at eye level vs above eye level.

With this in mind, the ANOVA results revealed a non- statistically significant effect on the position of window in the centre of the wall on the variation of illumination levels between VMPs at eye level vs above eye level for uncovered zones [F (1, 214) =0.961, p= 0.328]. However, there was a statistically significant effect of the window-to-wall area ratio [F (3, 212) = 56.45, p = 0.000] and window-to-floor area ratio [F(4, 211) = 32.05, p= 0.000] on the variation of illumination levels between VMPs at eye level vs above eye level.

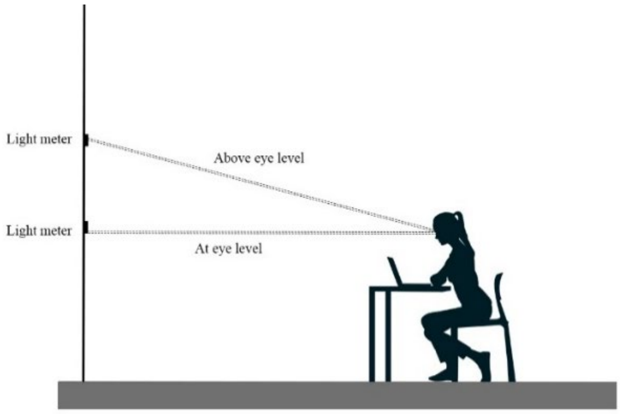


Figure 6-18 The vertical measuring points (VMPs) at the students' eye level while seated (1.20m) and above eye level (1.60m).

*F-statistic in ANOVA test is a ratio of two quantities that are expected to be roughly equal under the null hypothesis (The Minitab Blog, 2016).

Studio	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
E1	0.013	0.036	0.015	0.038	0.016	0.010	0.053	0.062	0.062
E1 (covered)	0.062	0.008	0.004	0.056	0.007	0.014	0.005	0.002	0.054
Em	0.197	0.178	0.182	0.231	0.233	0.193	0.213	0.161	0.160
GNC	0.000	0.001	0.020	0.001	0.001	0.001	0.005	0.003	0.002
GNCm	0.244	0.124	0.031	0.182	0.190	0.005	0.009	0.044	0.017
GNIn	0.012	0.010	0.007	0.009	0.007	0.010	0.010	0.006	0.001
GNPL	0.016	0.001	0.000	0.007	0.005	0.007	0.007	0.007	0.007
GNPm	0.004	0.012	0.258	0.008	0.010	0.003	0.016	0.003	0.001
GNJm	0.017	0.014	0.043	0.490	0.047	0.046	0.065	0.320	0.205
GNJm (covered)	0.089	0.176	0.140	0.018	0.233	0.170	0.190	0.044	0.050

Table 6-5 Results of the t-tests' p-values for the investigated studios throughout the measurement period.

- Not significant (P>0.05)
- Significant (P <0.05)

6.3.3 **Analysis of illuminance levels in zone 1**

This section presents the illuminance levels that were registered vertically and horizontally in each zone by using the colour map charts. The findings are presented in the median values as a better representation for central tendency. The illumination levels registered by vertical measuring points from the highest to lowest median values for zone 1 are reported in Table 6-6, and the vertical measuring points (VMPs) inside the investigated studios in Zone 1 are presented in Figure 6-19. In terms of VMPs in zone 1, the findings revealed that the maximum mean illumination levels were registered by meter (26) in studio GNIn in July (3602 lux) and 4142 lux at eye level and above eye level, respectively. Median values registered 3146 lux and 3618 lux at eye level and above eye level, respectively. Likewise, findings revealed that studio GNIn also registered the highest illumination levels for February, April, May, June, August and September, while studio GNPL registered the highest illumination levels for March and October with a marginal difference in studio GNIn. With regards to the lowest illumination levels, meter (55) in studio E1 registered the lowest levels throughout the measurement period, with values close to those of studio GNC. With regards to the horizontal measuring points in zone 1, as reported in Table 6-8, the registered illuminance levels revealed similar results to those reported from the vertical measuring points. Accordingly, the maximum mean illumination levels were registered by meter (27) in studio GNIn in July (4371 lux), and the median values registered 3818 lux. Studio GNIn also registered the highest illumination levels for February, May and September, while meter (37) in studio GNPL registered the highest illumination levels in March, April and October. Meter (10) in studio GNC registered the highest illumination levels in June and August, while meter (58) in studio E1 registered the lowest illumination values throughout the measurement period, similar to the results obtained from the VMPs. The horizontal measuring points (HMPs) inside the investigated studios in Zone 1 are presented in Figure 6-20.

Vertical measuring points

Month	Highest median ←													Lowest median
Feb	665.62	554.75	373.22	364.46	313.28	241.28	233.7	205.74	189.57	85.87	85.81	82.38	27.39	25.41	17.41
Mar	375.02	357.74	355.82	346.26	336.97	188.83	185.07	178.45	171.9	169.52	152.75	107.99	82.04	56.71	42.71
Apr	2093.05	1541.12	1462.37	1414.71	1353.92	1194.37	1079.34	917	712.19	209.11	193.44	176.39	160.3	124.15	117.75
May	2463.35	1813.77	1478.22	1096.19	1079.24	881.44	704.86	679.53	528.49	210.02	203.08	175.16	97.67	87.32	56.28
Jun	2093.73	1541.61	1194.76	1079.67	917.29	712.42	599.1	577.57	449.19	184.07	180.65	155	102.99	95.07	69.13
Jul	3146.26	2214.49	1606.48	1562.88	1337.51	1270.72	891.44	859.4	668.36	468.65	451.17	417.23	162.53	144.66	112.42
Aug	1716.9	1038.26	1009.82	806.51	776.33	626.27	355.13	305.7	265.9	205.06	197.68	153.74	149.5	104.82	63.64
Sep	1405.73	878.49	815.46	815.4	725.37	354.02	341.27	314.91	265.42	251.54	249.5	212.82	152.34	98.49	56.25
Oct	494.1	434.76	413.27	373.37	367.54	333.64	235.24	216.87	212.65	78.32	70.17	57.8	31.97	15.57	11.05

Table 6-6 Illumination levels (lux) from highest to lowest median values for zones 1, registered by vertical measuring points

Studios														
GNIn						GNPL			GNC			E1		
Meter 24	Meter 23	Meter 62	Meter 25	Meter 65	Meter 26	Meter 32	Meter 34	Meter 33	Meter 1	Meter 2	Meter 3	Meter 55	Meter 54	Meter 56

Table 6-7 Colour code for vertical measuring points at zones 1

Studio GNIn Studio GNPL Studio GNC Studio E1

Scale 1:200

Figure 6-19 Vertical measuring points (VMPs) inside the investigated studios (Zone 1)

Horizontal measuring points

Month	High median ←																Low median
Feb	1006.24	679.04	586.18	531.91	460.44	408.63	354.17	319.13	318.07	285.14	257.9	218.94	130.63	122.93	49.29	36.54	14.7	9.7
Mar	953.65	839.87	805.39	800.27	716.33	531.63	502.27	341.53	315.28	307.57	253	251.15	237.74	173.04	163.8	64.42	33.37	24.88
Apr	3698.18	3629.79	3577.3	3349.84	2542.6	1895.78	1736.96	1391.79	955.56	679.5	578.67	487.91	326.15	294.53	261.63	174.54	93.45	82.69
May	3013.31	2801.5	2310.96	2202.66	2064.71	2014.7	1862.72	1828.17	1721.01	1649.45	1553.59	1132.47	414.91	397.58	340.74	119.38	62.16	59.54
Jun	2831.08	2562.37	1965.11	1873.01	1750.44	1713.18	1686.67	1583.95	1553.98	1475.92	1402.6	962.98	517.71	358.02	205.46	116.57	86.08	59.66
Jul	3817.68	2927.95	2790.59	2607.96	2552.46	2359.91	2180.39	2089.73	1434.75	1283.57	856.19	678.64	557.24	539.47	473.87	159.64	72.69	63.59
Aug	1007.85	869.21	850.91	764.6	656.82	635.94	593.04	581.66	537.8	496.87	475.88	383.22	362.78	325.59	295.53	103.41	49.7	42.42
Sep	1669.08	1546.82	1416.54	1414.03	1159.95	1099.01	1005.22	929.42	907.61	858.65	630.09	556.68	315.52	308.96	196.33	81.58	75.75	27.84
Oct	853.31	852.4	618.29	541.67	424.74	367.84	357.84	321.1	248.83	176.57	152.66	151.14	119.14	116.33	100.58	28.48	12.9	9

Table 6-8 Illumination levels (lux) from highest to lowest median values for zones 1, registered by horizontal measuring points

Studios																	
GNIn					GNPL				GNC					E1			
Meter 28	Meter 27	Meter 29	Meter 30	Meter 63	Meter 36	Meter 41	Meter 37	Meter 40	Meter 8	Meter 10	Meter 11	Meter 7	Meter 69	Meter 60	Meter 53	Meter 57	Meter 58

Table 6-9 Colour code for horizontal measuring points at zones 1 (exclude window step meters)

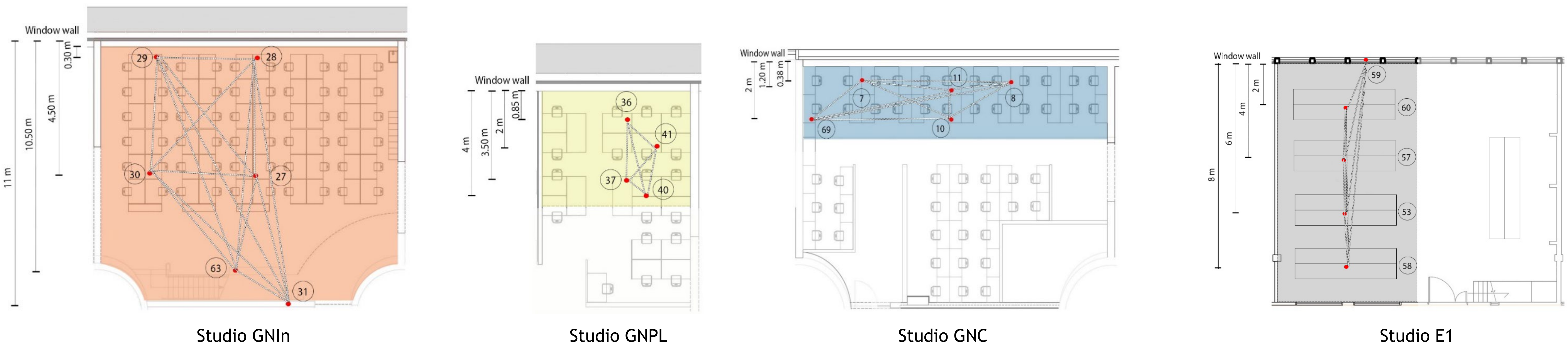


Figure 6-20 Horizontal measuring points (HMPs) inside the investigated studios (zone 1)

Scale 1:200

6.3.3.1 **Analysis of illuminance levels in zone 2**

In terms of zone 2 (the area in the double-volume studio covered by the mezzanine above), the maximum mean illuminance levels registered by the vertical measuring points were by meter (56) in studio GNJm in April, with 2311 lux and 2674 lux at eye level and above eye level, respectively. The median values were registered at 2467 lux and 2841 lux at eye level and above eye level, respectively. The illuminance levels registered by the vertical measuring points from the highest to lowest median values for zone 2 are reported in Table 6-10, in which studio GNJm registered the highest illuminance levels for April, June, July, August and September. Meanwhile, meter (35) in studio GNPL registered the highest illuminance levels for February, March, May and October and the lowest illuminance levels were registered in studio E1. The vertical measuring points (VMPs) inside the investigated studios in Zone 2 are presented in Figure 6-21.

With regards to the illuminance levels registered by the horizontal measuring points and reported in Table 6-12, the maximum mean illumination levels were registered in April by meter (38) in studio GNPL (2425.45 lux, median value 2578 lux) as well as registering the highest illuminance levels in February, March, July and October. Studio GNC registered the highest illuminance levels in May, June, August and September and studio E1 registered the lowest illuminance levels within all studios. Similar to zone 1, studios GNJm and GNPL did not face any external obstructions (buildings and trees) and were located at a higher level in comparison to studios E1 and GNC. The latter studios were located on lower levels and faced external obstructions that blocked parts of visible sky. The horizontal measuring points (HMPs) inside the investigated studios in Zone 2 are presented in Figure 6-22.

Vertical measuring points at eye level

Month	Highest median ←					Lowest median
Feb	174.33	40.78	30.89	25.7	24.61	19.35
Mar	409.67	150.61	83.08	59.03	47.92	35.96
Apr	2467.45	1564.61	1165.68	116.07	109.79	92.94
May	388.37	146.02	138.14	96.01	41.17	36.51
Jun	807.81	377.9	330.09	81.94	52.13	44.19
Jul	608.65	491.13	376.34	263.24	108.47	102.62
Aug	500.93	289.5	114.32	112.96	48.71	46.06
Sep	523.14	411.59	195	89.79	65.46	62.65
Oct	378.97	30.15	25.74	22.57	10.93	9.39

Table 6-10 Illumination levels (lux) from highest to lowest median values for zones 2

Studios					
GNJm		GNPL	GNC	E1	
Meter 56	Meter 55	Meter 35	Meter 4	Meter 68	Meter 61

Table 6-11 Colour code for vertical measuring points in zones 2

Figure 6-21 Vertical measuring points (VMPs) inside the investigated studios (Zone 2)

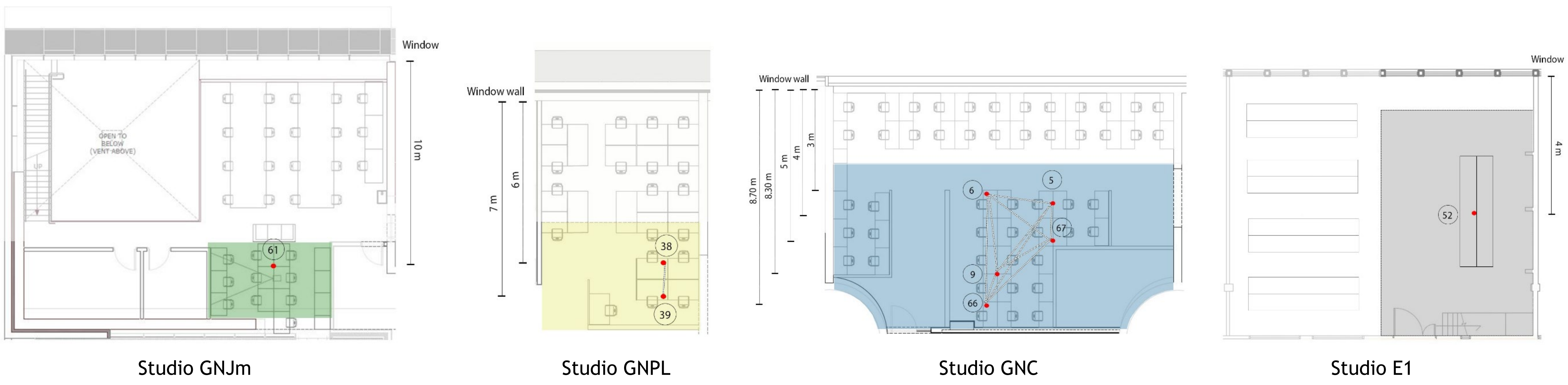
Horizontal measuring points

Month	Highest median ←								Lowest median
Feb	186.86	181.53	113.87	70.61	59.84	28.71	23.47	19.04	17.25
Mar	905.72	580.14	525.09	225.46	145.95	66.24	58.82	53.45	33.52
Apr	2576.8	983.01	774.43	295.1	196.59	186.37	76.61	64.51	37.95
May	1317.94	917.75	595.7	564.89	334.62	189.54	128.13	106.45	50.72
Jun	1010.41	780.4	561.16	413.97	412.87	284.52	132	102.94	55.01
Jul	1162.7	1138.43	1028.27	759.48	423.91	394.01	139.32	78.38	70.2
Aug	970.68	836.96	312.85	288.71	264.95	122.46	96.6	83.33	32.79
Sep	583.98	562.67	457.86	416.98	248.92	166.92	99.44	77.63	28.86
Oct	315.57	184.77	125.34	110.63	49.91	37.98	17.95	16.68	13.63

Table 6-12 Illumination levels (lux) registered by horizontal measuring points from highest to lowest median values for zones 2

Studios								
GNPL		GNC					GNJm	E1
Meter 38	Meter 39	Meter 5	Meter 6	Meter 66	Meter 67	Meter 9	Meter 61	Meter 52

Table 6-13 Colour code for horizontal measuring points at zones 2



Scale 1:200

Figure 6-22 Horizontal measuring points (HMPs) inside the investigated studios (Zone 2)

6.3.3.2 **Analysis of illuminance levels in zone 3**

In zone 3 (the mezzanine level), the maximum mean illuminance levels registered by the vertical measuring points were in studio GNJm in April and May, with 3792 lux and 4387 lux at eye level and above eye level, respectively. The median values registered 4048 lux and 4661 lux at eye level and above eye level, respectively. The illuminance levels registered by the vertical measuring points from the highest to lowest median values for zone 3 are reported in Table 6-14. Studio GNJm also registered the highest illuminance levels for March, April, May, June, July, August and September. Meanwhile, studio GNCm registered the highest illuminance levels for February, with studio GNPm showing a marginal difference registering the highest illuminance levels for October. Studio Em registered the lowest illuminance levels as it had limited access to the window as well as external obstructions. The vertical measuring points (VMPs) inside the investigated studios in Zone 3 are presented in Figure 6-23.

For the illuminance levels registered by the horizontal measuring points and reported in Table 6-16, studio GNJm registered the maximum mean illumination levels in April, with 5573 lux, median value 5920 lux. Similarly, studio GNJm registered the highest median values for February, March, May, July and September, while studio GNPm registered the highest illuminance levels in June, August and October with close values to studio GNJm. Studio Em registered the lowest illuminance levels with close values to studio GNCm. The horizontal measuring points (HMPs) inside the investigated studios in Zone 3 are presented in Figure 6-24.

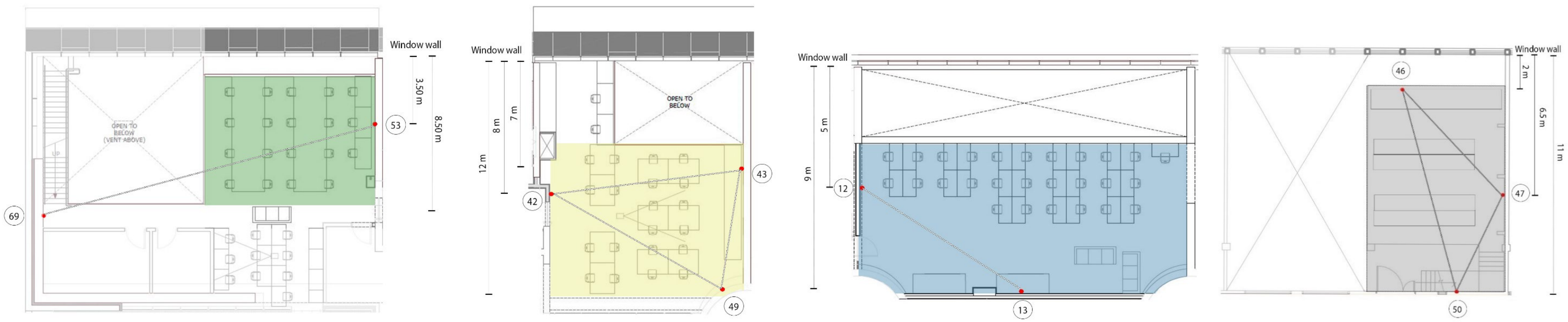
Vertical measuring points at eye level

Month	Highest median	←								Lowest median
Feb	90.47	67.06	61.59	56.04	53.52	52.18	47.98	23.08	6.42	4.83
Mar	233.01	162.22	140.76	106.82	104.3	100.65	82.47	36.73	9.65	7.74
Apr	4047.98	3440.5	306.79	212.15	199.35	105.63	62.08	36.18	31.67	20.25
May	4047.98	2989.71	434.69	244.9	231.15	194.26	170.36	44.79	10.46	6.77
Jun	1285.55	1169.23	1070.62	828.15	755.5	599.55	323.62	41.98	10.67	6.31
Jul	1379.74	1071.29	1010.31	878.84	788.87	290.63	263.17	60.57	18.46	9.43
Aug	1174.95	615.87	354.53	328.76	226.28	161.28	159.26	45.56	8.22	7.31
Sep	1607.46	872.91	745.05	612.08	605.39	156.49	137.93	66.45	19.58	18.53
Oct	178.4	146.56	144.96	38.19	35.96	33.33	32.76	9.01	2.88	2.49

Table 6-14 Illumination levels (lux) registered by the vertical measuring points from highest to lowest median values for zones 3

Studios									
GNJm		GNPm			GNCm		Em		
Meter 53	Meter 69	Meter 43	Meter 49	Meter 42	Meter 12	Meter 13	Meter 46	Meter 47	Meter 50

Table 6-15 Colour code for vertical measuring points at zones 3



Studio GNJm Studio GNPm Studio GNCm Studio Em

Scale 1:200

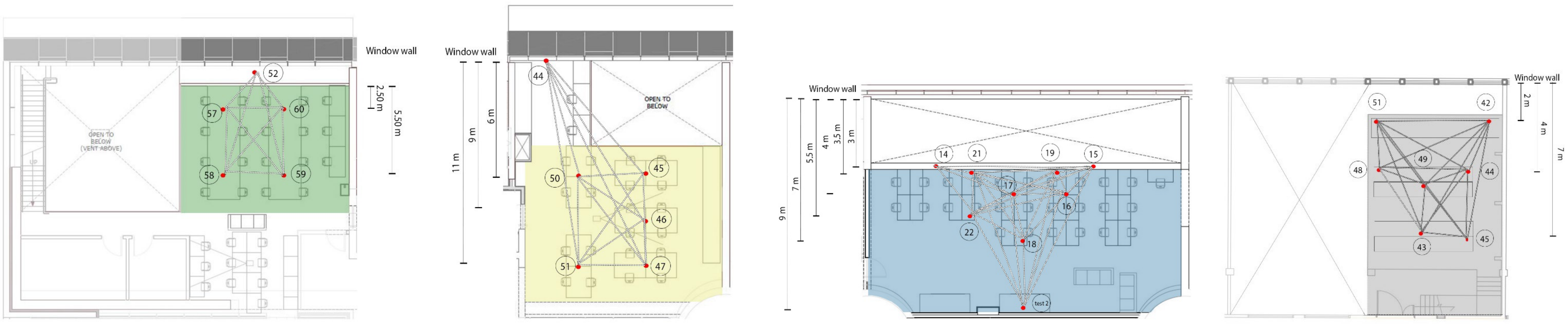
Figure 6-23 Vertical measuring points (VMPs) inside the investigated studios (Zone 3) Horizontal measuring points

Month	Highest median ←																							Lowest median
Feb	206.84	200.02	168.68	131.36	128.78	125.08	117.01	72.07	68.17	63.57	60.71	56.64	51.96	50.05	47.17	43.72	43.53	41.54	38.14	34.2	16.75	14.1	9.74	4.21	2.95
Mar	909.37	861.53	230.58	206.3	198.22	193.73	187.14	174.12	118.48	112.63	111.2	101.08	96.73	85.75	82.25	77.08	75.37	75.26	67.57	66.86	26.81	24.17	16.12	6	3.45
Apr	5920.48	5401.78	2182.18	2099.63	281.91	279.77	273.24	221.37	206.79	185.73	181.52	178.51	175.96	175.51	171.68	153.98	143.59	135.37	81.27	76.11	42.53	39.37	31.97	18.26	11.48
May	1636	1288.24	990.97	476.65	445.89	439.57	405.69	389.84	314.26	314.12	271.87	246.47	237.7	212.74	191.36	153.58	150.67	95.22	92.38	89.31	30.19	19.94	18.55	9.72	5.81
Jun	3849	2265.08	2239.2	2181.12	1544.89	1232.2	889.78	863.27	693.21	673.95	668.38	614.99	606.27	583.96	420.3	280.58	229.5	180.55	87.99	87.94	28.46	19.36	19.09	9.55	5.42
Jul	3062.35	2981.04	2609.67	1240.74	937.54	839.98	812.32	758.69	736.1	725.67	654.33	429.08	400.91	345.09	338.39	232.79	216.33	167.23	105.19	89.84	45.17	29.29	28.65	14.89	7.78
Aug	3094.61	2324.46	1952.21	727.81	607.49	519.44	512.08	330.92	304.85	278.14	239.33	216.06	157.85	146.1	108.52	106.8	102.93	99.8	61.46	61.38	33.85	22.86	21.91	11.51	6.12
Sep	2306.02	2220.12	1584.43	927.5	870.89	680.29	296.29	288.44	250.99	192.33	177.1	167.35	154.99	151.19	148.15	139.77	128.54	119.61	86.88	84.35	38.9	33	25.54	17.69	12.27
Oct	368.89	158.38	98.85	86.31	85.04	77.55	73.19	63.21	54.35	44.8	41.22	36.07	33.71	33.68	30.39	28.96	27.75	22.2	17.14	11.33	7.19	4.25	2.77	2.21	1.46

Table 6-16 Illumination levels (lux) registered by the horizontal measuring points from highest to lowest median values for zone 3

Studios																								
GNJm				GNPm					GNCm									Em						
Meter 60	Meter 59	Meter 57	Meter 58	Meter 45	Meter 46	Meter 47	Meter 50	Meter 51	Meter 22	Meter 17	Meter 21	Meter 16	Meter 18	Meter 14	Meter 15	Meter 19	Meter Test 2	Meter 51	Meter 42	Meter 44	Meter 49	Meter 48	Meter 43	Meter 45

Table 6-17 Colour code for horizontal measuring points at zones 3 (exclude window step meters)



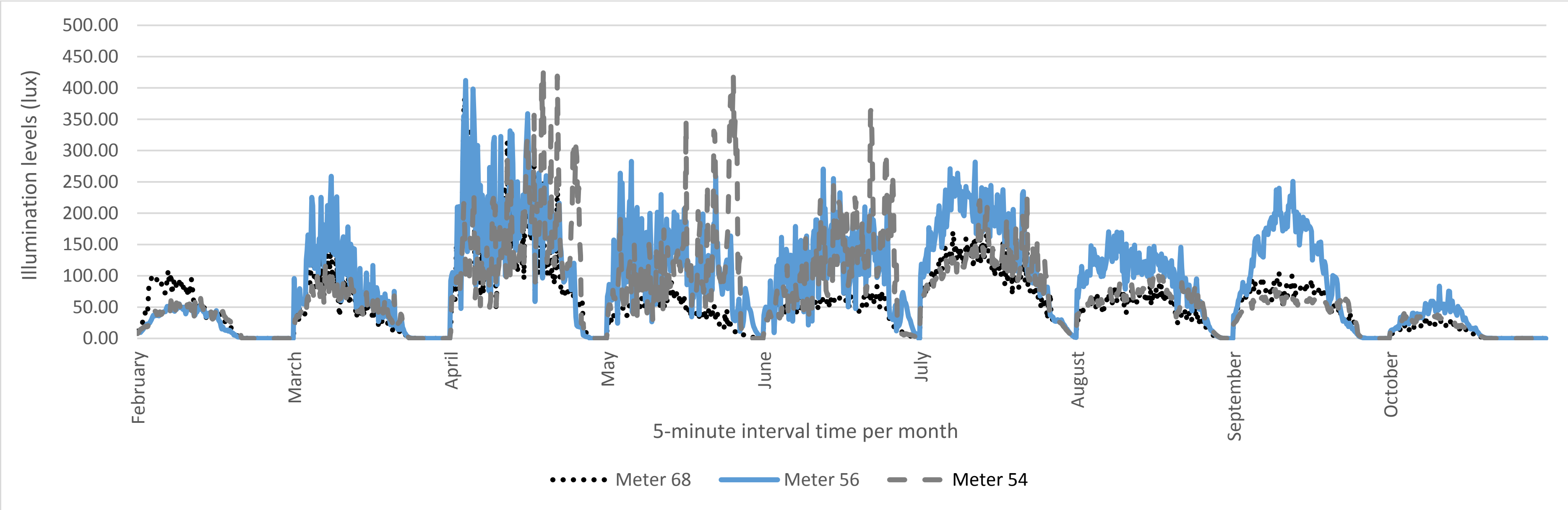
Studio GNJm   Studio GNPm   Studio GNCm   Studio Em

Scale 1:200

Figure 6-24 Horizontal measuring points (HMPs) inside the investigated studios (Zone 3)

It is important to mention that there were two factors affecting the illumination levels registered by the VMPs. The first one related to the distance of the vertical measuring points from the windows, while the second was concerned with the direction of the vertical measuring points. This result was found in studio E1, where meter (54) was placed on a wall perpendicular to the window at a distance of around 7m, while meter (56) was placed on a wall that was facing the window at a distance of around 11m from the window. The numerical median values presented in Table 6-6 showed that meter (56) registered higher illumination levels than meter (54) throughout the measurement period, due to their differences in direction from the window. Similarly, in studio GNIn, VMPs (26) and (65) at 10.50m distance from the window registered higher illuminance levels than VMPs (24) and (25) at 2.50m distance from the window. The same applied to studio GNCm, where meter (13) at a distance of 9m from the window registered higher illuminance levels than meter (12) at a 5m distance from the window. Also, in studio GNPm, where meter (49) was at a 12m distance from the window, higher illuminance levels were registered than meters (42) and (43) at 8m distance from the window (see Table 6-14 and Figure 6-23).

Nevertheless, the previous findings only refer to the measuring points that were not covered by any mezzanine floor level. To illustrate this, although meter (68) was placed at the same distance and direction as meter (56) in studio E1, it registered lower illumination levels than meter (54) due to it being covered by a mezzanine floor (Figure 6-25). Likewise, in studio GNPL, meter (35) was placed under the mezzanine floor and registered lower illuminance levels than meters (33) and (34), as shown in Figure 6-26.



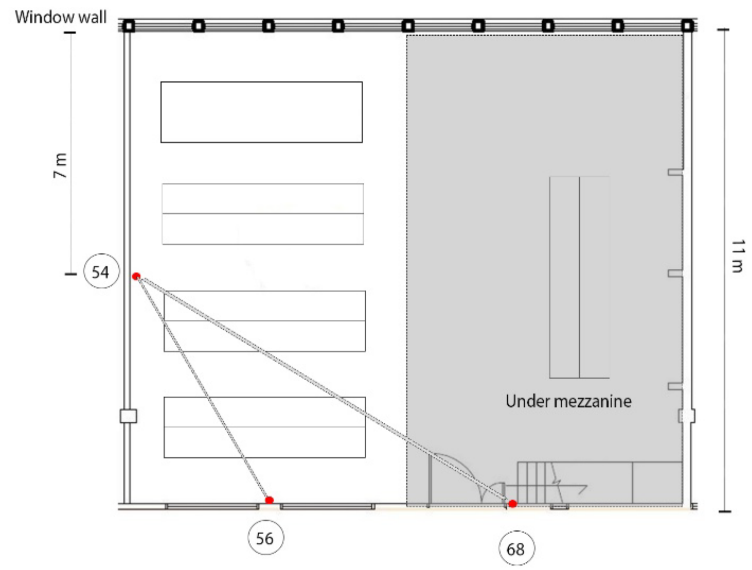
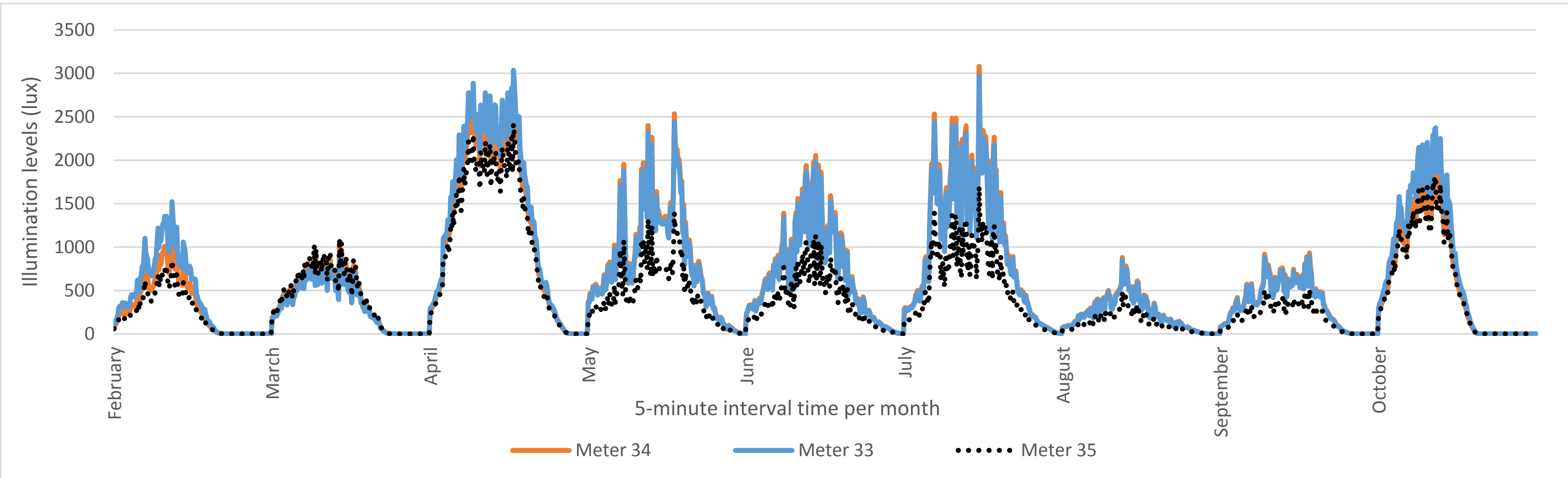


Figure 6-25 Left: Comparison between illuminance levels registered by VMPs (68), (56) and (54) in studio E1. Right: Location of VMPs in studio E1.



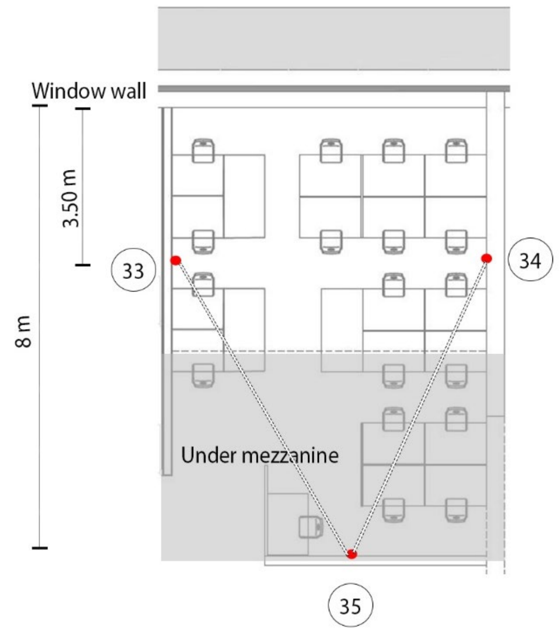


Figure 6-26 Left: Comparison between illuminance levels registered by VMPs (34), (33) and (35) in studio GNPL. Right: Location of VMPs in studio GNPL

6.4 Further analysis (obstruction, windowsill height, W/W % and W/F %)

According to the previous interpretation from the registered illuminance levels by the vertical and horizontal measuring points, it was found that zone 3 (which represents the studios at mezzanine level) has the highest illumination levels, followed by zone 1 (double-volume open plan floor) and finally zone 2 (the area in the double-volume studio which is covered by the mezzanine above). This is due to the presence of windows, mainly at the mezzanine levels.

An analysis of variance (One-way ANOVA test) was used to investigate whether the daylight levels showed a difference between studios. The results revealed a statistically significant difference ($P<0.05$) in the registered mean illumination levels between the studios by VMPs and HMPs throughout the measurement period in zone 1 and zone 3. This could be related to the window area, window-to-wall area ratio, window-to-floor area ratio, distance of measuring points from the window, studio floor level and external obstructions. On the other hand, for zone 2, the ANOVA test revealed there to be a statistically significant difference ($P<0.05$) in the registered illuminance levels by the vertical measuring points between studios for the following months: February, March, May, September and October, while no significant difference was found in April, June, July and August. Meanwhile, for the horizontal measuring points, no significant difference ($P>0.05$) in illuminance levels was found between the studios throughout the measurement period. This is due to the presence of the mezzanine floor above, with its coverage highly reducing the spread of daylight over horizontal surfaces (horizontal measuring points). Thus, no illumination differences between the studios in zone 2 and the factor of darkness became the dominant attribute. The findings for the ANOVA test are reported in Appendix I. 1, Appendix I. 2

Additionally, the post hoc test (Tukey HSD) conducted for multiple comparisons revealed that the significant differences in illumination levels registered by the VMPs and HMPs in zone 1 were mainly between studios GNIn and GNPL with studios GNC and E1 (Appendix I. 3). This result stems from the fact that studios GNIn and GNPL did not face any external obstructions (buildings and trees) due to them being located at higher levels (+18.525 m) than studios GNC and E1, which faced external obstructions and were located at lower levels (+4.375 m for GNC and +5 m for E1). Therefore, the highest illumination levels were registered in studios that were located on higher levels where the sky is more visible, and there were fewer external obstructions to block the daylight from penetrating inside. Further ANOVA test results reported in Appendix J. 1 and Appendix J. 2 revealed that external obstructions have a statistically significant effect on the registered illuminance levels, mainly in zone 1 and zone 3, as summarized in Table 6-18.

Measuring points	Zone 1	Zone 2	Zone 3
Vertical measuring points	✓ significant	✓ significant except for Feb, march, May, Aug and Oct.	✓ significant except for April and May
Horizontal measuring points	✓ significant except for Jun and Aug	✓ significant except for March, May, Jun, Jul, Aug, Sept and Oct.	✓ significant except for February

Table 6-18 Summary of ANOVA test results to determine if the external obstructions have significant effects on the illumination levels along the measurement period. **Significant ($P<0.05$)**

Based on the previous results, two classifications were applied to the investigated studios, taking into account the floor level from the ground and the presence of external obstructions. Table 6-19 demonstrates the classification of the studios in Glasgow and Edinburgh, where other major factors, such as distance of measuring points from the window, window-to-wall area ratio (W/W%) and window-to-floor area ratio (W/F%) were highlighted. The external obstructions were estimated based on Version et al. (2013), who suggested an estimation of obstruction factor (OF) based on the objects (buildings and trees) seen from desk height and 3.3 m to a window.

Studio	Studio Floor level	External obstructions	Double-volume or Mezzanine level	Investigated parameter
E1	+5 m	✓	Double-volume	Windowsill height
GNC	+4.375	✓	Double-volume	
Em	+7.5 m	✓	Mezzanine level	W/F % and W/W %
GNCm	+8.375	✓	Mezzanine level	
GNIn	+18.525	X	Double-volume	W/F % and effect of mezzanine level above
GNPL	+18.525	X	Double-volume	
GNPm	+22.40	X	Mezzanine level	W/F %, W/W % and effect of height
GNJm	+22.40	X	Mezzanine level	

Table 6-19 Classification of the investigated studios based on the floor level from the ground and external obstructions (Glasgow and Edinburgh).

6.4.1 Double - volume studios with external obstructions (zone 1)

In this category, two double-volume studios were examined; E1 and GNC, whereby they had close floor level values from the ground and close window-to-wall area ratios of about 53.3% and 50%, respectively. The obstruction factor (OF) obtained for studios was 0.40 (view ≥ 90% obstructed). Meanwhile, other parameters differed for the two studios, such as windowsill height (1 m for studio E1 and 4 m for studio GNC), window-to-floor area ratio (16.6% for studio E1 and 40% for studio GNC), window area (48 m^2 for studio E1 and 60 m^2 for studio GNC) and the window glazing slope (vertical window for studio E1 and inclined window for studio GNC). Consequently, the one-way ANOVA test results, which are presented in Appendix K. 1 revealed the statistically significant effect ($p<0.05$) of the windowsill height, window-to-floor area ratio and window area on illuminance levels registered by VMPs, except in April. On the other hand, this effect was not dominant throughout the measurement period for registered illuminance levels by HMPs, such as in April, June, July and October. With respect to the effect of façade fenestration in different windowsill heights on the depth of light penetration inside studios and at specific distances from the window wall, further analysis was conducted using the Paired-Samples T-test between the two studios E1 and GNC. Figure 6-27 and Table 6-20 show some relevant information on the distance of specific horizontal measuring points (HMPs) from the window wall.

The findings revealed that the registered mean illuminance levels by HMPs in studio GNC was statistically higher than studio E1, at 2, 4 and 8m distances from the window and throughout the measurement period (Figure 6-29, Figure 6-30, and Figure 6-31). Meanwhile, studio E1 (meter 59) registered higher illuminance levels at a very close distance from the window, due it was placed on the windowsill step Figure 6-28. It was found that the high windowsill height with inclined glazing had a more significant effect on the illuminance levels than the lower windowsill height with vertical glazing. However, no consideration was given to the overlooking view from the students' eye level while seated in studio GNC. The interpretations for the paired-samples t-test results are presented in Appendix K. 2.

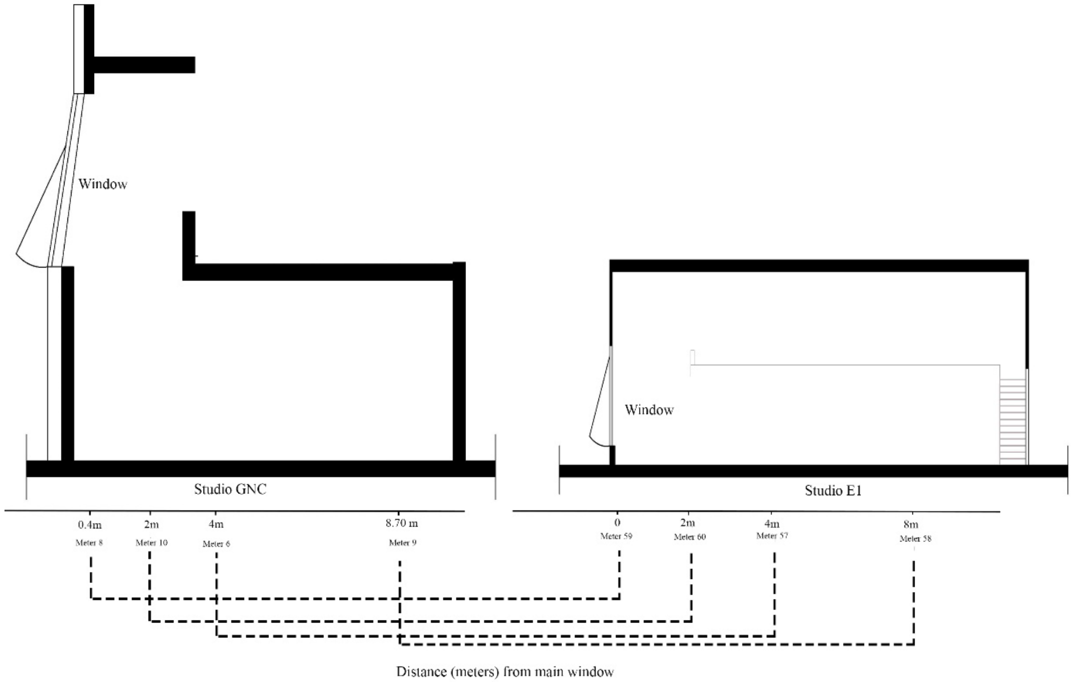


Figure 6-27 Horizontal measuring points inside studios GNC and E1.

Distance from the window	Studio E1	Studio GNC
Close to the window (zero-0.38 m)	meter 59	meter 8
2m distance from window	meter 60	meter 10
4m distance from window	meter 52, meter 57	meter 6
8m distance from window	Meter 58	Meter 9 (mezzanine effect)

Table 6-20 The distance of horizontal measuring points from the window wall in E1 and GNC studios.

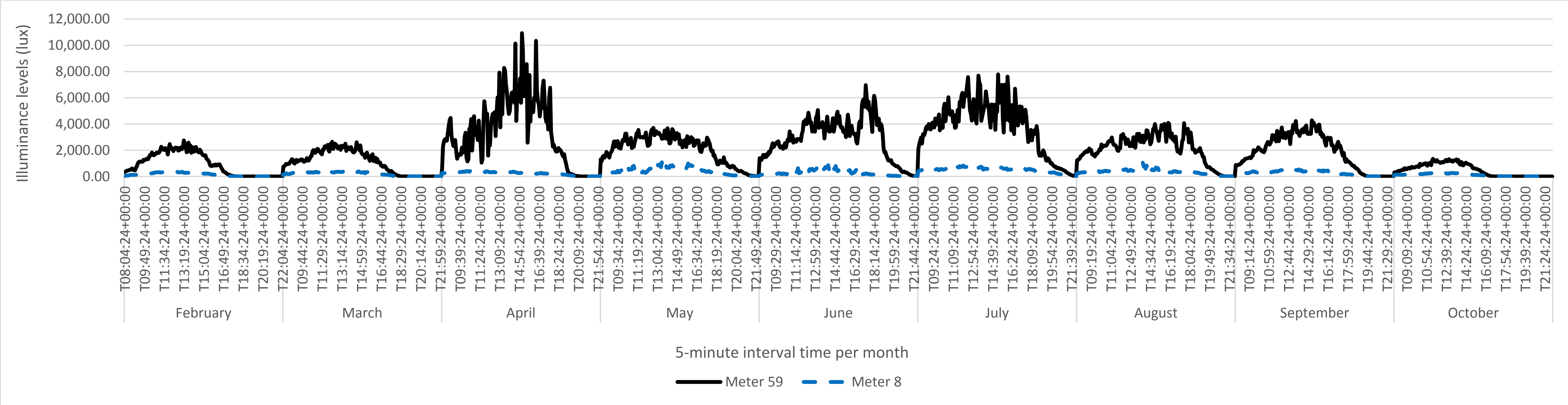


Figure 6-28 HMPs at close distance from the window (zero-0.38 m), studio E1 (meter 59) and studio GNC (meter 8).

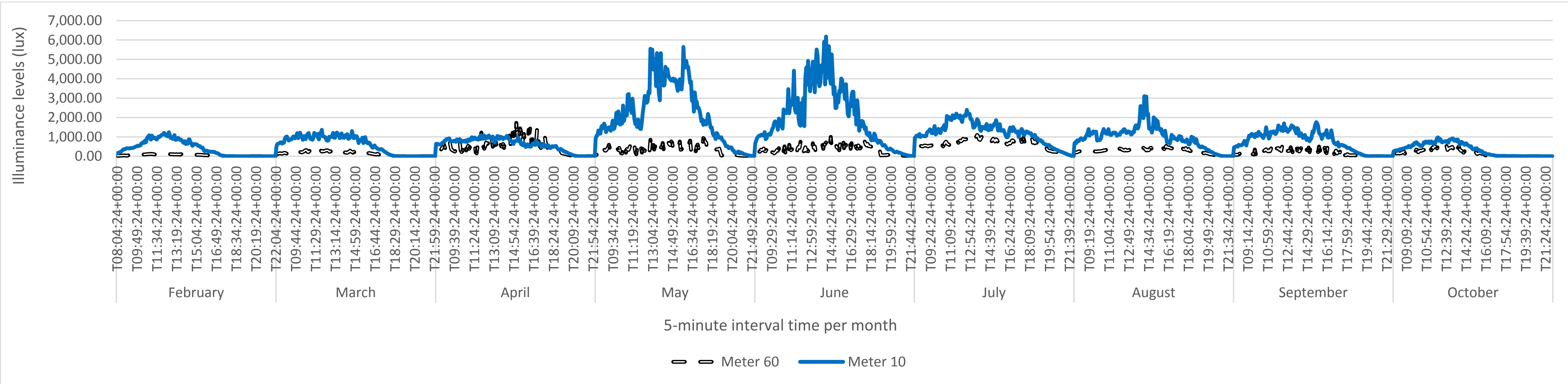


Figure 6-29 HMPs at 2m distance from the window, studio E1 (meter 60) and studio GNC (meter 10).

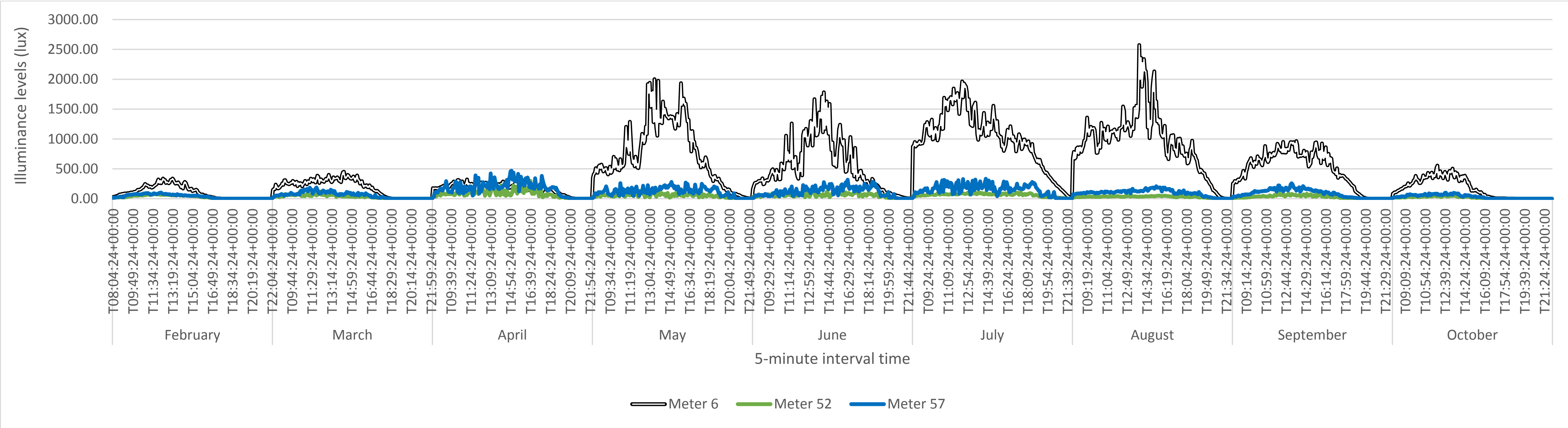


Figure 6-30 HMPs at 4m distance from the window, studio E1 (meters 52 & 57) and studio GNC (meter 6).

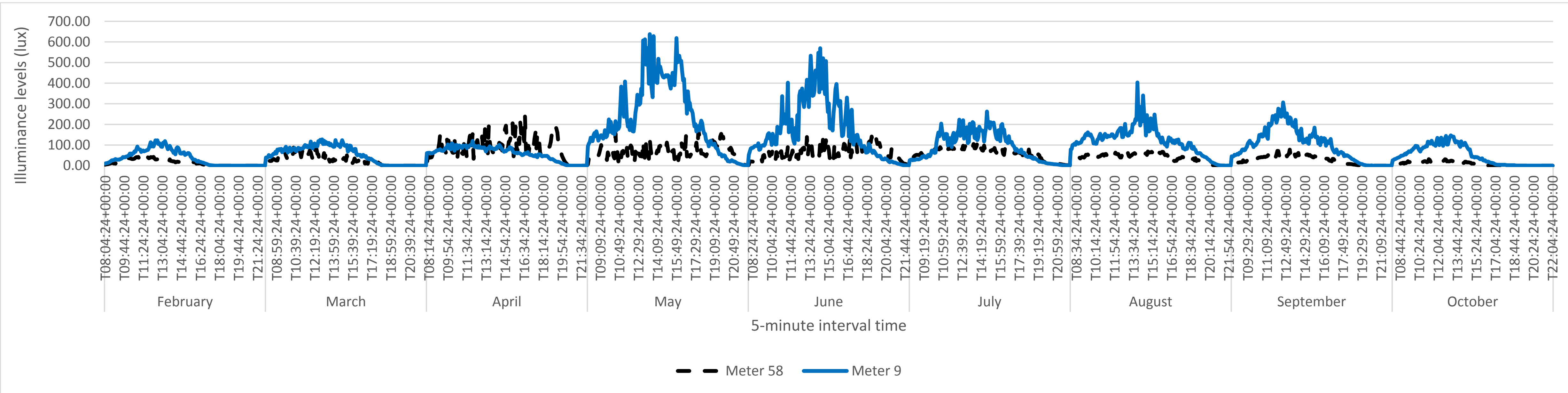


Figure 6-31 HMPs at 8m distance from the window, studio E1 (meters 58) and studio GNC (meter 9).

6.4.2 **Double - volume studios with no external obstructions (zone 1)**

For the double-volume studios with no external obstructions, studio GNIn and studio GNPL had similar floor level from the ground (+18.52 m), similar windowsill height (4 m), and close window-to-wall area ratio, 44% and 50%, respectively. On the other hand, the window-to-floor area ratio was different in about 32% and 50%, respectively, and the window area was 117 m^2 and 56 m^2, respectively. In addition, studio GNIn lacked a mezzanine level, in contrast to studio GNPL, which had a mezzanine level at 6 m distance from the window. From this perspective, one-way ANOVA test results presented in Appendix L. 1, revealed the statistically significant effect ($p<0.05$) of the window-to-floor area ratio on VMPs only in June and August, and on HMPs only in March, April, September and October. Whereas the window area has statistically significant effect ($p<0.05$) on VMPs only in June, August and September, while on HMPs only in March, April and October. For the comparison analysis between the two studios using the Paired-Samples T-test, Figure 6-32 and Table 6-21 show relevant information on the distance of specific horizontal measuring points (HMPs) from the window wall, taking into account the presence of the mezzanine floor above in studio GNPL.

The findings revealed that there is a statistically significant difference ($p<0.05$) in the registered illuminance levels between the two studios, where illuminance levels in studio GNIn varied from month to another in comparison with studio GNPL. However, in general, studio GNPL registered higher illuminance levels than studio GNIn at a very close distance to the window wall in March, April and October (Figure 6-33). Meanwhile, studio GNIn registered higher mean illuminance levels than studio GNPL at the middle and back of studio, and throughout the measurement period (Figure 6-34 and Figure 6-35). Here, it can be noted that the larger window area, the higher illuminance levels registered by HMPs. The interpretations for the paired-samples t-test results are presented in Appendix L. 2.

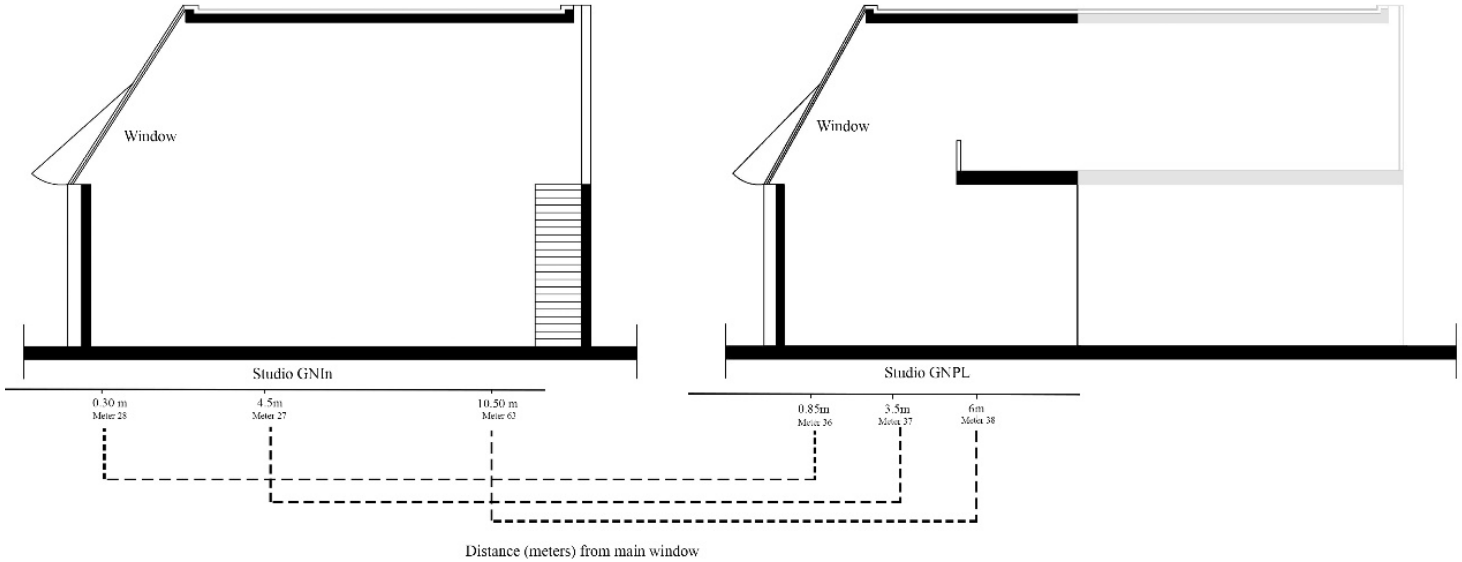


Figure 6-32 Horizontal measuring points inside studios GNIn and GNPL.

Distance from window	Studio GNIn	Studio GNPL
Close to the window (0.30-0.85m)	meter 28	meter 36
3.5-4.5m distance from window	meter 27	meter 37
6-10m distance from window (mezzanine effect)	meter 63	meter 38

Table 6-21 The distance of the investigated horizontal measuring points from the window wall in GNIn and GNPL studios.

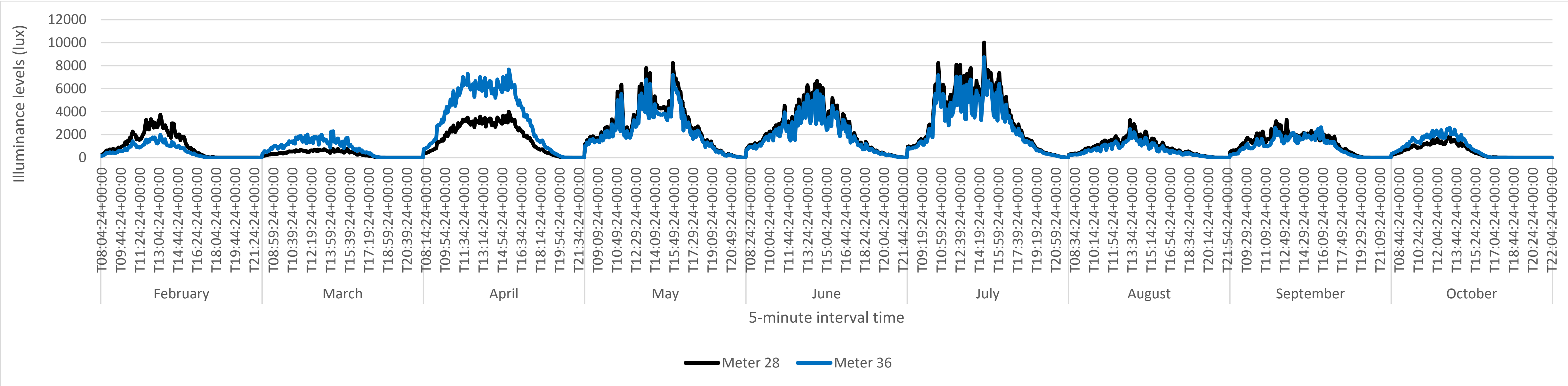


Figure 6-33 HMPs at close distance from the window (0.30-0.85 m), studio GNIn (meter 28) and studio GNPL (meter 36).

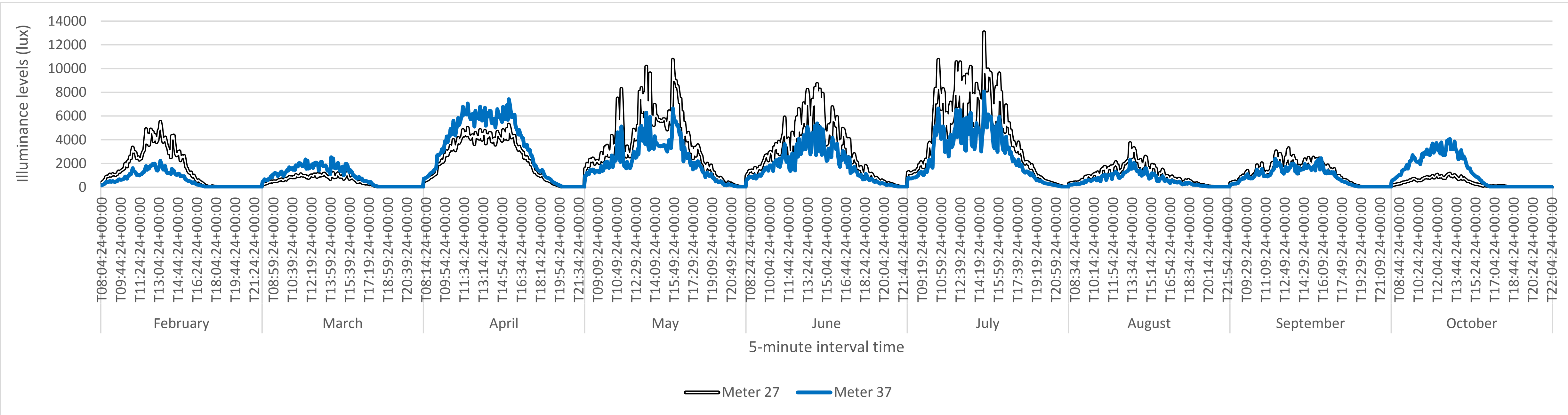


Figure 6-34 HMPs at 3.5-4.5m distance from the window, studio GNIn (meter 27) and studio GNPL (meter 37).

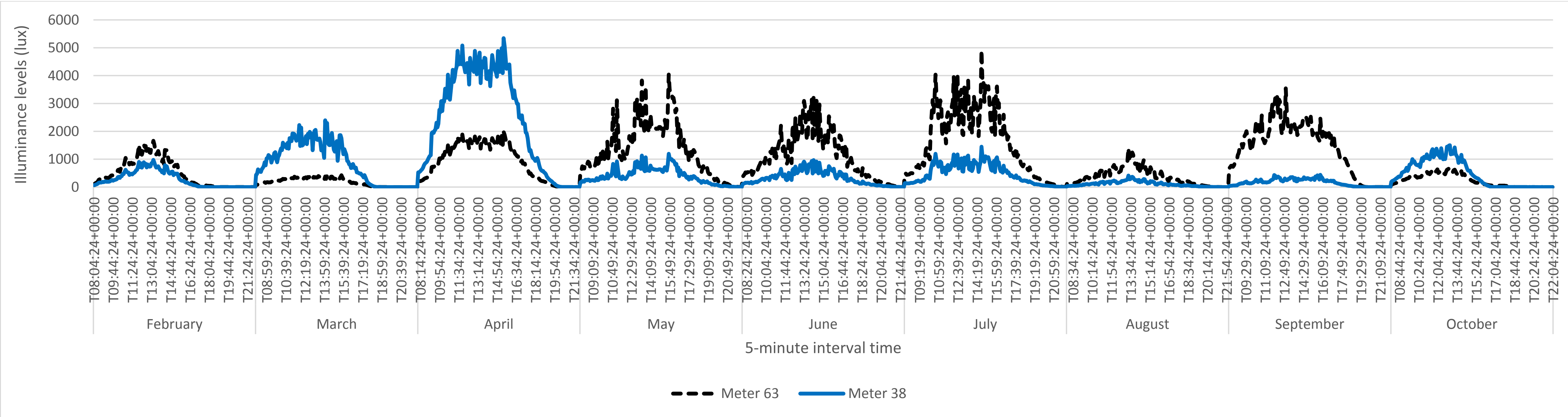


Figure 6-35 HMPs at 6-10m distance from the window, studio GNIn (meter 63) and studio GNPL (meter 38).

6.4.3 **Mezzanine studios with external obstructions (zone 3)**

With regards to the mezzanine levels, studio Em and studio GNCm were both mezzanine studios with external obstructions (OF = 0.4). They also had close floor level values from the ground, +7.5 m and +8.37 m, respectively. However, other factors differed between the studios, such as the window-to-floor area ratio: 4% and 57%, respectively, and window area: 4 m^2 and 60 m^2, respectively. In addition, the window-to-wall area ratio was 18% and 100% for Em and GNCm, respectively, while the window head height was 0.5 m and 4 m, respectively. In that respect, the one-way ANOVA test revealed a statistically significant effect ($p<0.05$) of W/F%, W/W%, window area and window head height on the registered mean illuminance levels by VMPs, except in February and on HMPs throughout the measurement period as presented in Appendix M. 1.

Figure 6-36 and Table 6-22 show the horizontal measuring points used in the Paired-Samples T-test. The findings revealed statistically significant differences between the two studios, in which the registered illuminance levels in studio GNCm are higher than studio Em among different distances from the window wall and throughout the measurement period (Figure 6-37, Figure 6-38, Figure 6-39 and Figure 6-40). Here, the window head height had a vital role in the penetrated daylight. In studio Em, the window head height was less than the student's seating eye level, which in return reduced the illumination levels inside the studio dramatically. Appendix M. 2 presents the interpretations for the paired-samples t-test results.

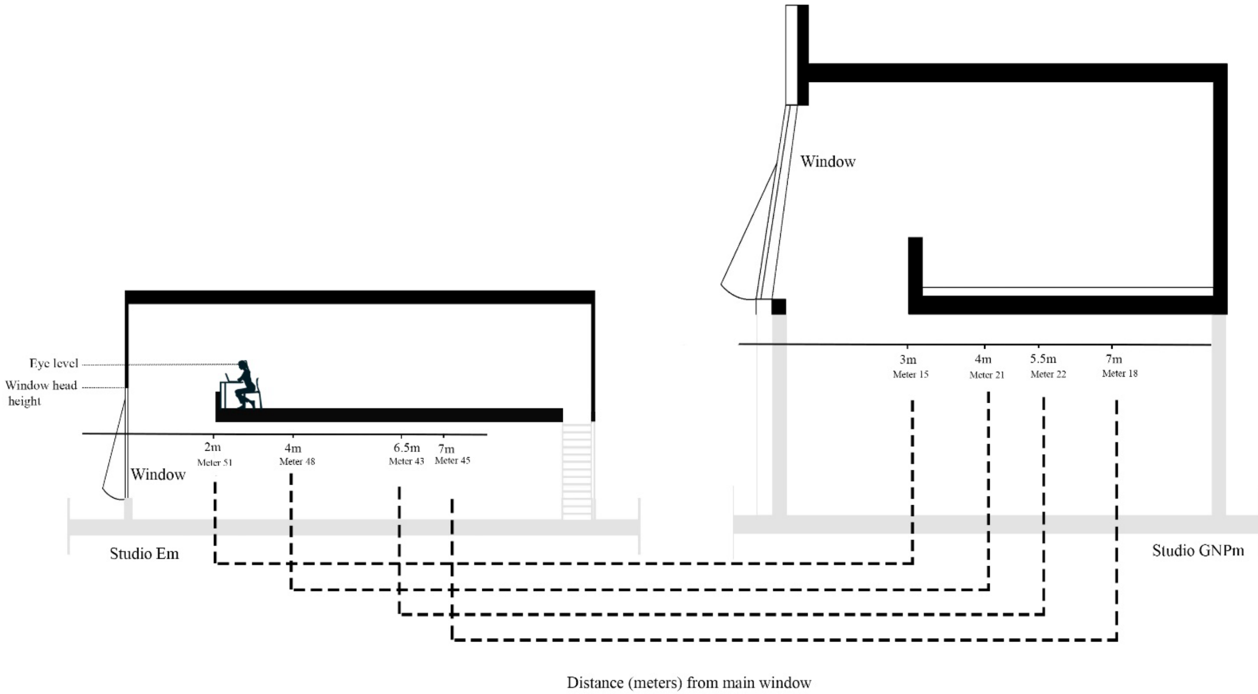


Figure 6-36 **Horizontal measuring points inside studios Em and GNPm.**

Distance from the window	Studio Em	Studio GNCm
2m-3m distance from window	meter 51	meter 15
4m distance from window	meter 48	meter 21
5.5-6.5m distance from window	meter 43	meter 22
7m distance from window	meter 45	meter 18

Table 6-22 The distance of horizontal measuring points from the window wall in Em and GNCm studios.

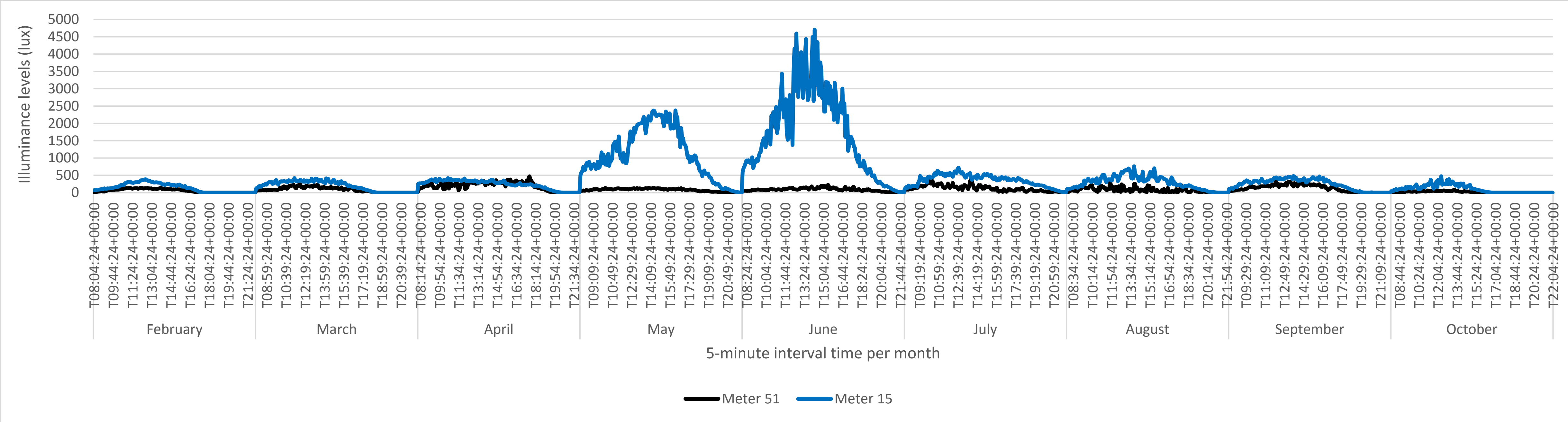


Figure 6-37 HMPs at 2-3m distance from the window, studio Em (meter 51) and studio GNCm (meter 15).

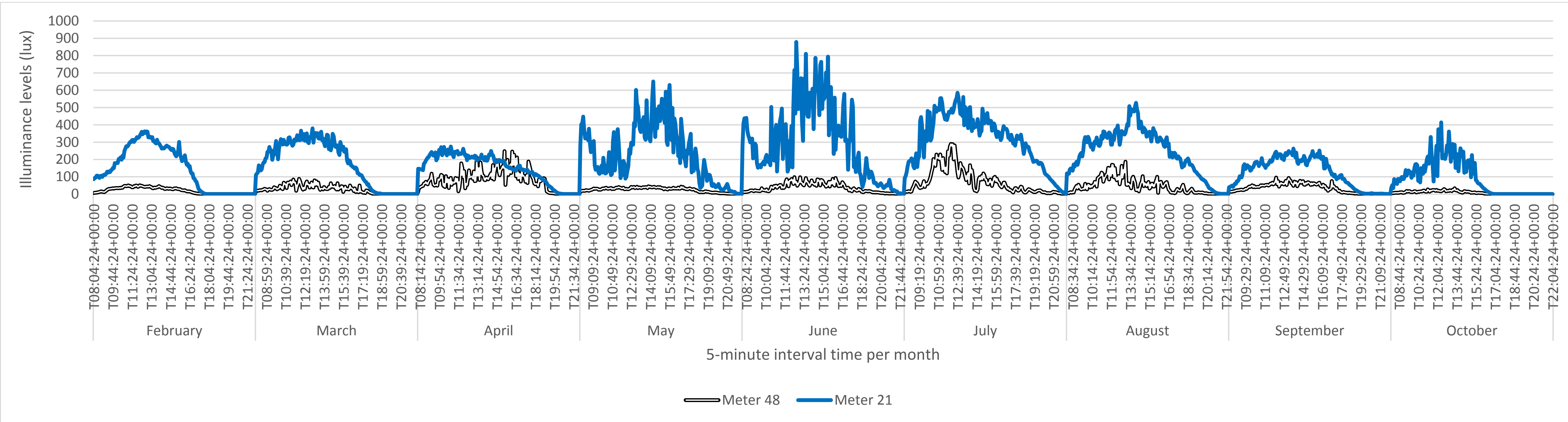


Figure 6-38 HMPs at 4m distance from the window, studio Em (meter 48) and studio GNCm (meter 21).

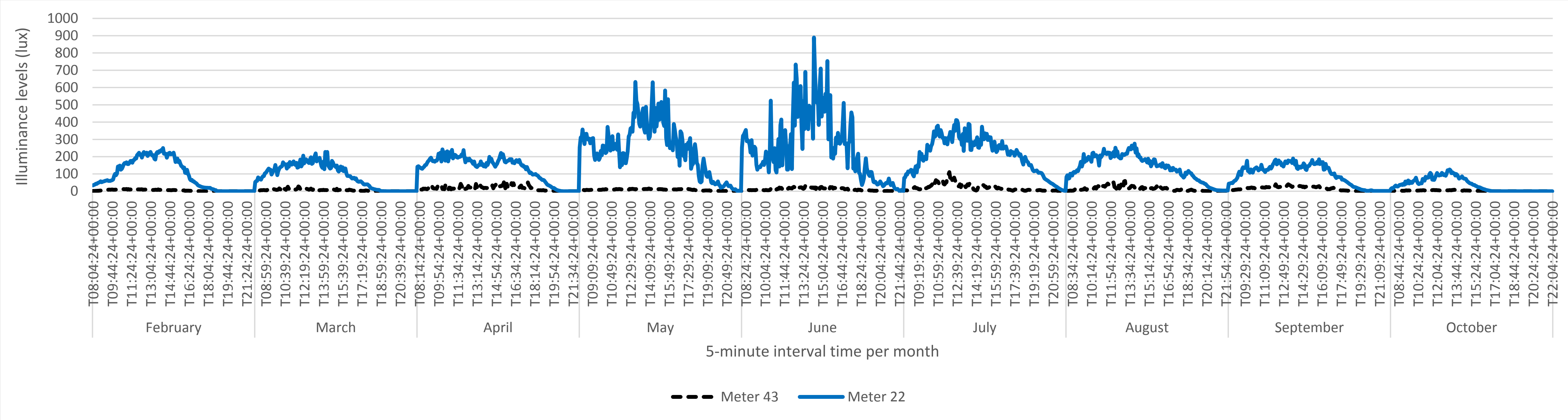


Figure 6-39 HMPs at 5.5-6.5m distance from the window, studio Em (meter 43) and studio GNCm (meter 22).

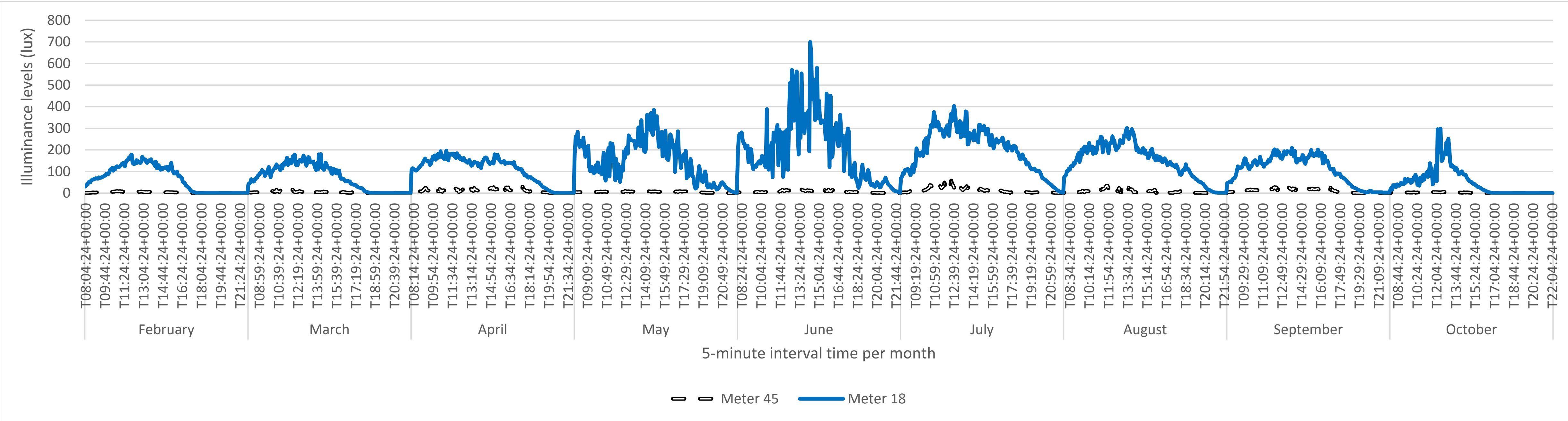


Figure 6-40 HMPs at 7m distance from the window, studio Em (meter 45) and studio GNCm (meter 18).

6.4.4 **Mezzanine studios with no external obstructions (zone 3)**

In contrast to previous mezzanine studios, studio GNPm and GNJm were both mezzanine studios with similar floor levels of +22.40 m, but with no external obstructions. The two studios had differences in the window-to-floor area ratio: 36% and 18% for GNPm and GNJm, respectively, the window-to-wall area ratio: 100% and 75%, respectively and the window area: 32 m^2 and 24 m^2, respectively. Although both studios had South-facing windows, these were closed by curtains most of the year, and the effect of sunlight was mostly blocked by external obstructions. Similar to the previous studios, a one-way ANOVA test revealed a statistically significant effect of W/F%, W/W%, and window area on the illuminance levels registered by VMPs only in April, May and October. Whereas, by HMPs, the difference was only significant in March, April and May, as presented in Appendix N 1. The effect of façade fenestration on the penetrated daylight levels inside studios was considered the distance of measuring points from the window wall, as demonstrated in Figure 6-41 and Table 6-23.

The Paired-Samples T-test results showed statistically significant differences ($p<0.05$) between the two studios. The registered illuminance levels varied throughout the measurement period. However, in general, studio GNJm registered higher illuminance levels than studio GNPm at a 5.5 m to 6 m distance from the window Figure 6-42, while there was no observed difference for studios at 9-10 m distance from the window Figure 6-43. Meanwhile, studio GNPm registered higher mean illuminance levels than studio GNJm at 10-11.5 m distance from the window, because of the height difference in this particular area between the two studios Figure 6-44. It can be concluded that, although studio GNPm has higher a window-to-floor area ratio, window-to-wall area ratio and window area than studio GNJm, the illuminance levels in studio GNPm were registered lower than studio GNJm. The interpretations for the paired-samples t-test results are presented in Appendix N 2.

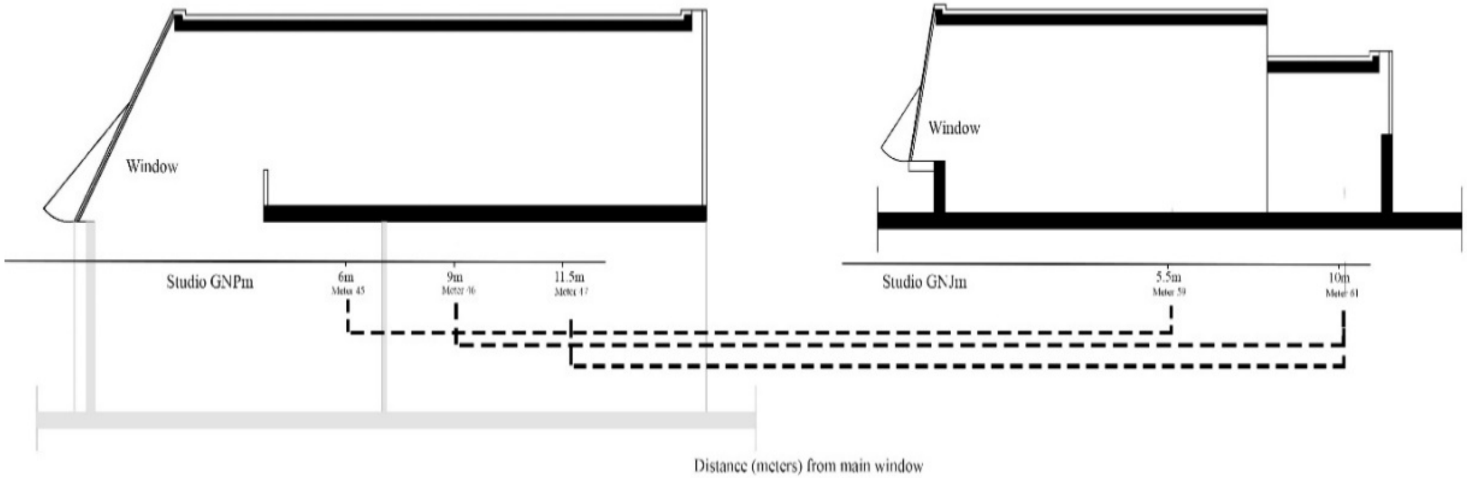


Figure 6-41 Horizontal measuring points inside studios GNPm and GNJm.

Distance from the window	Studio GNPm	Studio GNJm
5.5-6m distance from the window	meter 45	meter 59
9-10m distance from the window (height effect)	meter 46	meter 61
10-11.5m	meter 47	meter 61

Table 6-23 The distance of horizontal measuring points from the window wall in GNPm and GNJm studios.

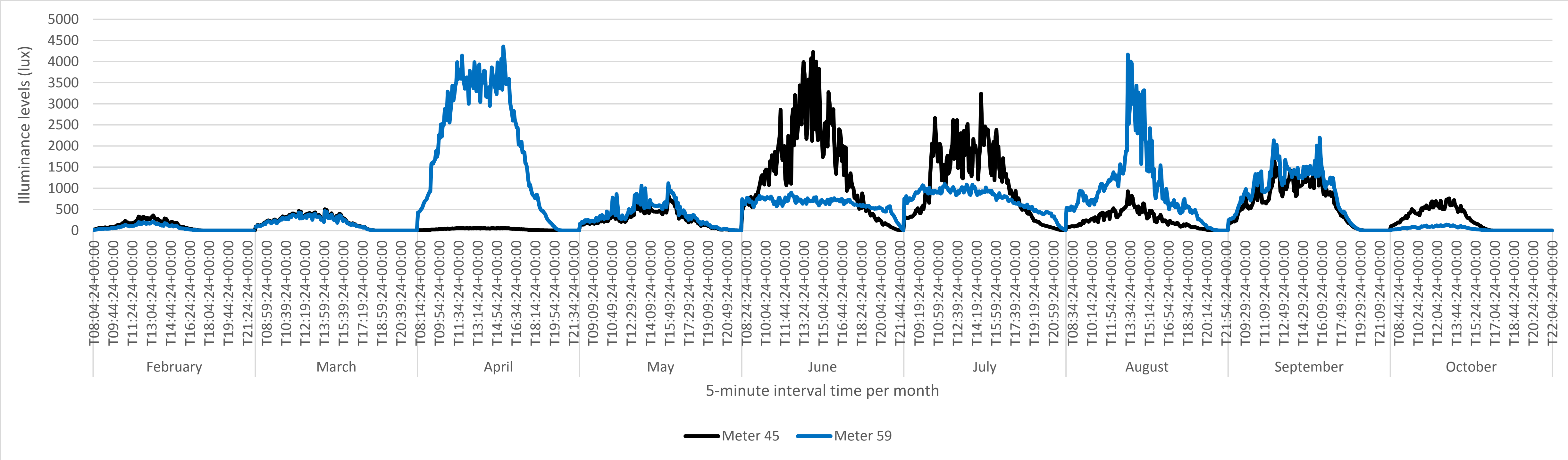


Figure 6-42 HMPs at 5.5-6m distance from the window, studio GNPm (meter 45) and studio GNJm (meter 59).

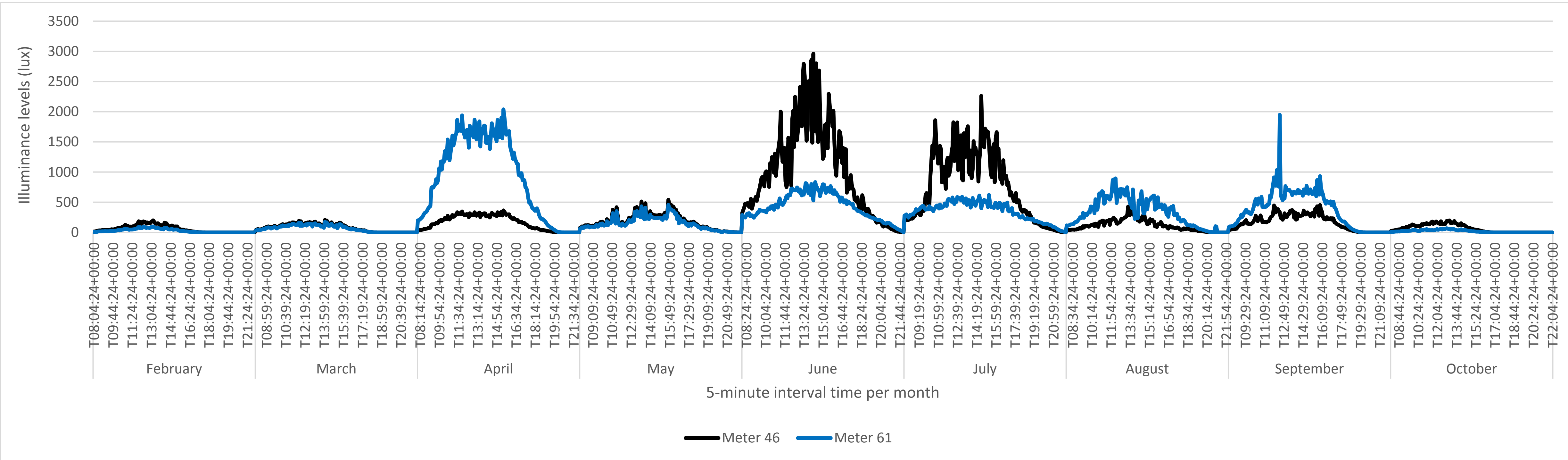


Figure 6-43 HMPs at 9-10m distance from the window, studio GNPm (meter 46) and studio GNJm (meter 61).

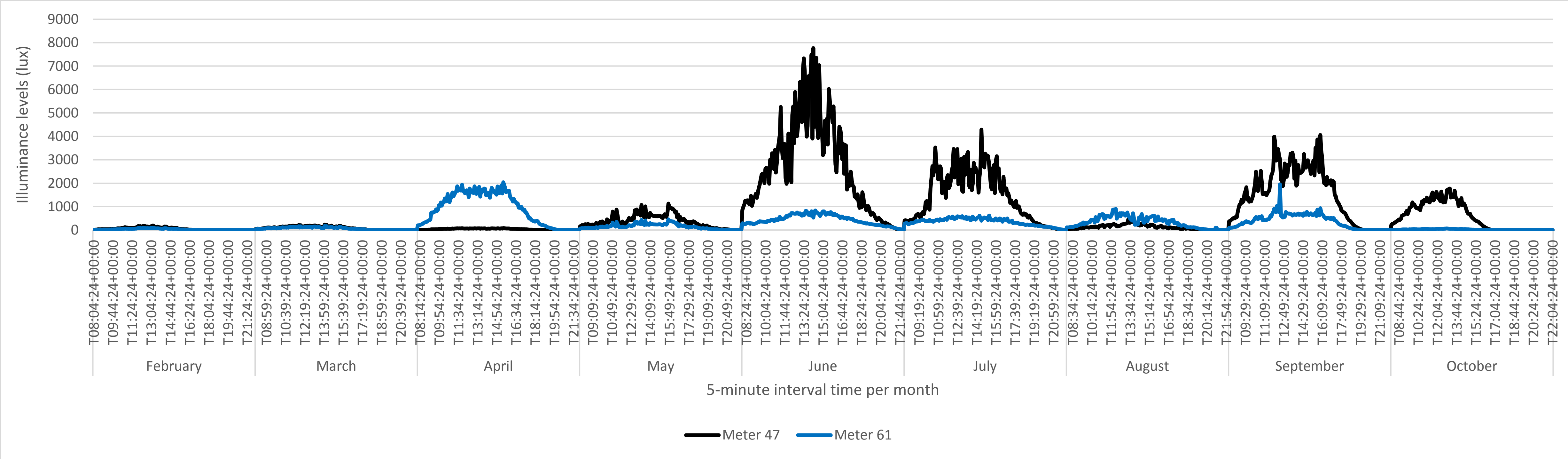


Figure 6-44 HMPs at 10-11.5m distance from the window, studio GNPm (meter 47) and studio GNJm (meter 61).

Part 2

6.5 Daylight levels assessment in relation to the guidelines

The daylight levels inside a space can be presented in an absolute value as the illumination level at a reference point, or as a percentage of the total illumination at a reference point to the illumination from the whole unobstructed sky, which is known as the daylight factor (see p.46). Accordingly, the performance of daylight inside buildings is often characterised and controlled by standard codes of practice and building regulations, such as lighting codes (Raynham, Boyce, Fitzpatrick, & Society of Light and Lighting., 2012), standards (British Standards Institution. et al., 2019) and guides ("Lighting for the built environment LG10: Daylighting — a guide for designers," 2014) & (Butcher & Society of Light and Lighting., 2011). These regulations were introduced to ensure the safety of people in terms of visual comfort and task performance purposes. A key example of this is the SLL code published by the Society of Light and Lighting in the UK (Raynham et al., p. 73, 2012) that presents fundamental information, suggestions and recommendations on lighting practice and performance for different types of buildings.

Yet, although the SLL code presents the recommended maintained illuminance $\bar{E}_m$ on the reference surface for the educational building (Table 6-24), and the British Standards recommended the daylight provision by daylight openings in vertical and inclined surfaces (Table 6-25), there are still no suggestions or recommendations that relate to creative spaces in educational buildings (such as an architecture and design studio). This issue has been discussed in the literature review, drawing attention to how the theory and typology of creative spaces are still under development. With this in mind, as the task illuminance requirements for both daylight and electric lighting are the same ("Lighting for the built environment LG10: Daylighting — a guide for designers," 2014), this study has relied on guidelines relating to the art rooms in art schools when evaluating the illuminance levels inside the investigated studios, in which the recommended illuminance levels are between 500-750 lux.

Type of area, task or activity	$\bar{E}m$ /lx	U_o
Classroom, tutorial rooms	300	0.60
Classroom for evening classes and adults education	500	0.60
Art rooms	500	0.60
Art rooms in art schools	750	0.70
Technical drawing rooms	750	0.70
Preparation rooms and workshops	500	0.60

Table 6-24 SLL code for light and lighting in an educational building.

$\bar{E}_m$: maintained illuminance

U_o: Illuminance uniformity on the reference surface

Level of recommendation for vertical and inclined daylight opening	Target illuminance ET/lx
Minimum	300
Medium	500
High	750

Table 6-25 Recommendations of daylight provision by daylight openings in vertical and inclined surfaces (British Standards Institution. et al., 2019).

6.5.1 **Daylight factor assessment in relation to the guidelines**

When considering the daylight factor, the Lighting Guide 5: lighting for education (Butcher & Society of Light and Lighting., p. 24, 2011) recommends that interior spaces should have a minimum average daylight factor of no less than 2% in order to achieve sufficient daylight within a room. In addition to this, if the average daylight factor in a space is at least 5%, then the provided uniformity is satisfactory and electric lighting will not normally be needed during the daytime. Meanwhile, if the average daylight factor inside is between 2% and 5%, then supplementary electric lighting will usually be needed. Furthermore, Energy and Environment in Architecture: A Technical Design Guide in U.K (Baker & Steemers, 2002, p. 44) has argued that increasing the glazing area to above 40% of wall area will increase both the minimum DF and the low uniformity ratio for non-domestic sector small buildings with 3m room height.

Other recommendations emerged from the Lighting for the Built Environment guide (*Lighting for the built environment LG10: Daylighting — a guide for designers*, p. 53, 2014), such as the building rating system being identified based on daylight credits, as demonstrated in Table 6-26:

Building Research Establishment Environmental Assessment Method (BREEAM)	80% of floor area should have an average daylight factor > 2%.
The British Standard (Bs) 8206 Part 2: 2008	Average daylight factor > 2% across the office floor area for the space to appear predominantly daylit.
	For spaces with an average daylight factor > 5% then electric lighting will not normally be needed during the daytime.
The Leadership in Energy and Environmental Design (LEED) 2012/3	Maximum points: achieve spatial daylight autonomy, where at least 75% of the floor area is illuminated by daylight alone. A space is defined as being daylit alone if daylight exceeds 300 lux for at least 50% of the annual business hours.

Table 6-26 Daylight compliance criteria based on the UK Chartered Institution of Building Services Engineers (CIBSE)

From this perspective, this study has examined the daylight factor in studios based on that 2% is the minimum level of average daylight factor, as has been suggested by most of the previous guidelines. The calculations of the daylight factor at reference points have used multiple measuring points across studios. The results are based on measurements taken in February, as the daylight factor assumption is based on an overcast sky, where there is no direct sunlight, as well as sky is in uniform luminous and change of orientation have no effect (Alshaibani, 2016, p. 742).

6.5.2 **Research Hypothesis**

The architect ER Robson argued in 1874 that 'A classroom is only well lighted when it has 30 square inches [19300 mm^2] of glass to every square foot [92900 mm^2] of floor plan', which is equivalent to a 20% window-to-floor area ratio within the classroom' (Wu & Ng, 2003, p. 112). Furthermore, he argued that the light from the North had been found to be the best light for classrooms as it is cooler and steadier than the light from the South, where the sunlight could cause a painful glare. As these arguments have been widely implemented in the UK, the expectation of the relationship between the window-to-floor area ratio and the illuminance levels was formulated in the following hypothesis 1:

'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.'

The assessment of the hypothesis has considered the zone categories of the investigated studios, whereby all studios have a window-to-floor area ratio (W/F%) of over 20%, except studios E1 and Em, which have window-to-floor area ratios of about 16.6% and 4%, respectively.

6.5.2.1 **Hypothesis testing**

Starting with studio E1 (W/F% = 16.6%), the value from HMP (M 59) registered the highest illumination levels among all the measuring points as it was placed on the windowsill step and registered 3750.84 lux in July (Figure 6-45). However, for the rest of HMPs, M 60 which was placed at 2m distance from the window, was the only measuring point that confirmed the hypothesis, which it registered 514.56 lux and 623.33 lux for April and July, respectively. Meanwhile, the rest of the horizontal and vertical measuring points registered mean illuminance levels of less than 200 lux throughout the measurement period, as presented in Figure 6-46.

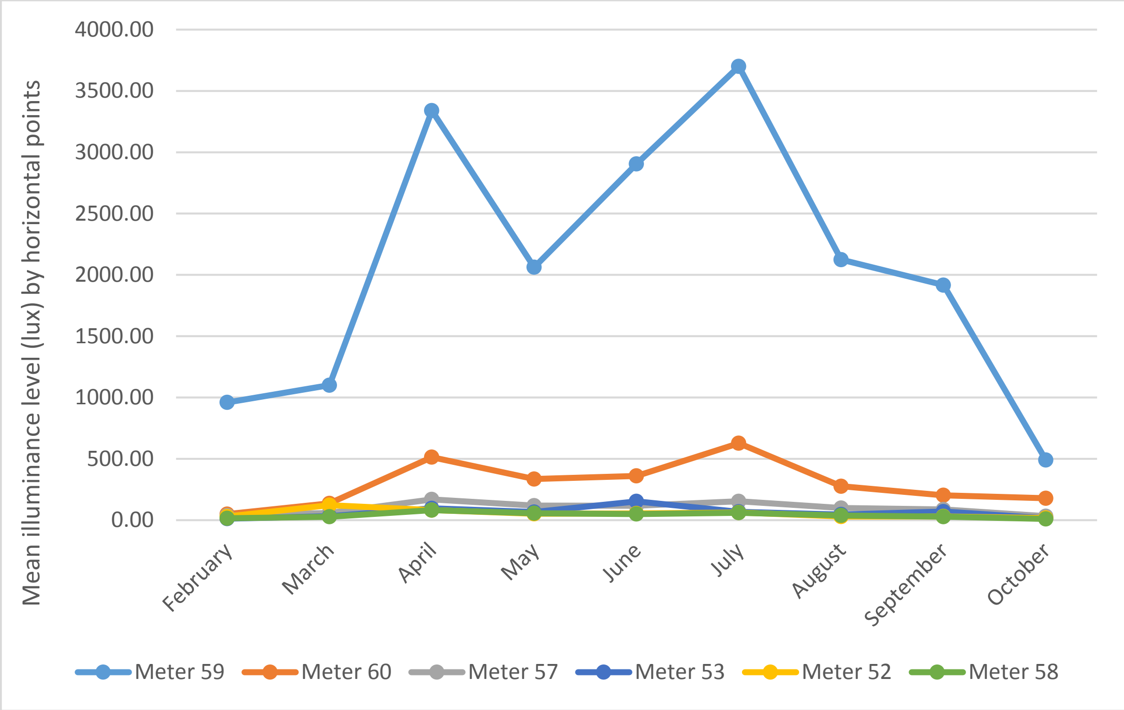


Figure 6-45 Difference between mean illuminance levels registered by meter 59 and the rest of the horizontal measuring points in studio E1, Edinburgh.

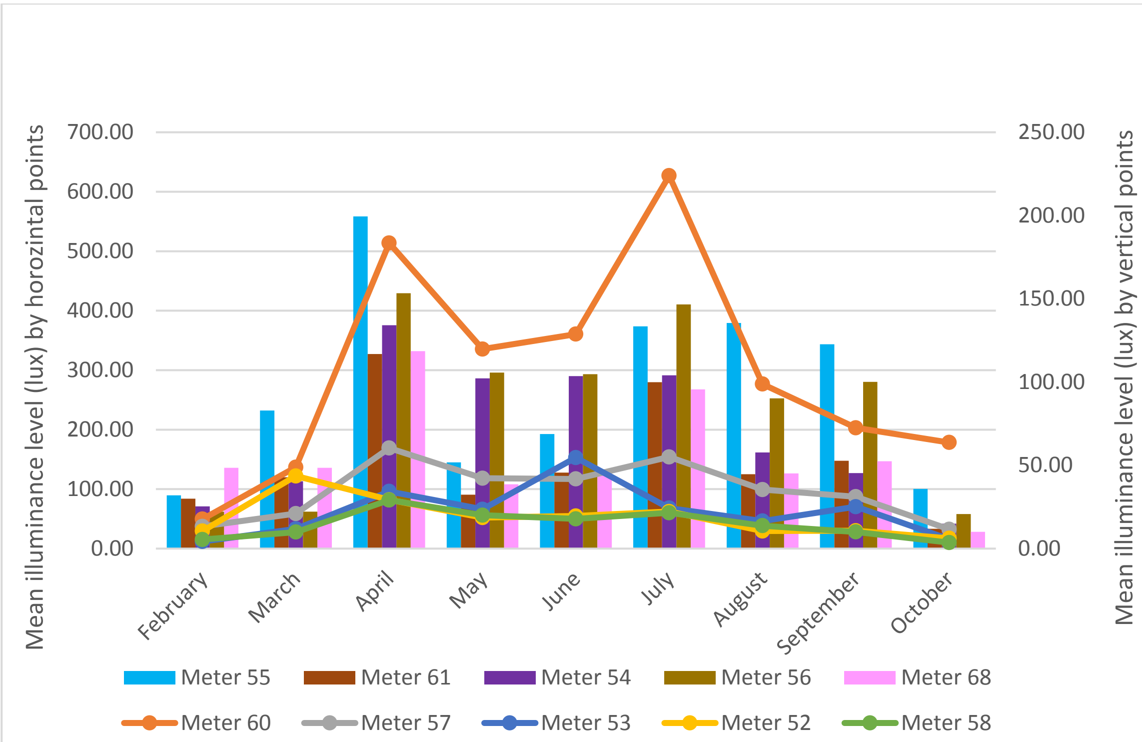


Figure 6-46 Mean illuminance levels registered by the vertical and horizontal measuring points in studio E1, Edinburgh. Vertical measuring point Horizontal measuring point

The daylight factor calculations revealed that the maximum daylight factor was registered at 16.72% by M 59 with zero distance from the window, as it was placed on the windowsill step. Meanwhile, the rest of the reference points (M 60, M 57, M 53, M 58) each registered DF% of about 0.86%, 0.51%, 0.21% and 0.27%, respectively. All the reference points from 2m to 8m distance from the window (students' desks locations) registered 0.46% for the average daylight factor (DF_{ave}). Consequently, the DF_{ave} for 82% of floor area is less than the 2% as it is the minimum DF_{ave} recommended in the previously mentioned lighting codes and guidelines, and supplementary electric lighting is therefore needed. The daylight factor at reference points on the working plane (DF) from windowsill step to 8m deep is presented in Figure 6-47.

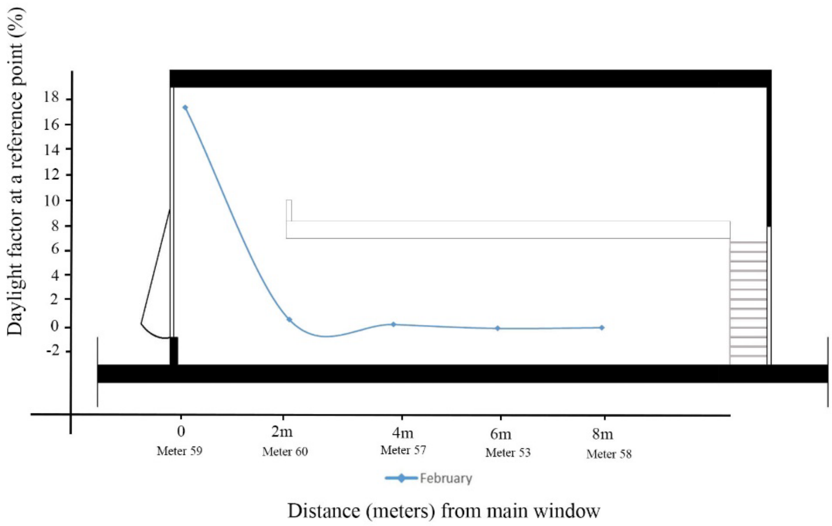


Figure 6-47 Daylight factor (DF) at reference points across studio E1, Edinburgh.

In terms of the mezzanine studio Em (W/F% = 4%), none of the horizontal measuring points confirmed the hypothesis as the maximum mean illuminance level was registered at 195.35 lux in April by M 51, which was the closest one to the window. The mean illumination levels registered by the vertical and horizontal measuring points in studio Em are presented in Figure 6-48. For the daylight factor, the maximum was registered at 1% in February by M 51 with a 2m distance from the window. The rest of reference points (M 48, M 43 and M 45) each registered 0.35%, 0.08% and 0.05%, respectively. Consequently, as all of the reference points covered 55.5% of floor area and registered DF_{ave} of less than 1%, supplementary electric lighting is required, as was the case with studio E1.

[Figure 6-49](#) presents the daylight factor at reference points on the working plane (DF) from 2m to 7m distance from the window in the mezzanine studio Em.

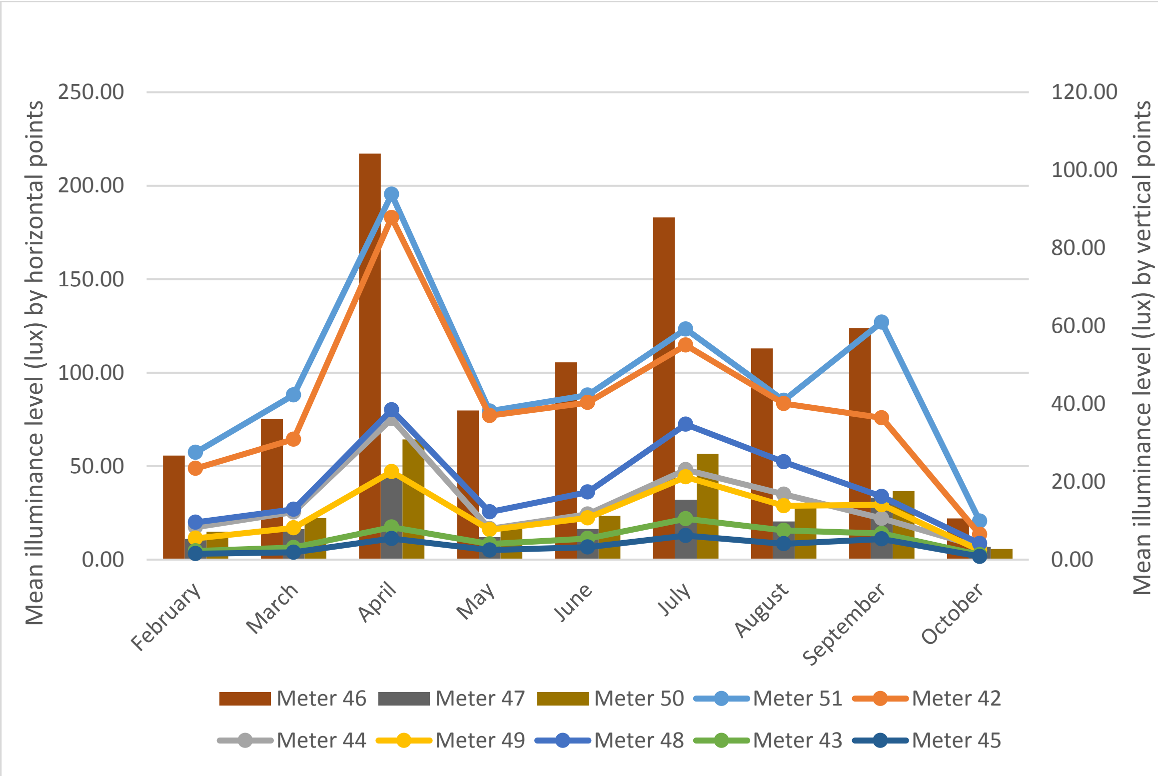


Figure 6-48 Mean illumination levels registered by the vertical and horizontal measuring points in studio Em, Edinburgh. ▬ Vertical measuring point. —•— Horizontal measuring point

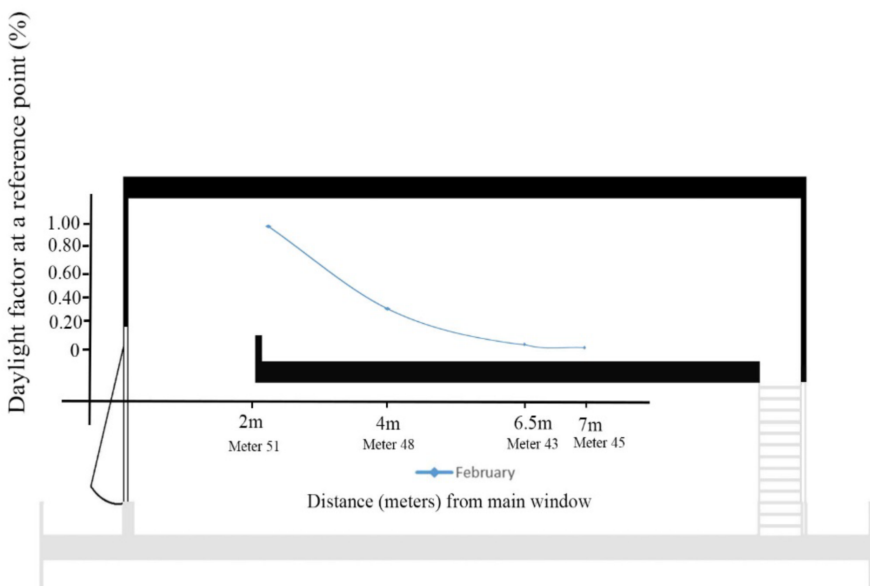


Figure 6-49 Daylight factor (DF) at reference points across studio Em, Edinburgh.

In terms of studio GNC (W/F% = 40%), all of the HMPs in area that is not covered by the mezzanine floor confirmed the hypothesis, except in February and October. The maximum mean illuminance level registered 3866.83 lux in June by M 69, followed by M 10 which was registered 2043.18 lux. In contrast, M 66 and M 9, which were located at the furthest distance from the window and under the mezzanine floor did not confirm the hypothesis, as they registered less than 200 lux throughout the measurement period. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNC are presented in Figure 6-50.

The maximum daylight factor in studio GNC was registered at 18.2% by M 10 at a 2m distance from the window wall. The rest of the reference points (M 8, M 11, M 5, M 6 and M 66) each registered 6.17%, 10.82%, 12.40%, 4.55% and 1.12%, respectively. As such, the furthest area located from the window and under the mezzanine level (M 66) is the only area that required supplementary artificial light. Figure 6-51 presents the daylight factor at reference points on the working plane (DF) from 0.4 m to 8.70 m distance from the window in the GNC studio.

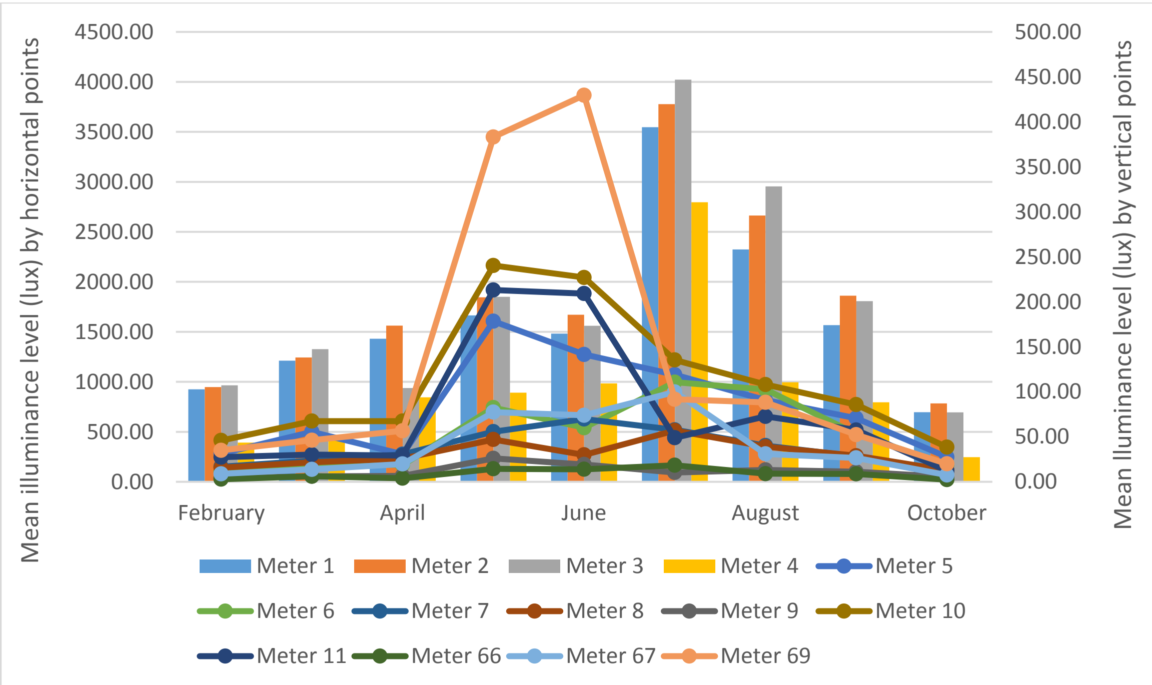


Figure 6-50 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNC, Glasgow. ▬ Vertical measuring point. —•— Horizontal measuring point.

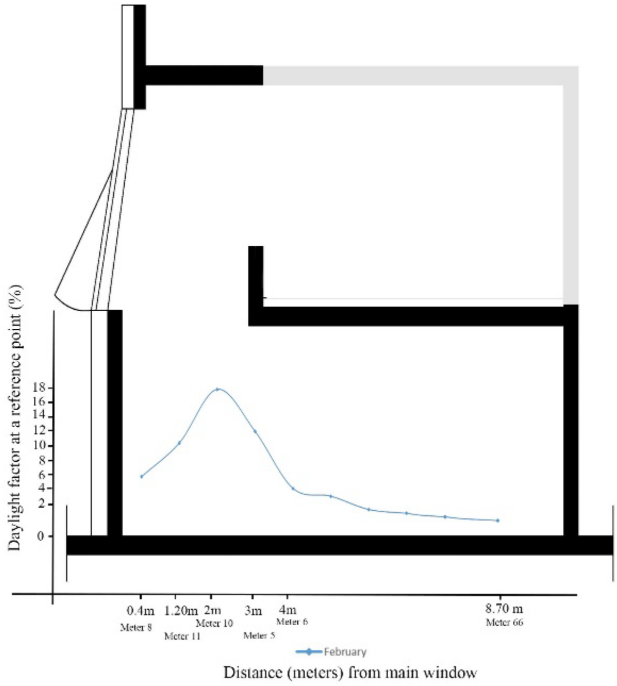


Figure 6-51 Daylight factor (DF) at reference points across studio GNC.

With regards to the mezzanine studio GNCm (W/F% = 57%), all HMPs confirmed the hypothesis, except for values in February, March, April, September and October. M15 registered the largest mean illuminance of 1722.05 lux in June, which contrasts the ground studio GNC, where the maximum mean illuminance level was registered at 3866.83 lux in June by M 69. Some of the HMPs, such as M 16 and M 17, only confirmed the hypothesis in June, July and August. Meanwhile, the rest of the measuring points, such as M 22, M 21, M 18 and M 19, did not confirm the hypothesis throughout the measurement period. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNCm are presented in Figure 6-52. The maximum daylight factor was registered at 6.43% by M 21. The remaining reference points (M 15, M 22, M 18 and M test 2) each registered 6.13%, 4.27%, 3.03% and 3.60%, respectively. Consequently, there was no need for artificial lighting as the DF_{ave} registered 4.69% for the all floor area. Figure 6-53 presents the daylight factor measured at reference points on the working plane (DF) from 3m to 9 m distance from the window in the GNCm mezzanine studio.

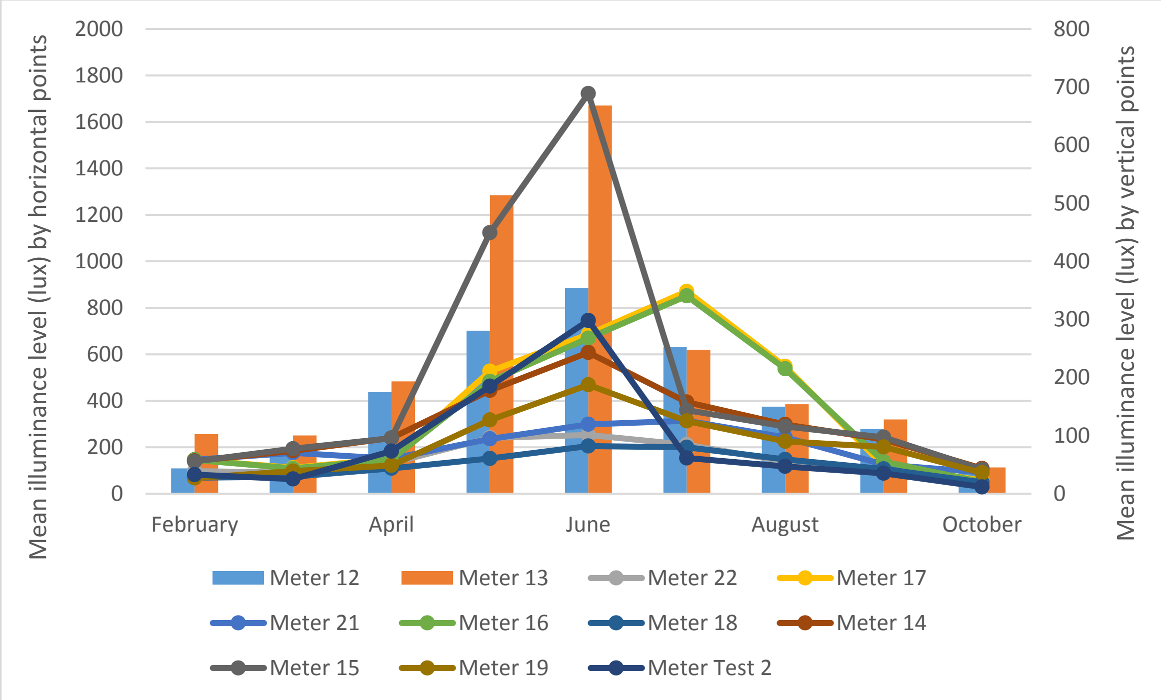


Figure 6-52 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNCm, Glasgow. ▬ Vertical measuring point. —●— Horizontal measuring point.

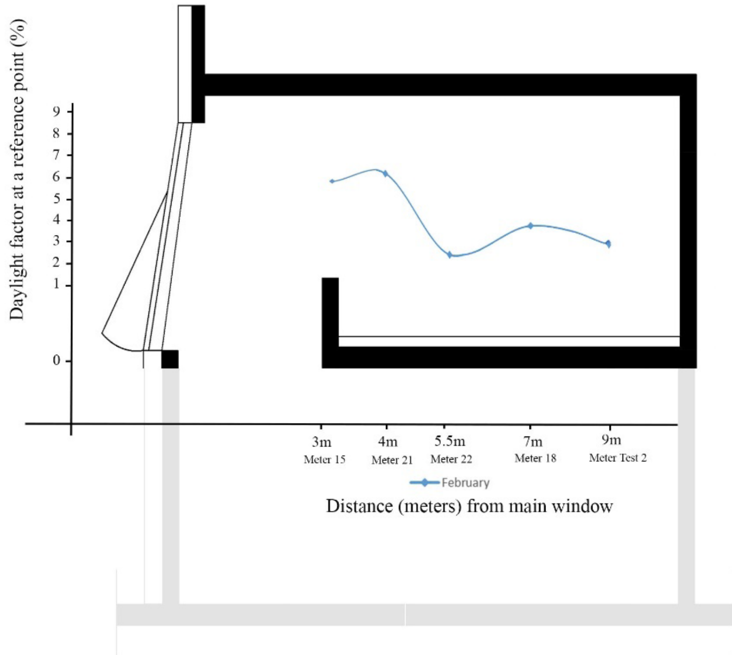


Figure 6-53 Daylight factor (DF) at reference points across studio GNcm.

For studio GNIn (W/F% = 32%), the HMPs confirmed the hypothesis throughout the measurement period, except for values in March, at which point the maximum mean illuminance level was registered at 4370.69 lux in July by M 27. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNIn are presented in Figure 6-54. The maximum DF was registered at 67.22% by M 27. The rest of the reference points registered 45.41% and 21.31% for M 28 and M 63, respectively. Based on the DF_{ave} result, which was registered 44.65%, there was no need for supplementary artificial light. Figure 6-55 presents the daylight factor at reference points on the working plane (DF) from 0.30 m to 10.50 m distance from the window in the GNIn studio.

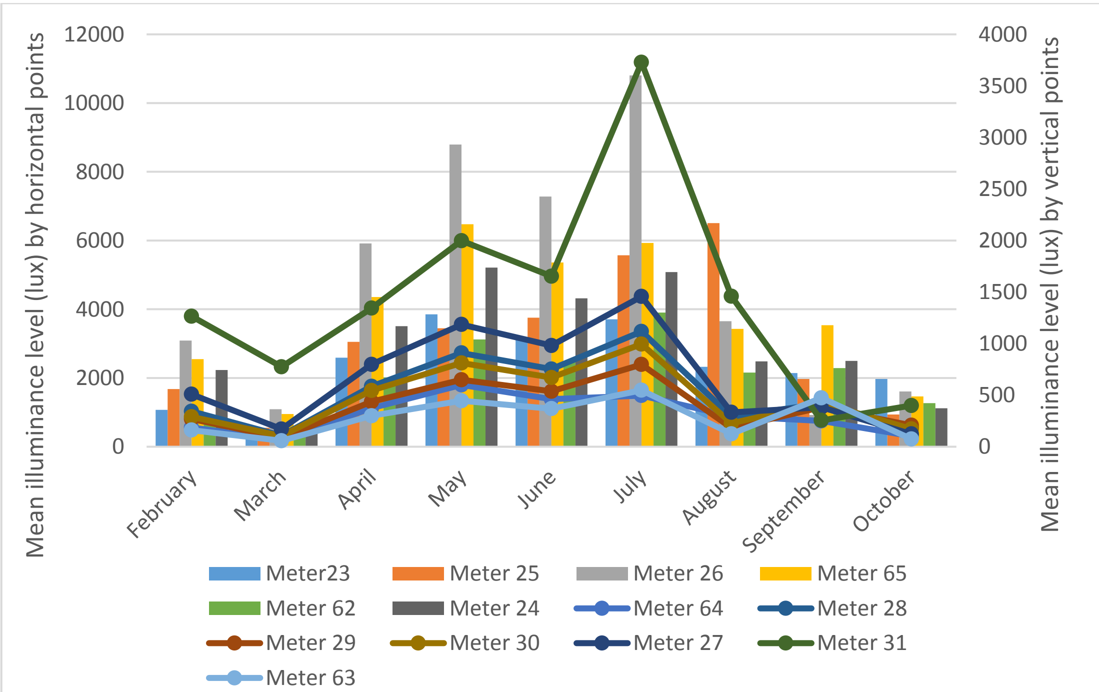


Figure 6-54 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNIn, Glasgow. ▬ Vertical measuring point. —●— Horizontal measuring point

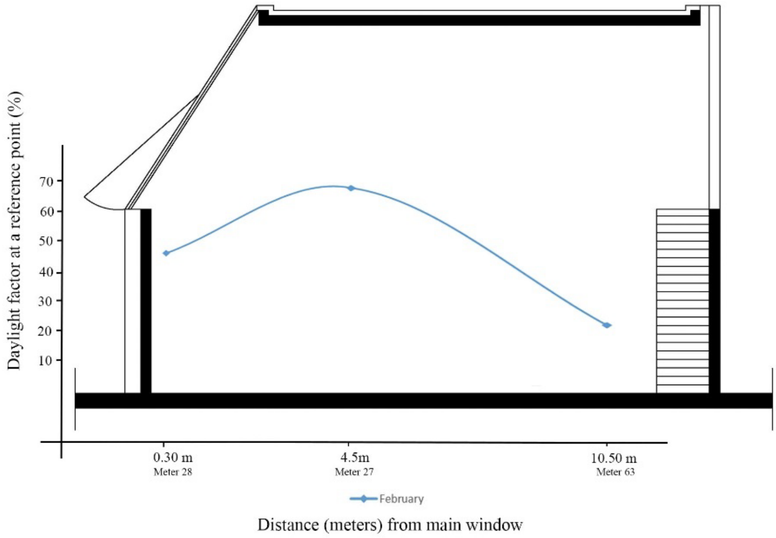


Figure 6-55 Daylight factor (DF) at reference points across studio GNIn.

In terms of studio GNPL (W/F% = 50%), the HMPs M 36, M 37 and M 40 confirmed the hypothesis throughout the measurement period, whereby the maximum mean illuminance level was registered 3480.96 lux in April by M 36. The rest of the HMPs that were located under the mezzanine (M 38 and M39) only confirmed the hypothesis in March, April, May, June and July. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNPL are presented in Figure 6-56. The maximum DF was registered at 27.11% by M 37. The rest of the reference points (M 36, M 38 and M 39) each registered 24.05%, 12.29% and 7.49%, respectively. As the DF_{ave} registered 17.73% for the full floor area of studio, there was no need for supplementary artificial light. Figure 6-57 presents the daylight factor at reference points on the working plane (DF) from 0.85 m to 7 m distance from the window in the GNPL studio.

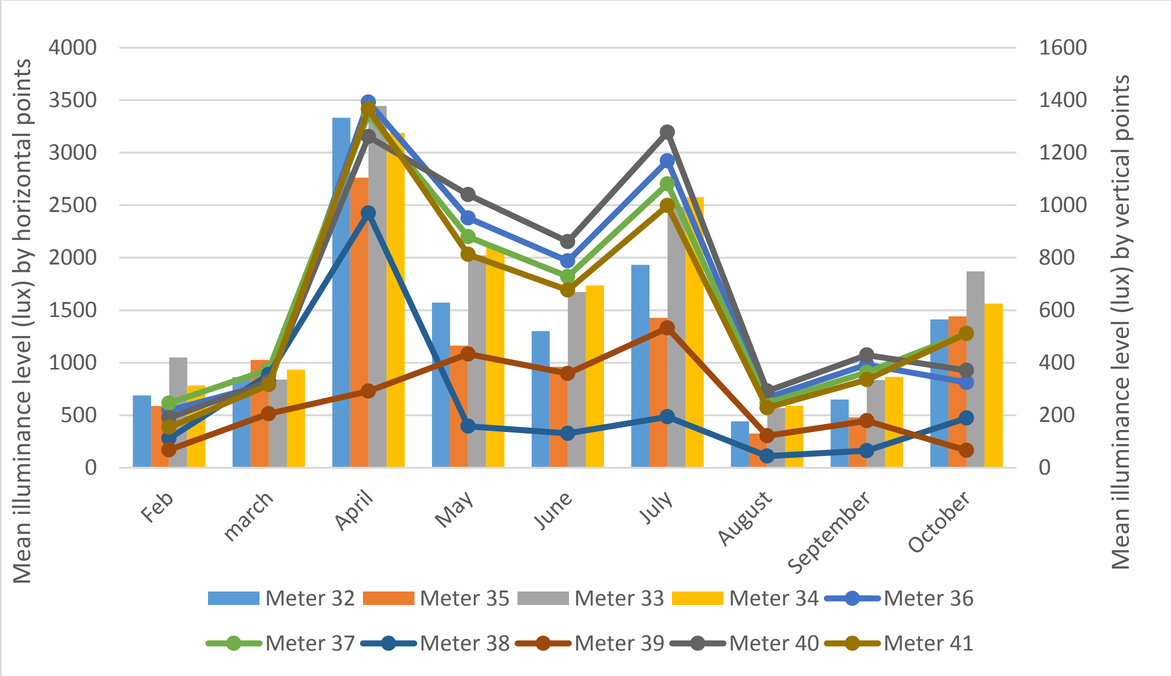


Figure 6-56 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNPL, Glasgow. ▬ Vertical measuring point.—•— Horizontal measuring point

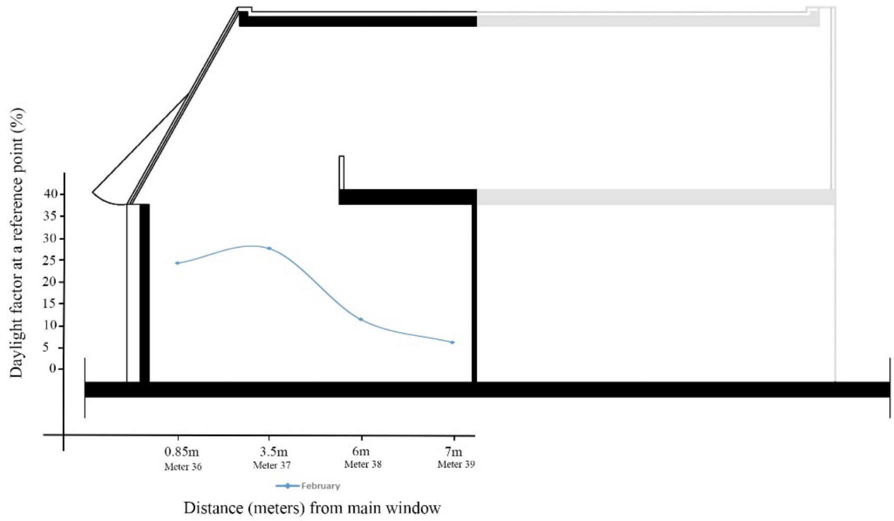


Figure 6-57 Daylight factor (DF) at reference points across studio GNPL.

With regards to studio GNPm (W/F% = 36%), values from the HMPs (M 45, M 46, M 47 and M 50, M 51) were the only ones that confirmed the hypothesis in June, July and September. Meanwhile, M 44 and M 48 confirmed the hypothesis throughout the measurement period as they were placed on the windowsill step. The maximum mean illumination level was registered at 4786.81 lux in June by M 51. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNPm are presented in Figure 6-58. The maximum DF was registered at 33.20% by M 44, as it was placed on the windowsill step. The rest of the reference points, M 45, M 46 and M 47, registered 4.47%, 2.50% and 2.31%, respectively. The DF_{ave} registered 10.62% and covered the full area of the studio; therefore, there was no need for supplementary artificial light. Figure 6-59 presents the daylight factor at reference points on the working plane (DF) from the window to 11.5 m distance from the window in the GNPm studio.

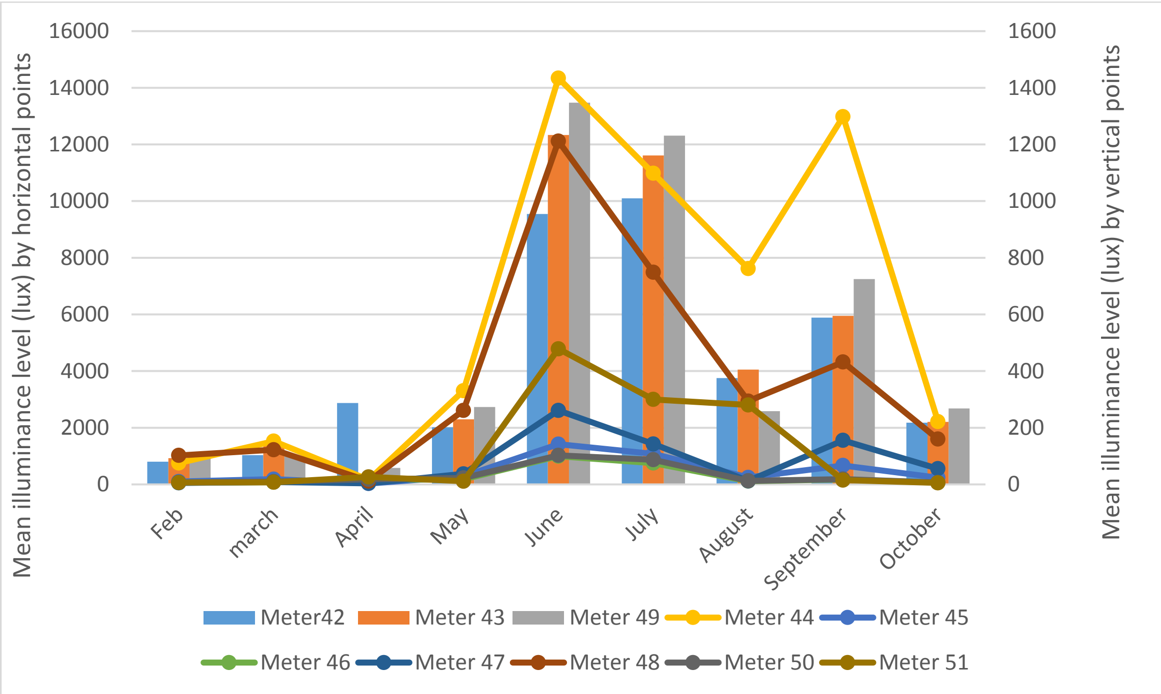


Figure 6-58 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNPm, Glasgow. Vertical measuring point. Horizontal measuring point

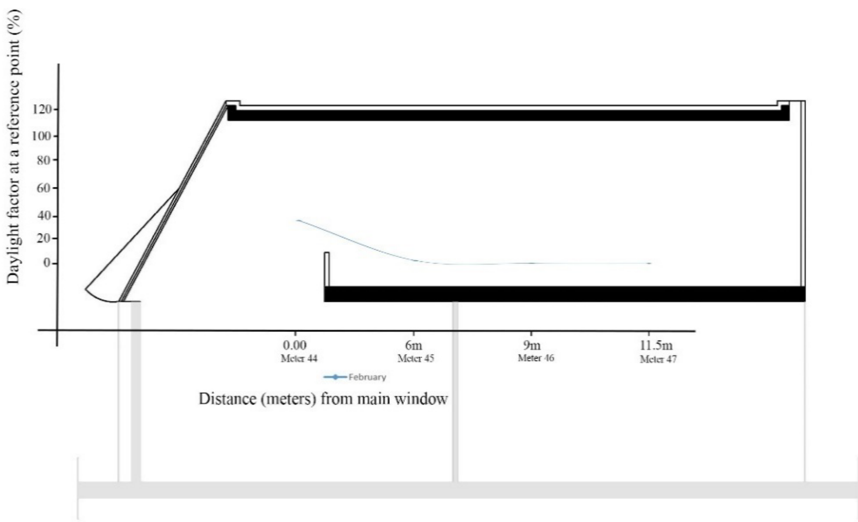


Figure 6-59 Daylight factor (DF) at reference points across studio GNPm.

Within studio GNJm (W/F% = 27%), the values from HMPs (M 57, M 58, M 59, and M 60) confirmed the hypothesis throughout the measurement period, except in February and October. The HMPs that were placed at the windowsill step (M 52 and M 54) confirmed the hypothesis too, except in October. The maximum mean illuminance level was registered at 5572.75 lux in April by M 57. In terms of M 61, which was placed at the furthest point from the window and under the lower roof level than the rest of the HMPs, it supported the hypothesis only in April with 925.27 lux. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GNJm are presented in Figure 6-60. The maximum DF was registered at 37.86% by M 52, when it was placed at the windowsill step. The rest of the reference points, M 59, M 60 and M 61, registered 13.16%, 2.73% and 1.25%, respectively. The DF_{ave} registered 13.75% and covered the full area of the studio; therefore, there was no need for supplementary artificial light, except for in the area belonging to reference point M 61. Figure 6-61 presents the daylight factor at reference points on the working plane (DF) from the window to 10 m distance from the window in the GNJm studio.

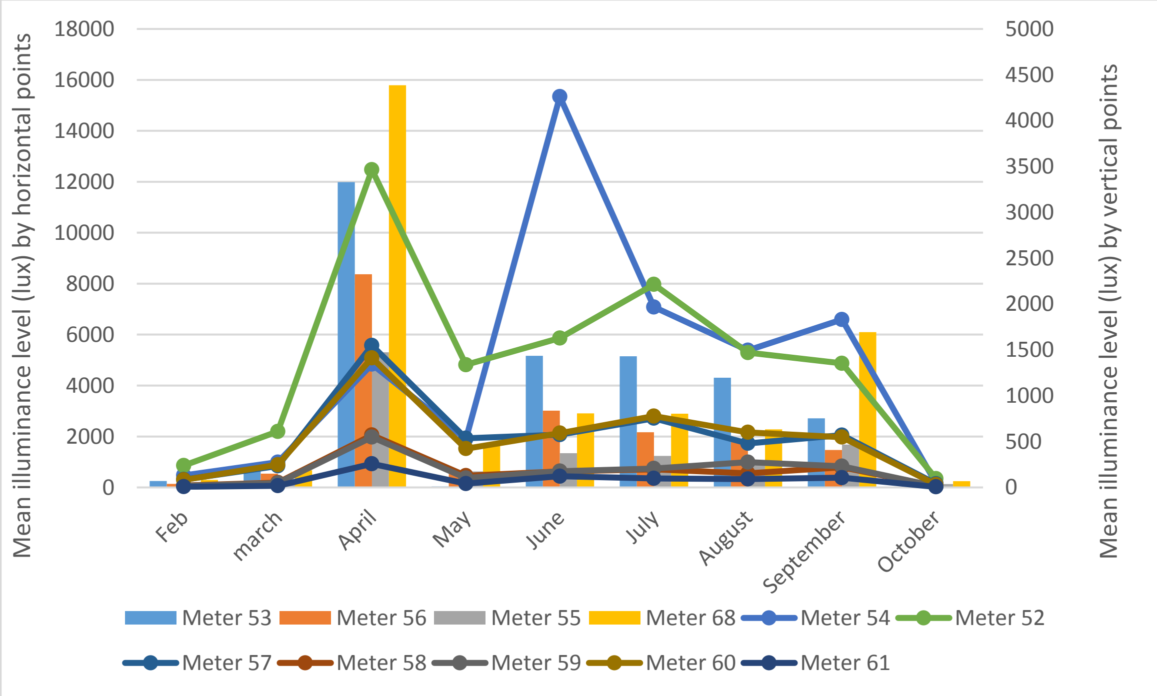


Figure 6-60 Mean illumination levels registered by the vertical and horizontal measuring points in studio GNPm, Glasgow. ▬ Vertical measuring point. —•— Horizontal measuring point

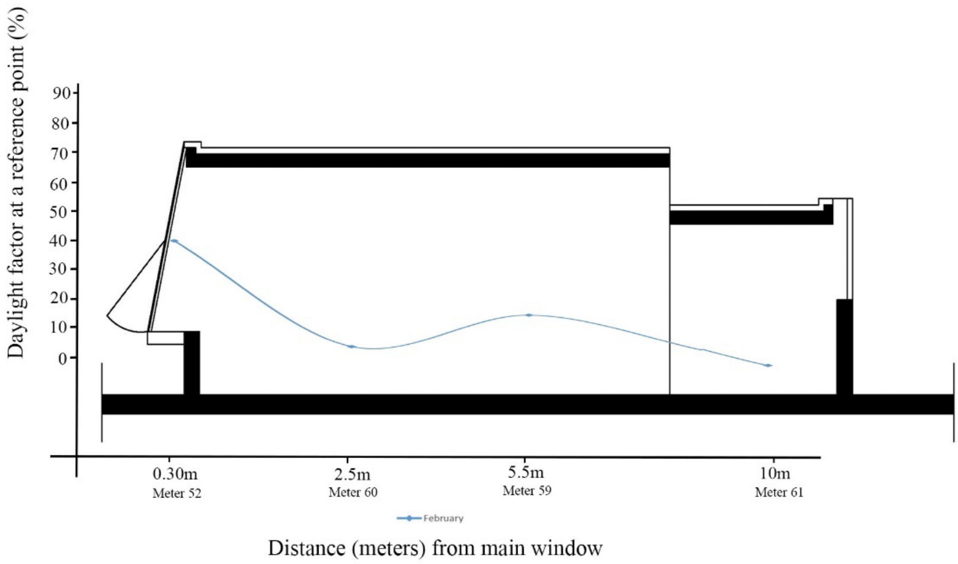


Figure 6-61 Daylight factor (DF) at reference points across studio GNJm.

6.6 **Summary**

This chapter demonstrates the field measurements that were conducted in eight studios in Glasgow and Edinburgh from February until November 2019. The investigated studios shared similar characteristics in terms of the design typology (double-volume open plan floor with mezzanine floor above), and house similar student tasks, furniture design and colour, orientation and, most importantly, are under an overcast sky. A group of light meters was placed in each studio, covering the area from the window wall to the furthest point of the studio horizontally at the students' desks and in the middle of every wall vertically. In addition to this, two light meters were placed on the building's roof in each city to measure daylight levels under an unobstructed sky. All the light meters in the two cities registered the illuminance levels at the same time. The vertical measuring points were placed at two levels: at the students' seated eye level and above eye level. The findings from the ANOVA test revealed that the window-to-wall area ratio and window-to-floor area ratio each have a statistically significant effect on the illuminance variation registered by the vertical measuring points at the students' seated eye level vs above eye level, while there is no statistically significant effect stemming from the position of the window in the centre of the wall on the illuminance variations between the two levels.

The physical characteristics of the studios were also analysed. The researcher noticed that the distribution of penetrated daylight inside the studios varies strongly from one zone to another. Therefore, the study divided each studio into three different zones for further analysis: zone one related to the area in the double-volume open studio that is not covered by the mezzanine above, zone two related to the area in the double-volume open studio that is covered by the mezzanine above, and zone three related to the mezzanine studio. The findings revealed that the vertical and horizontal measuring points in zone 3, which represents the studios at mezzanine level, have the highest illumination levels, followed by zone 1 (double-volume open plan floor) and then zone 2 (area in the double-volume studio that is covered by the mezzanine above). Furthermore, the ANOVA test results revealed that both the vertical and horizontal measuring points revealed significantly different illumination levels between the studios in zone 1 and zone 3. This finding could be related to the distance of the measuring points from the window, the studio floor level and any external obstructions. In terms of zone 2, while there is no significant difference in illumination levels based on the horizontal measuring points, the vertical ones show significant results in the following months: April, June, July and August.

For hypothesis testing, the findings revealed that studios with a window-to-floor area ratio of over 20% supported the hypothesis. However, this applied only in zones that are not covered by the mezzanine floor above and not for the entire measurement period, like in October and February. With regards to the daylight factor, studios with less than 20% of window-to-floor area ratio registered a DF_{avg} less than 2% in February, which meant that supplementary artificial light was needed. Whereas studios with a window-to-floor area ratio of over 20% registered a DF_{avg} over 5% in February. However, this does not apply in zone 2, which is covered by the mezzanine floor, and registered a DF_{avg} of less than 2% in February.

6.7 Discussion

The current chapter investigates the effect of façade fenestration on daylight levels under overcast sky conditions. The daylight levels were registered by vertical and horizontal measuring points within eight North-facing studios in Glasgow and Edinburgh. With the investigated studios being double-volume open plan floors with a mezzanine floor above, it was decided to divide each studio into zones and each zone was measured for daylight levels.

The findings revealed that the vertical and horizontal measuring points in zone 3, which represents the mezzanine level studios, have the highest illumination levels, followed by zone 1 (double-volume open plan floor) and then zone 2 (area in the double-volume floor under the mezzanine floor above). This finding due to the fact that the quantity and distribution of the daylight that measured in the studios were highly linked with the position of the window within the studio's typology: whether it was placed at the double-volume floor level or on the mezzanine level. For this study, the windows were located at the mezzanine levels (zone 3), except for the mezzanine studio Em where the windows were located in the double-volume studio level E1. Much of the related literature has emphasised the effect of the position of the window on the daylight (see Vartiainen et al., 2000). Accordingly, the various zones could be designed with different lighting so as to align with the different tasks' requirements. An argument that was demonstrated within Vartiainen et al.'s (2000) study suggested that areas near the window could be designed for tasks that required accurate vision, while areas in the back of the room could be designed for tasks with less lighting requirements. Similarly, as the current study found the area under the mezzanine floor (zone 2) to have less than 200 lux like in studios E1 and GNC, tasks requiring less daylight (such as computer labs or presentation display area) could be held here. In this case, darkness is the motive and mobilizing force in daylighting design.

Furthermore, other factors, such as window area, window-to-wall area ratio, window-to-floor area ratio, windowsill height, floor level from the ground and external obstructions significantly impacted the daylight levels too. This was noted in a comparison of studio E1 (double-volume studio with vertical window, W/W%= 53.3%, window area = 48m^2, sill height = 1m) with studio GNCm (mezzanine studio with inclined window (sloped), W/W%= 100%, window area = 60m^2, sill height = 0), where both of the studios have similar obstruction factor (OF = 0.40, view ≥ 90% obstructed). The results revealed that at a 2m distance from the window, the HMPs in studio GNCm registered higher illuminance levels than the HMPs in studio E1 throughout the measurement period.

From another perspective, although studio E1 supports the guidelines in terms of windowsill height and window head height (Raynham et al., p. 118, 2012), it registered lower mean illuminance levels throughout the measurement period in comparison with the rest of double-volume studios and in particular with studio GNC, which has a similar obstruction factor (OF = 0.4) and floor level from the ground. This is as a result of the window sloped glazing, where studio GNC (Inclined window (sloped), W/W%= 50%, window area = 60m^2, sill height = 4m) has close values of window area and window-to-wall area ratio to studio E1 (vertical window, W/W%= 53.3%, window area = 48m^2, sill height = 1m), yet it registered higher mean illuminance levels than studio E1 at 2m distance from the window. Although studio GNC has a higher windowsill height than studio E1, the inclined window had a significant effect on the penetrated daylight. On the other hand, studio GNC (inclined window with 4m sill height) in comparison with studio GNCm (inclined window with no sill height) at 2m distance, registered lower mean illuminance levels than studio GNCm. In that context, the study could make the following predictions if the two studios have a similar orientation (North), floor level from the ground, W/W%, external obstructions factor, window area, weather conditions and excluding zone 2 (area covered by mezzanine floor above):

1- For inclined windows, the less windowsill height, the more daylight levels will register at the area close to the window. Whereas the more windowsill height, the more daylight levels will register in the middle and back of the studio.

2- For inclined vs vertical windows, the inclined window will register more daylight levels for the full studio than the vertical window, even though the windowsill height is high. However, the consideration of providing a view to the interior spaces for aesthetic and psychological needs, makes the windowsill height crucial. The SLL code for light and lighting recommended that the window heads should be positioned above the standing eye height, while the sills should normally be below the eye level of the people seated. Special consideration must be given to the window heights in some buildings, such as schools and nurseries, in case the window can be opened (Raynham et al., p. 118, 2012).

Consequently, the inclined window is considered a significant option for optimising the daylight performance in overcast locations. This result is in line with Mackintosh's window design within the Glasgow School of Art, as demonstrated in the literature review, where the levels of illumination were argued to far exceed the lighting guidance. This is because the daylight factor (DF) registered 12% on the horizontal working plan at the front of the North-facing studio on the first floor, while the daylight factor never fell below 4% in the back of the studio because of the inclined window above (Lawrence, 2014, p. 106). Moreover, a study by Hanna (2002) confirmed that in summer, daylight in the North-facing was excessive near the window (12500 Lux) but remained adequate at the back of the studio (1000 Lux), while in winter daylight was only adequate near the window. Results related to the vertical measuring points showed a significant difference in the registered illuminance levels between VMPs at eye level and from above, because of the window-to-wall area ratio and window-to-floor area ratio. In addition, it was found that the direction of the VMPs has a more significant effect on the registered illuminance levels than the distance from the window. The variation due to position and orientation of measuring point was found as well in (Peeters et al. 2020) study.

With regards to the assessment of the daylight levels and daylight factor according to the guidelines, the different zones in studios varied in the registered illumination levels throughout the measurement period. Therefore, the codes, standards and guidelines for daylight in buildings are in need of revision and further development, as suggested by Mardaljevic & Christoffersen (2017) and Nabil & Mardaljevic (2006).

Furthermore, the average daylight factor method (DF_{avg}), which can be used in the early stages of design, is based on the overcast sky condition where the effect of sunlight is not included and the change of orientation has no effect (Li, Lam, & Wu, 2014). However, the study findings revealed that a higher daylight factor does not guarantee a better daylit space. To illustrate this, by comparing DF_{avg} with daylight levels, studios GNC, GNPm and GNJm registered mean illuminance levels of less than 500 lux for all HMPs in February, while the DF_{avg} was registered at over 5%. Similarly, studio GNCm registered mean illuminance levels of less than 200 lux for all HMPs in February, while the DF_{avg} registered 5%. On the other hand, studio GNIn registered mean illuminance levels of higher than 500 lux for all HMPs in February and DF_{avg} was registered at over 5%. Studios E1 and Em registered mean illuminance levels of less than 200 lux for all HMPs in February and DF_{avg} was registered at less than 2%. From a different angle and based on the researcher observations, artificial lights were turned on in all studios during the month of February. Consequently, the study argues that the daylight factor is not an accurate metric to assess the daylight inside spaces under overcast sky conditions. Yet, it is a proportional metric to the light coming from an available patch of sky to the inside spaces, which could be useful in early stages of design.

Chapter 7

Analysis of daylight levels for studios orientated to the South: Glasgow & Aberdeen case studies

7.1 **Introduction**

This chapter presents the findings from daylight measurements inside the studios, which are orientated to the south in two cities: Glasgow and Aberdeen. The investigated studios are of two typologies: double-volume open-plan studios and ordinary open-plan studios. Similar to the studios orientated to the North, all the studios host comparable student tasks, furniture design and colour, orientation and, most importantly, they both are under overcast skies. The findings in this chapter were used to test the first study's hypotheses: ***'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.'***

The chapter is divided into two main parts: the first one shows the spatial context of the studios and the results of the objective measurements (illuminance levels) that were registered by the vertical and horizontal measuring points. Following with the analysis of studios with vertical windows and a skylight and studios with vertical windows only. Meanwhile, the second part presents an assessment of daylight levels in relation to the guidelines and concludes by testing the above hypothesis. The structure diagram of daylight levels analysis is presented in Figure 6-1.

The main findings suggest that the positioning of the window in the centre of the wall, window-to-wall area ratio and window-to-floor area ratio each have a statistically significant effect on the illuminance variation registered by the vertical measuring points at the students' seated eye level vs from above. For the comparison of the studios, it can be concluded that studios with vertical windows and a skylight will register higher daylight levels than the studios with vertical windows only, even if they have a higher window-to-wall area ratio. Moreover, studios with vertical windows (sill height = 0) and a skylight were found to support the hypothesis throughout most of the measurement period, except in February, March and October. Meanwhile, the studios with vertical windows (sill height = 2m) and a skylight supported the hypothesis throughout the whole measurement period.

7.2 Spatial contextualisation of the selected studios

The current investigation was conducted in five studios: three studios in Glasgow (GSInu, GSpo, GSP), which have vertical windows and skylights, and two studios in Aberdeen (A1, A2) which only have vertical windows. The investigated studios are of two typologies: ordinary open-plan studios and double-volume open-plan studios, which all were South-facing. However, the skylight was North-orientated. All studios shared similar finishing's, such as white painted walls and ceilings, grey concrete floors, white desk tables and similar glazing materials. In terms of form and function, all studios were more or less of a similar plan shape (rectangular) with desk tables arranged perpendicular to the window wall.

In addition to this, all the investigated studios had external obstructions; buildings and trees and the main activities primarily involved design, drawing, painting, reading, model-making and digital work. All studios have different heights and their windowsills are at different heights from the floor. These differences were observed and noted so that they are taken into consideration during the analysis. The studios' survey information is reported in Table 7-1, and windows' characteristics in Table 7-2. Photographs in context are presented in section 7.2.1. In Glasgow case study, Figure 7-1 presents studios GSInu, GSpo and GSp. In Aberdeen case study, Figure 7-2 presents studios A1 and A2.

The use of artificial lightings and shading devices in each of the studio are included in section 7.2.2. All studios in Glasgow case study have Fluorescent Batten artificial lighting type in manual switching/on-off control system, while studios in Aberdeen case study have Academy LED range artificial lighting type in automatic and manual switching/on-off control system. The information about artificial lighting (light fixture type, quantity, colour, construction, control type), and shading devices in Glasgow and Aberdeen studios are reported in Table 7-3. Shading devices in one of the Glasgow studios (Gspo) are presented in Figure 7-3. External and internal shading devices in Aberdeen studios are presented in Figure 7-4. Wide panoramic fisheye photos fisheye photos for Glasgow and Aberdeen are presented in Figure 7-5, Figure 7-6, Figure 7-7, Figure 7-8, and Figure 7-9.

<table>
<tr><th rowspan="2">Characteristics</th><th colspan="6">Glasgow</th><th colspan="2">Aberdeen</th></tr>
<tr><th colspan="2">GSInu</th><th colspan="2">GSpo</th><th colspan="2">GSp</th><th>A1</th><th>A2</th></tr>
<tr><td>Design type</td><td colspan="2">Double-volume open plan</td><td colspan="2">Double-volume open plan</td><td colspan="2">Double-volume open plan</td><td>Ordinary open-plan</td><td>Ordinary open-plan</td></tr>
<tr><td>Studio floor level (m)</td><td colspan="2">+17.395
Fourth floor</td><td colspan="2">+17.395
Fourth floor</td><td colspan="2">+17.395
Fourth floor</td><td>+30.00
Fourth floor</td><td>+30.00
Fourth floor</td></tr>
<tr><td>Dimension (m) W*L*H</td><td colspan="2">14.65*8*7</td><td colspan="2">14.65*6*7</td><td colspan="2">14*7*7</td><td>26*8*4</td><td>12*8*4</td></tr>
<tr><td>Floor Area (m^2)</td><td colspan="2">117 m^2</td><td colspan="2">88 m^2</td><td colspan="2">98 m^2</td><td>208 m^2</td><td>96 m^2</td></tr>
<tr><td>Wall Area (m^2)</td><td colspan="2">102.55 m^2</td><td colspan="2">102.55 m^2</td><td colspan="2">98 m^2</td><td>104 m^2</td><td>48 m^2</td></tr>
<tr><td rowspan="4">Window Area (m^2)</td><td rowspan="2">Vertical</td><td rowspan="2">9 m^2</td><td rowspan="2">Vertical</td><td rowspan="2">29.3 m^2</td><td rowspan="2">Vertical</td><td>6 m^2</td><td rowspan="4">Total = 87.5 m^2</td><td rowspan="4">Total =
22.7 m^2</td></tr>
<tr><td>20 m^2</td></tr>
<tr><td>Skylight</td><td>14.65 m^2</td><td>Skylight</td><td>14.65 m^2</td><td>Skylight</td><td>14.65 m^2</td></tr>
<tr><td colspan="2">Total= 23.65 m^2</td><td colspan="2">Total= 43.95 m^2</td><td colspan="2">Total= 40.65 m^2</td></tr>
</table>

Table 7-1 Studios characteristic's in Glasgow and Aberdeen.

City	Studio	No. of windows	Window orientation	Window dimension (m)	window sill height (m)	Window/ Floor ratio	Window/Wall Ratio (each window)		Obstructions		
									Type	Height	Distance
Glasgow	GSInu	2	South	4.5*2	0	V: 8% Total: 20.21%	Vertical (south)= 8.77%	Total=21.29% Mean= 10.64%	Mackintosh building, 10 m distance, and 22.40 m height.		
			Skylight	14.65*2	5		Skylight= 12.52%				
	GSpo	2	South	14.65*2	0	V: 33% Total: 49.94%	Vertical= 28.57%	Total= 45.21% Mean= 22.60%	Mackintosh building, 10 m distance, and 22.40 m height.		
			Skylight	14.65*2	5		Skylight= 16.64%				
	GSp	3	South	3.70*2	0	V: 27% Total: 41.47%	Vertical= 26.53%	Total= 41.47 % Mean= 20.73%	Mackintosh building, 10 m distance, and 22.40 m height.		
			South	4.5*4	2						
			Skylight	14.65*2	5		Skylight= 14.94%				
Aberdeen	A1	5	South	5*3.5	0.50	42%	84.13%		Trees, 10 distance and 30m high.		
	A2	2	South	5*3.5 2.60*2	0.50	23.64%	47.29%		Trees, 10 distance and 30m high.		

Table 7-2 Window characteristic's in Glasgow and Aberdeen.

7.2.1 **Photographs in context (South orientated studios)**

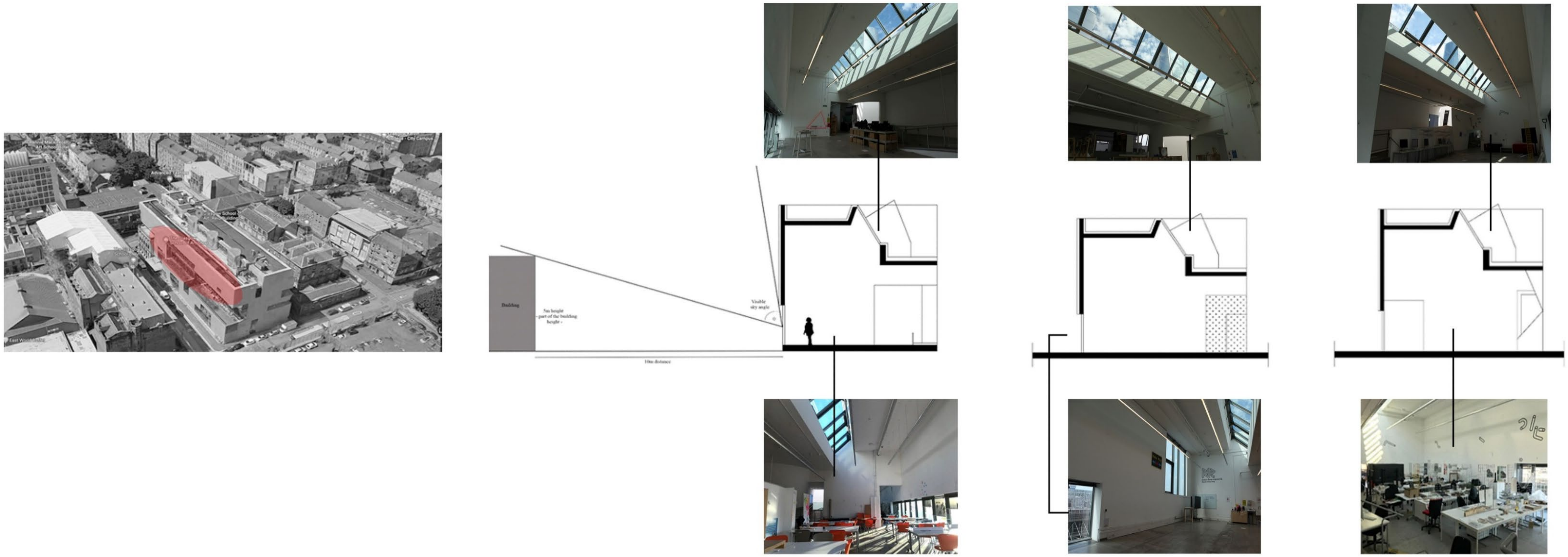


Figure 7-1 Glasgow case study (from left to right: studio GSInu, studio GSpo, and studio GSP).

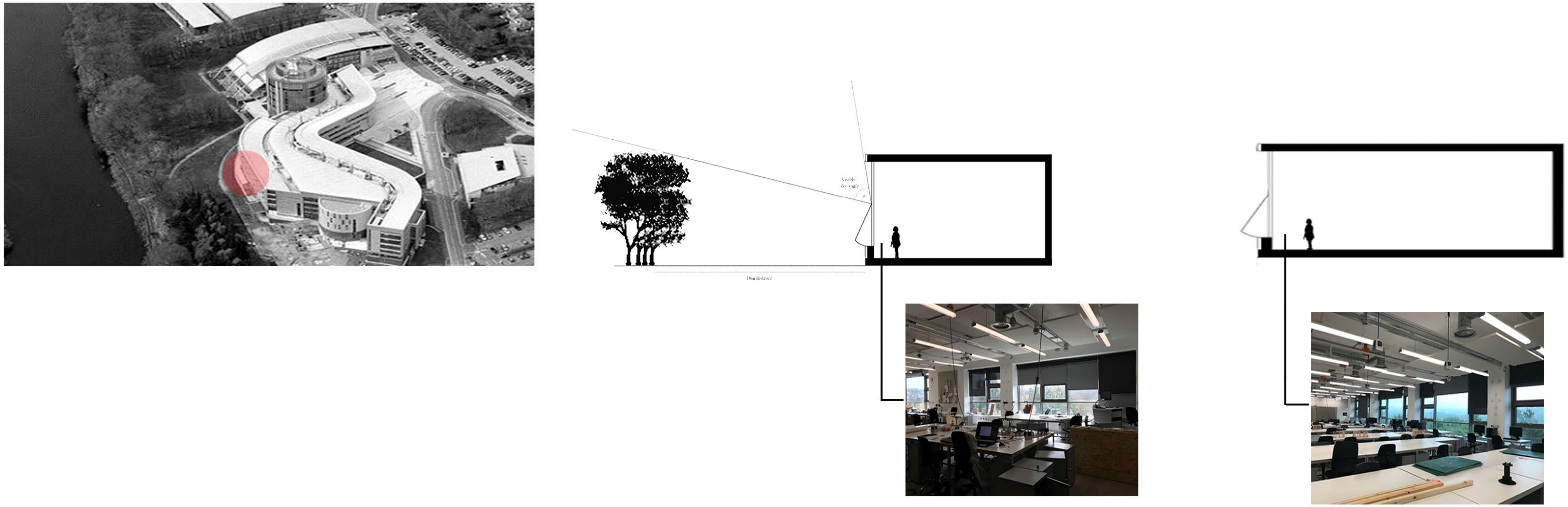


Figure 7-2 Aberdeen case study (left: studio A1, right: studio A2).

7.2.2 **Artificial lighting**

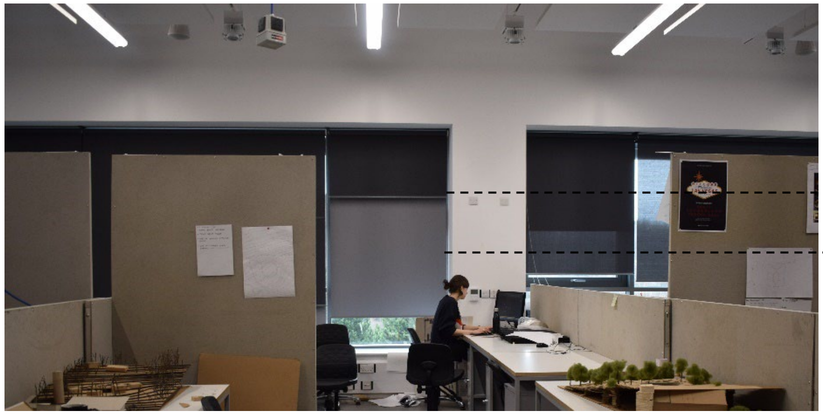
Analysis factor	Studio				
	GSInu	GSpo	GSP	A1	A2
Lighting fixture type	Fluorescent Batten (see Figure 6-6)			Academy LED range (see Figure 6-6)	
Quantity	3	3	3	36	15
Color characteristics	Warm/Yellow			Cool/White	
Construction	Suspended direct-indirect light. The ceiling is also white bright with reflected light.			Suspended direct-indirect light. The ceiling is also white bright with reflected light.	
Control type	- Manual switching, On-off control system - The detectors are programmed to time out after a duration of 15 minutes from the last detected movement within that area.			Philips dynalite system (Philips, 2021). -Automatic and manual switching (on-off control system). - The detectors are programmed to time out after a duration of 15 minutes from the last detected movement within that area. -All lighting adjacent to window elevations are programmed to daylight dim if there is sufficient natural daylight coming through the windows which is designed as part of the energy efficiency gained from this control system. - All Dynalite sensors include motion and light level sensing to automatically detect occupancy and control lighting levels.	
Shading devices	-Windows in South wall can be covered by curtains (sunscreen roller blind-grey colour). They let in plenty of light, while protecting from excessive sun's rays (Figure 7-3). -Skylights have no shading devices.			Three types of shading were observed in Aberdeen studios: 1-Curtains (sunscreen roller blind-grey colour). 2-Curtains (solid roller blind fabric-grey colour) 3-External horizontal shading panels.	

Table 7-3 Information about artificial lightings for Glasgow and Aberdeen case studies.

Figure 7-3 Curtains in studio GSpo.

Internal shading - curtains

External shading - panels



Sunscreen roller blind

Solid roller blind

Figure 7-4 Shading devices in Aberdeen

7.2.2.1 **Artificial lightings in context**

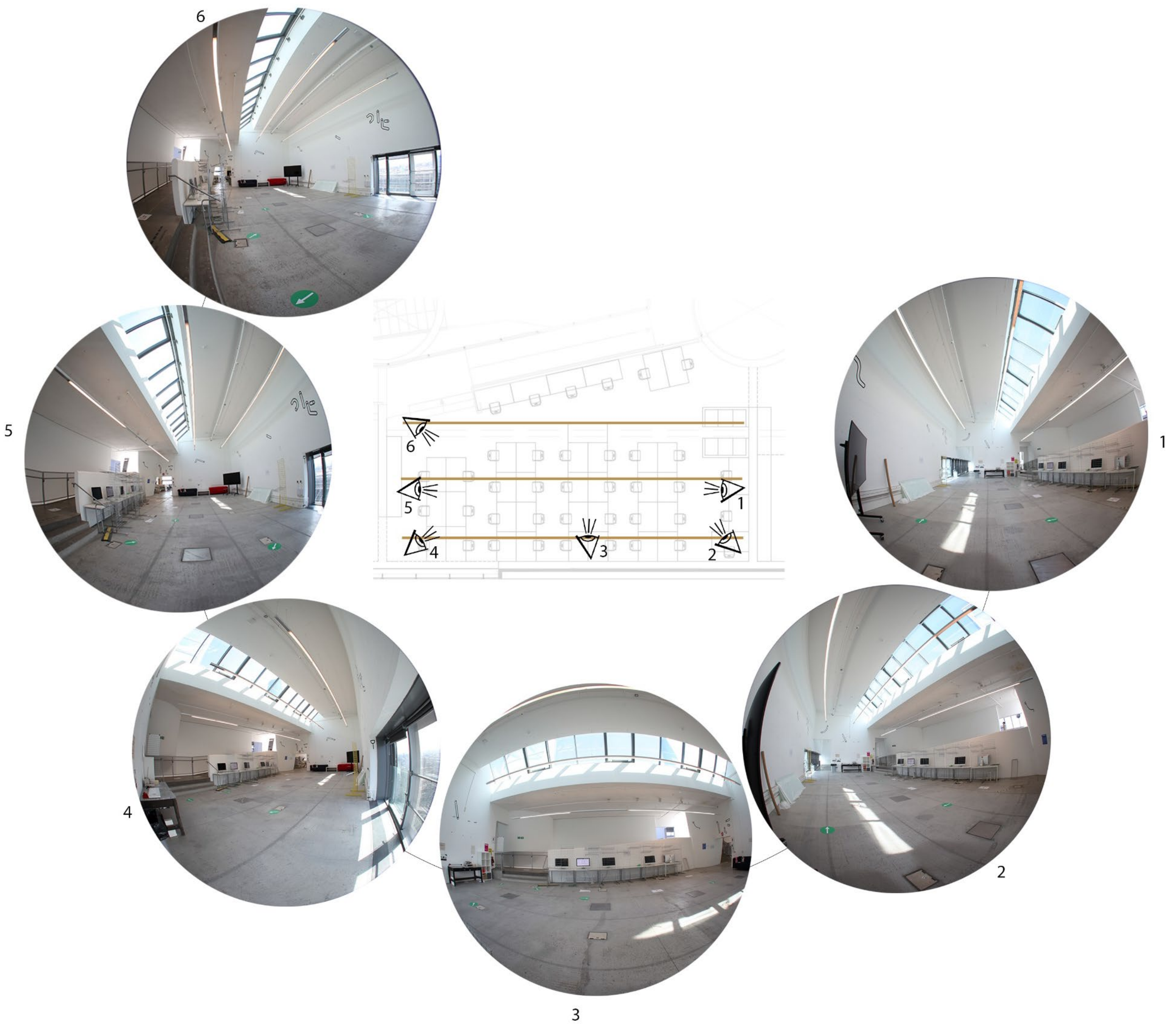


Figure 7-5 Wide panoramic fisheye photos show artificial lightings in studio GSInu, Glasgow.

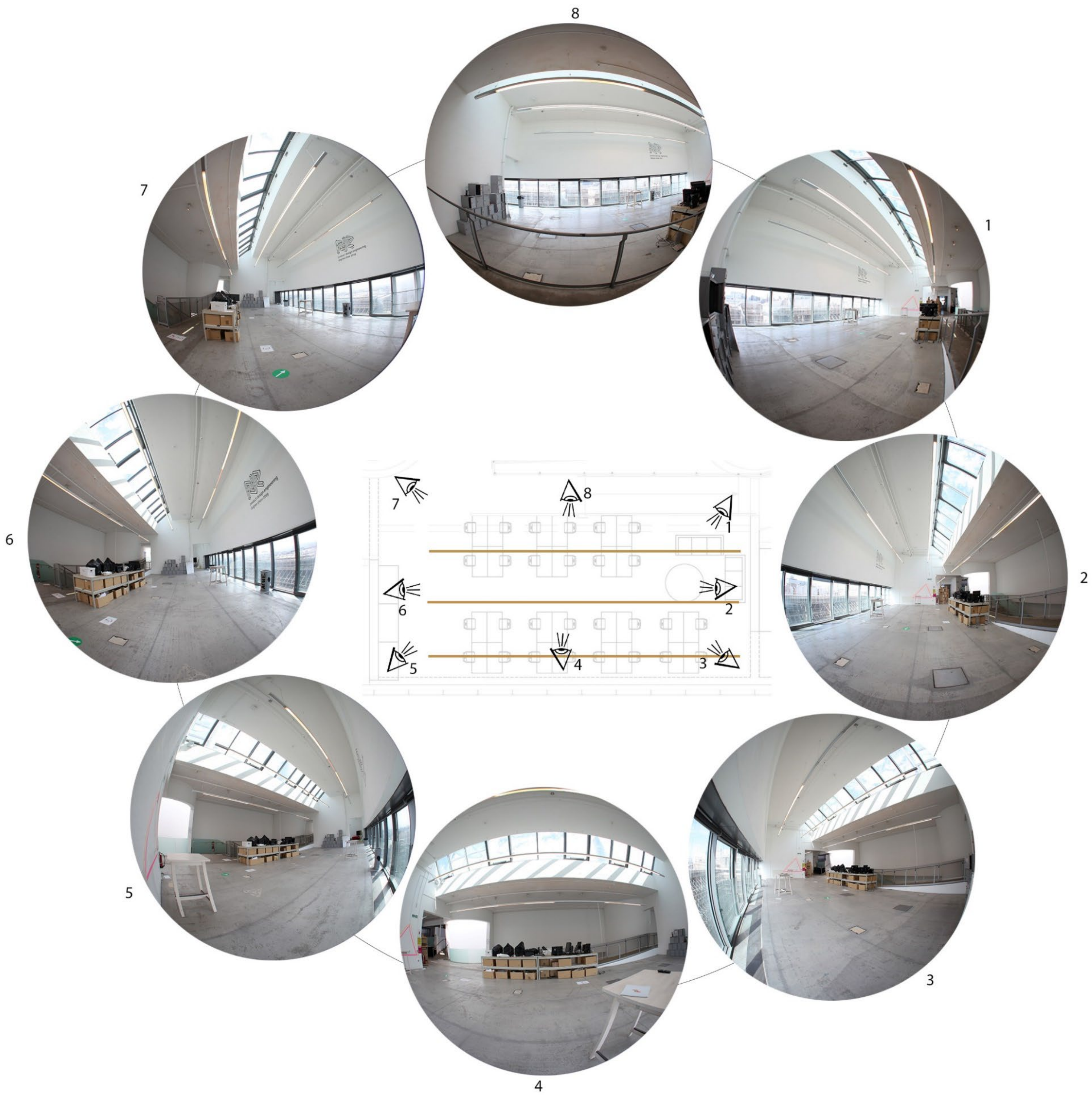


Figure 7-6 Wide panoramic fisheye photos for studio GSpo, Glasgow.

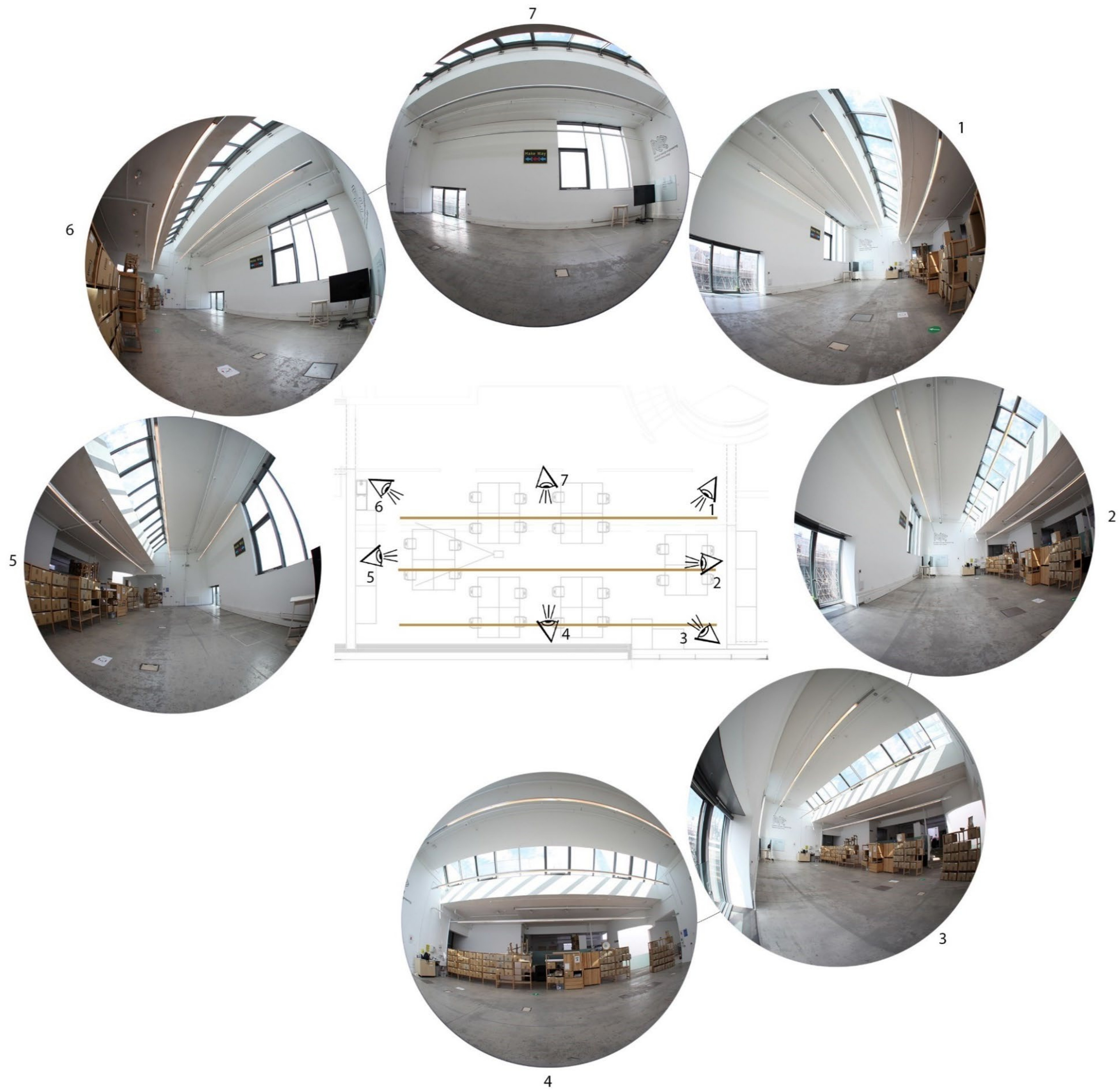


Figure 7-7 Wide panoramic fisheye photos for studio GSP, Glasgow.

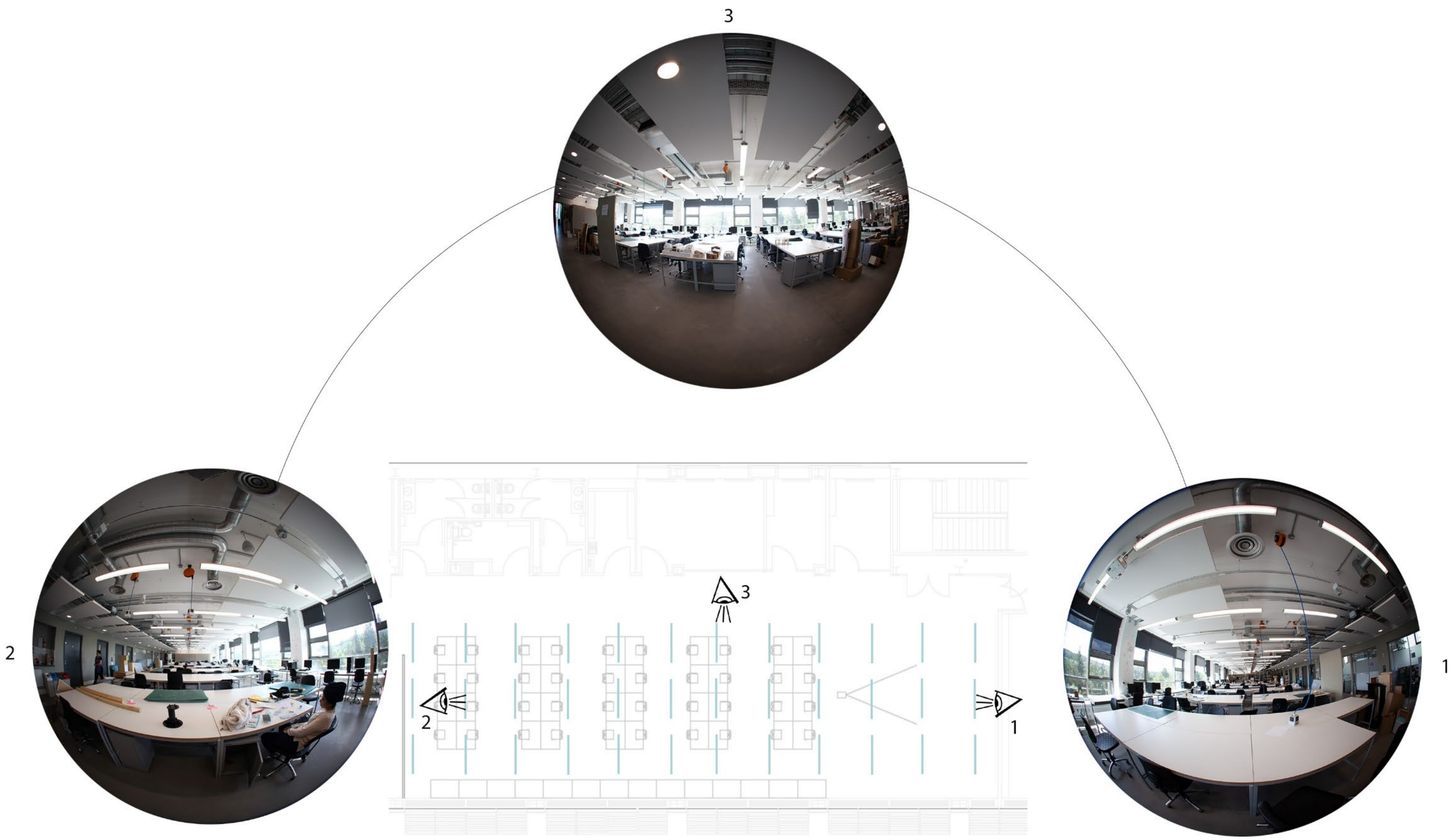


Figure 7-8 Wide panoramic fisheye photos for studio A1, Aberdeen.

Figure 7-9 Wide panoramic fisheye photos for studio A2, Aberdeen.

7.3 Objective measurements in South orientated studios

Approximately 61 light meters were used at this phase of measurement; 2 meters were placed on the roof of the Glasgow building and another 2 on the roof of the Aberdeen building to measure light levels from an unobstructed sky (Figure 7-10 and Figure 7-11). Appendix C.5 presents the average illuminance levels registered under unobstructed sky (Glasgow & Aberdeen). The remaining meters were placed inside the studios on the students' desks from the window wall, to the middle, to the furthest point of each studio horizontally, and in the middle of every wall vertically. Appendix O. 3 shows the details of the light meters placed in the Glasgow and Aberdeen studios.

Figure 7-10 Aberdeen building roof meter

Figure 7-11 Glasgow building roof meter

The objective measurements that were measured in each studio mainly related to the studios' physical characteristics, such as their spatial and window dimensions and their quantitative daylight measurements, such as illuminance levels. As weather in overcast locations tends to be varied and changeable over time (Met Office, 2016), the daylight measurements were investigated at a 5-minute interval, six days per month, from February to November, 2019. The investigated studios in the two cities did not have any mezzanine level nor zones with lower roof heights, as was found in the North-facing studios. As such, none of the measuring points (vertical and horizontal) in the studios were categorised into different zones. The following daylight analysis is based on an examination of the penetrated daylight levels by placing vertical measuring points (VMPs) on vertical walls in each studio and by placing horizontal measuring points (HMPs) on the students' desks.

7.3.1 **Vertical measuring points (at eye level vs above eye level)**

The vertical measuring points (VMPs) on the vertical walls were placed at two heights; at the students' eye level while seated (1.20 m) and above eye level (1.60 m). Several paired sample t-tests were used to statistically determine whether or not two data sets on illuminance were statistically different, using $P<0.05$ as a basis to reject the null hypothesis. The two data sets in each studio and throughout the measurement period were: the VMPs illuminance levels (lux) at eye level and the VMPs illuminance levels (lux) above eye level. Table 7-4 reports the *p-values* for the several t-tests that were conducted in each studio.

The analysis revealed a non-statistically significant difference between the VMPs at eye level and above eye level, in studio GSP and studio A1 throughout the measurement period, with March being the exception for the latter studio. This means that the penetrated daylight was uniformly vertically distributed between the two levels. Meanwhile, the rest of the studios showed a statistically significant difference ($p<0.05$) between the two levels throughout the measurement period, which means that there was a noticeable illuminance variation between the two levels.

Regarding these results, the one-way ANOVA test revealed the location of the window in the centre of the wall to have a statistically significant effect on the variation of illumination levels between VMPs at eye level and above eye level ($F(1, 241) = 113.23$, $p= 0.000$). Furthermore, a statistically significant effect was found for Window-to-floor area ratio ($F(3, 239) = 85.28$, $p= 0.00$) and window-to-wall area ratio ($F(2, 240) = 46.42$, $p= 0.00$) on the variation of illumination levels between the two levels.

Studio	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
A1	0.305	0.003	0.128	0.157	0.088	0.181	0.248	0.072	0.084
A2	0.037	0.004	0.004	0.59	0.003	0.016	0.016	0.007	0.002
GSInu	0.001	0.001	0.002	0.251	0.001	0.001	0.001	0.001	0.002
GSPo	0.057	0.044	0.014	0.024	0.031	0.023	0.032	0.38	0.076
GSP	0.316	0.239	0.282	0.338	0.328	0.248	0.285	0.266	0.240

Table 7-4 P-values results of the several t- tests to determine whether illuminance levels registered by VMPs at eye level are statistically significant different (P<0.05) from the one registered above eye level in studios and throughout the measurement period.

- Not significant (P>0.05)
- Significant (P<0.05)

7.3.2 **Analysis of illuminance levels**

Illuminance levels, measured vertically and horizontally in each studio are presented in colour map charts. The 'median' as a measure of central tendency was calculated from data sets. In terms of the vertical measuring points (VMPs), the measurements revealed that the maximum mean illuminance levels were registered in studio GSP in May: 1341.26 lux and 1542.46 lux at eye level and above eye level, respectively. The median values registered 1401.94 lux and 1612.23 lux at eye level and above eye level, respectively. The illuminance levels registered by the vertical measuring points from the highest to lowest median values for the investigated studios are reported in Table 7-5. The vertical measuring points (VMPs) inside the investigated studios are presented in Figure 7-12. Studio GSP also registered the highest illuminance levels for February, March, April, May, July, September and October. Meanwhile, studio GSInu registered the highest illuminance levels in June and August. The lowest illuminance levels were registered in studio A2 throughout the measurement period.

Regarding the illuminance levels registered by the horizontal measuring points (HMPs) reported in Table 7-7, the maximum mean illuminance levels were registered in studio GSP in May 4013 lux, alongside a median value of 4195 lux as well as it registering the highest illuminance levels in March, April, June, July, September and October. Meanwhile, studio GSInu registered the highest illuminance levels in February and August. The lowest illuminance levels were registered in studios A1 and A2.

Consequently, studio GSP registered the highest illuminance levels for both the vertical and horizontal measuring points throughout most of the measurement period. Meanwhile, studio A2 registered the lowest illuminance levels from the vertical measuring points throughout the measurement period, while studios A1 and A2 registered the lowest illuminance levels from the horizontal measuring points throughout the measurement period. This finding could be related to the window area, window-to-wall area ratio, window-to-floor area ratio, distance of measuring points from the window, studio floor level from the ground and presence of a skylight. The horizontal measuring points (HMPs) inside the investigated studios are presented in Figure 7-13.

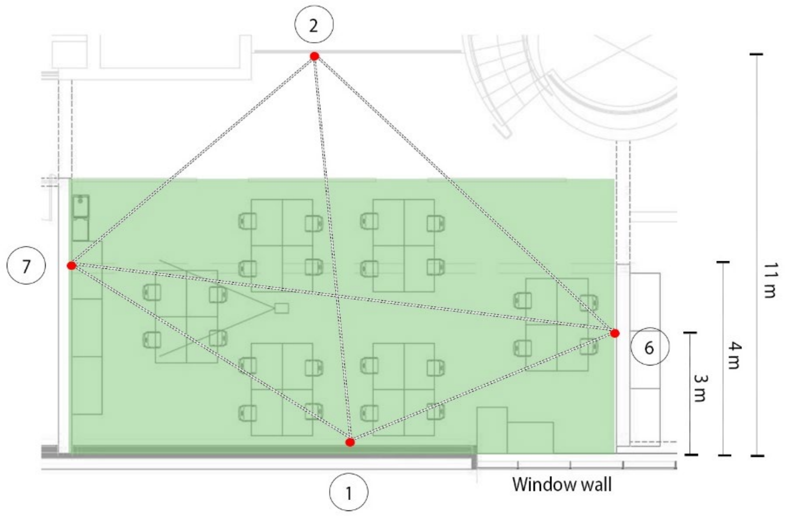
Vertical measuring points at eye level

Month	High median ←																					Low median
Feb	310.76	210.64	207.65	203.71	171.92	164.60	130.76	128.03	116.67	113.72	108.05	88.97	80.23	51.64	21.91	21.72	19.63	17.53	14.29	12.08	10.67	9.91
Mar	366.81	280.94	280.69	265.89	262.00	245.94	237.33	228.48	219.52	213.72	212.81	202.95	171.68	170.90	123.88	119.80	94.43	26.63	24.10	16.62	14.62	13.57
Apr	637.56	377.99	299.89	284.79	275.55	258.15	226.89	95.44	77.56	60.04	59.20	58.92	47.09	45.35	42.23	39.87	39.59	34.83	29.08	18.10	18.00	17.01
May	1401.94	1300.61	1070.65	1037.07	1026.26	944.83	841.39	489.62	378.89	334.10	271.50	210.22	207.18	206.70	151.70	147.39	132.96	111.58	86.01	70.48	65.37	28.36
Jun	800.76	745.98	713.96	669.79	669.04	616.96	592.85	589.66	574.08	570.68	565.72	548.05	547.81	501.31	422.42	356.03	280.53	244.50	220.14	189.33	131.20	52.78
Jul	874.49	542.22	536.27	535.24	525.79	495.78	461.55	454.64	448.69	422.11	416.87	377.74	347.08	315.90	215.21	202.54	160.34	155.02	149.18	126.67	94.63	38.07
Aug	952.63	792.22	769.11	757.24	732.75	720.69	653.48	648.69	604.98	556.78	545.73	514.59	236.14	199.58	115.41	93.32	91.90	90.05	83.05	74.88	68.48	30.03
Sep	848.24	612.44	592.88	454.57	384.60	374.45	372.90	333.51	332.60	317.94	252.09	245.62	47.50	25.54	20.75	17.65	15.17	13.94	12.47	8.67	6.60	5.61
Oct	381.53	293.87	293.47	263.91	238.29	223.97	209.57	197.79	168.36	164.39	140.48	138.64	134.62	127.26	108.23	99.14	98.58	77.38	65.64	64.61	58.83	36.63

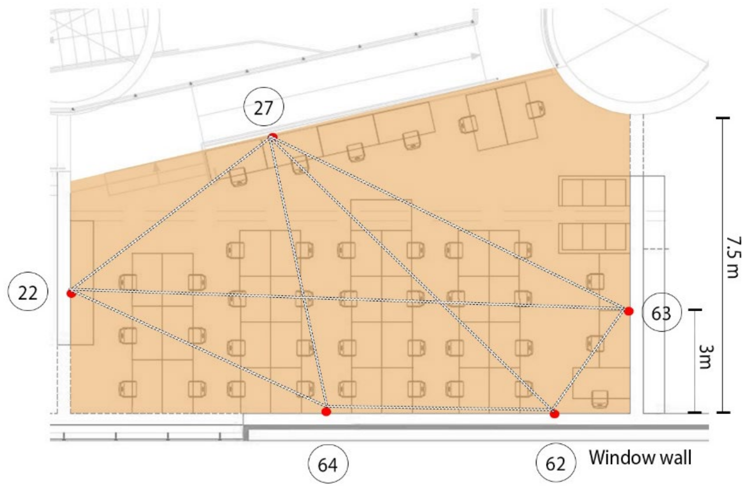
Table 7-5 Illumination levels (lux) from highest to lowest median values registered by vertical measuring points in Glasgow and Aberdeen.

GSP				GSInu					GSPo			A1					A2				
Meter 7	Meter 1	Meter6	Meter 2	Meter 64	Meter 63	Meter 27	Meter 62	Meter 22	Meter 4	Meter 21	Meter 20	Meter 50	Meter 49	Meter 59	Meter 60	Meter 51	Meter 53	Meter 57	Meter 52	Meter 68	Meter Test 2

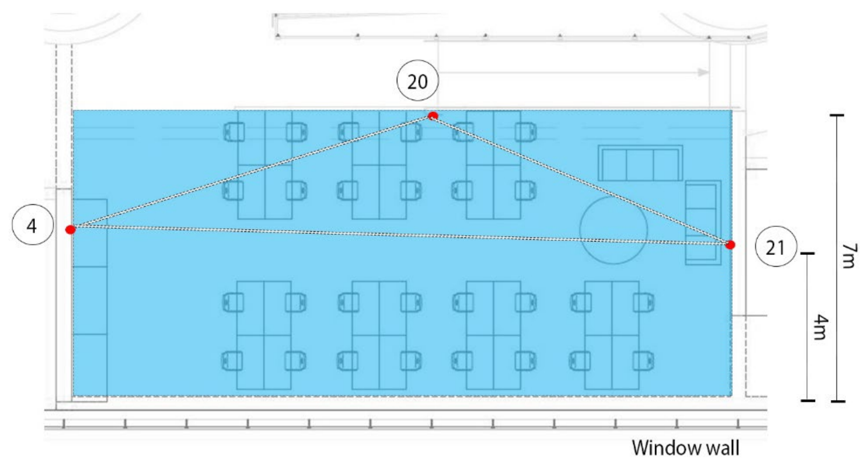
Table 7-6 Colour code for vertical measuring points.



Studio GSP

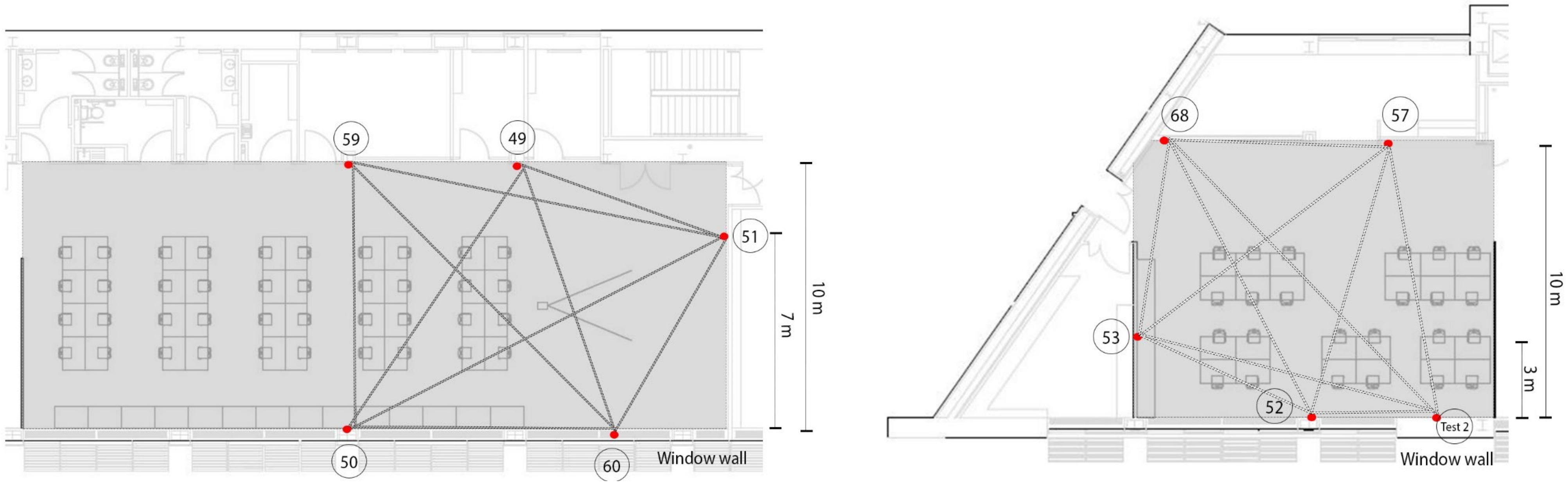


Studio GSInu



Studio GSPo

Scale 1:200



Studio A1 Studio A2

Figure 7-12 Vertical measuring points (VMPs) inside the investigated studios.

Horizontal measuring points

Month	High median ←																													Low median
Feb	4549	396	394	318	317	291	287	285	283	265	263	253	247	225	221	215	193	192	180	174	109	105	98	98	82	46	28	20	15	10	7
Mar	935	848	703	685	678	678	655	588	586	554	545	528	499	460	431	426	424	411	406	385	378	356	317	288	268	207	176	144	143	135	134
Apr	1139	1040	940	928	892	873	726	716	703	594	558	533	513	248	225	209	174	160	152	143	130	114	90	63	62	49	43	30	28	20	13
May	4195	4098	3910	3745	3730	3500	3294	3123	3055	2460	2447	2228	1786	871	866	611	560	531	522	454	406	232	220	210	120	103	96	54	46	37	22
Jun	2912	2251	2151	2097	2079	2014	2009	1983	1970	1872	1833	1773	1736	1626	1571	1552	1513	1450	1406	1303	1231	1154	1031	959	935	496	428	362	317	310	86
Jul	1545	1423	1397	1386	1385	1367	1267	1222	1209	1149	1121	1079	1063	994	921	899	898	893	890	800	751	471	460	375	320	193	182	135	78	62	59
Aug	2380	2334	2180	2121	2076	2056	1970	1912	1900	1840	1694	1692	1524	1497	1489	1484	1327	1221	1220	1189	1072	245	207	207	176	106	82	76	58	49	48
Sep	1455	1412	1222	1093	1075	1043	964	947	912	859	834	799	783	782	774	708	694	613	564	544	537	44	36	32	21	18	17	14	13	10	8
Oct	643	634	473	472	466	435	417	407	397	396	382	369	358	357	349	281	257	252	238	227	183	122	110	99	97	62	53	52	24	12	8

Table 7-7 Illumination levels (lux) from highest to lowest median values registered by horizontal measuring points in Glasgow and Aberdeen.

GSP							GSInu							GSPo						A1					A2			
Meter 9	Meter 66	Meter 8	Meter 5	Meter 11	Meter 67	Meter 3	Meter 30	Meter 29	Meter 23	Meter 24	Meter 25	Meter 26	Meter 65	Meter 12	Meter 14	Meter 13	Meter 19	Meter 16	Meter 15	Meter 42	Meter 44	Meter 43	Meter 46	Meter 47	Meter 56	Meter 61	Meter 55	Meter 54

Table 7-8 Colour code for horizontal measuring points (exclude window step meters).

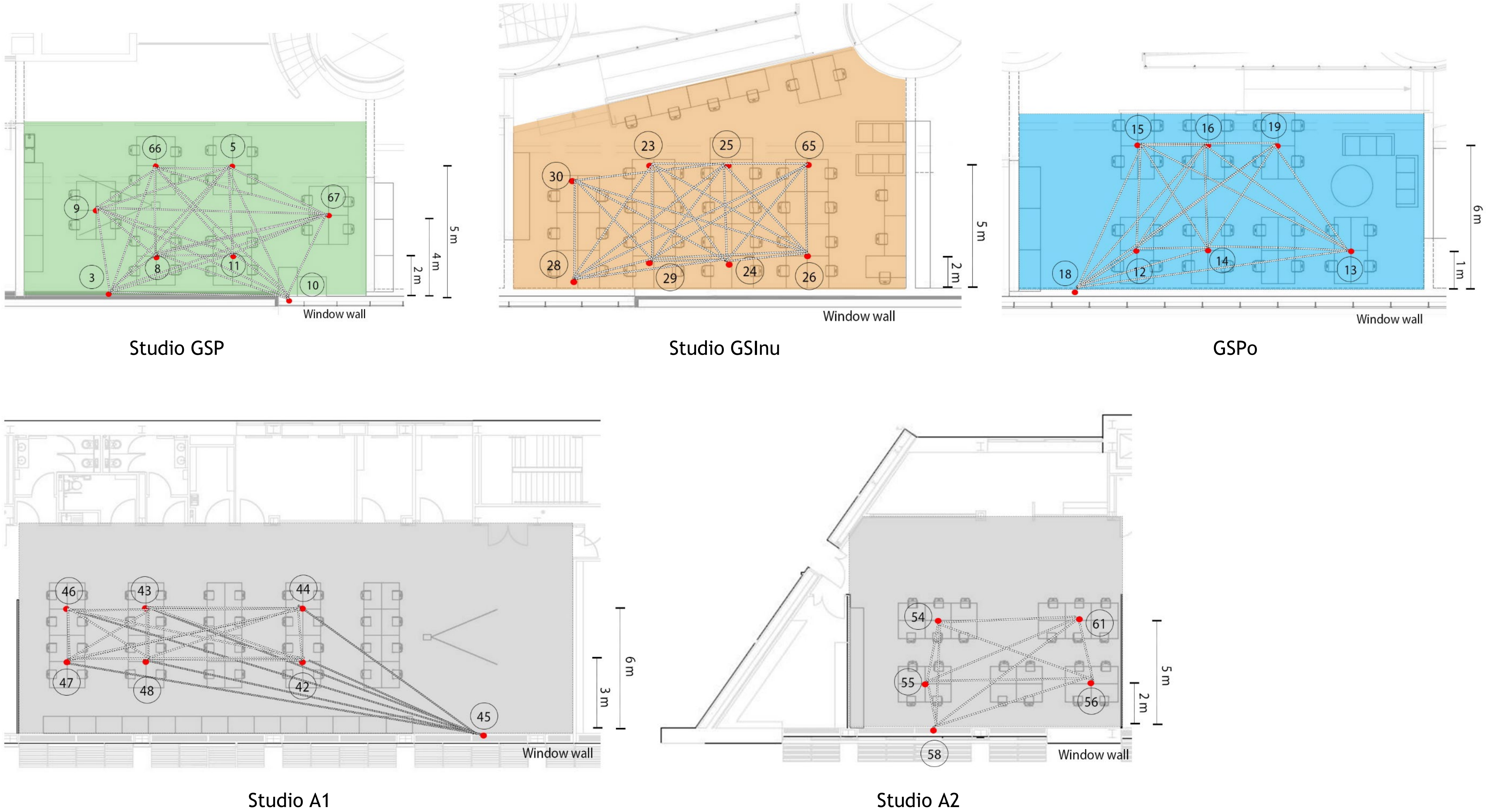


Figure 7-13 Horizontal measuring points (HMPs) inside the investigated studios.

Scale 1:200

7.4 Further assessment (Vertical window only vs vertical window with skylight)

For the current case studies, the studios were South-facing and had two typologies; ordinary open-plan studios with vertical windows (A1 and A2) and double-volume open-plan studios with vertical windows in different dimensions and arrangements, along with skylights (GSlnu, GSpo, GSp). For the external obstructions, all of the studios demonstrated a similar external obstructions factor, OF = 0.85 (view ≥ 50%). However, the ANOVA results reported in Appendix P. 1 revealed there to be a statistically significant difference ($p<0.05$) between studios on the registered mean illuminance levels by VMPs and HMPs.

Furthermore, the ANOVA test findings reported in Appendix Q. 1 revealed a statistically significant effect ($p<0.01$) for studio typology, presence of skylight and windowsill height on illuminance levels throughout the measurement period. Similarly, the window area, window-to-floor area ratio and window-to-wall area ratio were found to have statistically significant effects ($p<0.05$) on the registered illuminance levels throughout the measurement period (Appendix Q. 2). In the following analysis, the effect of vertical windows only vs vertical windows with skylights on the daylight levels and distribution inside studios is examined by the Paired Sample T-test. The classification of the horizontal measuring points was based on two distances: 1m-2m distance from the window and 5m-6m distance from the window, as showed in Figure 7-14 and reported in Table 7-9.

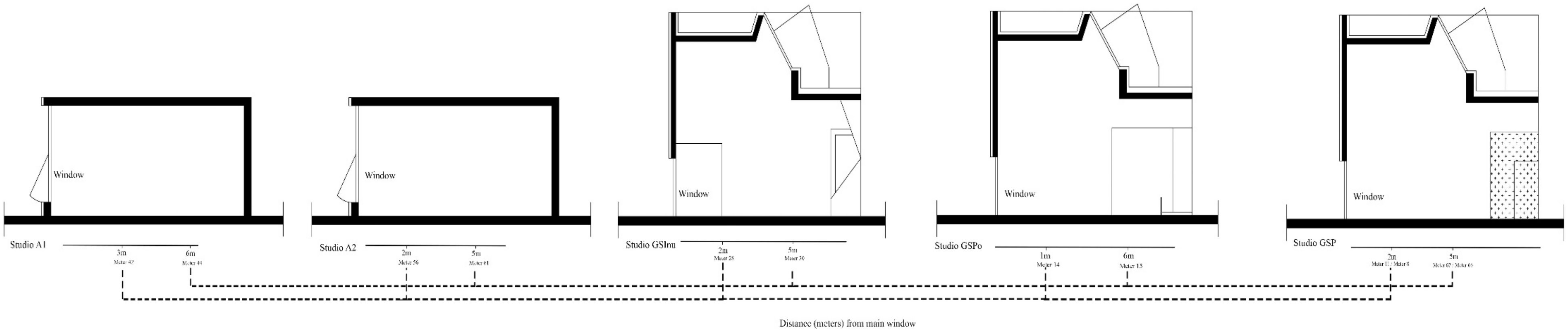


Figure 7-14 Horizontal measuring points inside South-facing studios

Studios		A1	A2	GSInu	GSpo	GSp
Sill height (vertical window)		0.50 m	0.50 m	0	0	W1: 0 W2: 2 m
Skylight		No skylight		With skylight		
Distance from the window	1-2m distance from the window	Meter 42	Meter 56	Meter 28	Meter 14	W1: meter 11, W2: meter 8
	5-6m distance from the window	Meter 44	Meter 61	Meter 30	Meter 15	W1: meter 67 W2: meter 66

Table 7-9 Classification of horizontal measuring points in South-facing studios, based on the distance from the window.

Table 7-10 shows the paired-samples t-test results for both distances in February, while the rest of the months are presented in (Appendix R. 1) for 1m-2m distance from the window and (Appendix R. 2) for 5m-6m distance from the window. The results for comparison 7 pairs of studios throughout the measurement period are as follows:

At 1-2m distance from the window: Studio GSPo (meter 14) with studio A1 (meter 42): A significant difference was found in illumination levels between meter 14 and meter 42. Studio GSPo (meter 14) with studio A2 (meter 56): A significant difference was found in illumination levels between meter 14 and meter 56. Studio GSPo (meter 14) with studio GSInu (meter 28): A significant difference was found in illumination levels between meter 14 and meter 28. Studio GSPo (meter 14) with studio GSp (meter 11): A significant difference was found in illumination levels between meter 14 and meter 11. Finally, studio GSPo (meter 14) with studio GSp (meter 8): A significant difference was found in illumination levels between meter 14 and meter 8. **At 5-6m distance from the window**: Studio GSPo (meter 15) with studio A1 (meter 44): A significant difference was found in illumination levels between meter 15 and meter 44. Studio GSPo (meter 15) with studio A2 (meter 61): A significant difference was found in illumination levels between meter 15 and meter 61. Studio GSPo (meter 15) with studio GSInu (meter 30): A significant difference was found in illumination levels between meter 15 and meter 30. Studio GSPo (meter 15) with studio GSp (meter 67): A significant difference was found in illumination levels between meter 15. Finally, Studio GSPo (meter 15) with studio GSp (meter 66): A significant difference was found in illumination levels between meter 15 and meter 66.

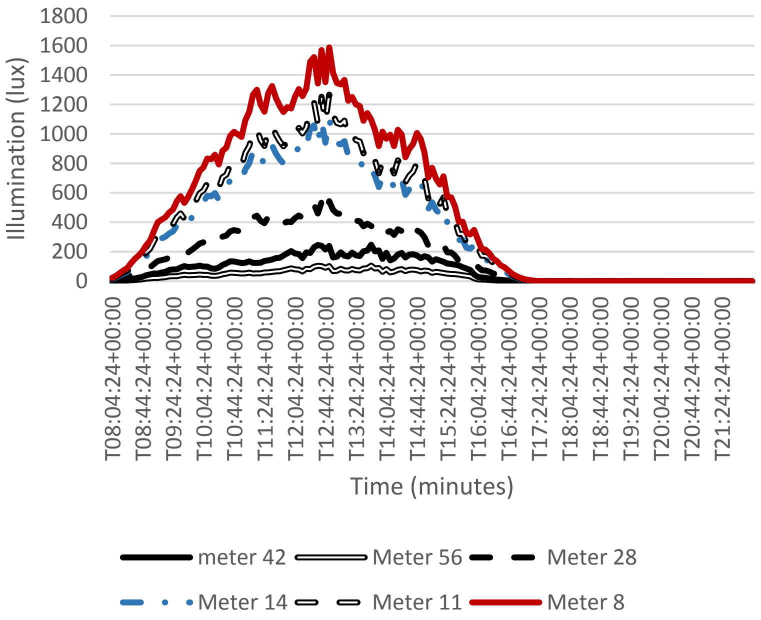
Another statistical comparison was conducted between studio A1 and studio GSP as both of them had a similar window-to-floor area ratio which was about 42% and 41.47%, respectively. However, studio A1 does not have a skylight meaning that both studios have a different window-to-wall area ratio which is about 84% and 14.94%, respectively. The results are as follows:

At 1-2m distance from the window: Studio A1 (meter 42) with studio GSp (meter 11): A significant difference was found in illumination levels between meter 42 and meter 11. **At 5-6m distance from the window**: Studio A1 (meter

44) with studio GSp (meter 67): A significant difference was found in illumination levels between meter 44 and meter 67. Similarly, a statistical comparison between studio A2 and studio GSInu was conducted as both of them have close values of window area 23 m^2 and 24 m^2, respectively and window-to-floor area ratio for about 24% and 20%, respectively. However, studio A2 does not have a skylight and so both studios have a different W/W% which is about 47% and 21%, respectively. **At 1m-2m distance from the window**: Studio A2 (meter 56) with studio GSInu (meter 28): A significant difference was found in illumination levels between meter 56 and meter 28. **At 5m-6m distance from the window**: Studio A2 (meter 61) with studio GSInu (meter 30): A significant difference was found in illumination levels between meter 61 and meter 30.

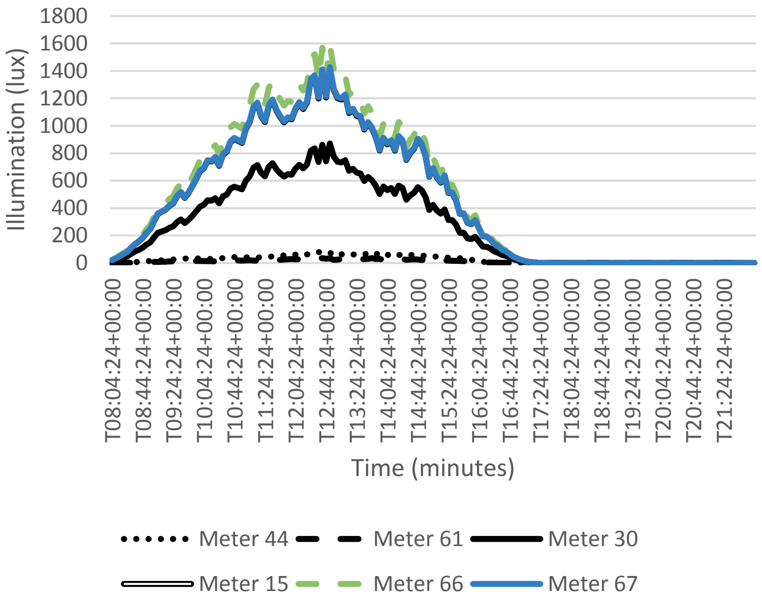
From the results, it can be concluded that at a distance of 1m-2m from the window, studio GSp registered the highest illuminance levels throughout the year, as previously shown in the colour chart. Similarly, at a distance of 5m-6m from the window, studio GSp registered the highest illuminance levels throughout the year, except for meter 66, which registered lower values than studio GSPo. This result could be related to the window dimension and sill height, whereby the window (2) in studio GSp is 2m sill height, while the window in studio GSPo has no sill height as it was placed on the floor.

For the paired comparison between studio A1 and studio GSp as both had similar window-to-floor area ratio, the results at the two distances of 1m-2m and 5m-6m from the window revealed that studio GSp had a statistically significant difference ($p<0.01$) from studio A1, and registered higher illuminance levels throughout the measurement period, even though studio A1 has higher values of window area and window-to-wall area ratio. Likewise, for the comparison of studio A2 with studio GSInu, due to them both having close values of window area and window-to-floor area ratio, the results at the two distances from the window revealed that studio GSInu had a statistically significant difference ($p<0.01$) from studio A2, and registered higher illuminance levels throughout the measurement period, even though studio A2 has higher window-to-wall area ratio. Therefore, it can be concluded that the studios with vertical windows and a skylight will register more daylight levels than studios with vertical windows only, even if they have a higher window-to-wall area ratio.

	1m-2m distance from the window
Feb	

Interpretation

Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	556.84	301.06	18.25	103	.00	104	.90	.00
	Meter 42	121.44	66.18						
Pair 2	Meter 14	556.84	301.06	18.66	103	.00	104	.90	.00
	Meter 56	51.80	28.23						
Pair 3	Meter 14	556.84	301.06	18.86	103	.00	104	1.00	.00
	Meter 28	273.84	148.06						
Pair 4	Meter 14	556.84	301.06	-18.86	103	.00	104	1.00	.00
	Meter 11	638.56	345.25						
Pair 5	Meter 14	556.84	301.06	-18.86	103	.00	104	1.00	.00
	Meter 8	724.45	391.69						
Pair 6	Meter 42	121.44	66.18	-18.36	103	.00	104	.90	.00
	Meter 11	638.56	345.25						
Pair 7	Meter 56	51.80	28.23	-18.36	103	.00	104	.90	.00
	Meter 28	273.84	148.06						

	5m-6m distance from the window	Interpretation
Feb		see table below

Pair		Paired samples statistics: Mean	Paired samples statistics: Std. Deviation	Pair sample test: t	Pair sample test: df	Pair sample test: Sig.	Paired samples correlation: N	Paired samples correlation: r	Paired samples correlation: Sig
Pair 1	Meter 15	714.80	386.47	18.75	103	.00	104	.90	.00
	Meter 44	39.14	21.33						
Pair 2	Meter 15	714.80	386.47	18.81	103	.00	104	.90	.00
	Meter 61	17.26	9.41						
Pair 3	Meter 15	714.80	386.47	18.86	103	.00	104	1.00	.00
	Meter 30	439.13	237.42						
Pair 4	Meter 15	714.80	386.47	-18.86	103	.00	104	1.00	.00
	Meter 67	719.71	389.12						
Pair 5	Meter 15	714.80	386.47	-18.86	103	.00	104	1.00	.00
	Meter 66	800.27	432.68						
Pair 6	Meter 44	39.14	21.33	-18.75	103	.00	104	.90	.00
	Meter 67	719.71	389.12						
Pair 7	Meter 61	17.26	9.41	-18.78	103	.00	104	.90	.00
	Meter 30	439.13	237.42						

Table 7-10 The Paired-Samples T- test results for the difference in the illuminance levels between studios at 1m-2m and 5m-6m distances from the window.

7.5 Daylight levels assessment in relation to the guidelines- hypothesis testing

Similar to the assessment of the studios orientated to the North, the appraisal of daylight in the studios in this section uses the SLL code and the British Standards as criterions. They provide some lighting guidelines; for example, the recommended illuminance level for art rooms in art studios ranges from 500-750 lux. Accordingly, the tested hypothesis is ***'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.***

Starting with studio A1 (W/F% = 42%), the HMP (45) was placed on the windowsill step, registered 6901.57 lux in June, which was the highest illumination level of all the measuring points (Figure 7-15). However, the rest of the HMPs confirmed the hypothesis mostly in June as meter 43 registered 1739.68 lux, meter 42 registered 549.59 lux and 499.16 lux in June and July, respectively. Meters 46, 47 and 48 registered illuminance values of 1141.53, 1362.91 and 2073.49 lux, respectively. With regards to studio A2 (W/F% = 24%), the HMP (58) registered the highest illumination levels among all the measuring points as it was placed on the windowsill step, which recorded 5920.45 lux (Figure 7-17). For the rest of the HMPs, meter 55 was the only one to confirm the hypothesis, with it registering 473.60 lux and 487.77 lux in June and July, respectively. The mean illuminance levels registered by the vertical and horizontal measuring points in studio A1 are presented in Figure 7-16, and studio A2 are presented in Figure 7-18.

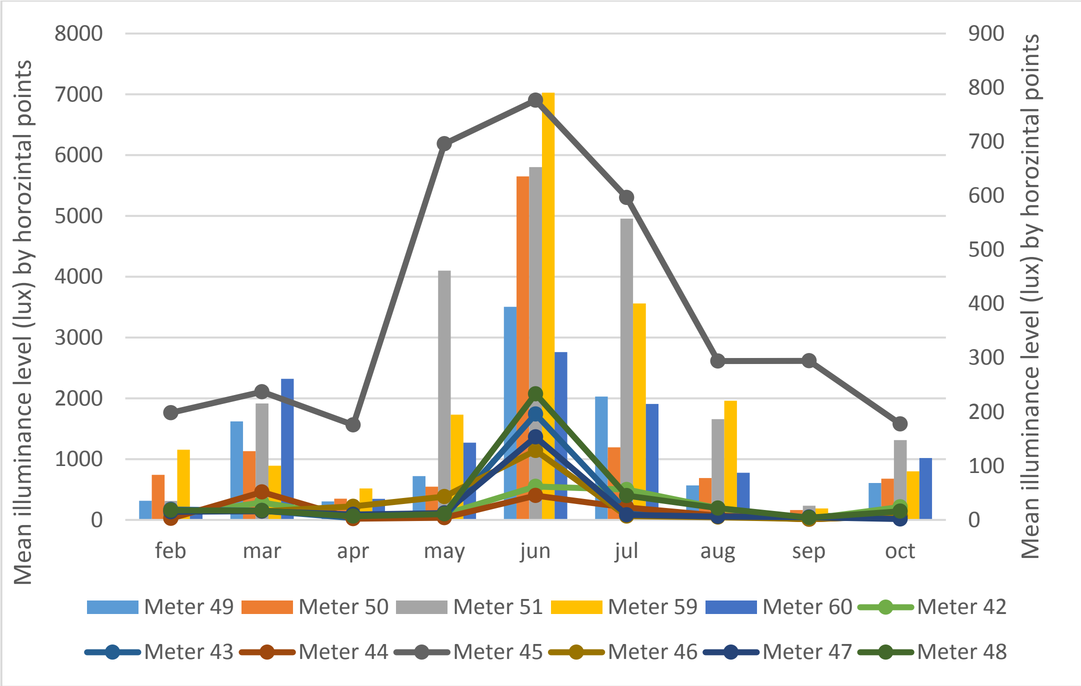


Figure 7-15 **Difference between mean illuminance levels registered by meter 45 and the rest of the HMPs in studio A1, Aberdeen. ▬ Vertical measuring point ─•─ Horizontal measuring point.**

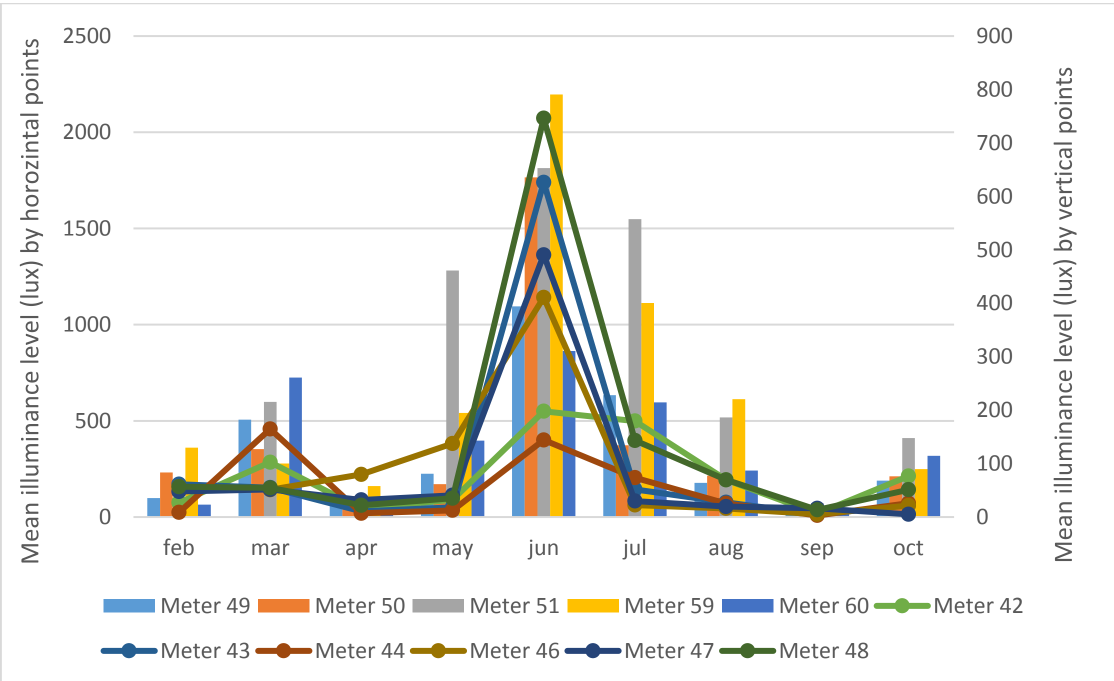


Figure 7-16 Mean illuminance levels registered by vertical and horizontal measuring points in studio A1, Aberdeen. ▬ Vertical measuring point ─•─ Horizontal measuring point.

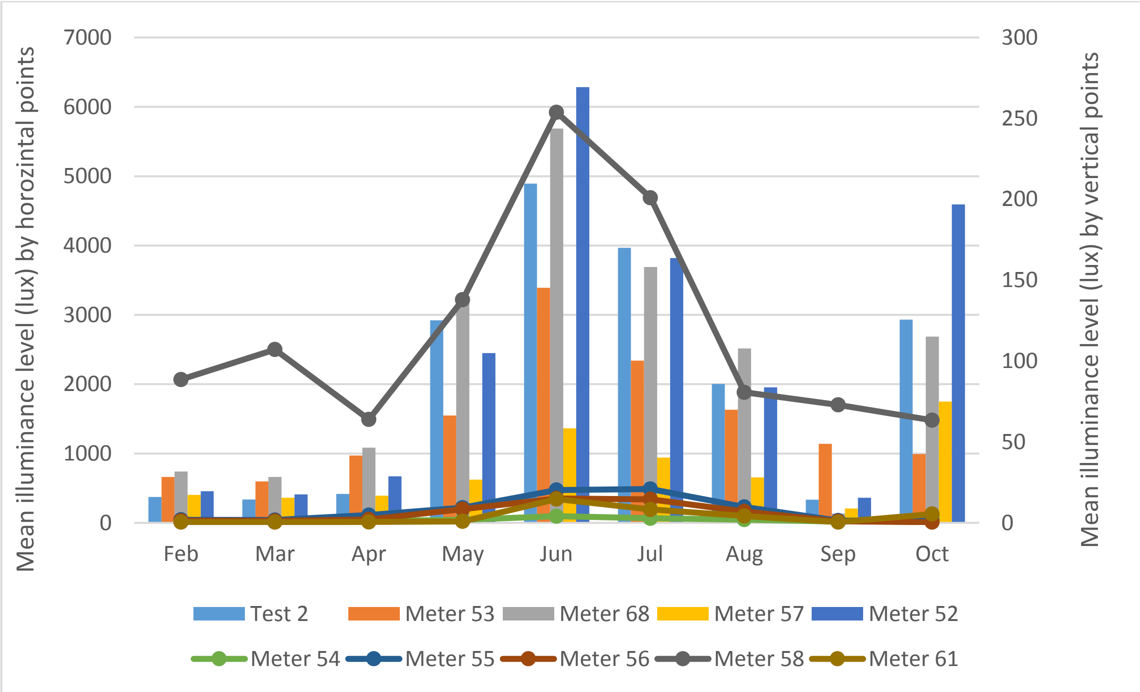


Figure 7-17 Difference between mean illuminance levels registered by meter 58 and the rest of the HMPs in studio A2, Aberdeen. Vertical measuring point Horizontal measuring point.

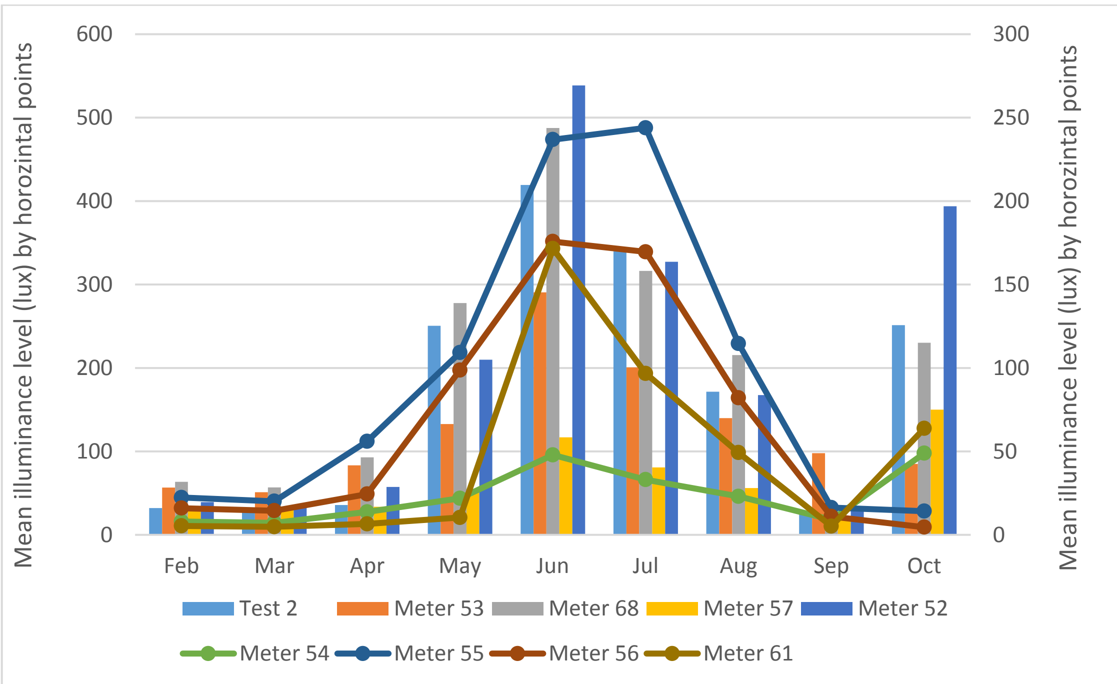


Figure 7-18 Mean illuminance levels registered by vertical and horizontal measuring points in studio A2, Aberdeen. Vertical measuring point Horizontal measuring point.

With regards to studio GSInu (W/F% = 20%), most of the HMPs confirmed the hypothesis in May, June, July, August and September. Meter 23 produced the highest illumination levels among all the measuring points, with it registering 3023.54 lux in June. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GSInu are presented in Figure 7-19.

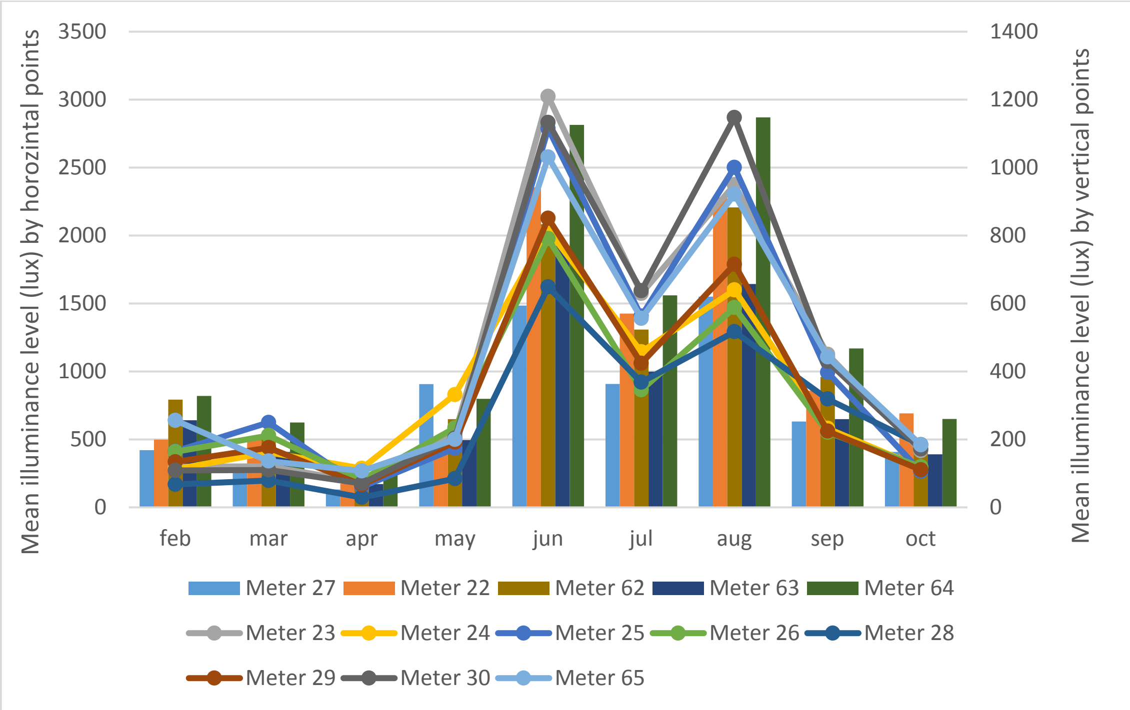


Figure 7-19 Mean illuminance levels registered by vertical and horizontal measuring points in studio GSInu, Glasgow. Vertical measuring point Horizontal measuring point.

For studio GSPo (W/F% = 50%), the HMPs confirmed the hypothesis in April, May, June, July, August and September. Meter 18 registered the highest illumination levels among all the measuring points as it was placed on the windowsill step and registered 4907.58 lux in June. Finally, studio GSp (W/F% = 41%) was the only studio in which all the HMPs confirmed the hypothesis throughout the measurement period. Meter 10 registered the highest illumination levels among all the measuring points as it was placed on the windowsill step and registered 6446.92 lux in May. The mean illuminance levels registered by the vertical and horizontal measuring points in studio GSPo are presented in Figure 7-20, and in studio GSp are presented in Figure 7-21.

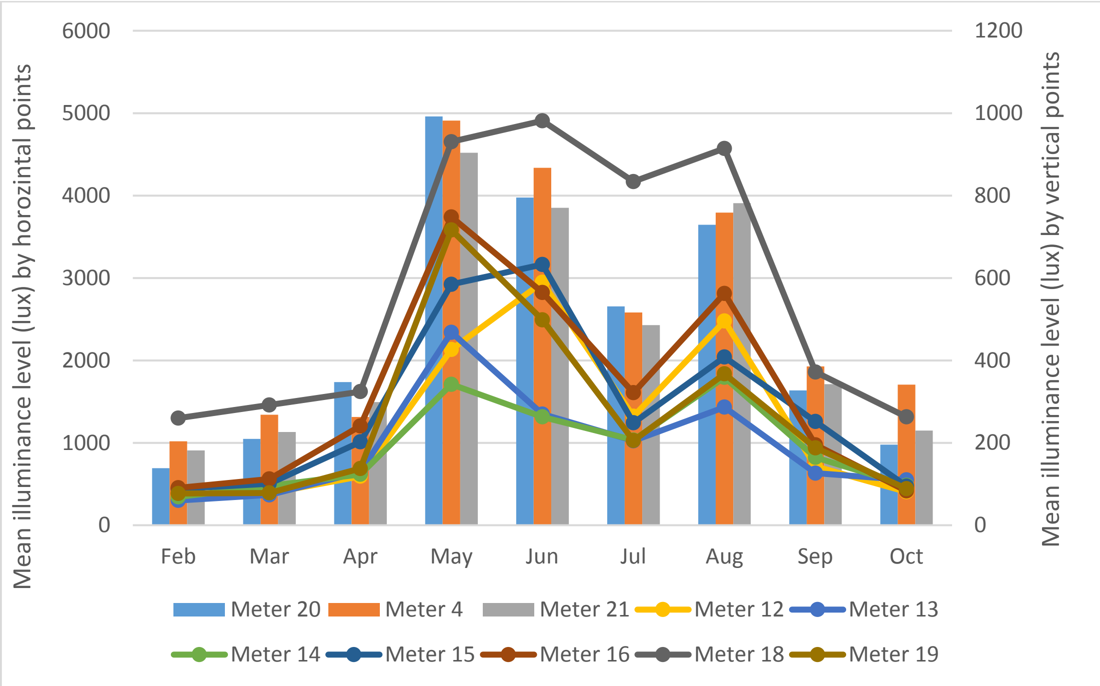


Figure 7-20 Mean illuminance levels registered by vertical and horizontal measuring points in studio GSPo, Glasgow. Vertical measuring point Horizontal measuring point.

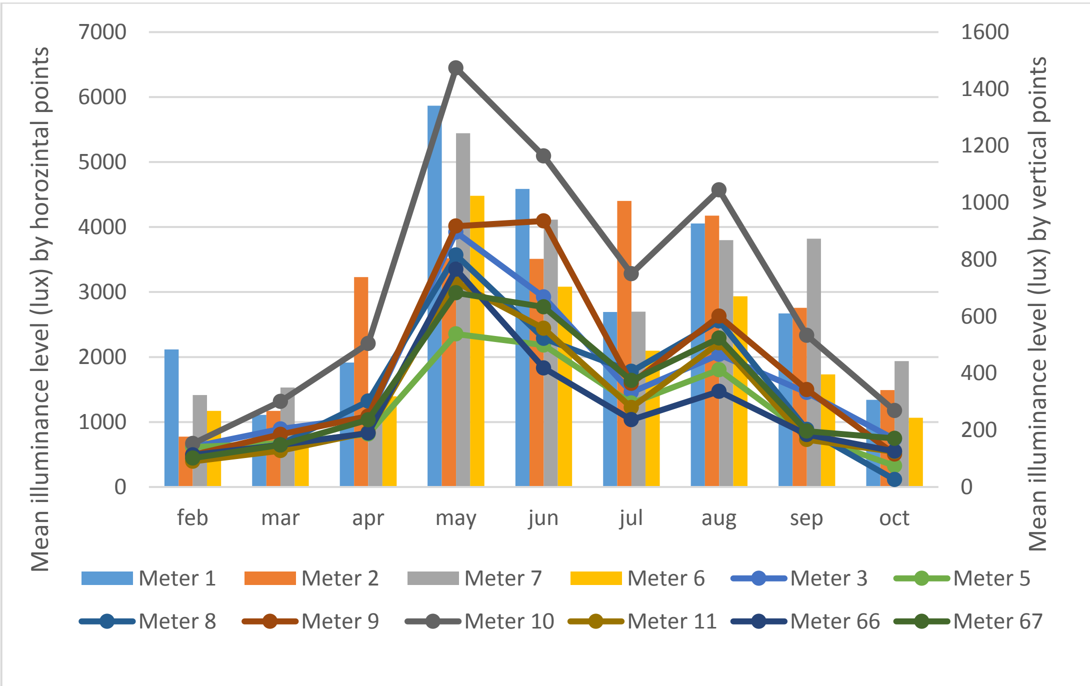


Figure 7-21 Mean illuminance levels registered by vertical and horizontal measuring points in studio GSP, Glasgow. Vertical measuring point Horizontal measuring point.

In conclusion, the studios with vertical windows and no skylight, such as studio A1 and studio A2, only confirmed the hypothesis in June despite having W/F% of above 20%. Meanwhile, studios with vertical windows (sill height = 0) and a skylight confirmed the hypothesis throughout most of the measurement period, except in February, March and October. Studios with vertical windows (sill height = 2m) and a skylight confirmed the hypothesis throughout the measurement period. It is important to mention that the skylights in the investigated studios are considered to be 'passive skylights' as they do not utilise any moving or mechanical components to track the azimuth of the sun to assist or modify the delivery of natural light inside spaces (Sharp, Lindsey, Dols, & Coker, 2014). Yet, they were North-orientated, which led to more diffused daylight coming in. However, some students mentioned the glare problem they faced inside studios, mainly because of the vertical windows. For example, one of the students from studio GSp commented, '*very bright; people sometimes need to wear sunglasses because of it*'. Likewise, another student from studio GSPo commented that there was '*glare from natural light on laptop*'. This finding opens new subjective arguments regarding the efficiency of placing vertical windows in studios orientated to the South, where solar gain is troublesome and some form of sunlight protection such as blinds is needed.

7.6 **Summary**

This chapter presents the results of the field measurements that were conducted in five studios in Glasgow and Aberdeen from February until November 2019. The studios were made up of two design typologies: double-volume open-plan studios (GSInu, GSPo and GSp), which have vertical windows and skylights, and ordinary open-plan studios (A1 and A2), which only have vertical windows. All studios had similarities in terms of activities, furniture design and colour, orientation and, most importantly, they were under overcast sky conditions. Several light meters were placed in each studio, covering the area from the window wall to the furthest point of the studio horizontally on the students' desk and in the middle of every wall vertically. In addition to this, two light meters were placed on the building's roof in each city to measure daylight levels under an unobstructed sky. All the light meters in the two cities registered the illuminance levels at the same time.

The daylight measurements registered by vertical and horizontal measuring points showed that studios with vertical windows and skylight had higher illuminance levels throughout the measurement period than studios with only vertical windows, even if they have a higher window–to-wall area ratio. Furthermore, one-way ANOVA analysis revealed a statistically significant effect ($p<0.01$) of the location of the window at the centre of the wall, window–to–floor area ratio and window–to–wall area ratio on the variation of illumination levels between VMPs that placed at eye level vs above.

To examine the impact of façade fenestration on daylight levels, the findings from one-way ANOVA test showed a statistically significant effect ($p<0.01$) of studio typology, presence of skylight, windowsill height, window area, window-to-floor area ratio and window-to-wall area ratio on the registered illuminance levels by VMPs and HMPs throughout the measurement period.

In terms of hypothesis testing, the findings showed that studios with vertical windows (sill height = 2) and a skylight confirmed the hypothesis throughout the measurement period. Meanwhile, the studios with vertical windows (sill height = 0) and a skylight confirmed the hypothesis throughout most of the measurement period, except in February, March and October. In the case of studios with only vertical windows and no skylight, even though they had a W/F% of over 20%, the hypothesis was only confirmed by daylight measurements in June.

7.7 Discussion

The daylight levels for the second phase of the study were measured using light meters located at vertical and horizontal surfaces inside five South-orientated studios in Glasgow and Aberdeen. The studios' typologies were mainly double-volume open-plan studios and ordinary open-plan studios. One of the investigated studios (GSInm) was excluded from the analysis because it has two east-facing windows which would affect daylight levels, and in turn could undermine the internal validity of research.

In contrast with the studios orientated to the North, the findings confirmed a significant effect of the location of the window in the centre of the wall on the variation of illumination levels between the VMPs at two heights: eye level (1.2m) and above eye level (1.6m). Furthermore, it was found that there was a significant effect of the window–to–floor area ratio and window–to–wall area ratio on the illuminance variation between the VMPs at eye level and above eye level. Therefore, the location of a window can be arranged so as to create unusual or dramatic visual effects, if desired (The Society of Light and Lighting, 2014, p. 21).

In terms of the illuminance levels registered by the HMPs, the findings revealed that the studio typology, the presence of a skylight, the windowsill height, window area, W/F% and W/W% all have significant effects on the registered illuminance levels at all distances from the window and throughout the measurement period. Likewise, a Paired Sample t-test comparison between the studios based on their measured illuminance levels at 1-2m and 5-6m distance from the window revealed that studios with vertical windows and a skylight registered more daylight levels at the two distances and throughout the measurement period. The higher illuminance measured in studios with skylight GSInu, GSp and GSPo could be largely attributed to the high ratio of skylight-to-floor area of 12.52%, 14.94% and 16.64%, respectively. These results supported the findings noted in Wong's (2017) paper, whereby useful daylight illuminance could be achieved when the rooflight-to-floor area ratio was between 0.15 and 0.20. Similarly, the National Association of Rooflight Manufacturers in the UK demonstrated the recommended minimum rooflight area for desired illuminance levels, vertically or horizontally. The document recommended 15%-17% as a minimum for rooflight area to floor area ratio when the desired illuminance levels in the horizontal plane are from 500 lux - 750 lux. It also recommended a 17%-20% minimum rooflight area to floor area ratio when the desired illuminance levels in the vertical plane are 300 lux – 500+ lux (NARM, 2014, p. 8).

Consequently, a skylight is considered a more effective option to guarantee more penetrated daylight inside spaces under overcast sky conditions than vertical windows. This result was confirmed by other literature, such as the work by Treado et al. (1984), who found that clerestories are more effective than windows of the same size and also by Acosta et al. (2012), who noted that skylights provide homogeneous lighting over the horizontal plane. Similar findings were revealed by Müeller (2014), who argued that skylights should be used predominantly if possible along with windows at eye level to provide an adequate outside view. However, the high contrast between the surfaces surrounding the skylight and the sky can cause glare (Raynham et al., p. 119, 2012), particularly in sun-facing skylights with no external shading. Barrett et al. (2015, p.19) argued that expansive South-orientated glazing should be avoided and, if applied, then external shading should be provided. Likewise, the Society of Light and Lighting (2014) reported that rooflights are useful as a means to supplement side windows in order to brighten the back of a deep room. They can also be used alone in particular types of interior where side windows are not desirable. In general, the light penetrated from a horizontal or semi-horizontal rooflight was found to be three times higher than the light penetrated from the same sized vertical window. However, the direction of the rooflight is crucial, with the SLL society stating that rooflights facing the North in the northern hemisphere are usually the best choice for diffused daylight as the unwanted solar gain can be prevented.

Chapter 8

Subjective response to the effect of façade fenestration on daylight levels & experienced atmosphere: Glasgow & Edinburgh case studies

8.1 Introduction

This chapter uses a subjective perspective to discuss the effect of façade fenestration on daylight levels and experienced atmosphere in North-facing studios in Glasgow and Edinburgh. As students were located in two different studio design typologies (double-volume open plan studio vs mezzanine studio above), the study has considered whether this difference impacted upon students' evaluations of the façade windows. This chapter also examines the second hypothesis: *The characteristics of facade fenestration have a strong association with the experienced atmosphere*.

The total number of participants who completed the questionnaire was 171; 45 students came from Edinburgh studios and 126 students from Glasgow studios. 52.6% of participants were within the 18-21 age group. Before conducting any analytical procedures, the missing values and outliers were checked for all studios. The main statistical tests that were used were the Kruskal-Wallis H for testing the effect of the characteristics of façade fenestration, such as window area and windowsill height, on students' ratings for façade windows, daylight levels and experienced atmosphere. Factor analysis (dimension reduction) was used to reveal patterns of correlation among variables that were assumed to reflect most on the experienced atmosphere as positive or negative stimuli (coherent subsets). The nonparametric correlation test (Spearman's Rho) was used to test the association between objective variables (characteristics of façade fenestration) and subjective evaluation of daylight attributes and the experienced atmosphere (Table 8-1).

The chapter is divided into two main parts (Figure 8-1): part one is concerned with subjective responses to the effect of façade windows on daylight levels inside two typologies: a double-volume studio and a mezzanine studio. These subjective responses refer to the different function descriptors of façade windows, such as their contribution to studio's aesthetics, and also to the preferred window arrangement. Meanwhile, part two deals with users' subjective responses to the effect of façade windows on the experienced atmosphere. This is followed by a subjective evaluation of atmospheric states and their dimensions.

In addition, a correlation test between objective measurements (characteristics of façade fenestration) and subjective measurements (students' ratings of the experienced atmosphere). Finally, the contribution of subjective attribute of daylight on atmosphere was examined on both cloudy and bright days.

The results indicated that studio design typology has no statistically significant effect on students' preferences for a particular window arrangement, as students in all the investigated studios preferred one particular window arrangement, type I (see section 8.3.2). In addition to this, the characteristics of façade fenestration, such as window-to-wall area ratio, window-to-floor area ratio, window area, external obstructions and layers of views, each has a significant effect on the subjective response to windows descriptions, mainly on daylight levels during cloudy and bright days. Meanwhile, windowsill height and studio design typology were found to only have a significant effect on providing an attractive outside view. Finally, the second hypothesis has been rejected as the correlation test revealed a weak linear association between the characteristics of façade fenestration and experienced atmosphere.

Statistical analysis	Objective
Kruskal-wallis H test	To determine if there are statistically significant differences (effects) between two or more variables.
Wilcoxon Signed-Rank test	Used to compare two repeated measurements (two paired groups).
Factor analysis	To summarized patterns of correlations among observed variables and reduce a large number of variables to a small number of factors.
Spearman's Rho correlation	Used to measure the strength of association between two variables.

Table 8-1 Main statistical analysis tests that were used for the subjective appraisal.

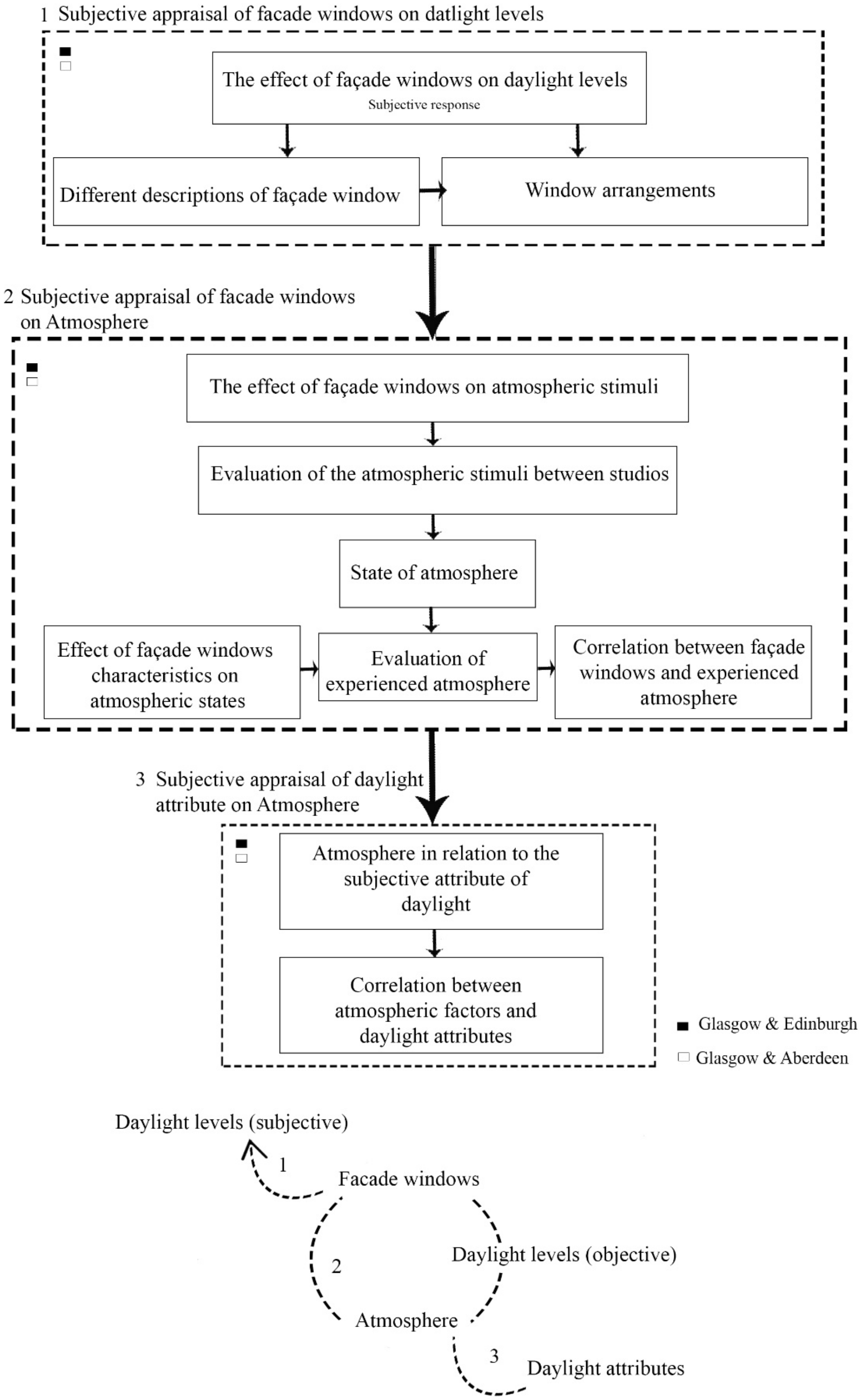


Figure 8-1 Structure diagram of the analysis of experienced atmosphere.

8.2 Demographic information for North-orientated studios

The total number of students who completed the questionnaire was 171, of which 45 students were from the Edinburgh studios and 126 students were from the Glasgow studios. In each studio, there were different year groups sharing the same space, except for the mezzanine studios, where there was only one group. Table 8-2 presents the students' degree type in each studio. Table 8-3 and Table 8-4 present demographic information relating to the students participating in the questionnaire for the studios in Glasgow and Edinburgh. Most of the participants were within the 18-21 age group (52.6%); 66.7% of the participants were female and 32.2% were male. As for the students' nationalities, 67.3% were from the UK, 14.6% were Europeans, 9.9% were Chinese, and 8.2% were from other countries, such as Canada, India and the USA.

Studio	Year group
E1	First year
	Third year
Em	Fourth year
GNC	Third year
	Fourth year
GNCm	First year
GNPL	Master year
GNPm	Master year
GNIn	Third year
GNJm	Second year
	Third year
	Fourth year

Table 8-2 Degree year group for Glasgow and Edinburgh studios.

Your age		Your gender			Total
		Female	Male	Prefer not to say	
Your age	17 or below	1	0	0	1(.6%)
	18-21	70	19	1	90 (52.6%)
	22-25	35	28	0	63 (36.8%)
	26-and above	8	8	1	17 (9.9%)
Total		114 (66.7%)	55 (32.2%)	2 (1.2%)	171

Table 8-3 Demographic information (age/gender) for Glasgow and Edinburgh studios.

Your residency		Your gender			Total
		Female	Male	Prefer not to say	
Residency	UK resident	83	30	2	115 (67.3%)
	European resident	14	11	-	25 (14.6%)
	China	8	9	-	17 (9.9%)
	Other: Total	9	5	-	14 (8.2%)
	Canada	1	2	-	
	Egypt	1	-	-	
	India	1	1	-	
	Indonesia	-	1	-	
	Japan	1	-	-	
	USA	2	1	-	
	Australia	1	-	-	
	Nepal	1	-	-	
	Prefer not to say	1	-	-	
Total		114	55	2	171

Table 8-4 Demographic information (residency/gender) for Glasgow and Edinburgh studios.

Figure 8-2, Figure 8-3 and Figure 8-4 present the students' responses to questions related to the period of time spent inside the studios. Most of them spent more than a year, except for the students in studios GNCm, GNPL, and GNPm, who spent 2-6 months. Most of the students spent 2-4 days a week in the studios, except for those in studios GNC and GNJm, who spent 5-7 days a week. Furthermore, most of the students spent 6-9 hours in the studios, except for those in studio GNPm. The students' opinions about the provision of adequate daylight and the experienced atmosphere in their studios are presented Figure 8-5 and Figure 8-6.

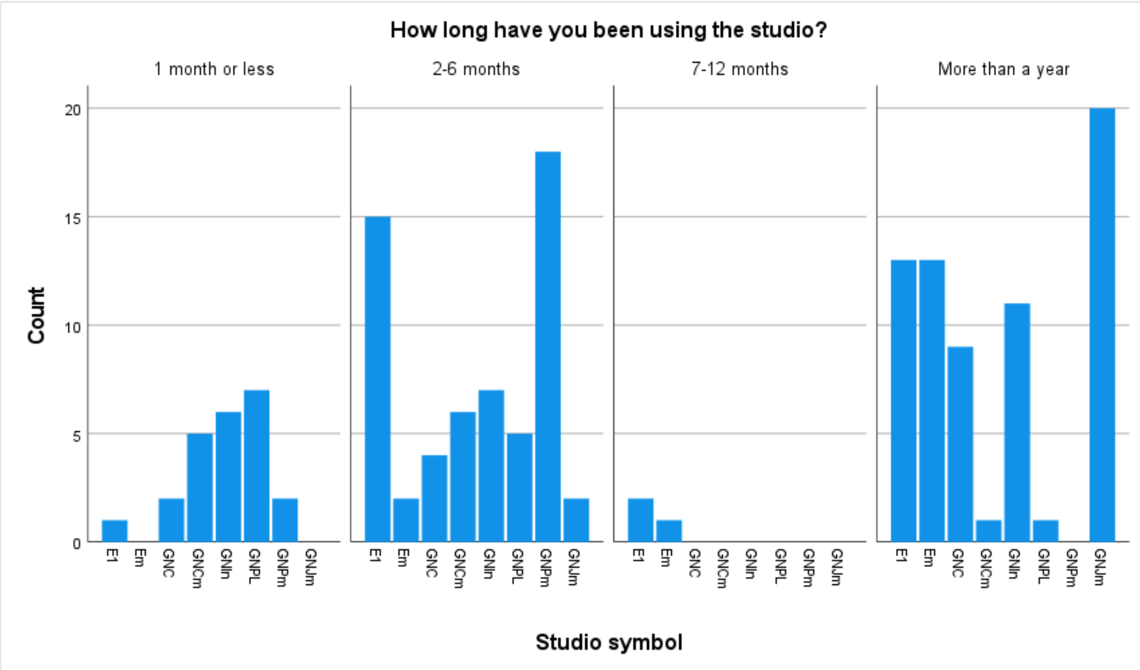


Figure 8-2 Students' responses regarding the period (in months) they have occupied their studios (Glasgow and Edinburgh).

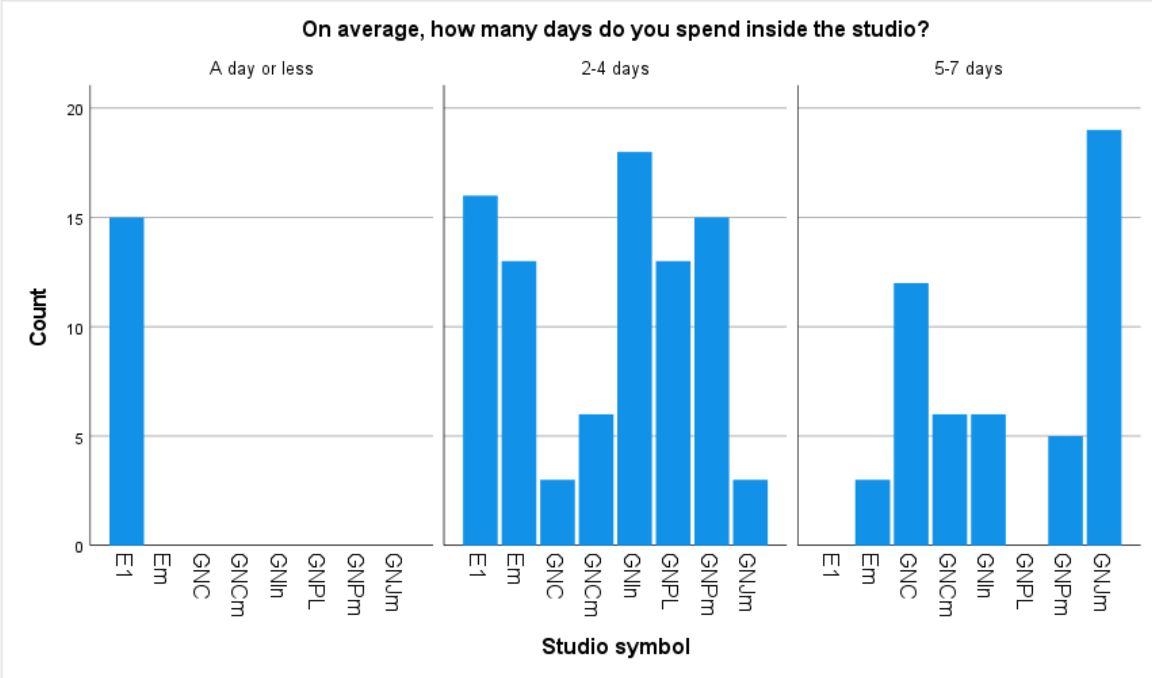


Figure 8-3 Students' responses regarding total days per week they have occupied their studios (Glasgow and Edinburgh).

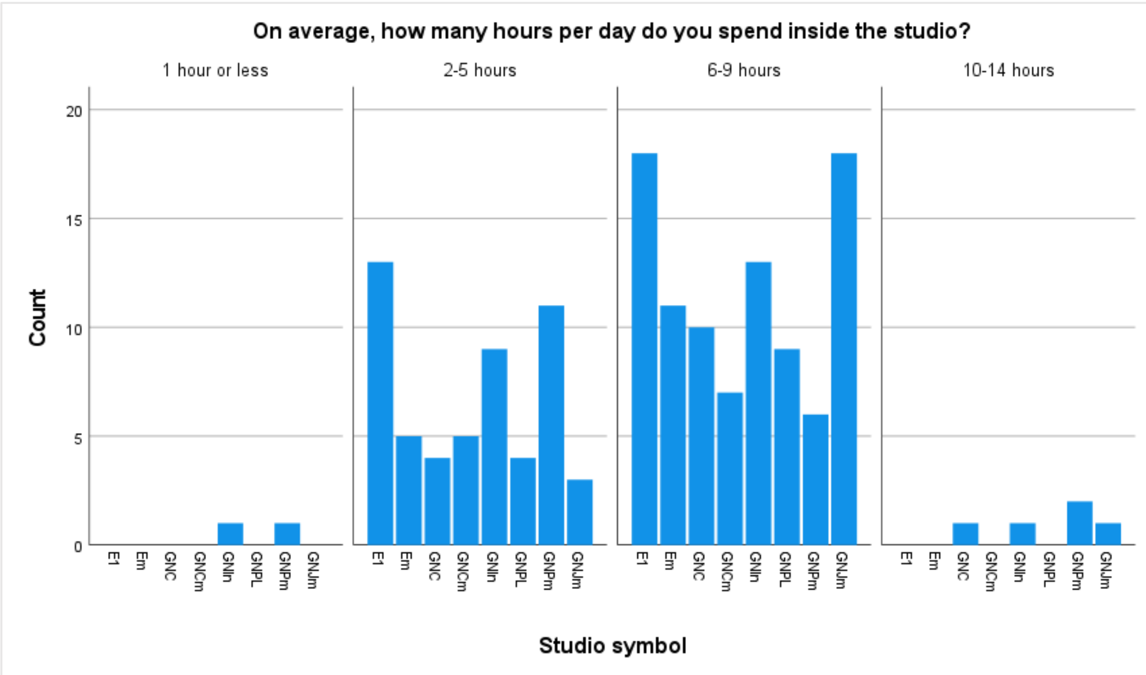


Figure 8-4 Students' responses regarding the total hours per day they occupy their studios (Glasgow and Edinburgh).

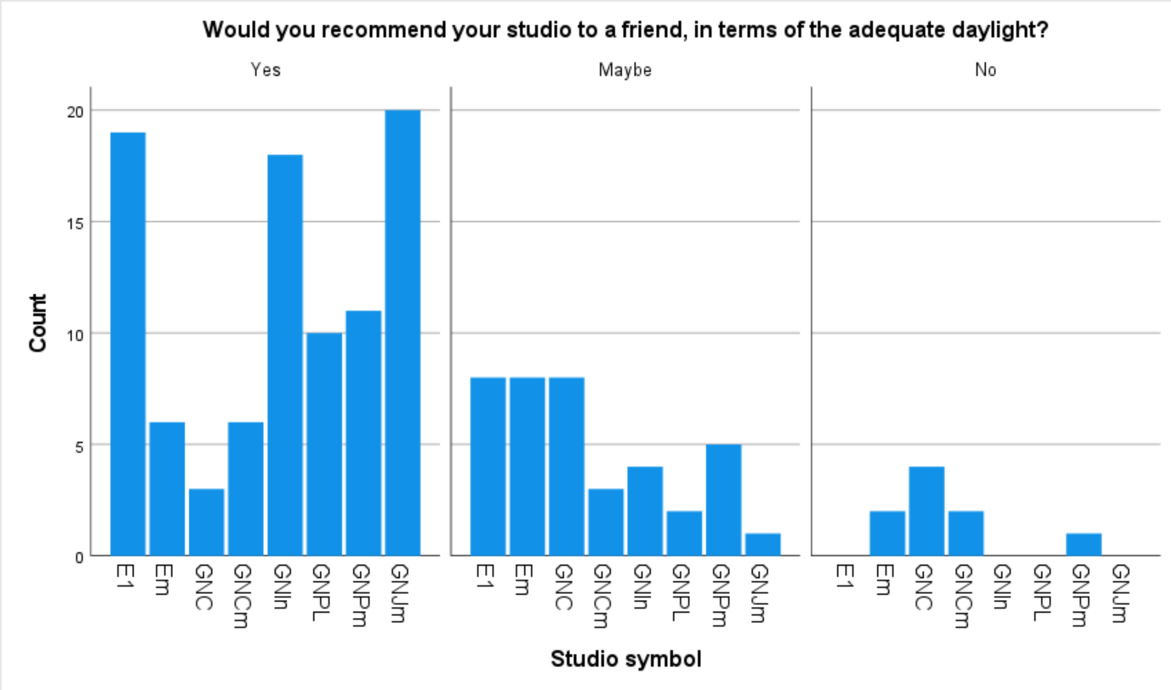


Figure 8-5 Students' opinions of their studios based on the daylight provided (Glasgow and Edinburgh).

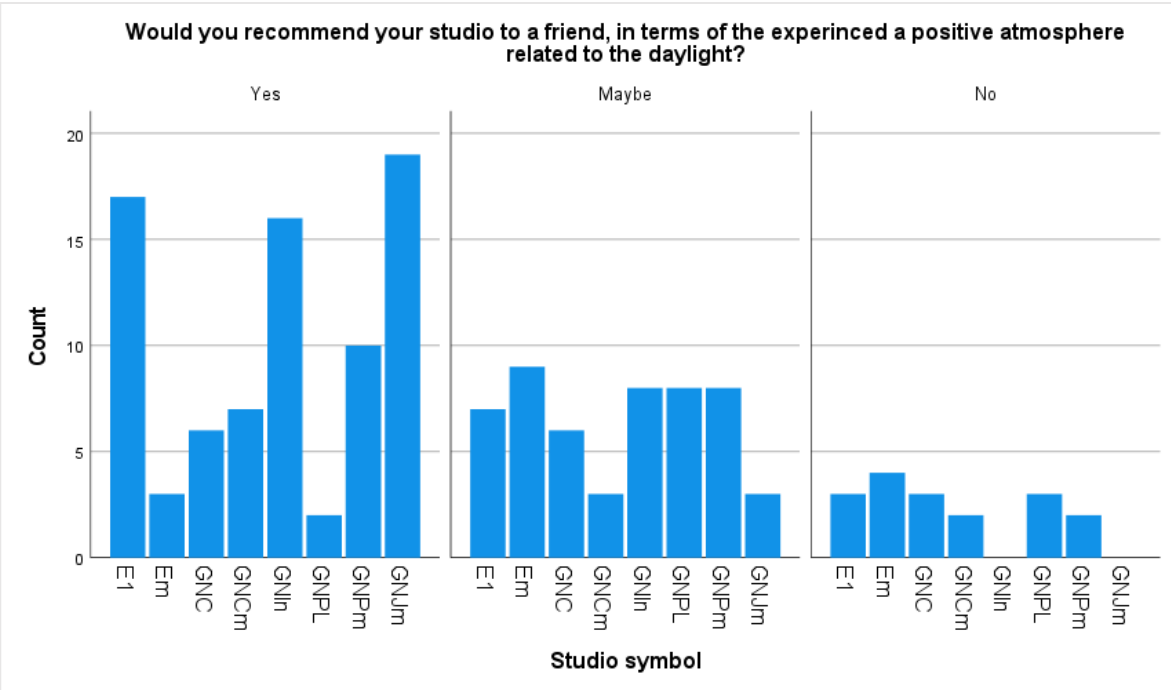


Figure 8-6 Students' opinions of their studios based on the experienced a positive atmosphere related to the daylight provided (Glasgow and Edinburgh).

8.3 Subjective responses to the effect of façade windows on daylight levels (double volume studio and mezzanine)

In this section, windows were evaluated based on whether they provide sufficient daylight levels on cloudy and bright days. Although most of the measurement points in studio E1 registered mean illuminance levels of less than 200 lux, the students' mean evaluation for the functionality of windows in providing sufficient daylight levels in the studio was rated as 'efficient' for both cloudy and bright days (Figure 8-7). However, in the mezzanine studio Em (Figure 6-2), where light measurements produced a mean of less than 200 lux, students rated the windows as 'occasionally' providing sufficient daylight levels on a cloudy day and as 'moderate' on a bright day. Within this, the Kruskal-Wallis H test revealed a statistically significant effect of window location at the double-volume level vs. mezzanine level on the students' appraisal of the daylight levels on a cloudy day (X^2 (1, N = 45) = 12.84, p = 0.000) and bright day (X^2 (1, N = 45) = 7.81, p = 0.005).

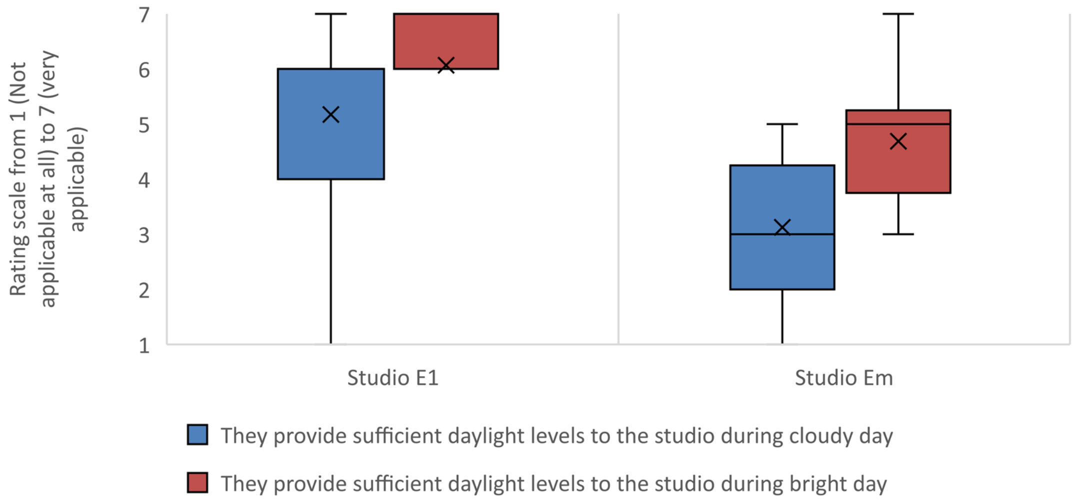


Figure 8-7 Boxplots present the variation in students' ratings in describing studios' windows based on the daylight levels in studios E1 and Em.

For studio GNC (Figure 8-8), students rated the windows as 'occasionally' providing sufficient daylight levels on cloudy days. This supported the objective measurements (illuminance levels), which registered less than 500 lux in February and October. However, although HMPs in zone 1 (uncovered by the mezzanine above) registered illuminance levels of more than 750 lux throughout the rest of the measurement period, students rated windows as being ‘moderate’ in providing sufficient daylight levels during bright days. In terms of studio GNCm, the students rated windows as being ‘moderate’ in providing sufficient daylight levels during cloudy days, and ‘efficient’ during bright days. The subjective responses support the objective daylight measurements, which were always above 750 lux in May, June, July and August. The Kruskal-Wallis H showed a statistically significant difference between the two studios (double-volume and the mezzanine) in terms of the impact of window location on students’ appraisal of daylight on cloudy days (X^2 (1, N = 27) = 6.09, p = 0.014) and bright days (X^2 (1, N = 27) = 8.25, p = 0.004).

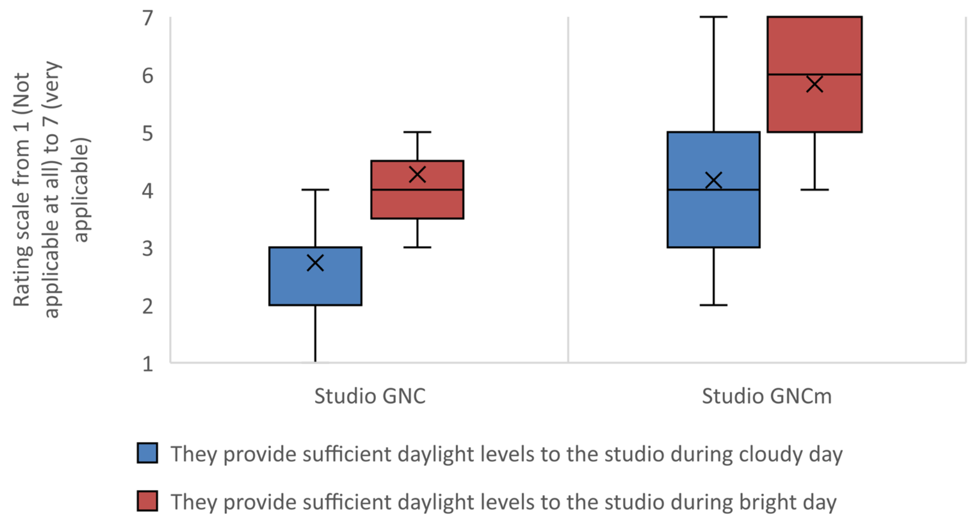


Figure 8-8 Boxplots present the variation in students' ratings in describing studios’ windows based on the daylight levels in studios GNC and GNCm.

With regards to studio GNPL (Figure 8-9), the students rated windows as ‘adequate’ in providing sufficient daylight levels during cloudy days, and ‘efficient’ on bright days. The subjective response in the current studio confirms the objective daylight measurements (illuminance levels) as they were registered as more than 750 lux throughout the measurement period. In contrast to studio GNC, the subjective responses from studio GNPL confirmed the objective one, even though the windows are located at the mezzanine studio level (GNPm). This result may be related to other factors, such as floor level and external obstructions.

In terms of studio GNPm (Figure 8-9), although the objective measurements registered more than 750 lux in June, July and September, the students' mean evaluations rated the windows as being 'efficient' in providing sufficient daylight levels during both cloudy and bright days. The Kruskal-Wallis H test revealed that there is no statistically significant effect of window location at the double-volume level (GNPL) vs mezzanine level (GNPm) on the students' evaluations of the daylight levels on cloudy (X^2 (1, N = 53) = 1.38, p = 0.23) and bright days (X^2 (1, N = 53) = 0.028, p = 0.868).

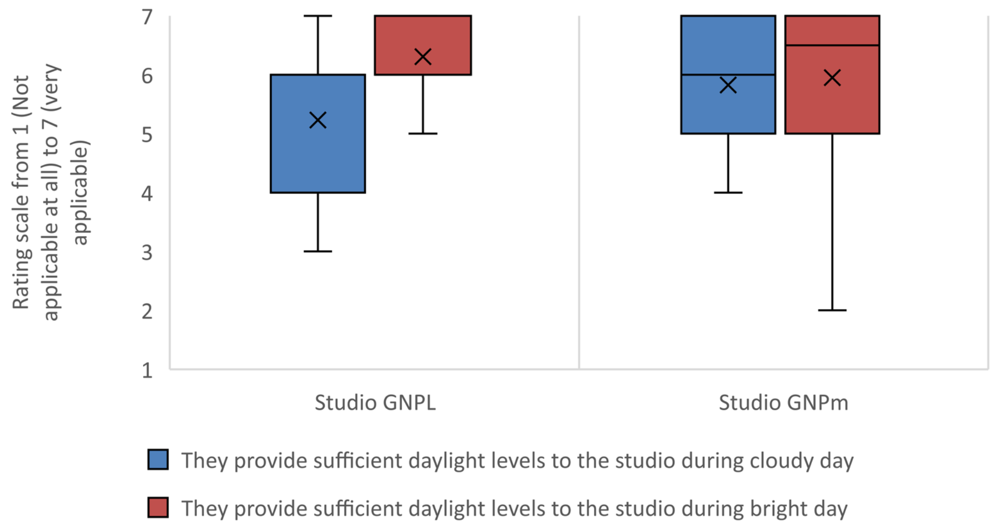


Figure 8-9 Boxplots present the variation in students' ratings in describing studios' windows based on the daylight levels in studios GNPL and GNPm.

For Studio GNIn (Figure 8-10), the students' mean evaluations rated windows as being 'efficient' in providing sufficient daylight levels during both cloudy and bright days, even though the windowsill height was 4m. The subjective responses for studio GNIn supported the objective measurements, in which illuminance levels registered more than 750 lux throughout the measurement period, except in March. In terms of studio GNJm (Figure 8-11), the students' mean evaluations rated windows as being 'efficient' in providing sufficient daylight levels during both cloudy and bright days. As such, the subjective responses support the objective measurements, in which illuminance levels registered more than 750 lux throughout the measurement period.

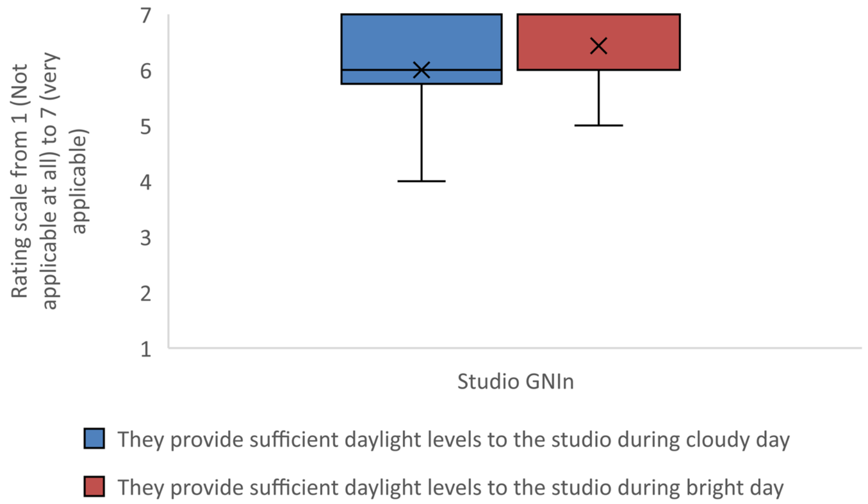


Figure 8-10 Boxplots present the variation in students' ratings in describing studios' windows based on the daylight levels in studios GNIn.

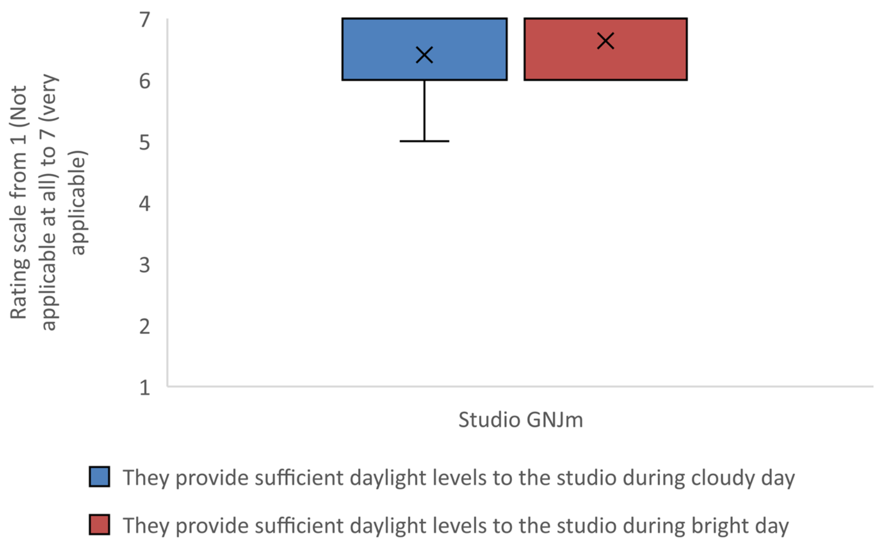


Figure 8-11 Boxplots present the variation in students' ratings in describing studios' windows based on the daylight levels in studios GNJm.

8.3.1 Subjective response to the different descriptions of façade window

The SLL code for light and lighting demonstrates that the size and proportion of windows should depend on the type of view, the size of internal space, their position and the mobility of occupants. Furthermore, the window heads should be positioned above the standing eye height, while the sills should be below the eye level of people seated. In the case of windows that are located on one wall only, the SLL code recommends that the total width of the windows should be at least 35% of the length of the wall (Raynham et al., p. 118, 2012). The guidance on the minimum window area for a satisfactory view when fenestration is restricted to one wall is reported in Table 8-5; here, higher proportions are recommended, based on the SLL code for light and lighting.

Depth of room from outside wall (max)/m	Glazed area as percentage of window wall as seen from inside (min)/%
<8	20
≥8≤11	25
>11≤14	30
>14	35

Table 8-5 Minimum glazed area for view when windows are restricted to one wall (Raynham et al., 2012).

The window information for the investigated studios in Glasgow and Edinburgh is reported in Table 8-6. Every studio has corresponded to the minimum ratio of window to wall and the ratio of window width to wall length, except for studio Em, where the students' seating level is higher than the head and sill of the windows, meaning that students have limited access to the windows and the outside view.

Studio	Depth of studio from outside wall(m)	Window-to-wall area ratio	Satisfactory view (SLL code)	Window-to-floor area ratio	Window sill height (m)	Ratio of window width to wall length (%)	Window head above the standing eye height	Window sill below the eye level while seated
E1	16 m	53.3%	✓	16%	1 m	89%	✓	✓
Em	12 m	18%	X	4%	-	-	X	✓
GNC	10 m	50%	✓	40%	4 m	100%	✓	X
GNCm	7 m	100%	✓	57%	0	100%	✓	✓
GNPL	5 m	50%	✓	50%	4 m	100%	✓	X
GNPm	11 m	100%	✓	36%	0	100%	✓	✓
GNIn	11 m	44%	✓	32%	4 m	100%	✓	X
GNJm	11 m	75%	✓	27%	1 m	100%	✓	✓

Table 8-6 Window information for Glasgow & Edinburgh studios

Students were asked from a list of descriptors to select the one that closely matches their studio windows. The list items included: windows provide sufficient daylight levels to the studio on cloudy and bright days, they provide an attractive outside view, they help to create a significant spatial experience, and they contribute positively to the studio's aesthetics and add character to the studio. These descriptions were treated as dependent variables. Likewise, the following aspects were considered as fixed factors (IVs) for the analysis: window-to-wall area ratio, window-to-floor area ratio, windowsill height, windowsill below eye level while seated, window area, design typology, external obstructions and layers of views: upper-only sky, upper (distant) sky down to the natural or man-made skyline, middle-natural or man-made objects such as fields, trees, hills and buildings, lower (close) – the foreground, for example plants and paving.

Accordingly, Kruskal-Wallis H test was used to examine the effect of the different fixed factors on the different descriptions of the studios' façade windows. The Kruskal-Wallis H test results reported in Table 8-7 revealed that that differences between studio types in terms of window-to-wall area ratio, window-to-floor area ratio, window area, external obstructions and layers of views, have yielded a significant statistical effect ($p<0.05$) on the window descriptions as viewed by the studio users. Meanwhile, the windowsill height and studio design typology were each found only to have a significant effect on providing an attractive outside view. They were not found to significantly affect ($p>0.05$) the creation of a spatial experience, contribute to the studio's aesthetics or add a character to the studio. Figure 8-12 presents boxplots of the students' variation ratings of the windows in their studios.

Factor	Window description	df	X^2	Sig.
Window-to-wall area ratio	They provide sufficient daylight levels to the studio during a cloudy day	3	32.24	**0.000**
	They provide sufficient daylight levels to the studio during a bright day	3	16.23	**0.001**
	They provide an attractive outside view	3	40.71	**0.000**
	They help to create a significant special experience	3	10.57	**0.014**
	The façade windows contribute positively to the studio's aesthetics	3	19.00	**0.000**
	They add a character to the studio	3	21.99	**0.000**
Window-to-floor area ratio	They provide sufficient daylight levels to the studio during a cloudy day	3	26.18	**0.000**
	They provide sufficient daylight levels to the studio during a bright day	3	14.49	**0.002**
	They provide an attractive outside view	3	45.15	**0.000**
	They help to create a significant special experience	3	9.56	**0.023**
	The façade windows contribute positively to the studio's aesthetics	3	15.35	**0.002**
	They add a character to the studio	3	12.47	**0.006**
Window sill height (m)	They provide sufficient daylight levels to the studio during a cloudy day	2	1.01	0.602
	They provide sufficient daylight levels to the studio during a bright day	2	0.87	0.644
	They provide an attractive outside view	2	20.71	**0.000**
	They help to create a significant special experience	2	1.26	0.531
	The façade windows contribute positively to the studio's aesthetics	2	0.76	0.682
	They add a character to the studio	2	1.61	0.447
Window sill below the eye level while seated	They provide sufficient daylight levels to the studio during a cloudy day	1	0.87	0.350
	They provide sufficient daylight levels to the studio during a bright day	1	0.66	0.414
	They provide an attractive outside view	1	20.62	**0.000**
	They help to create a significant special experience	1	0.17	0.677
	The façade windows contribute positively to the studio's aesthetics	1	0.68	0.410
	They add a character to the studio	1	0.23	0.630
	They provide sufficient daylight levels to the studio during a cloudy day	3	33.36	**0.000**

Window area	They provide sufficient daylight levels to the studio during a bright day	3	15.36	**0.002**
	They provide an attractive outside view	3	25.40	**0.000**
	They help to create a significant special experience	3	9.36	**0.025**
	The façade windows contribute positively to the studio's aesthetics	3	12.17	**0.007**
	They add a character to the studio	3	15.54	**0.001**
Design typology (double-volume vs. mezzanine)	They provide sufficient daylight levels to the studio during a cloudy day	1	0.85	0.35
	They provide sufficient daylight levels to the studio during a bright day	1	0.05	0.812
	They provide an attractive outside view	1	11.45	**0.001**
	They help to create a significant special experience	1	0.21	0.646
	The façade windows contribute positively to the studio's aesthetics	1	0.61	0.432
	They add a character to the studio	1	0.25	0.612
External obstructions	They provide sufficient daylight levels to the studio during a cloudy day	1	41.17	**0.000**
	They provide sufficient daylight levels to the studio during a bright day	1	16.68	**0.000**
	They provide an attractive outside view	1	21.08	**0.000**
	They help to create a significant special experience	1	10.04	**0.002**
	The façade windows contribute positively to the studio's aesthetics	1	6.67	**0.010**
	They add a character to the studio	1	6.07	**0.014**
Layers of views	They provide sufficient daylight levels to the studio during a cloudy day	3	56.96	**0.000**
	They provide sufficient daylight levels to the studio during a bright day	3	33.75	**0.000**
	They provide an attractive outside view	3	55.68	**0.000**
	They help to create a significant special experience	3	12.62	**0.006**
	The façade windows contribute positively to the studio's aesthetics	3	15.46	**0.001**
	They add a character to the studio	3	9.23	**0.026**

Table 8-7 Kruskal-Wallis H results for the effect of various window characteristics, design typology, external obstructions and view layers on different window descriptions (*N*=171).

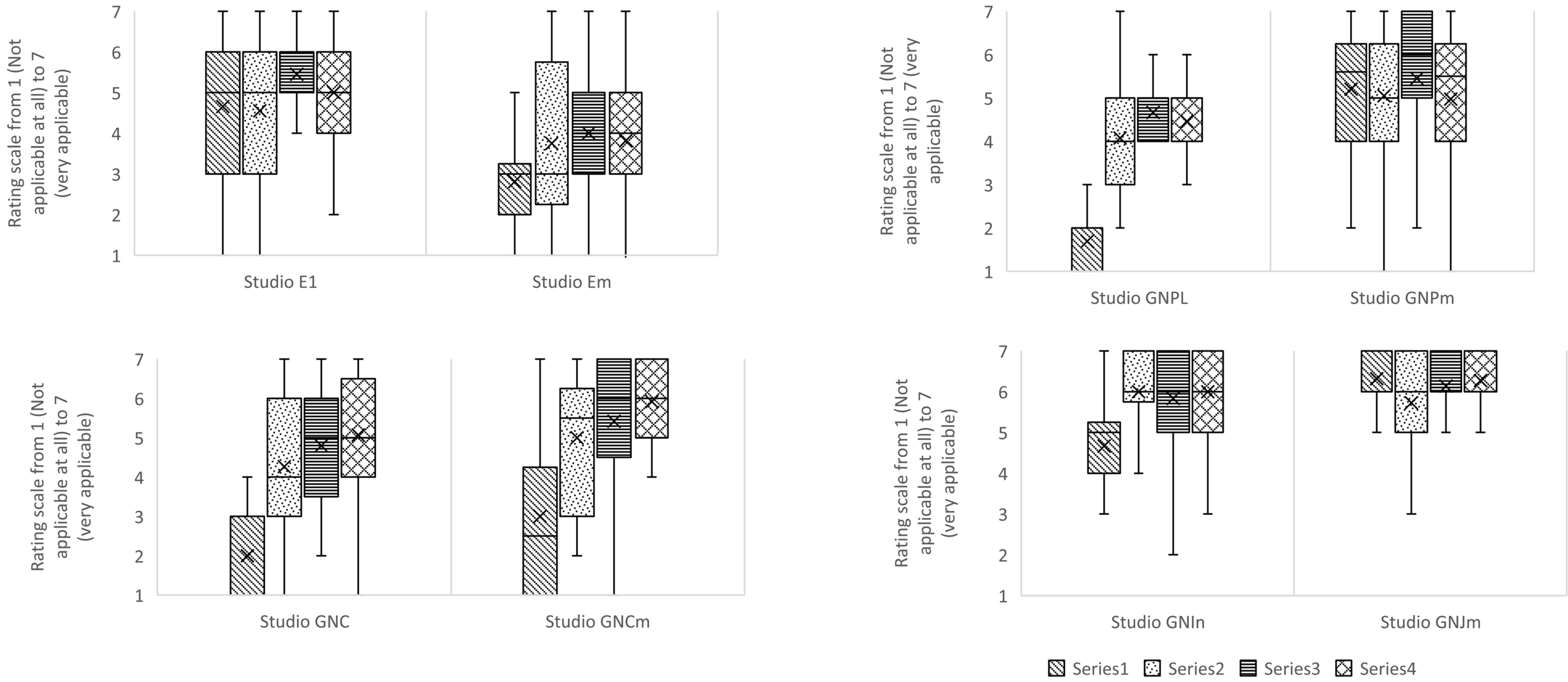


Figure 8-12 Boxplots of students' variation ratings on windows in their studios, Glasgow and Edinburgh.

Series1: Windows provide an attractive outside view. Series 2: Windows help to create a significant spatial experience. Series3: The façade windows contribute positively to the studio's aesthetics. Series 4: Windows add a character to the studio.

8.3.2 **Subjective preferences on window arrangements (double-volume vs mezzanine)**

In the previous section, students were asked to rate the functionality of the windows in their studios in terms of whether they provide sufficient daylight levels during cloudy and bright days. This section now investigates the subjective preferences within the practical scenario, whereby students were asked to choose the window arrangement that they thought would best utilise the daylight in their studio. As the students occupied two different studio typologies (double-volume studios and mezzanine studios), the Kruskal-Wallis H test revealed no statistically significant effect of the studio design typology on the students' preferences of a particular window arrangement (X^2 (1, *N* = 171) = 1.74, p = 0.187). Figure 8-13 presents the variation in preferred window arrangement between the two design typologies.

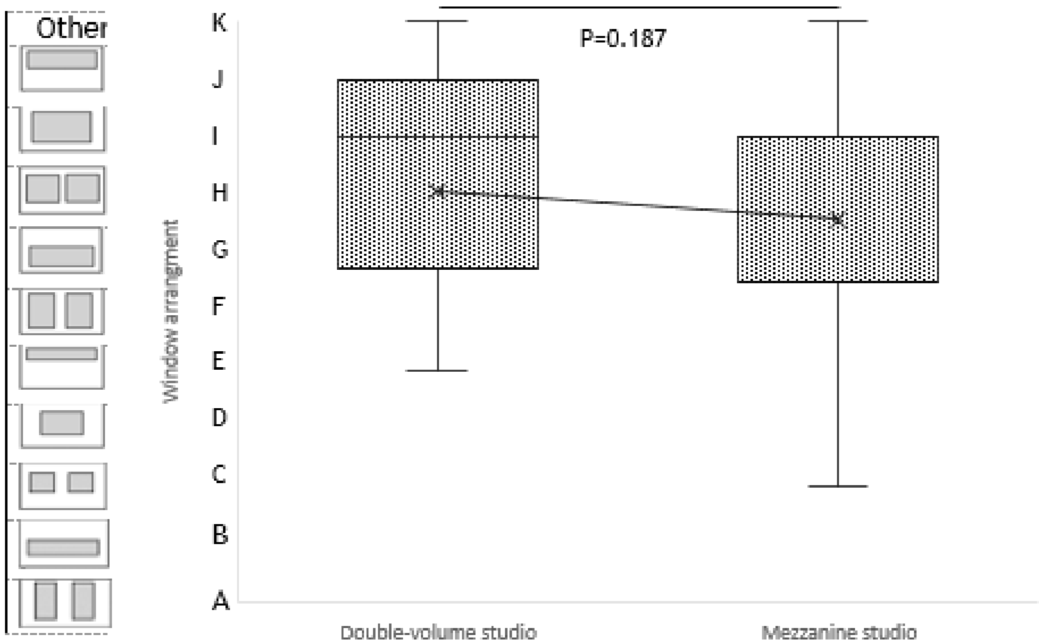


Figure 8-13 Boxplot presents the variation in choices of preferred window arrangements between students located in the two studios' design typologies: double-volume vs mezzanine, Glasgow and Edinburgh.

In terms of the preferred window arrangement, the findings demonstrate that most students, whether they were located in the double-volume studio or mezzanine studio, chose type I as the window arrangement that would make the most of the daylight in their studios. The percentage of students' choices for the window arrangement that would make the most of the daylight in their studio is reported in Table 8-8.

The results on the preferred window arrangement were compared with the current façade window in each studio. The Wilcoxon Signed-Rank test was used to examine if there is a statistically significant difference in students' choices between the existing window design and the preferred window arrangement. In all other studios, the Wilcoxon test computed a significant difference between the preferred window arrangement (type I) and the existing studio's windows in studio E1: ($z = -3.12$, $p = 0.002$), studio Em: ($z = -3.42$, $p = 0.001$), studio GNC: ($z = -2.57$, $p = 0.010$), studio GNCm ($z = -2.30$, $p = 0.021$), studio GNPL: ($z = -2.98$, $p = 0.003$), studio GNPm: ($z = -3.61$, $p = 0.000$), studio GNIn: ($z = -4.02$, $p = 0.000$) and studio GNJm: ($z = -2.02$, $p = 0.043$).

Although students evaluated the currents windows as being efficient in providing sufficient daylight levels in studios E1, GNCm, GNPL, GNPm, GNIn and GNJm, the students tended to prefer the type I window arrangement. The variation of students' preferences for window arrangements that would make the most of the daylight in their studios is presented in Figure 8-14.

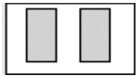
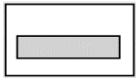
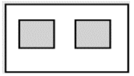
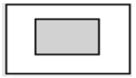
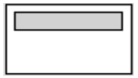
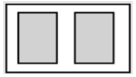
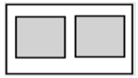
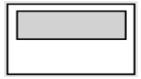
Studio	Suggested window arrangements										
	A 	B 	C 	D 	E 	F 	G 	H 	I 	J 	K Other:
E1	3.4%	-	-	-	-	13.8%	-	17.2%	**44.8%**	13.8%	3.4%
Em	-	-	-	-	12.5%	18.8%	-	12.5%	**31.3%**	18.8%	6.3%
GNC	6.7%	-	-	-	-	13.3%	-	-	**46.7%**	13.3%	13.3%
GNCm	-	-	8.3%	-	-	8.3%	-	-	**50%**	25%	8.3%
GNPL	-	7.7%	-	-	-	7.7%	15.4%	-	**46.2%**	15.4%	-
GNPm	-	-	-	-	-	22.5%	5%	5%	**30%**	17.5%	20%
GNIn	-	-	-	-	4.2%	12.5%	-	-	**50%**	16.7%	-
GNJm	-	-	-	-	-	-	-	-	**59.1%**	9.1%	4.5%

Table 8-8 Percentage of students' choices for the window arrangement that would make the most of the daylight in their studio, Glasgow and Edinburgh.

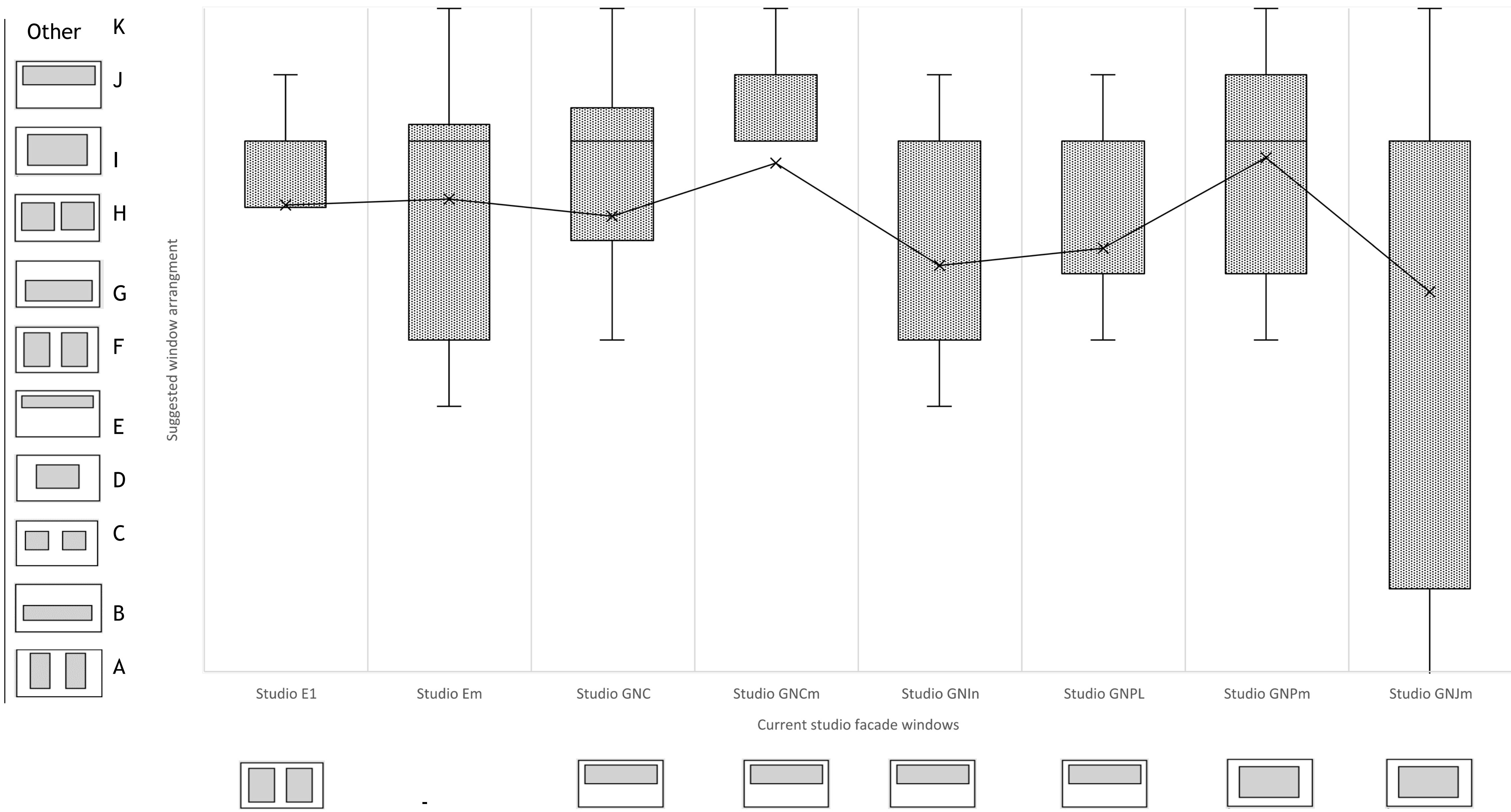


Figure 8-14 Boxplot presents the variation of students' preferences for window arrangements that would make the most of the daylight in their studio

8.4 Subjective responses to the effect of façade windows on experienced atmosphere (double-volume vs mezzanine)

As defined in the literature review, atmosphere is the first impression that a person perceives from their surrounding environment to internal sensation, so affecting our experience of a space. With regards to whether the interior spaces could have sensorial stimuli, from all studios, 55.6% of occupants answered maybe, 39.2% answered yes and 4.7% answered no. This suggests that the topic of sensorial stimuli is not yet familiar to most of the participants. However, for each of the considered studios, 77.2% of the responses acknowledged an awareness of the concept of atmosphere in architectural spaces, while 22.8% answered that the concept was unfamiliar. The high percentage of students that had an awareness of the concept came from them studying subjects related to interior design. Consequently, their opinions will not have come from them being occupants of the studio, but rather from their educational perspective in design, experiences and design cognition. These factors have been highlighted before in different subjects of architecture, such as in a study by Hanna (2013), which examined the correlation between years of experience with creativity parameters and design tools. In addition, a thesis by Gifford (1975) examined the influence of personal and situational factors in judgments of typical architecture, by dividing them into personal, external, stable and transitory factors and questioning the extent to which a variety of factors related to the description and evaluation of building characteristics. One significant finding revealed that participants with more education seem to be more critical in the overall evaluation of buildings.

This study's analysis of subjective responses to the experienced atmosphere began by asking students whether they perceived the following variables to be positive or negative stimuli within their studios: daylight (cloudy days and bright days); artificial light; temperature (winter and summer); acoustics; air quality; furniture arrangements and proximity; spaciousness; façade windows and overlooking view.

The internal consistency between the different variables was checked by Cronbach's alpha reliability test, in which the reliability coefficient is 0.811, showing considerable internal consistency between variables. From Appendix S. 1 it is evident that the correlation between the façade windows and daylight on a cloudy day has a significantly weak relationship ($r = .253$, $P<0.01$). However, the façade windows have a significantly moderate relationship with spaciousness ($r = .480$, $P<0.01$) and overlooking view ($r = .531$, $P<0.01$). The relationship between spaciousness and furniture arrangements has the highest significant correlation ($r = .663$, $P<0.01$) among the other variables. Variables with a correlation greater than .30 were considered in the factor analysis, as anything lower would suggest a weak relationship between variables (Tabachnick & Fidell, 2007, p. 614). To identify which variables contribute most to the perceived atmosphere, factor analysis was used to determine and describe the factors' variabilities and correlations. The results are reported in Table 8-9.

The factor analysis compiled the 12 variables that contribute to the experienced atmosphere and identified 4 independent factors which in total was responsible for 65.86% of the variance. Regarding the consistency between variables in each factor, the values for the reliability coefficient (Cronbach's alpha) for the first factor were considerable at 0.821. The obtained factors are as following:

- 1st factor: this factor includes *Spaciousness - furniture arrangements* as most stimuli contribute to the perceived atmosphere. Variables like 'furniture proximity', 'daylight on cloudy and bright days', 'artificial light', 'temperature in summer', 'acoustics', 'air quality', 'façade windows' and 'overlooking view' are most significant to this factor. This factor explains 34.5% of the variance.

- 2nd factor: represents *Daylight on cloudy and bright days*. A variable like 'temperature in winter' contributes to it, while 'air quality' and 'furniture arrangements and proximity' negatively correlate to this factor. This factor explains 12.16% of the variance.

- 3rd factor: reflects *Temperature in summer- daylight on a bright day*. The variables ‘façade windows’ and ‘overlooking view’ have a negative correlation. This factor explains 10.46% of the variance.

- 4th factor: includes *Temperature in winter* and the variable ‘daylight on a bright day’ has a negative correlation. This factor explains 8.65% of the variance.

	Factors			
Variable (stimuli)	1	2	3	4
Daylight on cloudy day	.443	.668	-	-
Daylight on bright day	.323	.472	.435	-.519
Artificial light	.306	-	-	-
Temperature in winter	-	.418	-	.757
Temperature in summer	.523	-	.579	-
Acoustics	.697	-	-	-
Air quality	.634	-.436	-	-
Furniture arrangements	.816	-.329	-	-
Furniture proximity	.770	-.301	-	-
Spaciousness	.831	-	-	-
Façade windows	.568	-	-.520	-
Overlooking view	.499	-	-.618	-
% Variance	34.5%	12.16%	10.46%	8.65%
Cronbach’s alpha	.821	.657	.530	.098

Table 8-9 Factor Matrix

Consequently, it is clear that most of the assumed variables (stimuli) contribute considerably to the studios’ atmosphere, as suggested by the first factor. The Kruskal-Wallis H test examines the effect of various characteristics related to the façade windows, such as window-to-wall area ratio and windowsill height, on stimuli related in the studios. The results in Table 8-10 reveal that window-to-wall area ratio and studios’ design typology, each have a statistically significant effect ($p<0.05$) on whether the façade windows are perceived as positive or negative stimuli. Meanwhile, window-to-wall area ratio, window-to-floor area ratio, window area, design typology, external obstructions and layers of views each have a statistically significant effect ($p<0.05$) on whether daylight is perceived as a positive or negative stimuli.

Factor	Stimuli in studio	df	X^2	Sig.
Window-to-wall area ratio%	Daylight on a cloudy day	3	13.85	**.003**
	Daylight on a bright day	3	10.83	**.013**
	Artificial light	3	1.055	.788
	Temperature in winter	3	3.91	.271
	Temperature in summer	3	13.19	**.004**
	Acoustics	3	4.20	.241
	Air quality	3	5.26	.153
	Furniture arrangements	3	1.11	.772
	Furniture proximity	3	3.42	.330
	Spaciousness	3	4.37	.224
	Façade windows	3	8.10	**.044**
	Overlooking view	3	25.84	**.000**
Window-to-floor area ratio %	Daylight on a cloudy day	3	5.05	.168
	Daylight on a bright day	3	8.56	**.036**
	Artificial light	3	6.96	.073
	Temperature in winter	3	6.70	.082
	Temperature in summer	3	9.58	**.022**
	Acoustics	3	6.33	.096
	Air quality	3	3.00	.391
	Furniture arrangements	3	5.62	.132
	Furniture proximity	3	12.18	**.007**
	Spaciousness	3	9.71	**.021**
	Façade windows	3	2.53	.469
	Overlooking view	3	16.77	**.001**
Windowsill height (m)	Daylight on a cloudy day	2	4.18	.124
	Daylight on a bright day	2	2.45	.293
	Artificial light	2	10.85	**.004**
	Temperature in winter	2	6.05	**.048**
	Temperature in summer	2	7.66	**.022**
	Acoustics	2	3.98	.136

	Air quality	2	4.83	.089
	Furniture arrangements	2	4.98	.083
	Furniture proximity	2	8.59	**.014**
	Spaciousness	2	5.59	.061
	Façade windows	2	4.44	.108
	Overlooking view	2	10.97	**.004**
Window sill below the eye level while seated	Daylight on a cloudy day	1	1.31	.251
	Daylight on a bright day	1	.005	.945
	Artificial light	1	7.92	**.005**
	Temperature in winter	1	1.72	.189
	Temperature in summer	1	1.62	.202
	Acoustics	1	.103	.749
	Air quality	1	.093	.760
	Furniture arrangements	1	2.09	.148
	Furniture proximity	1	4.45	**.035**
	Spaciousness	1	1.89	.168
	Façade windows	1	1.92	.166
	Overlooking view	1	9.13	**.003**
Window area	Daylight on a cloudy day	3	13.31	**.004**
	Daylight on a bright day	3	2.55	.465
	Artificial light	3	14.86	**.002**
	Temperature in winter	3	9.44	**.024**
	Temperature in summer	3	14.74	**.002**
	Acoustics	3	6.14	.105
	Air quality	3	5.10	.164
	Furniture arrangements	3	4.49	.213
	Furniture proximity	3	7.51	.057
	Spaciousness	3	5.58	.134
	Façade windows	3	2.10	.551
	Overlooking view	3	13.43	**.004**
Design typology (double-volume vs. mezzanine)	Daylight on a cloudy day	1	4.05	**.044**
	Daylight on a bright day	1	1.37	.241
	Artificial light	1	.539	.463
	Temperature in winter	1	.336	.562

	Temperature in summer	1	7.02	**.008**
	Acoustics	1	1.41	.234
	Air quality	1	1.82	.177
	Furniture arrangements	1	.045	.832
	Furniture proximity	1	.000	.991
	Spaciousness	1	.175	.675
	Façade windows	1	4.43	**.035**
	Overlooking view	1	9.48	**.002**
External obstructions	Daylight on a cloudy day	1	4.37	**.037**
	Daylight on a bright day	1	1.83	.176
	Artificial light	1	.130	.718
	Temperature in winter	1	3.43	.064
	Temperature in summer	1	12.58	**.000**
	Acoustics	1	.035	.851
	Air quality	1	1.90	.168
	Furniture arrangements	1	1.61	.204
	Furniture proximity	1	1.09	.295
	Spaciousness	1	.762	.383
	Façade windows	1	2.66	.103
	Overlooking view	1	12.19	**.000**
Layers of views	Daylight on a cloudy day	3	11.71	**.008**
	Daylight on a bright day	3	1.87	.599
	Artificial light	3	5.08	.165
	Temperature in winter	3	6.38	.094
	Temperature in summer	3	19.28	**.000**
	Acoustics	3	6.61	.085
	Air quality	3	8.90	**.031**
	Furniture arrangements	3	6.01	.111
	Furniture proximity	3	4.67	.197
	Spaciousness	3	5.52	.137
	Façade windows	3	5.47	.140
	Overlooking view	3	26.46	**.000**

Table 8-10 Kruskal-Wallis H results for the effect of various façade window characters, design typology, external obstructions and view layers on stimuli in Glasgow and Edinburgh studios (N= 171).

8.4.1 **Subjective evaluation of the atmospheric stimuli between studios**

From the previous analysis, it was found that the studio design typology has a statistically significant effect ($P<0.05$) on façade windows, daylight on a cloudy day and whether the overlooking view is considered to be negative or positive stimuli. Meanwhile, the Kruskal-Wallis H results revealed that the differences between the studios have a statistically significant effect on daylight on a cloudy day (X^2 (7, N = 171) = 16.70, p = 0.019), on a bright day (X^2 (7, N = 171) = 14.18, p = 0.048), the façade windows (X^2 (7, N = 171) = 17.59, p = 0.014), and whether the overlooking view (X^2 (7, N = 171) = 38.02, p = 0.000) is considered to be positive or negative stimuli. The variation of subjective responses between the studios in terms of evaluating daylight (on cloudy days and bright days), façade windows and whether the overlooking view is perceived as negative or positive stimuli is presented in Figure 8-15, Figure 8-16, Figure 8-17 and Figure 8-18.

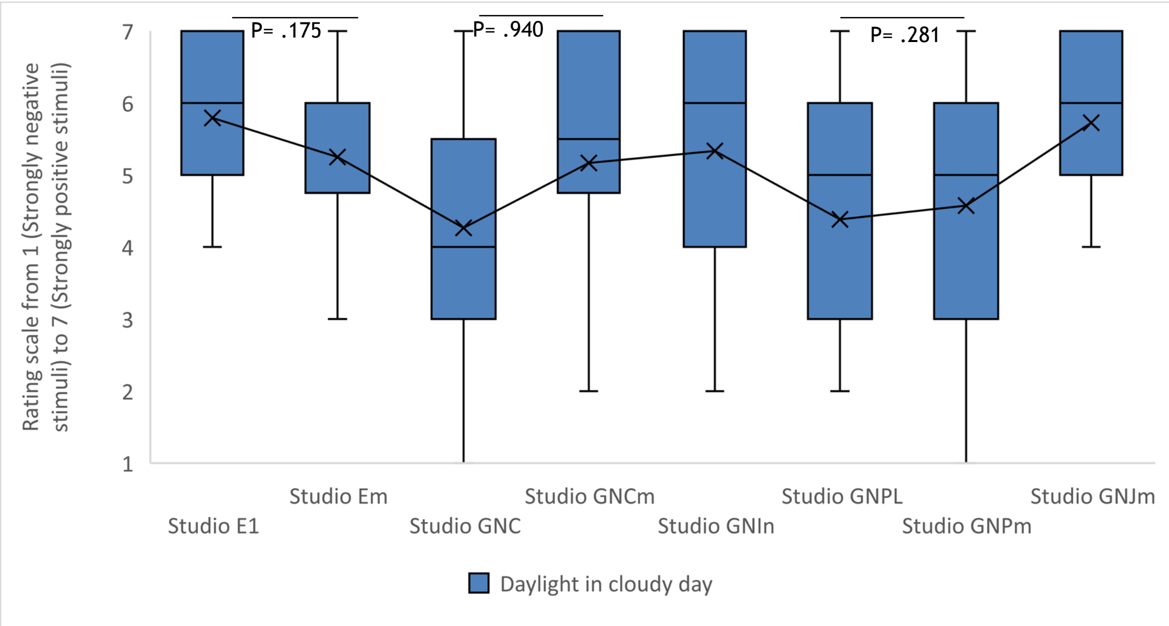


Figure 8-15 Boxplot representing the variation in subjective responses between studios in evaluating daylight on cloudy days as negative or positive stimuli.

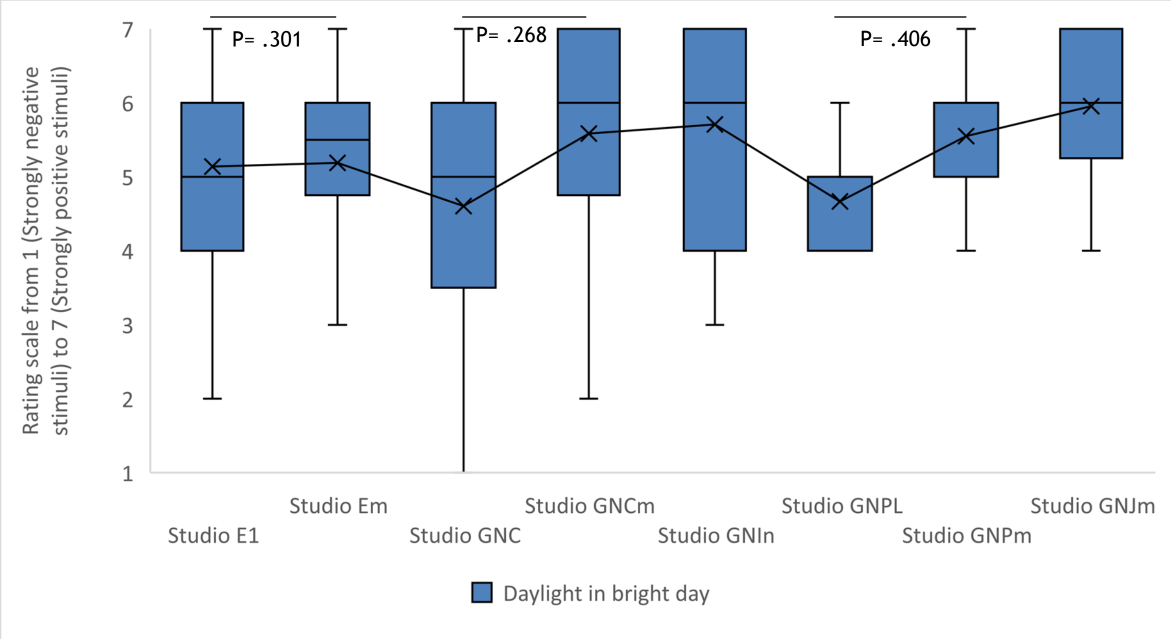


Figure 8-16 Boxplot representing the variation in subjective responses between studios in evaluating daylight on bright days as negative or positive stimuli.

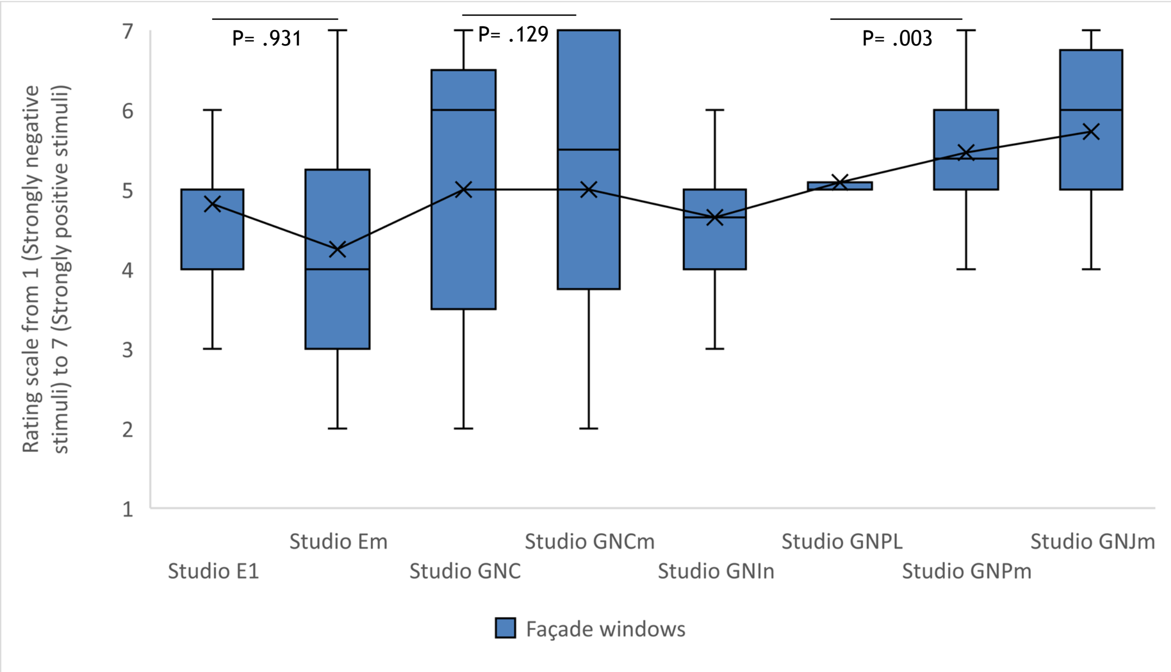


Figure 8-17 Boxplot representing the variation in subjective responses between studios in evaluating façade windows as negative or positive stimuli.

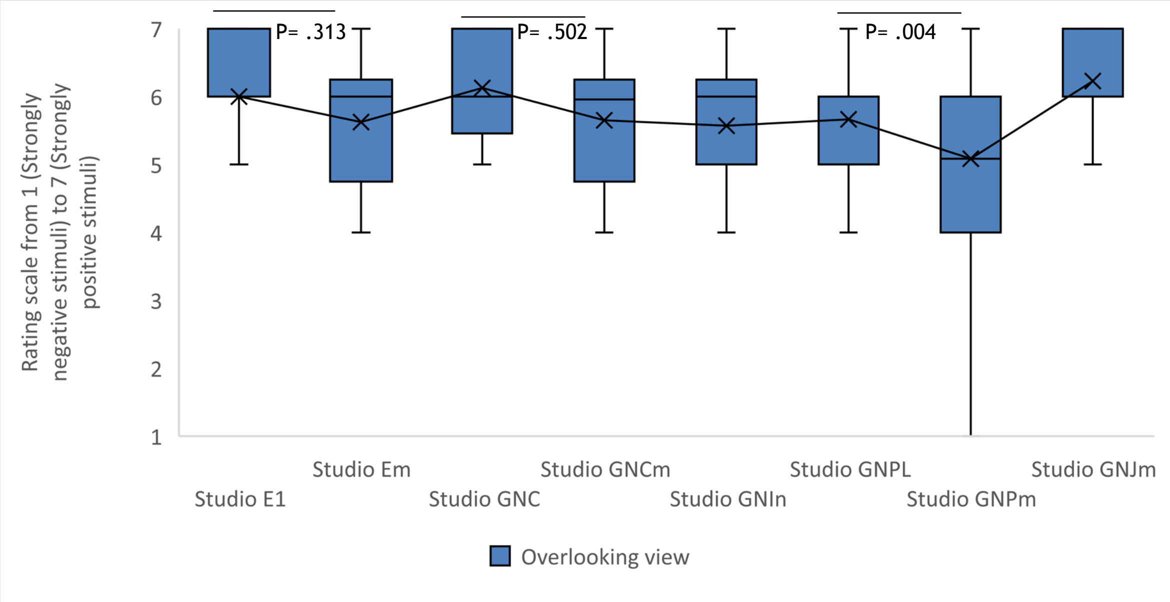


Figure 8-18 **Boxplot representing the variation in subjective responses between studios in evaluating overlooking view as negative or positive stimuli.**

8.4.2 State of atmosphere

It was claimed in the literature review that: 'atmospheres are quasi-objective or something existing intersubjectively that can be produced and contributed to by different aspects, particularly by light and sound, but also by objects, materials and the geometry of a room' (Böhme, 2017, p. 6). A concept confirmed as well by Vogels (2008), who describes atmosphere as: 'the experience of the surrounding environment in relation to ourselves, which takes place through the perception of external elements and internal sensations' (Vogels, 2008, p. 25).

The procedure for investigating the state of the atmosphere inside the studios from a subjective perspective utilised two methods: the semantic differential (SD) scale to describe the state of atmosphere and the Likert scale to evaluate the experienced atmosphere. These terms are both explained in the methodology chapter, in which they considered that they would present dimensions that describe meaningful and valid interpretation for perceiving an environment. For the SD rating scale, students were asked to select the best word to describe the state of the atmosphere in their studios from sixteen pairs of adjectives: Business-like - Cosy, Formal - Intimate, Dull - Stimulating, Terrifying - Pleasant, Dispirited - Lively, Tense - Relaxed, Public - Private, Boring - Exciting, Unattractive - Attractive, Inconvenient - Convenient, Passive - Active, Hostile -

Friendly, Unsociable – Sociable, Monotonous – Interesting, Dislike – Like and Frustrating – Satisfying. The mean rating on each atmosphere descriptor in each studio is shown in Table 8-11. The Kruskal-Wallis H test results highlighted some statistically significant differences between the studios in rating the various states of atmosphere. Figure 8-19 and Figure 8-20 present a comparison of the mean semantic differential ranking scales between the double-volume studios and mezzanine studios.

State	Mean values in each studio								Differences between studios (Kruskal-Wallis H)
	E1	Em	GNC	GNCm	GNPL	GNPm	GNIn	GNJm	.Sig
Business-like - Cosy	3.76	3.56	3.13	4.00	3.92	4.73	3.75	4.45	**.002**
Formal - Intimate	4.07	3.44	4.20	4.25	4.77	4.82	4.33	4.59	**.039**
Dull - Stimulating	4.55	3.88	3.67	5.00	3.38	4.33	4.50	5.00	**.004**
Terrifying - Pleasant	4.83	4.81	4.87	5.58	5.08	4.93	5.17	5.86	**.039**
Dispirited - Lively	4.66	4.50	4.73	5.08	4.77	4.70	4.46	5.82	**.037**
Tense - Relaxed	4.59	3.94	4.33	5.42	4.69	4.75	4.79	4.77	.121
Public - Private	3.69	3.56	3.93	4.33	3.23	3.97	3.88	4.32	.586
Boring - Exciting,	4.24	3.62	4.67	4.50	4.15	4.00	4.29	5.32	**.011**
Unattractive - Attractive	4.21	3.75	4.27	5.00	4.08	4.18	4.63	5.64	**.000**
Inconvenient - Convenient	5.03	5.74	4.06	5.50	4.15	4.15	4.54	5.68	**.000**
Passive - Active	4.86	4.75	4.47	4.50	4.77	4.58	4.79	5.73	.126
Hostile - Friendly	5.31	5.31	5.00	5.25	5.62	5.18	5.04	5.77	.465
Unsociable - Sociable	5.82	5.49	4.93	5.33	5.84	4.97	5.52	6.54	**.000**
Monotonous - Interesting	4.24	3.75	4.33	4.75	3.77	4.20	5.08	5.82	**.001**
Dislike - Like	5.28	4.75	5.00	5.58	4.69	4.75	5.38	6.27	**.000**
Frustrating - Satisfying	4.72	4.44	4.33	5.00	4.38	4.60	4.75	5.32	.295

Table 8-11 Mean comparative ratings for the investigated studios

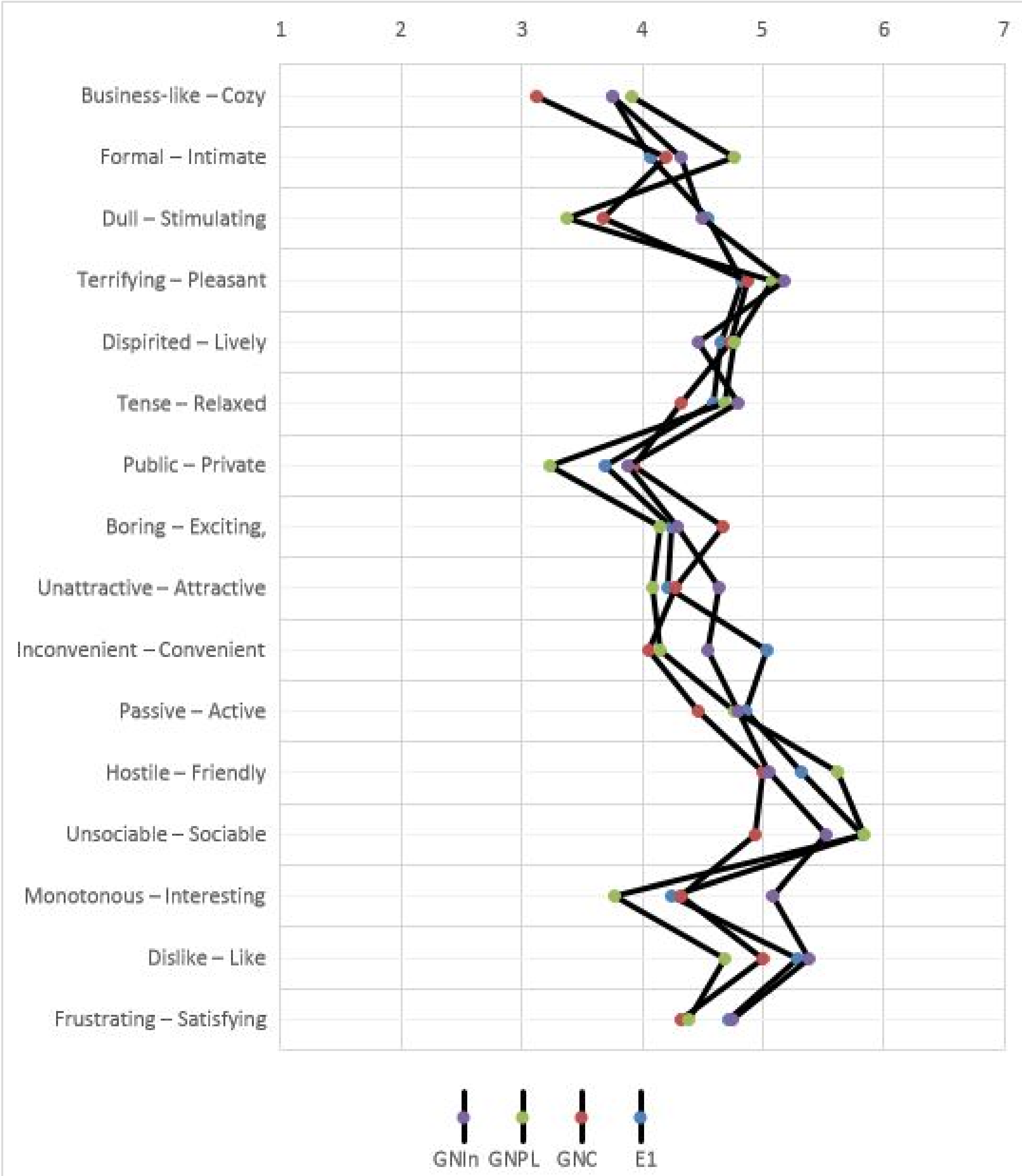


Figure 8-19 Comparison of mean semantic differential ranking scale between double-volume studios: GNIn, GNPL, GNC and E1

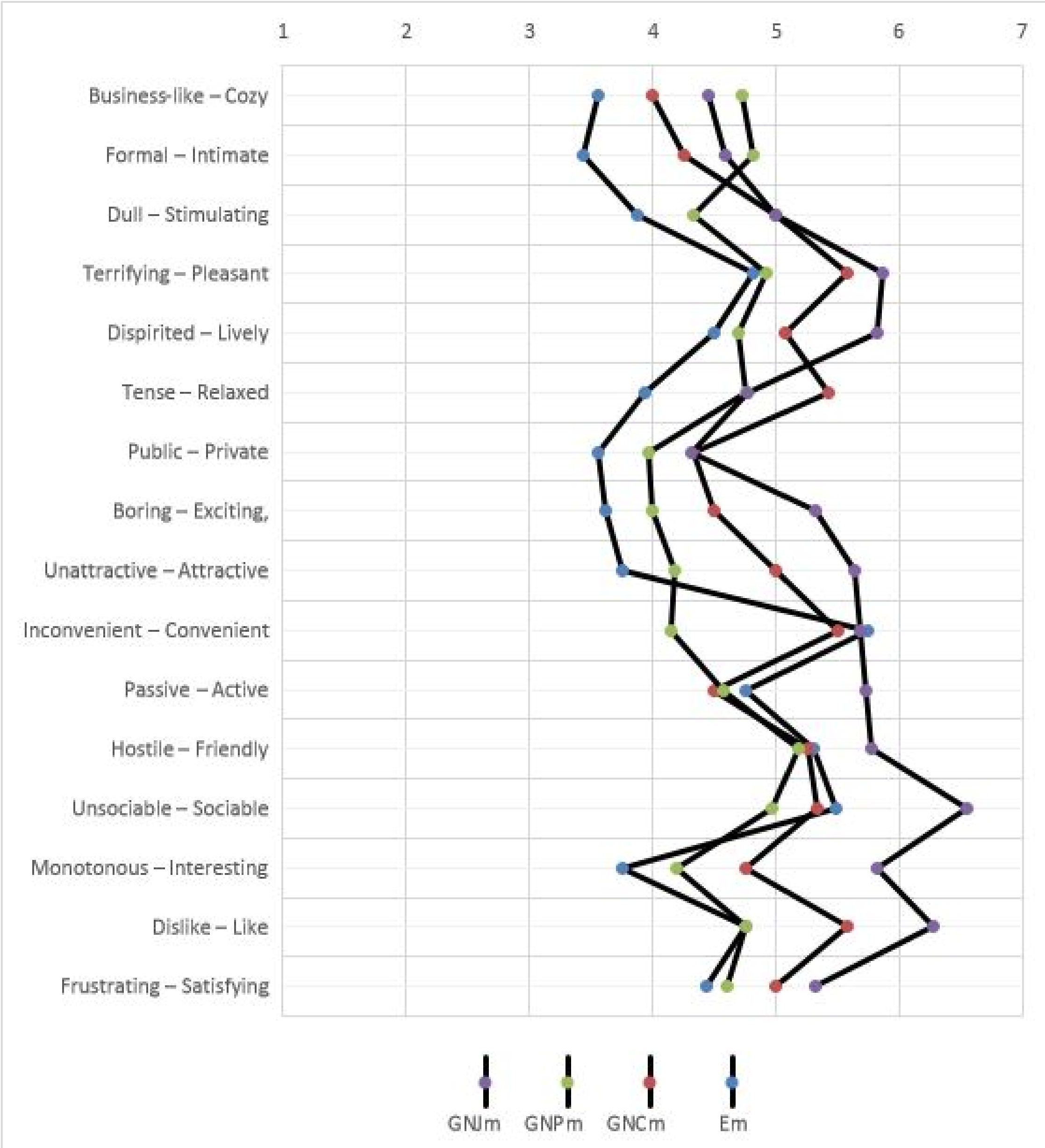


Figure 8-20 Comparison of mean semantic differential ranking scale between mezzanine studios: GNJm, GNPm, GNCm and Em.

8.4.2.1 **Effect of façade windows characteristics (North-facing) on atmospheric states**

Factor analysis was used to determine and describe the factors' variabilities and correlations. The three identified factors were responsible for 62.43% of the variance and Cronbach's alpha reliability test showed considerable internal consistency between the different descriptors, in which the reliability coefficient is 0.914. The results are reported in Table 8-12 and the obtained factors are as following:

- 1st factor: this factor includes *Dislike-like* as the best descriptor for the state of atmosphere. Most variables that contribute to this factor are: 'unattractive-attractive ', 'business-like - cosy', 'formal - intimate', 'dull - stimulating', 'terrifying - pleasant', 'dispirited - lively', 'tense - relaxed', 'public - private', 'boring - exciting', 'inconvenient - convenient', 'passive - active', 'hostile - friendly', 'unsociable - sociable', 'monotonous - interesting' and 'frustrating - satisfying'. This factor explains 45.87% of the variance.

- 2nd factor: this factor reflects *Formal-intimate* as the most significant descriptor to this factor. Variables contribute are: 'business-like-cosy', 'public-private' and have opposite descriptors with negative correlation to the 'inconvenient-convenient' and 'unsociable- sociable'. This factor explains 9.48% of the variance.

- 3rd factor: this factor represents Terrifying-Pleasant. The variables refer to in this description are 'tense-relaxed' and 'hostile - friendly' and have opposite meaning (negative correlation) to the 'boring - exciting' and 'monotonous - interesting'. This factor explains 7.08% of the variance.

Variable (state)	Factors 1	2	3
Business-like - Cosy	.515	.642	-
Formal - Intimate	.368	.761	-
Dull - Stimulating	.792	-	-
Terrifying - Pleasant	.606	-	.483
Dispirited - Lively	.743	-	-
Tense - Relaxed	.609	-	.450
Public - Private	.302	.442	-
Boring - Exciting	.746	-	-.404
Unattractive - Attractive	.805	-	-
Inconvenient - Convenient	.672	-.380	-
Passive - Active	.688	-	-
Hostile - Friendly	.716	-	.385
Unsociable - Sociable	.652	-.367	-
Monotonous - Interesting	.753	-	-.393
Dislike - Like	.830	-	-
Frustrating - Satisfying	.778	-	-
% Variance	45.87%	9.48%	7.08%
Cronbach's alpha	0.914	0.602	0.773

Table 8-12 Factor Matrix

In investigating the effect of façade fenestration characteristics on atmospheric states, the Kruskal-Wallis H results reported in Table 8-13 revealed that the window-to-wall area ratio had a statistically significant effect ($p<0.05$) on rating the atmospheric factors, while window-to-floor area ratio only had a statistically significant effect ($p<0.05$) on rating 'formal-intimate' and 'dislike-like' factors. Window area, external obstructions and layers of views have statistically significant effects ($p<0.05$) on rating 'formal-intimate' factor. On the other hand, windowsill height and studio design typology have no statistically significant effect ($p>0.05$) on rating the atmospheric factors.

State	Window-to-wall area ratio	Window-to-floor area ratio	Windowsill height	Window area	Design typology	External obstructions	Layers of view
Formal - Intimate	**.012**	**.042**	.225	**.003**	.226	**.002**	**.012**
Terrifying - Pleasant	**.024**	.228	.763	.450	.568	.219	.359
Dislike - Like	**.000**	**.011**	.891	.337	.733	.700	.385

Table 8-13 The Kruskal-Wallis H test results relating to the effect of façade widows characteristics, design typology, external obstructions and layers of views on different states of atmosphere, N=171.

8.4.2.2 **Evaluation of experienced atmosphere**

Students were asked to evaluate the experienced atmosphere in their studios based on the Likert scale comprising sixteen atmospheric dimensions: stimulating, pleasant, secure, lively, subdued, demarcated, airy, masculine, feminine, simple, complex, aged, modern, new, surprising and ordinary. Cronbach's alpha reliability test was used to measure the internal consistency between dimensions. The dimensions of subdued, masculine, feminine, complex, aged and ordinary were removed and the value of the reliability coefficient for the reminded ten dimensions has increased to a considerable value 0.74. The ten dimensions grouped into 4 factors using factor analysis, explain 71% of the variance (Table 8-14). Variables with a correlation greater than 0.30 were considered in the analysis. The consistency between variables in each factor was verified using Cronbach's alpha, where the considerable reliability coefficients are for the first and third factors, 0.79 and 0.66, respectively. The contribution of the original variables to the factors was determined and the regroup variables into factors were identified as follows:

- 1st factor: this factor describes the experienced atmosphere in studios as *Pleasant*. The words that contribute most to this factor are: 'stimulating', 'secure', 'lively', 'airy', 'modern', 'new' and 'surprising'. This factor explains 34.82 % of the variance.

- 2nd factor: this factor represents the *Simple* of the experienced atmosphere. The adjectives that refer to this are: 'airy' and 'demarcated'. Meanwhile, 'stimulating' and 'surprising' are the opposite adjectives with a negative correlation. This factor explains 13.95 % of the variance.

- 3rd factor: this factor reflects the dimension of *Modern* of the experienced atmosphere. The word that relates is: 'new', 'surprising'. The opposite words (negative correlation) are 'secure' and 'lively'. This factor explains 12.11 % of the variance.

- 4th factor: this factor includes the *Demarcated* dimension *of* experienced atmosphere with one related adjective, 'airy'. This factor explains 10.40 % of the variance.

	Factors			
Variable (dimension)	1	2	3	4
Stimulating	.760	-.318	-	-
Pleasant	.813	-	-	-
Secure	.581	-	-.488	-
Lively	.694	-	-.359	-
Demarcated	-	.301	-	.839
Airy	.539	.411	-	.323
Simple	-	.802	-	-
Modern	.645	-	.530	-
New	.701	-	.530	-
Surprising	.427	-.548	.422	-
% Variance	34.82%	13.95%	12.11%	10.40%
Cronbach's alpha	.791	.340	.663	.378

Table 8-14 Factor Matrix

The Kruskal-Wallis H was used to examine the effect of façade windows characteristics on the obtained atmospheric factors. The results reported in Table 8-15 revealed that window-to-wall area ratio and window area have statistically significant effects ($p<0.05$) on 'pleasant' and 'simple' factors. Meanwhile, window-to-floor area ratio, external obstructions and layers of view have a statistically significant effect ($p<0.05$) only on 'simple' factor of atmosphere. Windowsill height and design typology have no statistically significant effect ($p>0.05$) on any of atmospheric factors. The students' response on a 7-point scale to the atmospheric dimensions are presented in Appendix T. 1.

State	Window-to-wall area ratio	Window-to-floor area ratio	Windowsill height	Window area	Design typology	External obstructions	Layers of view
Pleasant	**.003**	.051	.976	**.041**	.871	.947	.782
Simple	**.003**	**.001**	.724	**.011**	.429	**.029**	**.019**
Modern	.321	.696	.598	.089	.461	.606	.681
Demarcated	.670	.786	.090	.145	.253	.948	.276

Table 8-15 The Kruskal-Wallis H test results relating to the effect of façade widows characteristics, design typology, external obstructions and layers of views on different dimensions of atmosphere, N=171.

8.4.2.3 Correlation between façade windows characteristics (North-facing) and experienced atmosphere

The relationship between the objective measurement of facade windows and subjective response attributes is examined in this section. It has been mentioned in the literature review that window size has a significant influence on the perceptual impressions of a space, in that large window sizes lead to more pleasant, interesting, exciting, bright, complex and spacious perceived spaces (Moscoso et al., 2020, p. 18). Similarly, the shape and distribution of faced openings were found to be the primary factors that affected the experience of a space, whereby a higher complexity of façade variations led to higher evaluations of interest (Chamilothori, 2019, p. 179). As such, the design elements in the classroom can generate certain affective impressions, such as 'cosy' and 'pleasant', as concluded in a study by Castilla et al. (2017). Within this study, the relationship between the objective and subjective variables was tested using a nonparametric correlation test (Spearman's Rho). The results presented in Figure 8-21 revealed a positive association between the window area and the experience of 'pleasant' dimension ($N= 171$, $r_s= .213$, $p <0.01$) and 'modern' dimension ($N= 171$, $r_s= .185$, $p <0.05$). Window-to-floor area ratio has a positive association only with 'formal-intimate' state ($N= 171$, $r_s= .181$, $p <0.05$). Similarly, window-to-wall area ratio has a positive association with ‘formal-intimate’ state ($N= 171$, $r_s= .242$, $p <0.01$) and a negative association with the ‘simple’ dimension ($N= 171$, $r_s= -.232$, $p <0.01$). On the other hand, external obstructions have a negative association with ‘formal-intimate’ state ($N= 171$, $r_s= -.233$, $p <0.01$) and a positive association the ‘simple’ dimension ($N= 171$, $r_s= .168$, $p <0.05$).

Although the façade fenestration characteristics have a statistically significant association with atmospheric factors, the values of correlation coefficient can be interpreted as weak linear associations between façade fenestration and the experienced atmosphere. Therefore, the findings have not confirmed the suggested hypothesis.

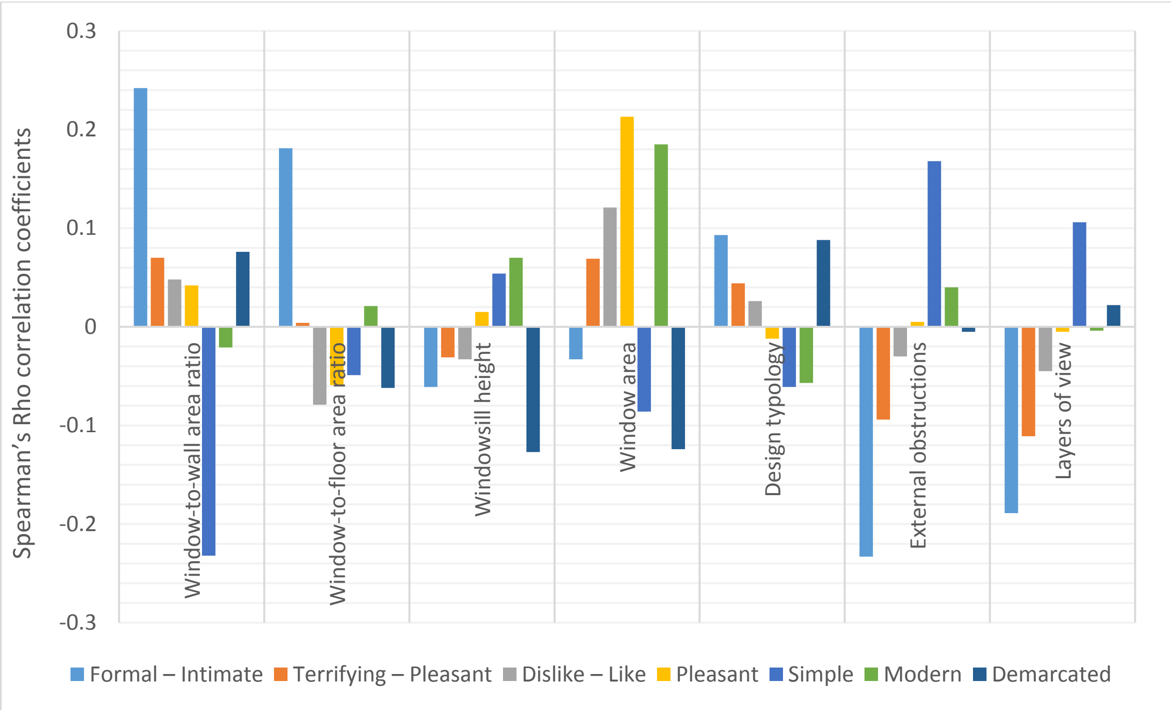


Figure 8-21 Spearman’s Rho correlation coefficients of the relationship between the characteristics of façade windows, atmospheric states and dimensions, North-facing studios.

8.5 Atmosphere in relation to the subjective attribute of daylight

The daylight evaluations considered two perspectives: objective and subjective. Within this section, students were asked to rate the contribution of daylight to their studios' atmospheres on both cloudy and bright days. Accordingly, factor analysis was used to determine the contribution of twelve variables of daylight to their studios' atmospheres: brightness, illumination, uniformity, room luminance, distribution of daylight, colour- grey, colour- yellowish, shadow, darkness, glare, visual comfort and lack of control-blinds in studios. The internal consistency between the different variables of daylight on a cloudy day was checked by Cronbach's alpha reliability test, in which variables like darkness and lack of control were removed to increase the reliability coefficient to 0.738.

The factor analysis identified three factors, which in total was responsible for 62.65% of the variance. The value for the reliability coefficient (Cronbach's alpha) for the first factor was considerable at 0.830. The results are reported in Table 8-16, and the obtained factors are as following:

- 1st factor: this factor determines *Brightness* as the most significant daylight variable that contributes to the experienced atmosphere. Variables like 'illumination', 'uniformity', 'room luminance', 'distribution of daylight', 'glare' and 'visual comfort' contribute to the factor. This factor explains 37.17% of the variance.

- 2nd factor: this factor reflects the *Colour-yellowish* of the daylight. The variables that contribute are: 'shadow', 'glare' and variables with a negative correlation like 'uniformity', 'colour-grey', and 'visual comfort'. This factor explains 14.61% of the variance.

- 3re factor: this factor includes *Colour-grey* of the contribution of daylight. The significant variables are 'colour-yellowish' and 'shadow'. This factor explains 10.86% of the variance.

	Factors		
Variable	**1**	**2**	**3**
Brightness	.875	-	-
Illumination	.867	-	-
Uniformity	.694	-.358	-
Room luminance	.826	-	-
Distribution of daylight	.740	-	-
Colour-Grey	-	-.347	.784
Colour- yellowish	-	.607	.330
Shadow	-	.599	.477
Glare from daylight	.382	.547	-
Visual comfort	.539	-.405	-
% Variance	37.17%	14.61%	10.86%
Cronbach's alpha	.830	.465	.182

Table 8-16 Factors matrix for the contribution of daylight (cloudy day) on the experienced atmosphere, North-facing studios.

Regarding the daylight on a bright day, the internal consistency between the different variables of daylight was checked by Cronbach's alpha reliability test, in which variables like colour-grey, shadow, darkness, visual comfort and lack of control were removed to increase the reliability coefficient to 0.750. The factor analysis identified only two factors which in total was responsible for 68.46% of the variance. The results are reported in Table 8-17, and the obtained factors are as following:

- 1st factor: reflects the *Brightness* of daylight. Variables like 'illumination', 'uniformity', 'room luminance', 'distribution of daylight', and 'glare' refer to the contribution of daylight on the experienced atmosphere. This factor explains 48.67% of the variance.

- 2nd factor: determines the *Colour-yellowish* of daylight. The variable 'glare' is significant to it, while other variables have negative correlation like 'uniformity', and 'distribution of daylight'. This factor explains 19.78% of the variance.

	Factors	
Variable	**1**	**2**
Brightness	.859	-
Illumination	.881	-
Uniformity	.628	-.538
Room luminance	.843	-
Distribution of daylight	.743	-.337
Colour- yellowish	-	.718
Glare from daylight	.386	.677
% Variance	48.67%	19.78%
Cronbach's alpha	.779	.432

Table 8-17 Factors matrix for the contribution of daylight (bright day) on the experienced atmosphere, North-facing studios.

In examining the effect of determined daylight attributes on the atmospheric factors, the Kruskal-Wallis H test results reported in Table 8-18 showed that on a cloudy day, the 'brightness' attribute has a statistically significant effect ($p<0.05$) on 'dislike-like', 'terrifying-pleasant', and 'demarcated' factors. Meanwhile, 'colour-yellowish' attribute has a statistically significant effect ($p<0.05$) on the 'pleasant' factor, however, 'colour-grey' attribute has a statistically significant effect ($p<0.05$) on the 'terrifying-pleasant' factor. On a bright day, the 'brightness' attribute has a statistically significant effect ($p<0.05$) on 'terrifying-pleasant' and 'pleasant' atmospheric factors, while 'colour-yellowish' attribute has a statistically significant effect ($p<0.05$) on 'dislike-like', 'terrifying-pleasant', and 'simple' factors.

Atmospheric factor	Cloudy day			Bright day	
	Brightness	Colour-yellowish	Colour-grey	Brightness	Colour-yellowish
Dislike-like	**.011**	.133	.609	**.000**	**.015**
Formal-intimate	.577	.098	.129	.558	.207
Terrifying-Pleasant	**.006**	.114	**.014**	**.000**	**.018**
Pleasant	.158	**.028**	.265	**.002**	.522
Simple	.084	.063	.111	.165	**.004**
Modern	.214	.182	.759	.361	.990
Demarcated	**.006**	.471	.083	.357	.819

Table 8-18 The Kruskal-Wallis H test results relating to the effect of daylight attributes (cloudy and bright days) on different factors of atmosphere, North-facing, N=171.

8.5.1 **Correlation between atmospheric factors and daylight attributes (North-facing studios)**

Stokkermans et al. (2017) urged that to create a certain atmosphere with light, the relationship between atmosphere and the perceptual attributes of light must be understood. Consequently, atmospheric factors were tested with perceptual daylight attributes (factors), such as brightness, colour (grey, yellowish) and objective daylight measurement, such as the vertical illuminance level on cloudy and bright days.

Figure 8-22 and Figure 8-23 show the relationship between the Spearman's Rho correlation coefficients and atmospheric factors on cloudy and bright days. The results are similar for both cloudy and bright days and indicated that the *brightness* attribute has a statistically significant positive association with the following atmospheric factors: 'terrifying-pleasant' (N= 171, r_s= .230, $p < 0.01$), 'dislike-like' (N= 171, r_s= .255, $p < 0.01$), 'pleasant' (N= 171, r_s= .204, $p < 0.01$) and 'demarcated' factor (N= 171, r_s= .177, $p < 0.05$). The *colour-yellowish* attribute has a statistically significant positive association with the 'dislike-like' factor (N= 171, r_s= .183, $p < 0.05$) and a negative association with the 'simple' factor (N= 171, r_s= -.211, $p < 0.01$). On the other hand, the *colour-grey* attribute has a statistically significant positive association with the 'simple' factor (N= 171, r_s= .190, $p < 0.05$) and the 'terrifying-pleasant' factor (N= 171, r_s= .195, $p < 0.05$) on a cloudy day. The vertical illuminance levels have a statistically significant positive association with only the 'formal-intimate' factor on a cloudy day (N= 171, r_s= .205, $p < 0.01$) and on a bright day (N= 171, r_s= .208, $p < 0.01$).

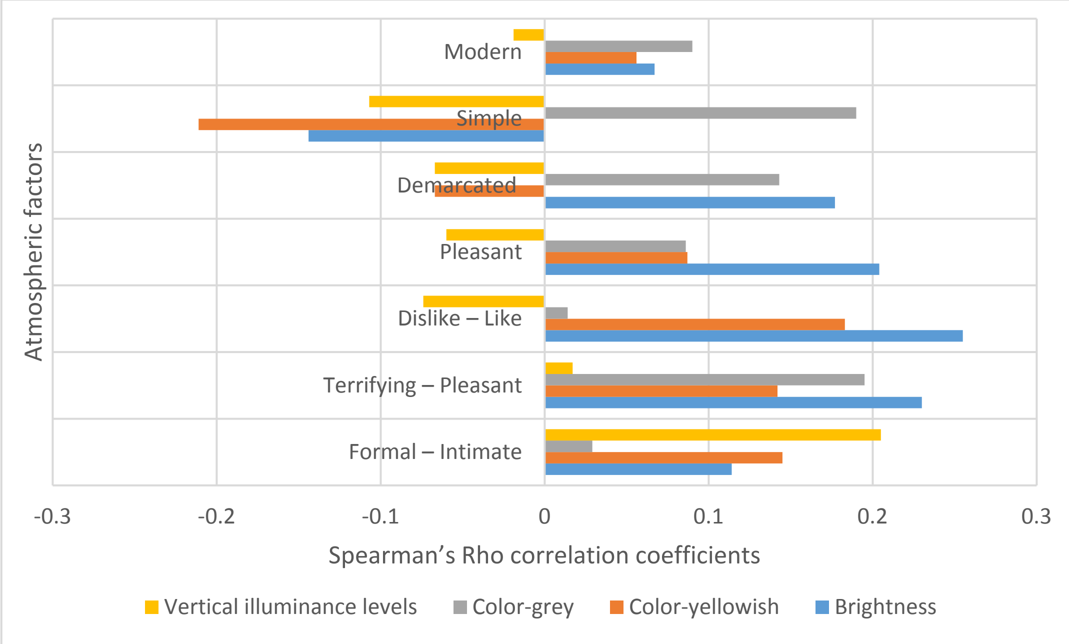


Figure 8-22 Spearman's Rho correlation coefficients of the relationship between the atmospheric factors, vertical illuminance levels and subjective daylight attributes (on a cloudy day), North-facing studios.

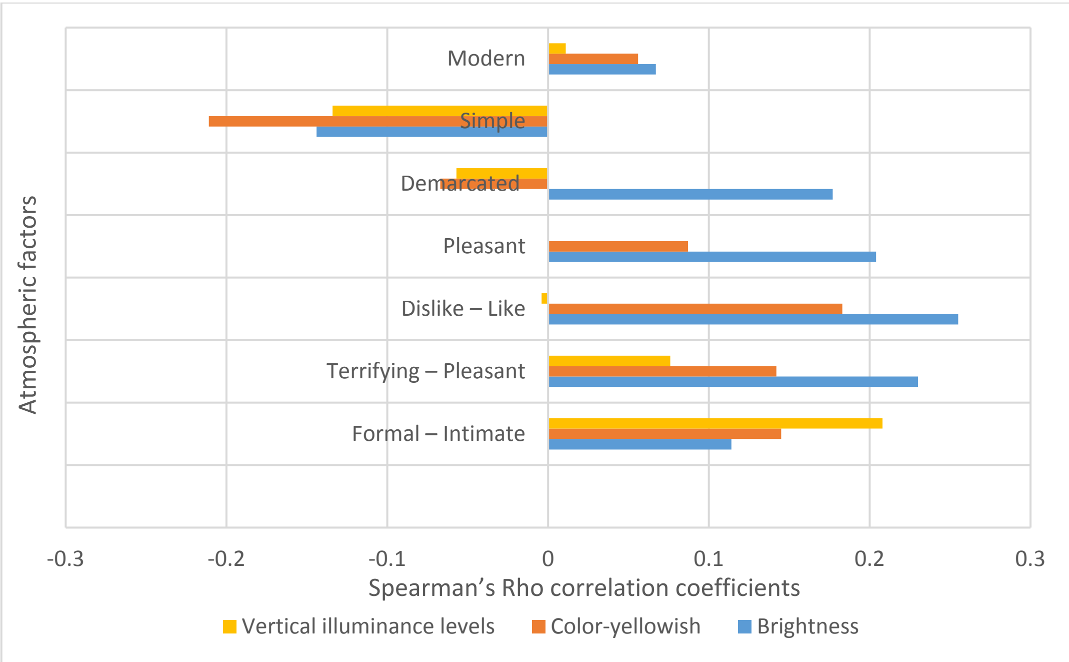


Figure 8-23 Spearman's Rho correlation coefficients of the relationship between the atmospheric factors, vertical illuminance levels and subjective daylight attributes (on a bright day), North-facing studios.

8.6 **Summary**

This chapter has focused on investigating the effect of façade fenestration on daylight levels and experienced atmosphere based on subjective responses in North-facing Glasgow and Edinburgh studios. As the studios were in two different design typologies (double-volume studios and a mezzanine one), the analysis has considered the effect of design typology on students' responses. Accordingly, the Kruskal-Wallis H test yielded a statistically significant effect of window location - at double-volume level or on the mezzanine level - on the students' ratings of windows in providing sufficient daylight levels on cloudy and bright days. However, this result was only found in the studios that were facing external obstructions and were located on a lower floor level from the ground, such as studios E1 – Em and studios GNC – GNCm. Meanwhile, there was no significant effect of window location in studios GNPL – GNPm, which were located on a higher floor level with no external obstructions.

The subjective ratings of windows from the perspective of providing sufficient daylight levels to the studio during cloudy and bright days have been compared with the guidelines recommendation of daylight levels between 500 – 750 lux. The results revealed that the subjective supported the objective measurements in all investigated studios, except in studio E1, where students evaluated the studios' windows as being efficient in providing sufficient daylight levels. Meanwhile, the average illuminance level measured was less than 200 lux.

Furthermore, the study investigated the effect of the façade windows' characteristics on the subjective ratings for different façade window descriptions, such as providing sufficient daylight levels on cloudy and bright days, providing an attractive outside view, helping to create a significant spatial experience, contributing positively to the studio's aesthetics and adding character to the studio. The Kruskal-Wallis H test results confirmed that there is a statistically significant effect ($p<0.05$) of window-to-wall area ratio, window-to-floor area ratio, window area, external obstructions and layers of views on the subjective response to the window descriptions. The windowsill height and studio design typology were found to have a significant effect only on providing an attractive outside view.

In terms of window arrangement, the Kruskal-Wallis H test revealed there to be no statistically significant effect of studio design typology on students' preferences for a particular window arrangement. Regardless of whether the students were located in the double-volume studio or the mezzanine studio, they showed a clear preference for type I window arrangement as it was perceived as the optimum for daylight provision. In addition, although the students evaluated the current studios' windows as being appropriate in providing sufficient daylight levels in the studios, the Wilcoxon Signed-Rank revealed a significant difference between choosing the preferred window arrangement (type I) and the existing windows in studios E1, Em, GNC, GNCm, GNIn, GNPL, GNPm and GNJm.

In assessing the subjective responses regarding the effect of façade windows on experienced atmosphere (double-volume vs mezzanine), factor analysis singles out the variables that contribute most to the perceived atmosphere. The first factor was identified as: *spaciousness - furniture arrangements*, and the variables that contribute to it are 'furniture proximity', 'daylight on cloudy and bright days', 'artificial light', 'temperature in summer', 'acoustics', 'air quality', 'façade windows' and 'overlooking view'. This factor explains 34.5% of the variance. The second factor was found to be *daylight on cloudy and bright days*, while the third and fourth were mainly concerned about the *temperature in summer and winter*. Regarding the effect of façade windows characteristics on stimuli related to the studios, the Kruskal-Wallis H test revealed that window-to-wall area ratio and studios' design typology, each had a statistically significant effect ($p<0.05$) on façade windows being perceived as positive or negative stimuli. Meanwhile, for daylight conditions, window-to-wall area ratio, window-to-floor area ratio, window area, design typology, external obstructions and layers of views were each found to have a statistically significant effect ($p<0.05$) on daylight being perceived as positive or negative stimuli.

The state of atmosphere was rated by the semantic differential scale, in which sixteen pairs of adjectives were determined into three factors by using factor analysis. The obtained factors are: *Dislike-like*, *Formal-intimate* and

Terrifying-pleasant. the Kruskal-Wallis H test results revealed that the window-to-wall area ratio was found to have a statistically significant effect ($p<0.05$) on rating the atmospheric factors, while the window–to- floor area ratio only has a statistically significant effect ($p<0.05$) on rating the atmospheric factors of 'formal–intimate' and 'dislike–like'. Window area, external obstructions and layers of views were identified as having statistically significant effects ($p<0.05$) only on rating 'formal–intimate' factor. Meanwhile, windowsill height and studio design typology have no statistically significant effect ($p>0.05$) on rating the atmospheric factors.

In evaluating the experienced atmosphere, the factor analysis determined four factors of atmospheric dimensions: *Pleasant, Simple, Modern* and *Demarcated* factors. The Kruskal-Wallis H test results revealed that window-to-wall area ratio and window area have statistically significant effects ($p<0.05$) on 'pleasant' and 'simple' factors. Window-to-floor area ratio, external obstructions and layers of view have statistically significant effect ($p<0.05$) only on the 'simple' factor. On the other hand, windowsill height and design typology have no statistically significant effect ($p>0.05$) on any of atmospheric factors.

For daylight attributes, factor analysis identified three factors of subjective daylight attributes on a cloudy day: *Brightness*, *Colour-yellowish* and *Colour-grey*, while two factors identified on a bright day: *Brightness* and *Colour-yellowish*. The Kruskal-Wallis H test results revealed that on a cloudy day, the 'brightness' attribute has a statistically significant effect ($p<0.05$) on 'dislike-like', 'terrifying-pleasant', and 'demarcated' factors. Meanwhile, 'colour-yellowish' attribute has a statistically significant effect ($p<0.05$) on the 'pleasant' factor, while 'colour-grey' attribute has a statistically significant effect ($p<0.05$) on the 'terrifying-pleasant' factor. On a bright day, the 'brightness' attribute has a statistically significant effect ($p<0.05$) on 'terrifying–pleasant' and 'pleasant' atmospheric factors, while 'colour-yellowish' attribute has a statistically significant effect ($p<0.05$) on 'dislike-like', 'terrifying–pleasant', and 'simple' factors.

Finally, although façade windows characteristics have a significant effect on atmospheric factors, the Spearman's Rho correlation test revealed a weak linear association between them. As such, hypothesis 2 has been rejected as it assumed there to be a strong association between the façade fenestration characteristics and experienced atmosphere. Furthermore, the correlation test showed a weak association between daylight factors (subjective & objective) and atmospheric factors.

8.7 **Discussion**

This chapter presents the analysis for the paper-based questionnaire designed to investigate the subjective responses to the effect of façade windows on daylight levels and the experienced atmosphere. The façade windows were examined in relation to various characteristics, such as the window area, windowsill height, window-to-wall area ratio, window-to-floor area ratio, as well as external obstructions and layers of view. As confirmed in the literature review, the creative space within its spatial design, configuration and aesthetic qualities is still a concept under development. These essential dimensions or characteristics are known as typology (Desmet & Fokkinga's, 2020). Creative spaces within higher education facilities (in this case, the design studio) are not yet considered a building typology, because the relationship between form and spatial qualities have not yet been determined. Within this study, the various elements of façade fenestration in the two main design typologies (the double-volume open plan studio and the mezzanine studio) were examined from the subjective perspective of building users in their natural setting.

The findings revealed that the different studio typologies did not have a significant effect on how the facade windows or daylight levels were evaluated by the students, yet they had a significant effect on evaluating the outside view. Regarding the façade windows characteristics, the window area was found to have a significant effect on providing sufficient daylight levels to the studios during cloudy and bright days. Likewise, it significantly affects the experienced atmospheric factors, such as whether the space is 'formal-intimate', 'pleasant' or 'simple', as well as helping to provide an attractive outside view. This result is in line with previous studies, such as that of Moscoso et al.(2020), which found that window size significantly influences the perceptual impressions of spaces (including factors like pleasant and exciting) as well as bringing higher satisfaction with the view. In another study, Moscoso et al. (2015) confirmed that window size and room reflectance each had statistically significant effects on the evaluation of the attributes, where large window sizes were considered crucial for more pleasant and exciting defined rooms. Likewise, Matusiak (2006) found that the width of the window has a stronger positive impact on impression than height does, while Butler & Biner (1989) found that large windows are preferred over smaller ones.

However, in this study, the Spearman's Rho correlation test revealed a weak linear association between the window area and atmospheric factors. Likewise, the window-to-wall area ratio and window-to-floor area ratio was each found to have a statistically weak association with the experienced atmospheric factors. This may be because this study was conducted in real-life settings, where other factors could influence the subjective responses, while the previous research studies were conducted in a lab or relied on simulation work where most of the factors were controlled. Consequently, the second hypothesis in this study was rejected due to the façade window characteristics not having a strong linear association with the experienced atmosphere. This finding is crucially important, not just because it contradicts the findings from previous research, but also because it confirms the arguments stated by atmospheric theorists, such as Edensor (2017), who noted atmosphere as varying in intensity and having different arrangements of objects, humans, nonhuman creatures and technologies that are characterised by change and multiplicity.

Furthermore, this finding is in line with those revealed from the factor analysis, whereby spaciousness, furniture proximity and furniture arrangements were found to contribute most to whether the atmosphere was experienced as a positive or negative stimuli, in comparison with façade windows and daylight. Additionally, Ne'Eman & Hopkinson's (1970) study investigated the subjective appraisal of windows and their sizing, considering the ways in which windows are expected to function and fulfil subjective satisfaction. The study found that neither the amount of light inside the building, the amount of light coming through the window, the sun altitude throughout the day, nor sky luminance are the main factors that govern appraisal of the minimum size of window. As such, the dimensional relationship between height and width does not play a crucial role in the judgment, and geometrically dimensional considerations (such as the size of the room or size of the window wall) remain complicated.

Windowsill height has a crucial role in studio design typology, particularly if it was determined by considering the SLL code guidelines, which stipulate that the sills should be below the eye level of the people seated (Raynham et al., p. 118, 2012). In this study, the window location (whether positioned at double-volume level or at the mezzanine level) has a statistically significant effect on the students' appraisal of windows in providing sufficient daylight levels during cloudy and bright days. However, this result was only found in studios that were facing external obstructions and located on the lower floor level from the ground, while no significant effect was found in studios located on a higher level without external obstructions.

Finally, the study found an agreement between the subjective response to the issue of window efficiency in providing sufficient daylight levels, and objective measurements of daylight that were assessed based on guidelines recommendations for daylight levels between 500-750 lux in art rooms in art schools. This means that the suggested guidelines from the SLL code for art schools and British standards can also be applied to design studios that are North-facing.

Chapter 9

Subjective response to the effect of façade fenestration on daylight levels & experienced atmosphere: Glasgow & Aberdeen case studies

9.1 **Introduction**

This chapter presents the findings on the effect of façade fenestration on daylight levels and experienced atmosphere from a subjective perspective in South-facing studios in Glasgow and Aberdeen. It examines the second hypothesis; 'The characteristics of facade fenestration have a strong association with the experienced atmosphere.' The investigated studios are of two typologies: double-volume open-plan studios with skylights and ordinary open-plan studios without skylight. Therefore, as these skylights bring light in, they will indirectly influence students' appraisal of façade windows as light admitting devices.

The total number of participants who had completed the questionnaire was 108, in which 54 students came from Aberdeen studios and 54 students from Glasgow studios. 49.7% of participants were within the 18-21 age group. The missing values and outliers were checked for all studios. For testing the effect of the characteristics of façade fenestration, such as window area and windowsill height on students' ratings for façade windows, daylight levels and experienced atmosphere, the Kruskal-Wallis H test was mainly used. Furthermore, factor analysis (dimension reduction) has been used to determine the variables that are assumed to have the most significant effect on the experienced atmosphere, by being considered either as positive or negative stimuli. A nonparametric correlation test (Spearman's Rho) has been used to examine the relationship between objective variables (characteristics of façade fenestration) and subjective evaluation of the experienced atmosphere.

The chapter is divided into two main parts: part one is involved about the effect of façade windows on daylight levels (studios with skylight vs without), different descriptions of façade windows and the preferred window arrangement based on subjective responses. Whereas part two is concerned about subjective responses on the effect of façade windows on experienced atmosphere. Subjective evaluation on atmospheric states and dimensions and finally a correlation test between characteristics of façade fenestration, daylight attributes and students' ratings on experienced atmosphere on both cloudy and bright days. For the chapter structure, see Figure 8-1.

The findings showed that there is no statistically significant effect of the presence of skylight on students' preferences of particular window arrangement; students in all studio seem to prefer one particular window arrangement (type I). In addition, none of the façade windows characteristics, such as window-to-floor area ratio, window area and type of view, were found to have a statistically significant effect on daylight levels during cloudy and bright days, creating spatial experience, contributing positively to the studio's aesthetics or adding character to the studio. Finally, the suggested second hypothesis has been rejected as the correlation test revealed a weak association between characteristics of façade fenestration, daylight attributes and experienced atmosphere.

9.2 Demographic information for South-orientated studios

The total number of participants that completed the questionnaire was 109, of whom 54 came from Aberdeen studios and 55 came from Glasgow studios. The largest age group (43.3%) corresponded to the 18-21-year-olds; 51.4% of the participants were female and 48.6% were male. Regarding the students' nationalities, 84.4% were from the UK, 10.1% were European, 1.8% were Chinese, and 3.6% came from other countries, such as Argentina, Japan, Pakistan, and Russia. In contrast with the north-facing studios, there were no different year groups sharing the same studio, except in studio A1 (2^{nd} year and 3^{rd} year group) and studio GSp (1^{st} year and3^{rd} year). Table 9-1 presents information for each studio regarding the students' degree type. Table 9-2 and Table 9-3 present demographic information relating to the participants in the Glasgow and Aberdeen studios.

Studio	Year group
A1	Second year
	Third year
A2	Fourth year
GSInu	Fourth year
GSpo	Master year
GSp	First year
	Third year

Table 9-1 Degree year group for Glasgow and Aberdeen studios.

Your age		Your gender: Female	Male	Prefer not to say	Total
Your age	17 or below	0	1	-	1 (.9%)
	18-21	35 (50.7%)	34 (49.3%)	-	69 (63.3%)
	22-25	18 (54.5%)	15 (45.5%)	-	33 (30.3%)
	26-and above	3 (50%)	3 (50%)	-	6 (5.5%)
Total		56 (51.4%)	53 (48.6) %	-	109

Table 9-2 Demographic information (age/gender) for Glasgow and Aberdeen studios.

Your residency		Your gender: Female	Male	Prefer not to say	Total
Residency	UK resident	49	43	-	92 (84.4%)
	European resident	5	6	-	11 (10.1%)
	China	-	2	-	2 (1.8%)
	Other:				
	Argentina	-	1	-	1 (.9%)
	Pakistan	-	1	-	1 (.9%)
	Japan	-	1	-	1 (.9%)
	Russia	-	1	-	1 (.9%)
Total		56	53	-	109

Table 9-3 Demographic information (residency/gender) for Glasgow and Aberdeen studios.

Most of the students occupied studios for more than a year, except studio GSInu, where students spent a period of 2-6 months. Furthermore, most of the students spent 2-4 days a week in the studios, except in studio GSp, where 1st year students spent a day or less in the studio. The total amount of time spent inside the studios was between 2-5 hours and 6-9 hours per day. Figure 9-1, Figure 9-2 and Figure 9-3 present the students' responses to questions related to the period of time they spent inside the studios.

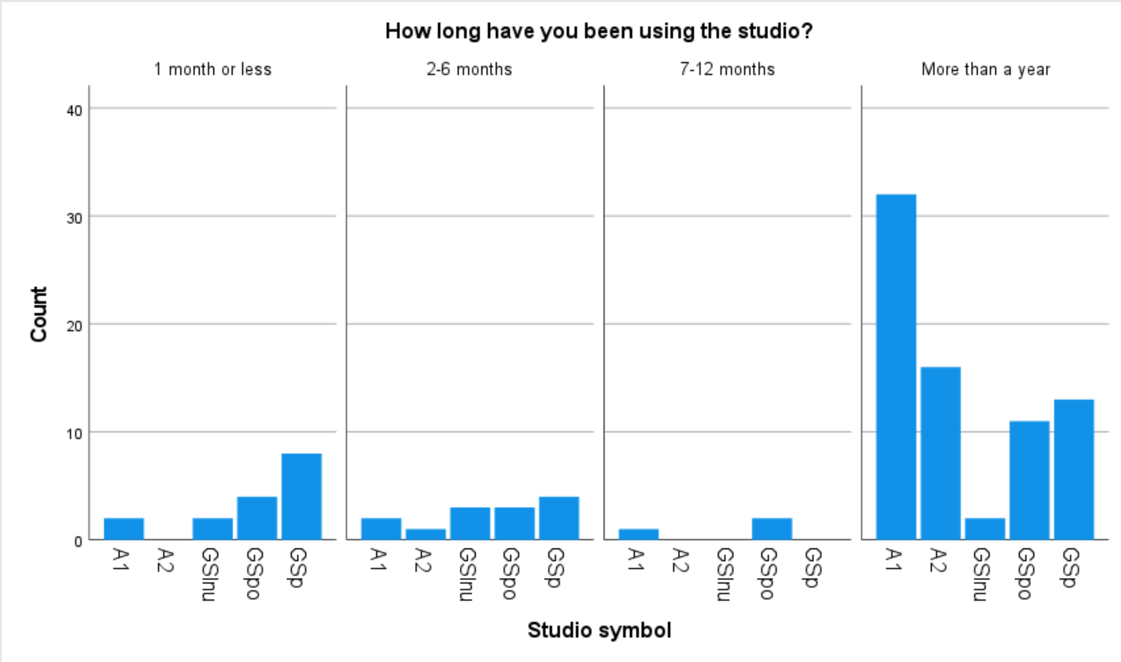


Figure 9-1 Students' responses regarding the period (in months) they have occupied their studios (Glasgow and Aberdeen).

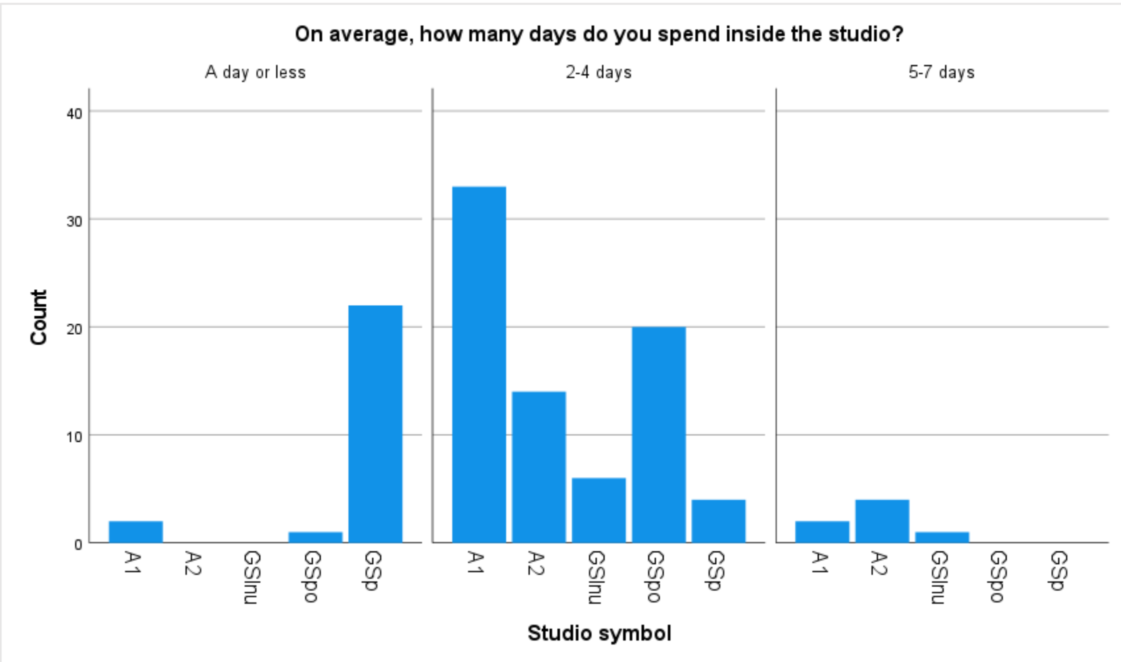


Figure 9-2 Students' responses regarding total days per week they have occupied their studios (Glasgow and Aberdeen).

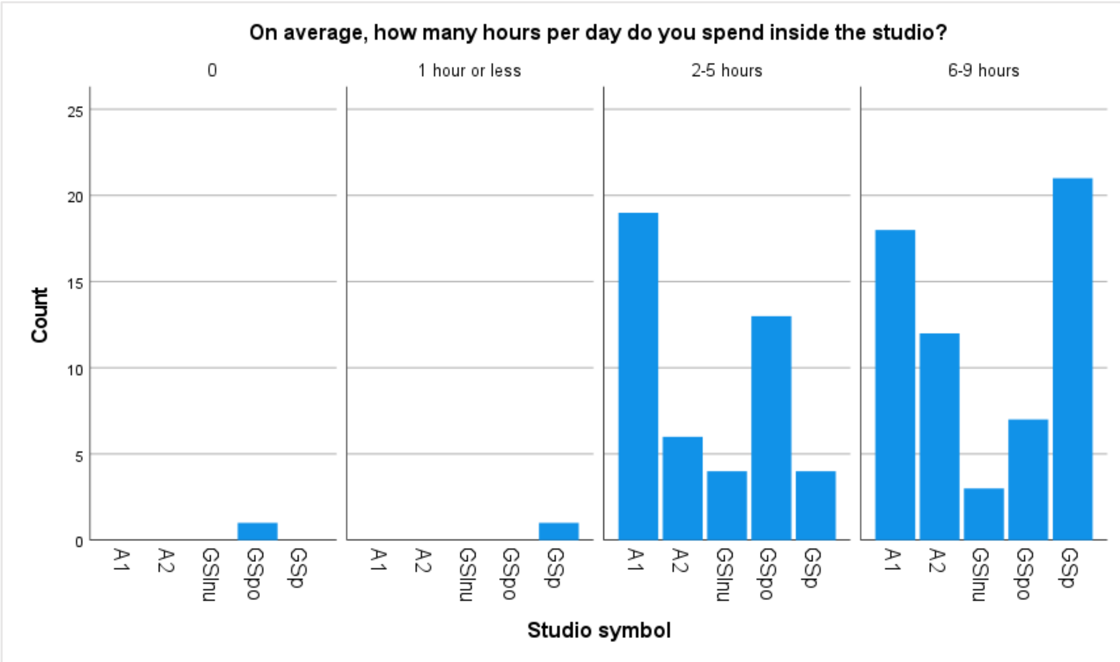


Figure 9-3 Students' responses regarding the total hours per day they occupy their studios (Glasgow and Aberdeen).

The students' opinions about the provision of adequate daylight and the experienced atmosphere in their studios are presented in Figure 9-4 and Figure 9-5.

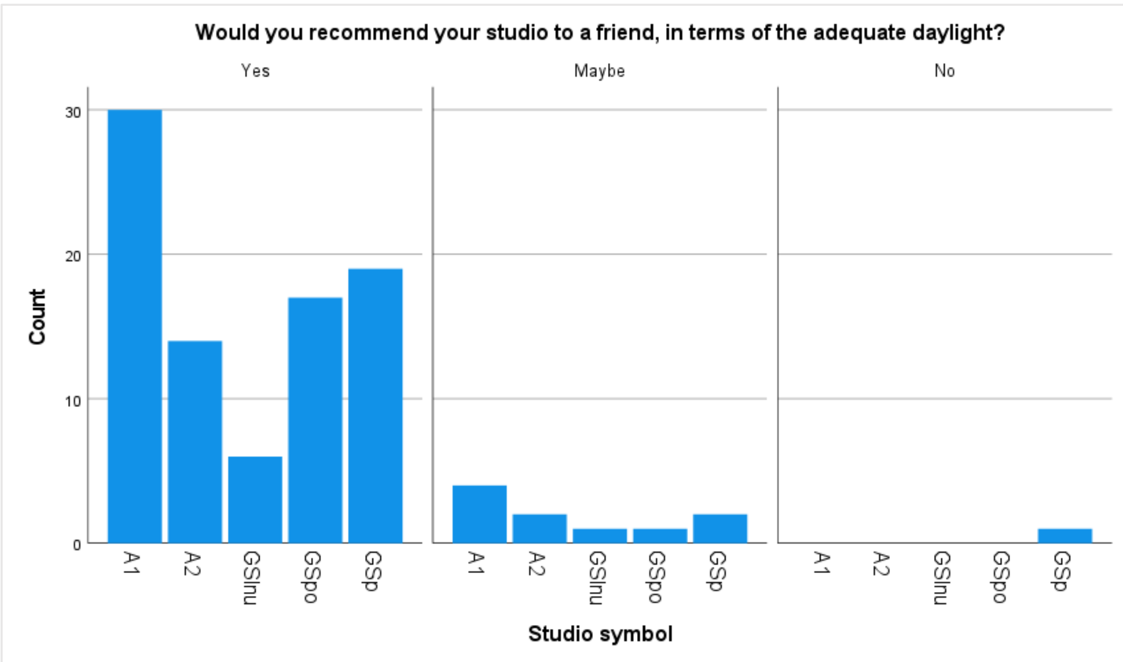


Figure 9-4 Students' opinions of their studios based on the daylight provided (Glasgow and Aberdeen).

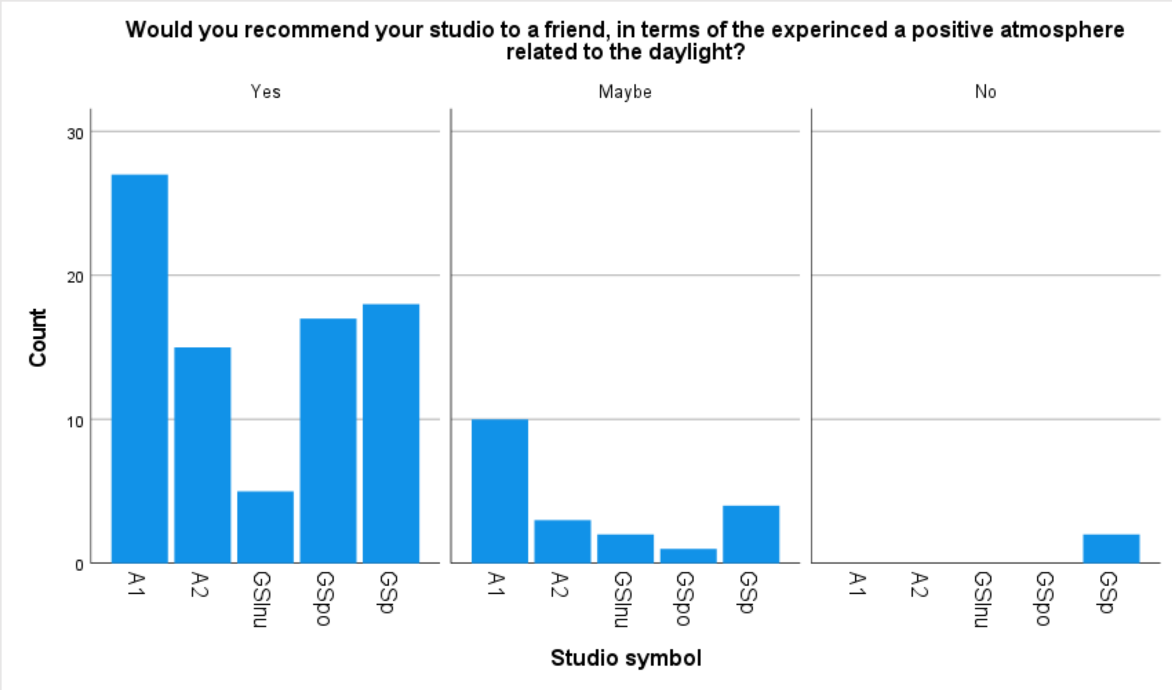


Figure 9-5 Students' opinions of their studios based on the experienced a positive atmosphere related to the daylight provided (Glasgow and Aberdeen).

9.3 Subjective responses to the effect of windows on daylight levels (studios with skylight vs without)

In this section, windows were evaluated from the students' perspective of whether or not they are providing sufficient daylight levels on cloudy and bright days. Sky lighted studios GSPo, GSInu and GSp; each registered mean illumination levels of more than 300,300 and 400 lux, respectively in February and October, and more than 500, 500 and 600 lux, respectively, for the rest of the measurement period. The students' mean evaluation for the functionality of the windows in providing sufficient daylight levels in the studio was rated as 'adequate' for all studios on a cloudy day and 'very efficient' for studio GSPo and GSp, 'efficient' for studio GSInu on a bright day (Figure 9-6). Therefore, the students' evaluations of the daylight levels on a bright day have supported the objective measurement, but not on a cloudy day as the measured daylight levels were below the 500-750 lux threshold, dictated by the guidelines for light and lighting.

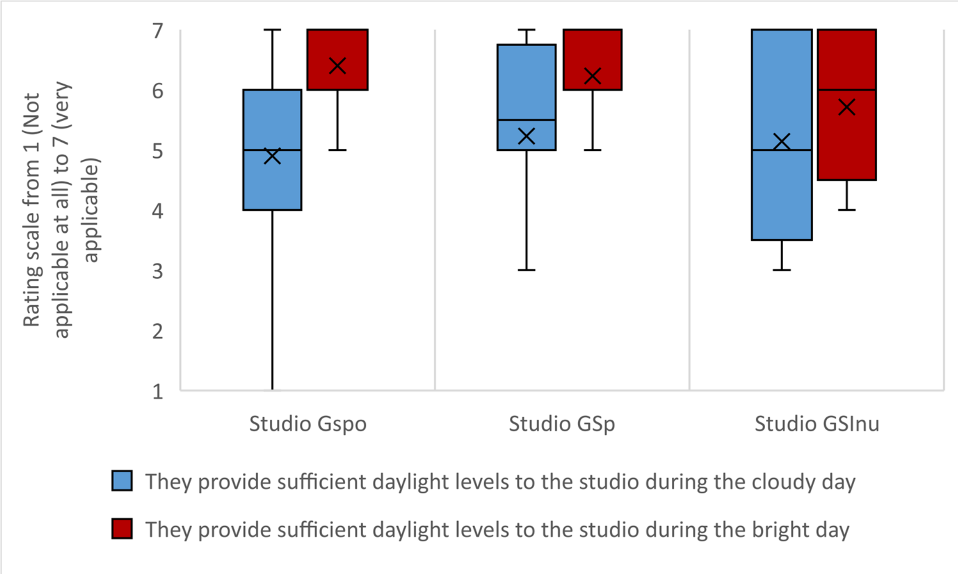


Figure 9-6 Boxplots presents students' ratings variation for the best describe their studios' windows based on the daylight levels. Studios GSPo, GSp and GSInu.

In studios without a skylight, studios A1 and A2 each registered a mean illumination value below 200 lux except for studio A1 where in June, the mean illumination figure was above 500 lux. Although the registered mean illumination levels were less than the recommended levels set out by the guidelines, students evaluated the functionality of the window in providing sufficient daylight levels on cloudy days in studios A1 and A2 as 'adequate' and 'efficient', respectively. Meanwhile, on bright days, studios A1 and A2 were rated as 'very efficient' (Figure 9-7).

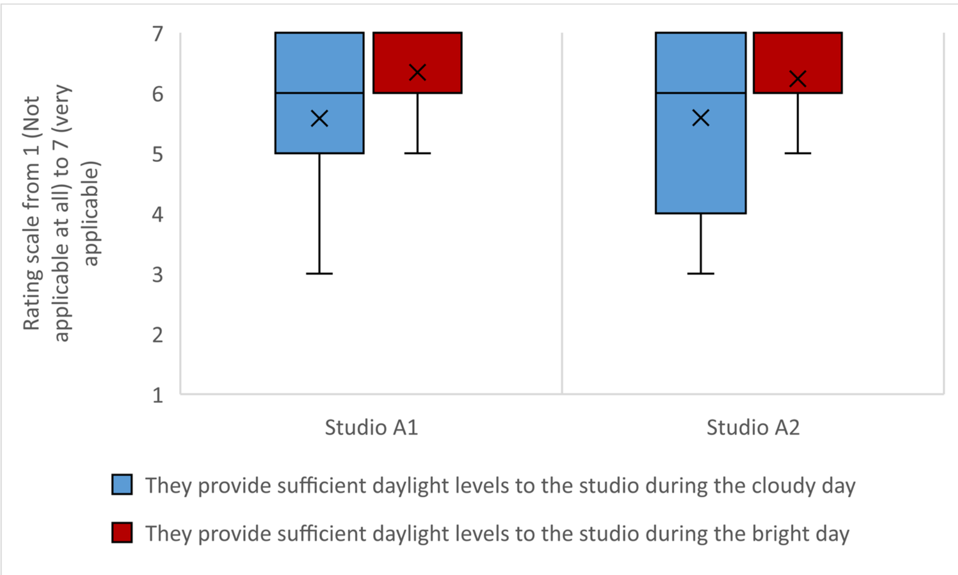


Figure 9-7 Boxplots presents students' ratings variation for the best describe their studios' windows based on the daylight levels. Studios A1 and A2.

The Kruskal-Wallis H test revealed that the presence of a skylight has no statistically significant effect on subjective responses to the sufficient daylight levels on cloudy day (X^2 (1, N = 108) = 1.51, p = 0.219) nor on bright day (X^2 (1, N = 108) = 0.037, p = 0.848). Moreover, the subjective responses did not support the objective measurement (mean illuminance levels) as found in the analysis above, where students tended to rate daylight levels as adequate/efficient for both cloudy and bright days.

9.3.1 Subjective response to the different descriptions of façade window

Students were asked to select a statement that best describes their studio windows from a list which included the following options: they provide sufficient daylight levels to the studio on cloudy and bright days, provide an attractive outside view, help to create a significant spatial experience, contribute positively to the studio's aesthetics and add character to the studio. These descriptions have been treated as dependent variables. On the other hand, window-to-wall area ratio, window-to-floor area ratio, windowsill height, window area, the presence of a roof window (skylight) and window arrangement (continuous strip windows, fragmented strip windows and fragmented windows; side, central and both side and central) were all considered to be fixed factors (IVs) for further analysis. In terms of layers of views, all the studios have middle view layers (natural or man-made objects such as fields, trees, hills and buildings); however, the type of view (trees vs buildings) has been considered in the analysis.

The analysis considered the SLL code for light and lighting, which stipulates that the size and proportion of windows should depend on the type of view, size of internal space, position and mobility of occupants. In addition to this, in the case that the windows are located on one wall only (Table 9-4), the SLL code recommends that the total width of the windows should be at least 35% of the length of the wall (Raynham et al., p. 118, 2012). This guidance was only used in studios with no skylights, i.e. A1 and A2. The window information for the Glasgow and Aberdeen studios is reported in Table 9-5, in which studios A1 and A2 corresponded to the minimum ratio of window-to-wall and ratio of window width-to-wall length.

Depth of room from outside wall (max)/m	Glazed area as percentage of window wall as seen from inside (min)/%
<8	20
≥8≤11	25
>11≤14	30
>14	35

Table 9-4 Minimum glazed area for view when windows are restricted to one wall

Studio	Depth of studio from outside wall(m)	Window-to- wall area ratio	Satisfactory view (SLL code)	Window-to- floor area ratio	Window sill height (m)	Ratio of window width to wall length (%)	Window head above the standing eye height	Window sill below the eye level while seated
GSPo	6 m	28.5 %	Presence of skylight	33 %	0	100%	✓	✓
GSP	7 m	26.5 %	Presence of skylight	26 %	0	26.42%	✓	✓
					2 m	32.14%	✓	X
GSInu	8 m	8.7 %	Presence of skylight	7.6 %	0	30.7%	✓	✓
A1	8 m	84.13 %	✓	42 %	0.50 m	100%	✓	✓
A2	8 m	47.29 %	✓	23.6 %	0.50 m	100%	✓	✓

Table 9-5 Window information in Glasgow & Aberdeen studios

The Kruskal-Wallis H test was used to examine the effect of the different fixed factors mentioned above on different descriptions of the studios' façade windows. The results in Table 9-6 confirmed that there is no statistically significant effect ($p>0.05$) of the façade window characteristics, window arrangements, presence of a roof window and type of view on providing sufficient daylight levels in the studio during cloudy and bright days. Furthermore, none of the façade characteristics were found to have a statistically significant effect on creating spatial experience, contributing positively to the studio's aesthetics or adding character to the studio. The characteristics of façade windows (apart from window-to-floor area ratio) only had a significant effect ($p<0.05$) on providing an attractive outside view. Figure 9-8 presents boxplots of the students' variation ratings of the windows in their studios.

Factor	Window description	df	X^2	Sig.
Window-to-wall area ratio	They provide sufficient daylight levels to the studio during a cloudy day	3	1.51	.678
	They provide sufficient daylight levels to the studio during a bright day	3	1.60	.659
	They provide an attractive outside view	3	53.6	**.000**
	They help to create a significant special experience	3	2.74	.433
	The façade windows contribute positively to the studio's aesthetics	3	3.25	.354
	They add a character to the studio	3	5.14	.162
Window-to-floor area ratio	They provide sufficient daylight levels to the studio during a cloudy day	2	.34	.841
	They provide sufficient daylight levels to the studio during a bright day	2	2.16	.339
	They provide an attractive outside view	2	3.79	.150
	They help to create a significant special experience	2	1.48	.476
	The façade windows contribute positively to the studio's aesthetics	2	4.41	.110
	They add a character to the studio	2	4.52	.104
Windowsill height (m)	They provide sufficient daylight levels to the studio during a cloudy day	1	1.51	.219
	They provide sufficient daylight levels to the studio during a bright day	1	.03	.848
	They provide an attractive outside view	1	52.20	**.000**
	They help to create a significant special experience	1	1.94	.163
	The façade windows contribute positively to the studio's aesthetics	1	.01	.898
	They add a character to the studio	1	.06	.798
Window area	They provide sufficient daylight levels to the studio during a cloudy day	2	.719	.698
	They provide sufficient daylight levels to the studio during a bright day	2	1.41	.493
	They provide an attractive outside view	2	23.27	**.000**
	They help to create a significant special experience	2	2.31	.315

	The façade windows contribute positively to the studio's aesthetics	2	2.57	.276
	They add a character to the studio	2	3.94	.139
Roof window (skylight)	They provide sufficient daylight levels to the studio during a cloudy day	1	1.51	.219
	They provide sufficient daylight levels to the studio during a bright day	1	.037	.848
	They provide an attractive outside view	1	52.20	**.000**
	They help to create a significant special experience	1	1.94	.163
	The façade windows contribute positively to the studio's aesthetics	1	.016	.898
	They add a character to the studio	1	.066	.798
Window arrangement	They provide sufficient daylight levels to the studio during a cloudy day	3	2.81	.421
	They provide sufficient daylight levels to the studio during a bright day	3	2.14	.542
	They provide an attractive outside view	3	53.83	**.000**
	They help to create a significant special experience	3	2.98	.394
	The façade windows contribute positively to the studio's aesthetics	3	2.66	.446
	They add a character to the studio	3	2.47	.479
Type of view	They provide sufficient daylight levels to the studio during a cloudy day	1	1.51	.219
	They provide sufficient daylight levels to the studio during a bright day	1	.037	.848
	They provide an attractive outside view	1	52.20	**.000**
	They help to create a significant special experience	1	1.94	.163
	The façade windows contribute positively to the studio's aesthetics	1	.016	.898
	They add a character to the studio	1	.066	.798

Table 9-6 Kruskal-Wallis H results for the effect of various façade window characteristics, roof window, window arrangement and view type on different window descriptions (N= 108).

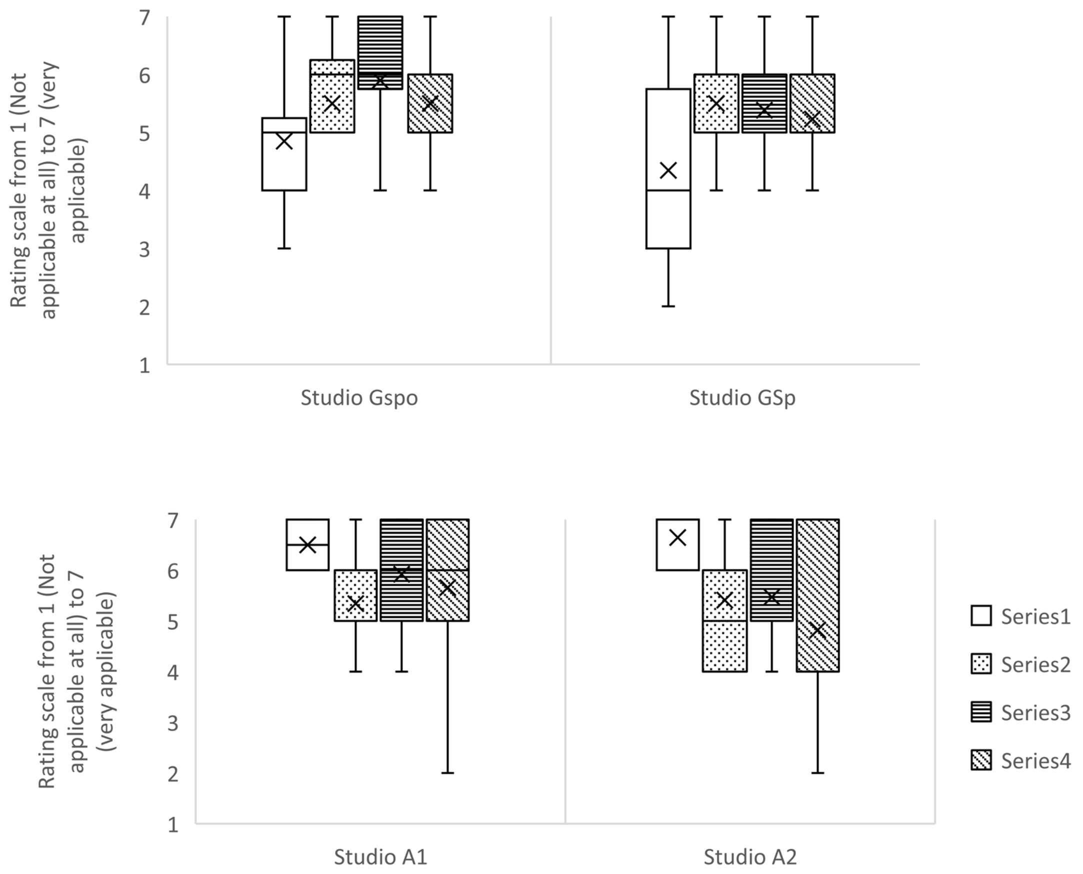


Figure 9-8 Boxplots linking student ratings (1-7) to window functions in each studio. Glasgow and Aberdeen. Series1: Windows provide an attractive outside view. Series 2: Windows help to create a significant spatial experience. Series3: The façade windows contribute positively to the studio's aesthetics. Series 4: Windows add a character to the studio.

9.3.2 Subjective preferences for window arrangements (studios with skylight vs without)

In the previous section, students have been asked to rate the functionality of window in their studios in terms if they perceive it to provide sufficient daylight levels during cloudy and bright days. In this section, it investigates the subjective preferences within a practical scenario, in which students have been asked to choose their preferred window arrangement that think it would admit the maximum amount of daylight in their studio. As students were occupied both studios, one with a skylight and another without, the Kruskal-Wallis H test confirmed that the presence of skylight and design typology had no significant effects on students' preferences for a particular window arrangement (X^2 (1, *N* = 108) = 1.43, p = 0.231). The variation of preferred window arrangement between studios with a skylight and without is presented in Figure 9-9.

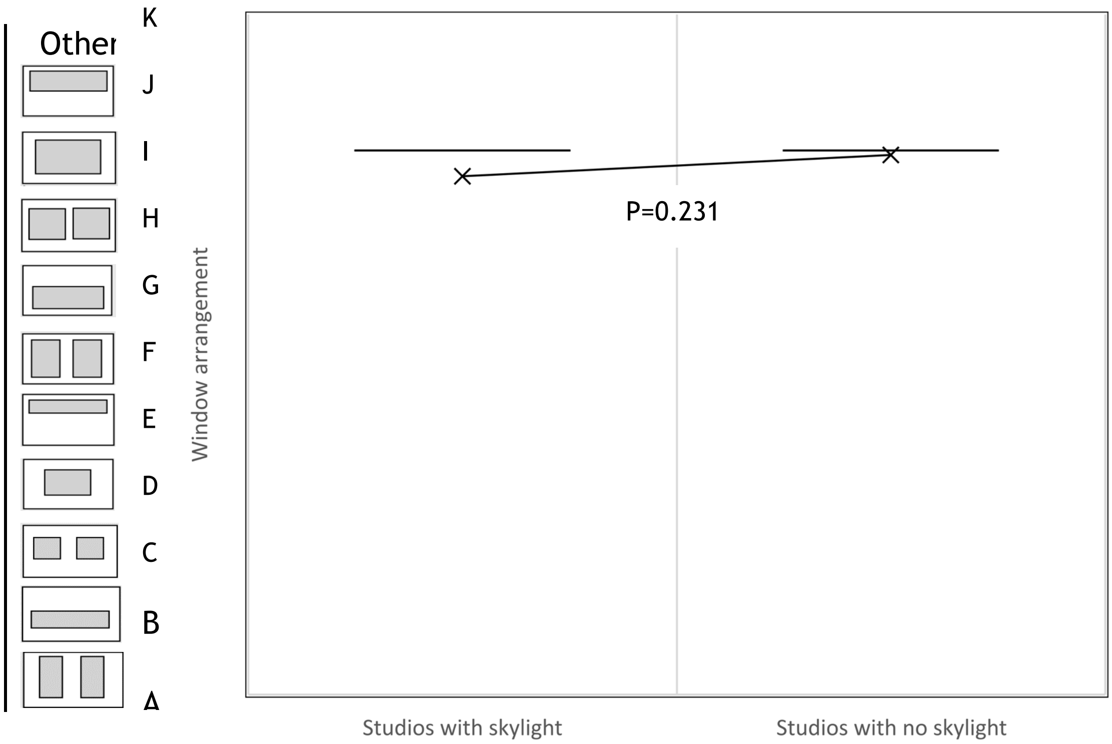


Figure 9-9 Boxplot presents the variation in choices of preferred window arrangements between students located in studios with and without skylight, Glasgow and Aberdeen.

In terms of the preferred window arrangement, the findings demonstrate that most students, whether they were located in the studios with a skylight or not, chose type I as the window arrangement that would make the most of the daylight in their studios. The percentage of students' choices for the window arrangement that would make the most of the daylight in their studio is reported in Table 9-7.

The results of the preferred window arrangement were compared with the existing façade window in each studio. The Wilcoxon Signed-Rank test was used to examine if there is a statistically significant difference in students' choices between the existing studio window and the preferred window arrangement. The results revealed that there is no statistically significant difference between choosing the preferred window arrangement (type I) and the existing facade window in some of studios, such as in A1 ($z = -1.436$, $p = 0.151$), studio A2 ($z = -1.39$, $p = 0.163$) and studio GSInu ($z = -2.22$, $p = 0.26$). These studios already have type I window arrangement, while other studios have different types. Consequently, students' ratings on the functionality of the studios' windows in providing sufficient daylight levels during cloudy and bright days as efficient confirm the statistics of no significant difference between existing and preferred window arrangement.

In other studios, although students felt that existing windows are adequate for daylight provision, the Wilcoxon, however, computed a significant statistical difference between the preferred window arrangement (type I) and the existing window in studio GSPo: ($z = -3.77$, $p = 0.000$), studio GSP: ($z = -1.96$, $p = 0.049$). The variation of students' preferences for window arrangements that would make the most of daylight in their studio is presented in Figure 9-10.

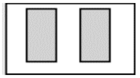
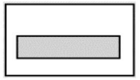
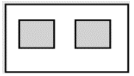
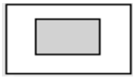
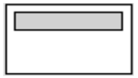
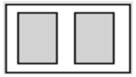
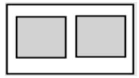
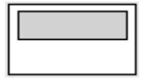
Studio	Suggested window arrangements										
	A 	B 	C 	D 	E 	F 	G 	H 	I 	J 	K Other:
GSPo	-	-	-	-	-	20.0%	-	-	**70.0%**	5.0%	5.0%
GSP	-	-	-	-	11.5%	3.8%	-	-	**61.5%**	15.4%	7.7%
GSInu	-	-	-	-	14.3%	14.3%	-	-	**42.9%**	14.3%	14.3%
A1	-	-	-	-	-	-	-	15.8	**57.9**	18.4	7.9
A2	-	-	-	-	-	-	-	11.8%	**64.7%**	5.9%	17.6%

Table 9-7 Percentage of students' choices for the window arrangement that would make the most of the daylight in their studio, Glasgow and Aberdeen.

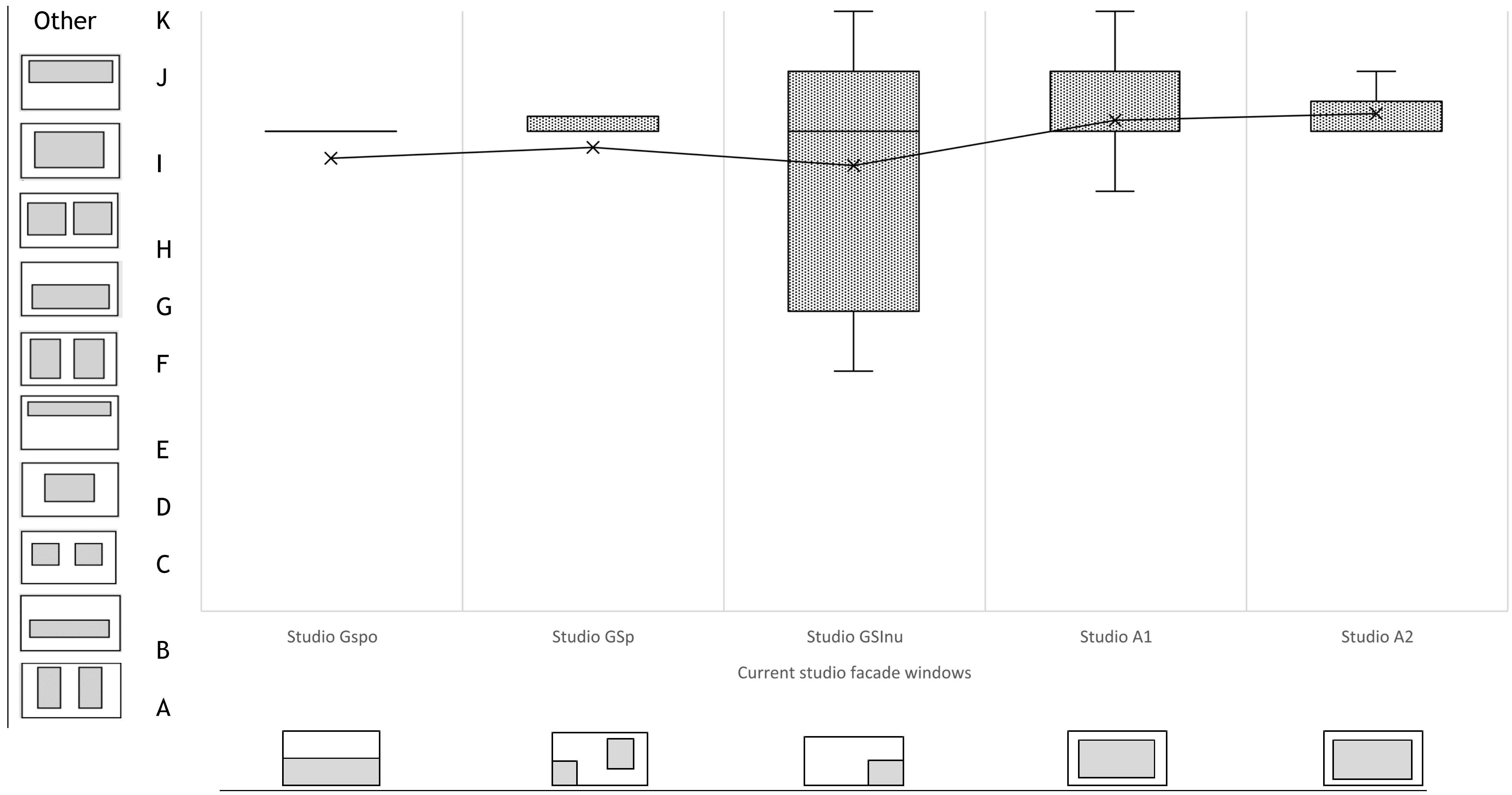


Figure 9-10 Boxplot presents the variation of students' preferences for window arrangements that would make the most of the daylight in their studio.

9.4 Subjective responses to the effect of façade windows on experienced atmosphere (studios with skylight vs without)

In the investigated studios in Glasgow and Aberdeen, 79.9% of the responses acknowledged an awareness of the concept of atmosphere in architectural spaces, while 19.3 % intimated that the concept was unfamiliar. As with studios North-oriented, a high percentage of the students who showed awareness of atmosphere as a concept could be due to the fact they had acquired relevant knowledge from studying design or architecture. With regards to whether the interior spaces of all studios could have sensorial stimuli, 50.3% of occupants answered yes, 46.2% responded maybe and 2.1% replied no. The analysis of subjective responses to the experienced atmosphere began with asking students whether they perceived the following variables to be positive or negative stimuli within their studios: daylight (cloudy days and bright days); artificial light; temperature (winter and summer); acoustics; air quality; furniture arrangements and proximity; spaciousness; façade windows and overlooking view.

To investigate which variable contributes most to the perceived atmosphere, factor analysis determines this and compute the factors' variabilities and correlations. The internal consistency between the different variables was checked by Cronbach's alpha reliability test, in which the computed reliability coefficient is 0.716, showing considerable internal consistency between factors. From Appendix U. 1, it is evident that there is a statistically weak relationship between the façade windows and daylight in a bright day ($r = .315$, $P<0.01$). However, the façade windows have a statistically moderate relationship with overlooking view ($r = .518$, $P<0.01$). The relationship between Furniture proximity and furniture arrangements produced a significant correlation ($r = .670$, $P<0.01$) among the other variables as atmospheric stimuli. Variables with a correlation greater than .30 were considered in the factor analysis, as anything lower would suggest a weak relationship between variables (Tabachnick & Fidell, 2007, p. 614). The results are reported in Table 9-8.

The factor analysis compiled the 12 variables that contribute to the experienced atmosphere and identified 4 perceptually independent factors. They explain 66.50% of the variance, hence the most important one, while other factors had a significantly lower contribution to the experienced atmosphere. Regarding the consistency between variables in each component, the value for the reliability coefficient (Cronbach's alpha) for the first factor was considerable at 0.741. The obtained factors are presented in Table 9-8 and as follows:

- 1st factor: includes *furniture arrangements - proximity* as the most stimuli contribute to the perceived atmosphere. Variables like 'daylight on a bright day', 'temperature in winter, 'acoustics', 'air quality', 'spaciousness' and 'overlooking view' are very significant to this factor. This factor explains 26.71% of the variance.

- 2nd factor: determines *Daylight on bright and cloudy days* as the most stimuli contribute to the perceived atmosphere. The variables that contribute most to this factor are: 'temperature in summer', 'façade windows' and have a negative correlation to the variables 'furniture arrangements and proximity' and 'spaciousness'. This factor explains 16.65% of the variance.

- 3rd factor: reflects *Temperature in summer- acoustics*. Variables like 'daylight on a cloudy day' and 'artificial light' contribute to this factor, while 'façade windows' and 'overlooking view' have a negative correlation. This factor explains 12.52% of the variance.

- 4th factor: includes *Artificial light* as most stimulus contributes to the perceived atmosphere. Variables that contribute to this factor are: 'temperature in winter', 'acoustics', and have a negative correlation with 'temperature in summer' and 'spaciousness'. This factor explains 10.60% of the variance.

	Factors			
Variable (stimuli)	1	2	3	4
Daylight on a cloudy day	-	.645	.308	-
Daylight on a bright day	.326	**.734**	-	-
Artificial light	-	-	.316	**.760**
Temperature in winter	.419	-	-	.381
Temperature in summer	-	.495	**.461**	-.335
Acoustics	.568	-	.318	.313
Air quality	.756	-	-	-
Furniture arrangements	**.769**	-.325	-	-
Furniture proximity	.759	-.339	-	-
Spaciousness	.617	-.462	-	-.348
Façade windows	-	.478	-.631	-
Overlooking view	.507	-	-.661	-
% Variance	26.71%	16.65%	12.52%	10.60%
Cronbach's alpha	.741	.608	.330	.419

Table 9-8 Factor Matrix

The following analysis investigates the effect of various factors related to the façade windows, such as window-to-wall area ratio and windowsill height, on various stimuli within the studios. The results in Table 9-9 revealed that the window-to-floor area ratio is the only factor that has a statistically significant effect ($p<0.05$) on daylight on bright days being perceived as positive or negative stimuli, while none of the factors have a statistically significant effect on façade windows. This result is in line with the previous analysis of the subjective response to the different descriptions of façade windows, where none of the characteristics of façade fenestration were found to have a statistically significant effect on descriptions relating to spatial experience, studio's character and its aesthetics. In addition, the presence of a skylight was found to have a statistically significant effect ($p<0.05$) on whether artificial light, furniture proximity and overlooking view were perceived as positive or negative stimuli.

In the studios oriented to the south, factors relating to façade fenestration were not found to have a significant impact on which made a direct contribution to the experienced atmosphere in general. Rather, they were found to act like an interaction variable that could affect a specific stimulus, such as furniture, which in turn contributes to other stimuli in generating the overall experience.

Factor	**Stimuli in studio**	**df**	**X^2**	**Sig.**
Window-to-wall area ratio	Daylight on a cloudy day	3	2.95	.399
	Daylight on a bright day	3	5.15	.161
	Artificial light	3	9.96	**.019**
	Temperature in winter	3	2.55	.466
	Temperature in summer	3	5.63	.131
	Acoustics	3	3.60	.307
	Air quality	3	5.73	.126
	Furniture arrangements	3	3.88	.274
	Furniture proximity	3	8.13	**.043**
	Spaciousness	3	2.24	.523
	Façade windows	3	.371	.946
	Overlooking view	3	11.97	**.007**
Window-to-floor area ratio	Daylight on a cloudy day	2	1.35	.508
	Daylight on a bright day	2	7.03	**.030**
	Artificial light	2	.067	.967
	Temperature in winter	2	2.17	.337
	Temperature in summer	2	3.56	.168
	Acoustics	2	1.18	.554
	Air quality	2	3.27	.195
	Furniture arrangements	2	1.35	.508
	Furniture proximity	2	2.04	.360
	Spaciousness	2	2.63	.268
	Façade windows	2	1.80	.406
	Overlooking view	2	3.33	.189
Windowsill height (m)	Daylight on a cloudy day	1	2.37	.124
	Daylight on a bright day	1	.409	.523

	Artificial light	1	9.04	**.003**
	Temperature in winter	1	1.52	.217
	Temperature in summer	1	4.87	.027
	Acoustics	1	2.81	.093
	Air quality	1	3.64	.056
	Furniture arrangements	1	2.83	.092
	Furniture proximity	1	3.96	**.046**
	Spaciousness	1	1.28	.256
	Façade windows	1	.044	.834
	Overlooking view	1	11.01	**.001**
Window area	Daylight on a cloudy day	2	.654	.721
	Daylight on a bright day	2	4.36	.113
	Artificial light	2	5.62	.060
	Temperature in winter	2	1.85	.396
	Temperature in summer	2	2.07	.354
	Acoustics	2	.705	.703
	Air quality	2	1.48	.476
	Furniture arrangements	2	1.24	.536
	Furniture proximity	2	2.77	.250
	Spaciousness	2	.132	.936
	Façade windows	2	.307	.858
	Overlooking view	2	9.64	**.008**
Skylight	Daylight on a cloudy day	1	2.37	.124
	Daylight on a bright day	1	.409	.523
	Artificial light	1	9.04	**.003**
	Temperature in winter	1	1.52	.217
	Temperature in summer	1	4.87	.027
	Acoustics	1	2.81	.093
	Air quality	1	3.64	.056
	Furniture arrangements	1	2.83	.092
	Furniture proximity	1	3.96	**.046**
	Spaciousness	1	1.28	.256
	Façade windows	1	.044	.834
	Overlooking view	1	11.01	**.001**

Window arrangement	Daylight on a cloudy day	3	3.96	.266
	Daylight on a bright day	3	6.19	.103
	Artificial light	3	12.98	**.005**
	Temperature in winter	3	3.83	.280
	Temperature in summer	3	10.55	**.014**
	Acoustics	3	5.86	.118
	Air quality	3	5.99	.112
	Furniture arrangements	3	3.46	.325
	Furniture proximity	3	8.53	**.036**
	Spaciousness	3	5.62	.132
	Façade windows	3	1.79	.617
	Overlooking view	3	11.10	**.011**
Type of view	Daylight on a cloudy day	1	2.37	.124
	Daylight on a bright day	1	.409	.523
	Artificial light	1	9.04	**.003**
	Temperature in winter	1	1.52	.217
	Temperature in summer	1	4.87	**.027**
	Acoustics	1	2.81	.093
	Air quality	1	3.64	.056
	Furniture arrangements	1	2.83	.092
	Furniture proximity	1	3.96	**.046**
	Spaciousness	1	1.28	.256
	Façade windows	1	.044	.834
	Overlooking view	1	11.01	**.001**

Table 9-9 Kruskal-Wallis H results for the effect of various façade windows characteristics, skylight, window arrangement and view type on stimuli in Glasgow and Aberdeen studios (N= 108).

9.4.1 **Subjective evaluation of the atmospheric stimuli between studios**

The previous analysis (Table 9-9) indicated no statistically significant effect of the presence of a skylight on the daylight or façade windows being considered as positive or negative stimuli. Similarly, the Kruskal-Wallis H test results revealed that the differences between studios have no statistically significant effect on rating the daylight on a cloudy day (X^2 (1, N = 108) = 4.49, p = 0.344), on a bright day (X^2 (1, N = 108) = 7.47, p = 0.113) and façade windows (X^2 (1, N = 108) = 2.11, p = 0.715). Meanwhile, the differences between studios have statistically significant effect on the artificial light (X^2 (1, N = 108) = 13.02, p = 0.011) and overlooking view (X^2 (1, N = 108) = 11.98, p = 0.017).

The variation of subjective responses between the studios regarding daylight evaluation on cloudy and bright days, façade windows, overlooking view and whether artificial light is perceived as negative or positive stimuli is presented in Figure 9-11, Figure 9-12, Figure 9-13, Figure 9-14 and Figure 9-15.

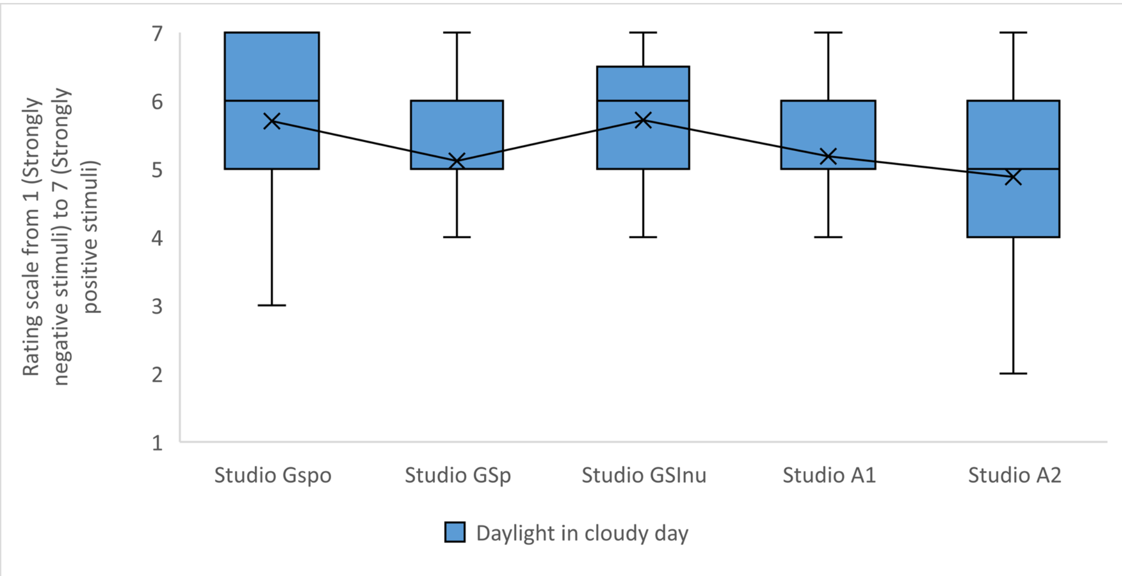


Figure 9-11 Boxplot representing the variation in subjective responses between studios in evaluating daylight on cloudy days as negative or positive stimuli.

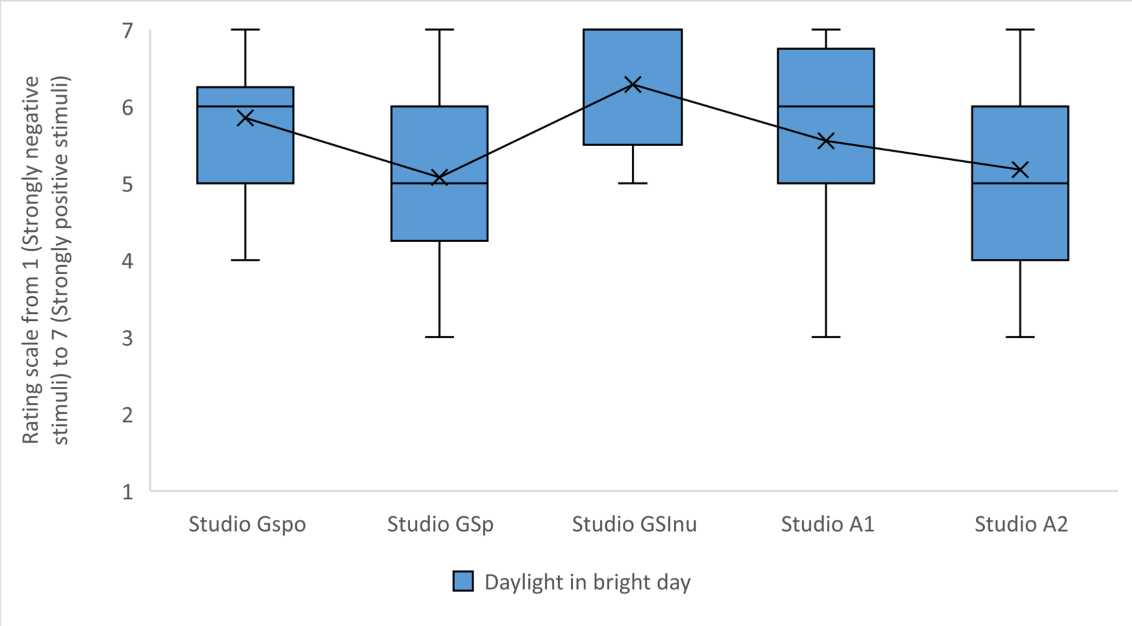


Figure 9-12 Boxplot representing the variation in subjective responses between studios in evaluating daylight on bright days as negative or positive stimuli.

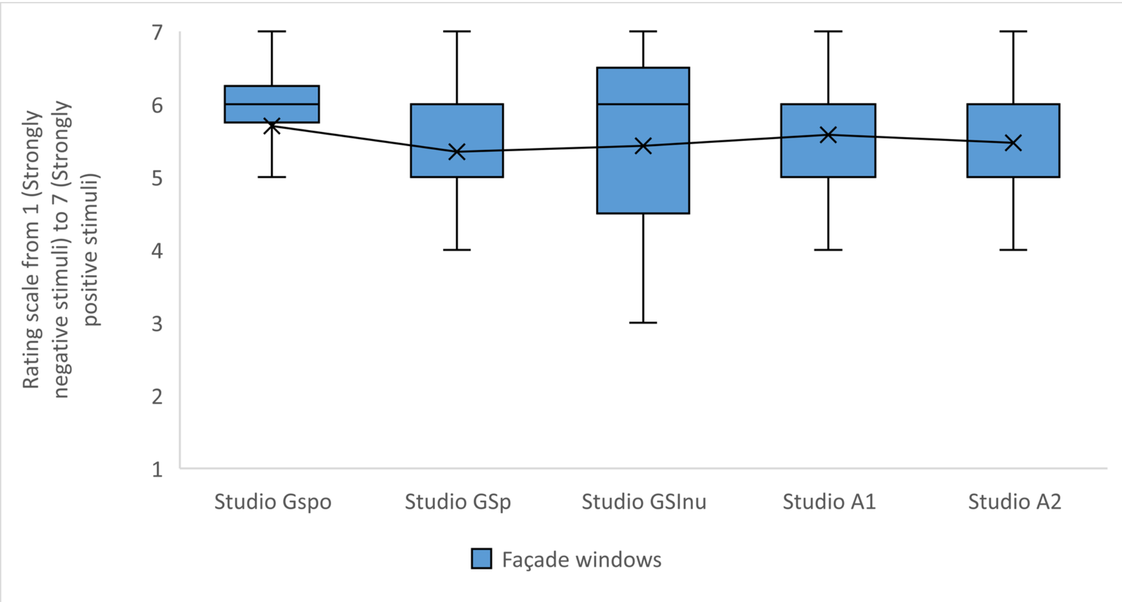


Figure 9-13 Boxplot representing the variation on subjective responses between studios in evaluating façade windows as negative or positive stimuli.

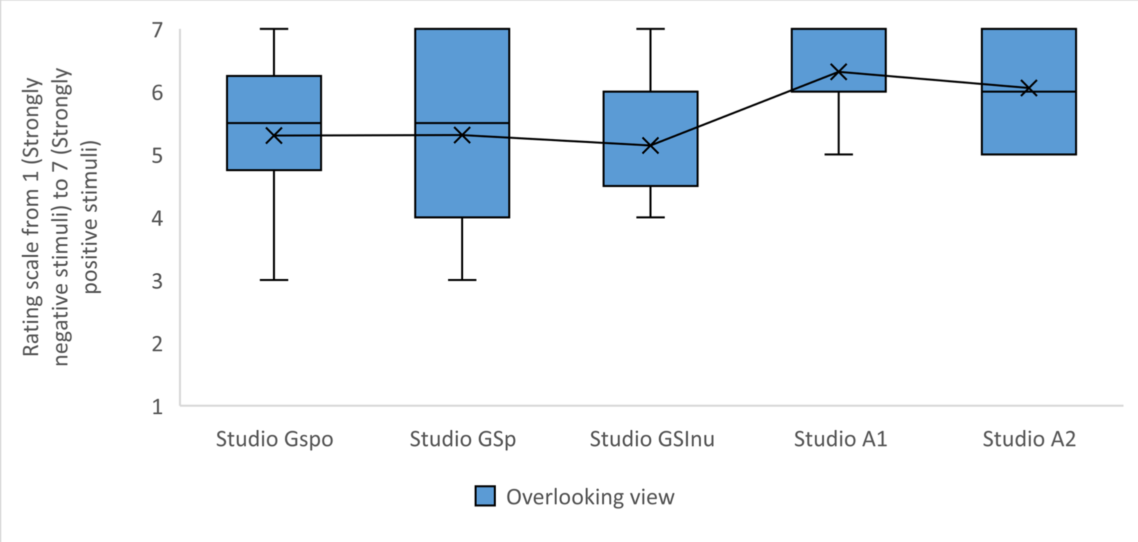


Figure 9-14 Boxplot representing the variation in subjective responses between studios in evaluating overlooking view as negative or positive stimuli.

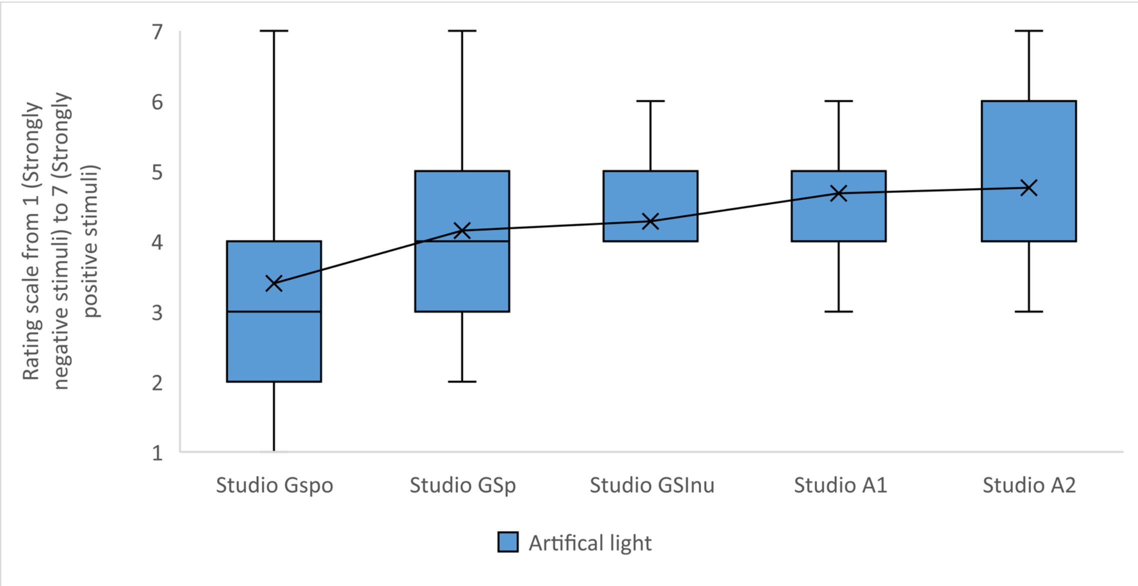


Figure 9-15 Boxplot representing the variation in subjective responses between studios in evaluating artificial light as negative or positive stimuli.

9.4.2 **State of atmosphere**

The state of atmosphere inside the South-oriented studios was investigated and measured using two methods: the semantic differential (SD) scale to describe the state of atmosphere and the Likert scale to evaluate the experienced atmosphere. Using the (SD) rating scale, students were asked to choose the word which best describes the state of the atmosphere in their studios from sixteen pairs of adjectives. The mean of each SD scale is displayed in Table 9-10. The Kruskal-

Wallis H test results highlight the statistically significant differences ($p<0.05$) between studios; in terms of mean rating on each atmospheric descriptor apart from 'business-like_cosy', 'terrifying – pleasant', 'dispirited – lively', 'tense-relaxed' and 'hostile – friendly'. Figure 9-16 presents a comparison of the mean semantic differential ranking scales between studios.

State	Studios					Differences between studios (Kruskal-wallis H)
	GSPo	GSP	GSInu	A1	A2	**.Sig**
Business-like - Cosy	3.95	4.04	5.14	3.92	4.24	.141
Formal - Intimate	4.16	4.48	5.43	3.97	4.12	**.036**
Dull - Stimulating	3.89	5.21	5.29	4.87	5.18	**.005**
Terrifying - Pleasant	5.05	5.68	6.00	5.79	5.53	.108
Dispirited - Lively	4.74	5.68	5.71	5.61	5.35	.134
Tense - Relaxed	4.58	5.52	5.29	5.24	5.24	.086
Public - Private	1.90	4.00	2.71	3.16	3.06	**.000**
Boring - Exciting,	3.58	5.04	5.57	4.76	4.47	**.001**
Unattractive - Attractive	4.21	5.48	5.57	4.87	5.06	**.014**
Inconvenient - Convenient	4.32	5.56	4.86	5.53	5.24	**.007**
Passive - Active	4.26	5.38	4.86	5.39	4.88	**.007**
Hostile - Friendly	5.31	6.08	5.71	6.05	5.41	.087
Unsociable - Sociable	5.93	6.24	6.14	6.39	5.35	**.003**
Monotonous - Interesting	3.68	5.28	5.71	5.39	5.18	**.000**
Dislike - Like	4.26	6.20	5.43	5.95	5.41	**.000**
Frustrating - Satisfying	4.26	5.80	5.57	4.97	5.66	**.000**

Table 9-10 Mean comparative ratings for the investigated studios

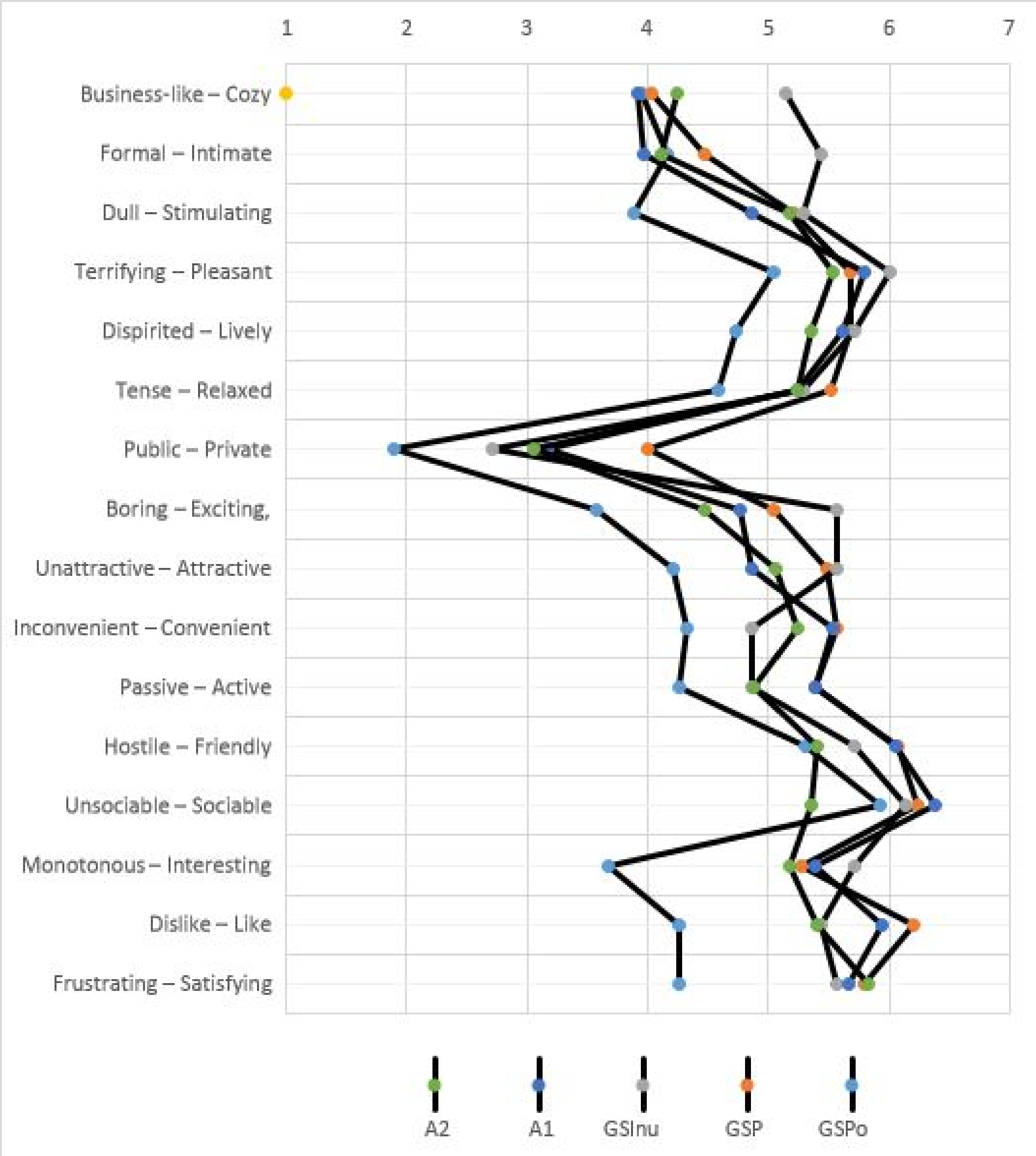


Figure 9-16 Comparison of mean semantic differential ranking scale between studios: GSPo, GSP, GSInu, A1 and A2.

9.4.2.1 Effect of façade windows characteristics (South-facing) on atmospheric states

In investigating the effect of façade fenestration characteristics on atmospheric states, factor analysis was used to identify the most variables that contribute to the state of atmosphere. The four determined factors were responsible for 64.97% of the variance. The reliability Cronbach's alpha coefficient is 0.891, which showed considerable internal consistency between the different variables. The results are reported in Table 9-11, and the obtained factors are as following:

- 1st factor: determines *Dislike-like* of the atmospheric state inside studio. Adjectives contribute to this factor are: 'unattractive-attractive', 'business-like – cosy', 'formal-intimate', 'dull-stimulating', 'terrifying-pleasant', 'dispirited-lively', 'tense-relaxed', 'public-private', 'boring – exciting', 'inconvenient-convenient', 'passive-active', 'hostile – friendly', 'unsociable-sociable', 'monotonous-interesting' and 'frustrating-satisfying'. This factor explains 40.18% of the variance.

- 2nd factor: reflects *Business-like – cosy* state of atmosphere. The variable 'formal-intimate' is significant to this factor, while 'inconvenient-convenient' and 'hostile-friendly' states have a negative correlation. This factor explains 9.59% of the variance.

- 3rd factor: represents *Tense - relaxed* of atmospheric state. Most variables contribute are: 'formal-intimate', 'unsociable-sociable' and have a negative correlation with 'boring-exciting' and 'unattractive-attractive' states. This factor explains 7.81% of the variance.

- 4th factor: similar to the previous factor, this factor includes *Tense - relaxed* state of atmosphere. The most significant variables are 'terrifying-pleasant' and 'frustrating-satisfying', while variables like 'passive-active', 'hostile-friendly' and 'unsociable-sociable' have a negative correlation. This factor explains 7.39% of the variance.

Variable (state)	Factors 1	2	3	4
Business-like - Cosy	.312	.732	-	-
Formal - Intimate	.384	.701	.393	-
Dull - Stimulating	.716	-	-	-
Terrifying - Pleasant	.724	-	-	.306
Dispirited - Lively	.691	-	-	-
Tense - Relaxed	.532	-	.486	.364
Public - Private	.437	-	-	-
Boring - Exciting	.770	-	-.365	-
Unattractive - Attractive	.640	-	-.412	-
Inconvenient - Convenient	.551	-.461	-	-
Passive - Active	.656	-	-	-.309
Hostile - Friendly	.669	-.363	-	-.388
Unsociable - Sociable	.498	-	.393	-.558
Monotonous - Interesting	.710	-	-	-
Dislike - Like	.795	-	-	-
Frustrating - Satisfying	.792	-	-	.301
% Variance	40.18%	9.59%	7.81%	7.39%
Cronbach's alpha	.891	.469	.646	.789

Table 9-11 Factors matrix

The Kruskal-Wallis H results in Table 9-12 revealed that the window arrangement had a statistically significant effect ($p<0.05$) on rating 'tense-relaxed' and 'dislike-like' atmospheric factors, while window-to-floor area ratio had a statistically significant effect ($p<0.05$) on rating 'business-like - cosy' factor. On the other hand, windowsill height, window area, the presence of skylight and layers of view had no statistically significant effect ($p>0.05$) on the atmospheric factors.

State	Window-to-wall area ratio	Window-to-floor area ratio	Windowsill height	Window area	Skylight	Window arrangement	Type of view
Business-like - Cosy	.077	**.044**	.664	.053	.664	.140	.664
Tense - Relaxed	.963	.198	.975	.871	.975	**.043**	.975
Dislike - Like	.350	.137	.240	.198	.240	**.000**	.240

Table 9-12 The Kruskal-Wallis H test p-values results relating to the effect of façade windows characteristics, skylight, window arrangement and type of view on different states of atmosphere, N= 108.

9.4.2.2 Evaluation of experienced atmosphere

Using the Likert scale, students were asked to evaluate the experienced atmosphere in their studios in terms of sixteen dimensions: stimulating, pleasant, secure, lively, subdued, demarcated, airy, masculine, feminine, simple, complex, aged, modern, new, surprising and ordinary. However, subdued, masculine, feminine, complex, aged and ordinary dimensions were removed to increase the reliability coefficient to a considerable value 0.73. Using factor analysis, the ten dimensions grouped into three factors, explain 59.40% of the variance (Table 9-13). The obtained factors are as following:

- 1st factor: determines the experienced atmosphere as *Pleasant*. The most significant adjectives to this factor are 'stimulating', 'secure', 'lively', 'airy', 'simple', 'modern' and 'new'. This factor explains 33.04% of the variance.

- 2nd factor: reflects the *Surprising* dimension of atmosphere. Adjectives like 'simple', 'modern' and 'new' refer to this factor. Meanwhile, variables like 'secure' and 'lively' have a negative correlation. This factor explains 46.81% of the variance.

- 3rd factor: represents the dimension of *Demarcated* the experience atmosphere. The words that contribute to it are 'surprising' and negatively correlate with 'airy' and 'simple' dimensions. This factor explains 59.10% of the variance.

	Factors		
Variable (dimension)	1	2	3
Stimulating	.754	-	-
Pleasant	.768	-	-
Secure	.735	-.354	-
Lively	.621	-.392	-
Demarcated	-	-	.539
Airy	.440	-	-.487
Simple	.415	.311	-.586
Modern	.698	.342	-
New	.548	.543	-
Surprising	-	.651	.486
% Variance	33.04%	46.81%	59.10%
Cronbach's alpha	.782	.624	.238

Table 9-13 Factor matrix

The effect of façade windows characteristics on the atmospheric dimensions was examined using the Kruskal-Wallis H test. The results reported in Table 9-14 showed that window arrangement has a statistically significant effect ($p<0.05$) on the 'pleasant', 'surprising' and 'demarcated' dimensions. Meanwhile, the window area has no statistically significant effect on any of the atmospheric dimensions. Window-to-wall area ratio, window-to-floor area ratio, windowsill height, skylight and layers of view were each found to have a statistically significant effect ($p<0.05$) on the 'demarcated' dimension. The students' appraisal of different dimensions of atmosphere presented in Appendix V. 1.

State	**Window-to-wall area ratio**	**Window-to-floor area ratio**	**Windowsill height**	**Window area**	**Skylight**	**Window arrangement**	**Type of view**
Pleasant	.268	.148	.094	.331	.094	**.001**	.094
Surprising	.163	.213	.651	.078	.651	**.030**	.651
Demarcated	**.038**	**.404**	**.042**	.176	**.042**	**.044**	**.042**

Table 9-14 The Kruskal-Wallis H test p-values results relating to the effect of façade widows characteristics, skylight, window arrangement and on different dimensions of atmosphere, N=108.

9.4.2.3 Correlation between façade windows characteristics (South-facing) and experienced atmosphere

The relationship between the objective measurement of facade windows and subjective response attributes is examined using a nonparametric correlation test (Spearman's Rho). The results in Figure 9-17 showed that the window arrangement was found to have a positive association with the following atmospheric factors: 'tense-relaxed' (N=108, r_s = .269, p<0.01), 'dislike-like' (N=108, r_s = .385, p<0.01), 'pleasant-stimulating' (N=108, r_s = .306, p<0.01) and 'surprising' (N=108, r_s = .232, p<0.05). Meanwhile, windowsill height and type of view each has a positive association with the 'demarcated' factor (N=108, r_s = .196, p<0.05). On the other hand, the presence of skylight has a negative association with the 'demarcated' factor (N=108, r_s = -.196, p<0.05).

For testing the hypothesis, the correlation coefficient values obtained from the analysis can be interpreted as weak linear associations between the characteristics of façade fenestration and the experienced atmosphere. Accordingly, the second hypothesis has been rejected.

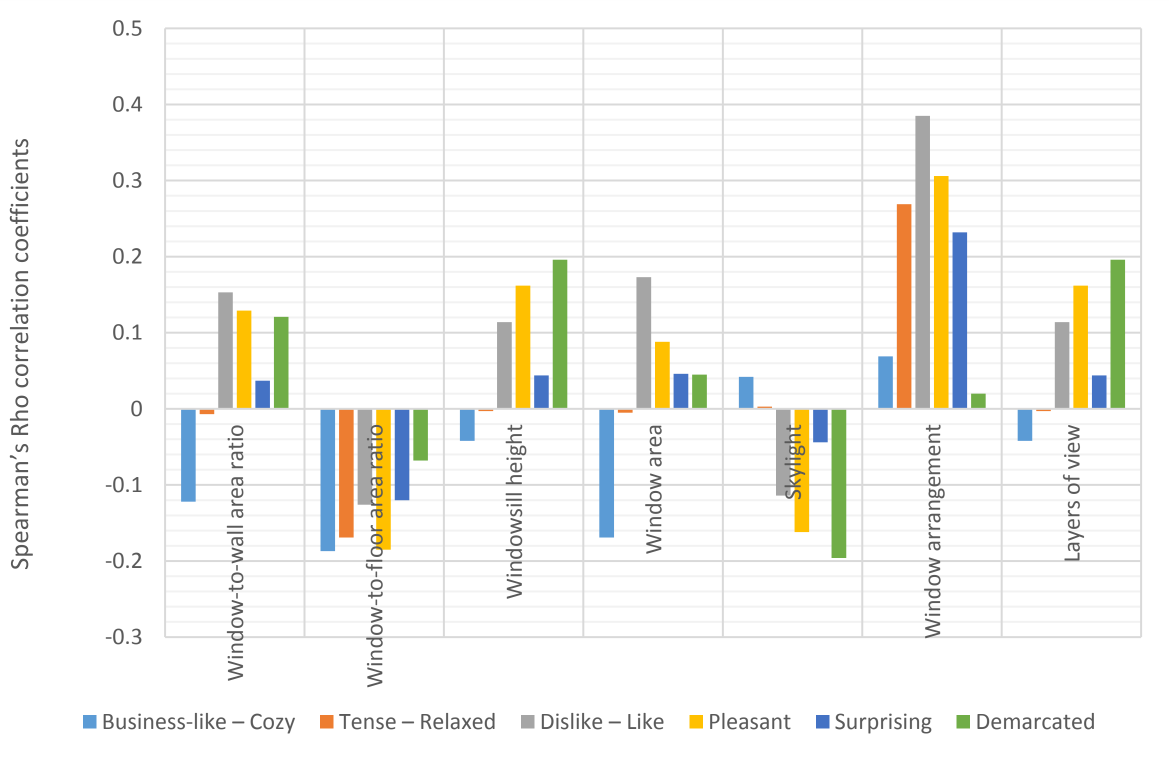


Figure 9-17 Spearman's Rho correlation coefficients of the relationship between the characteristics of façade windows, atmospheric states and dimensions, South-facing studios.

9.5 Atmosphere in relation to the subjective attribute of daylight

The contribution of twelve variables of daylight attribute in studios' atmospheres was determined on both cloudy and sunny days by using the factor analysis. The internal consistency between the different variables on a cloudy day was checked by Cronbach's alpha reliability test; however, variables like colour-grey and darkness were removed to increase the reliability coefficient to a considerable value of 0.719. The factor analysis determined two factors that in total was responsible for 54.17% of the variance. The results are reported in Table 9-15, and the identified factors are as following:

-1st factor: this factor determines the *Illumination* of daylight. Variables like 'brightness', 'uniformity', 'room luminance', 'distribution of daylight', 'glare', and 'visual comfort' are significant to the factor. This factor explains 38.52% of the variance.

-2nd factor: this factor represents the *Shadow*. The most significant variables to this factor are: 'colour-yellowish', 'glare', and the opposite variable is the 'visual comfort' with negative correlation. This factor explains 15.65% of the variance.

	Factors	
Variable	1	2
Brightness	.834	-
Illumination	.913	-
Uniformity	.676	-
Room luminance	.784	-
Distribution of daylight	.783	-
Colour- yellowish	-	.699
Shadow	-	.737
Glare from daylight	.478	.497
Visual comfort	.536	-.443
Lack of control-blinds	-	-
% Variance	38.52%	15.65%
Cronbach's alpha	.827	.230

Table 9-15 Factors matrix for the contribution of daylight (cloudy day) on the experienced atmosphere, South-facing studios.

For the bright day, to increase the internal consistency between the different variables of daylight, only five variables were involved in the analysis. The value for the reliability coefficient (Cronbach's alpha) was considerable 0.70. The findings for the factor analysis are reported in Table 9-16, where only one factor was obtained.

- 1st factor: this factor determines the *Room luminance*. The variables that contribute most to this factor are: like 'brightness', 'illumination', 'uniformity', and 'distribution of daylight'. This factor explains 53.41% of the variance.

	Factors
Variable	**1**
Brightness	.816
Illumination	.818
Uniformity	.546
Room luminance	.835
Distribution of daylight	.582
% Variance	53.41%
Cronbach's alpha	.70

Table 9-16 Factors matrix for the contribution of daylight (bright day) on the experienced atmosphere, South-facing studios

In investigating the effect of the identified daylight attributes on the atmospheric factors for cloudy and bright days, the Kruskal-Wallis H test results in Table 9-17 showed that on a cloudy day, the 'shadow' is the only attribute that has a statistically significant effect ($p<0.05$) on experience the 'business-cosy' atmospheric factor. On the other hand, none of the other attributes were found to significantly affect the atmospheric factors. Although the 'brightness' attribute was not determined by the factor analysis, the test found that it has a statistically significant effect ($p<0.05$) on experience the 'tense-relaxed' and 'pleasant' factors of atmosphere on a bright day.

Atmospheric factor	Cloudy day			Bright day	
	Illumination	Shadow	Brightness	Room luminance	Brightness
Dislike-like	.150	.273	.054	.061	.328
Business-like - cosy	.700	**.035**	.276	.735	.408
Tense - relaxed	.117	.086	.466	.081	**.039**
Pleasant	.700	.172	.652	.094	**.038**
Surprising	.212	.509	.446	.941	.426
Demarcated	.183	.935	.177	.051	.235

Table 9-17 The Kruskal-Wallis H test results relating to the effect of daylight attributes (cloudy and bright days) on different factors of atmosphere, South-facing, N=108.

9.5.1 Correlation between atmospheric factors and daylight attributes (South- facing studios)

The relationship between the daylight attributes and atmospheric factors were examined using the Spearman's Rho correlation test. The obtained daylight attributes like illumination, shadow, room luminance and the vertical illuminance level tested with atmospheric factors, such as 'business-like - cosy', 'tens relaxed', 'dislike-like', 'pleasant', 'surprising' and 'demarcated' on cloudy and bright days.

Figure 9-18 presents the relationship between the Spearman's Rho correlation coefficients and atmospheric factors on a cloudy day. The findings revealed that the *illumination* is the only attribute that has a statistically significant positive association with the following atmospheric factors: 'tense-relaxed' (N= 108, r_s= .205, $p <0.05$) and 'demarcated' (N= 108, r_s= .194, $p <0.05$). The vertical illuminance levels have no statistically significant association with any of atmospheric factors.

On the other hand, for the bright day (Figure 9-19), the room luminance attribute has a statistically significant positive association with the following atmospheric factors: 'tense-relaxed' (N= 108, r_s= .207, $p <0.05$), 'dislike-like' (N= 108, r_s= .216, $p <0.05$) and 'pleasant' (N= 108, r_s= .196, $p <0.05$). Meanwhile, the vertical illuminance levels have statistically significant negative association with the 'demarcated' factor (N= 108, r_s= -.189, $p <0.05$).

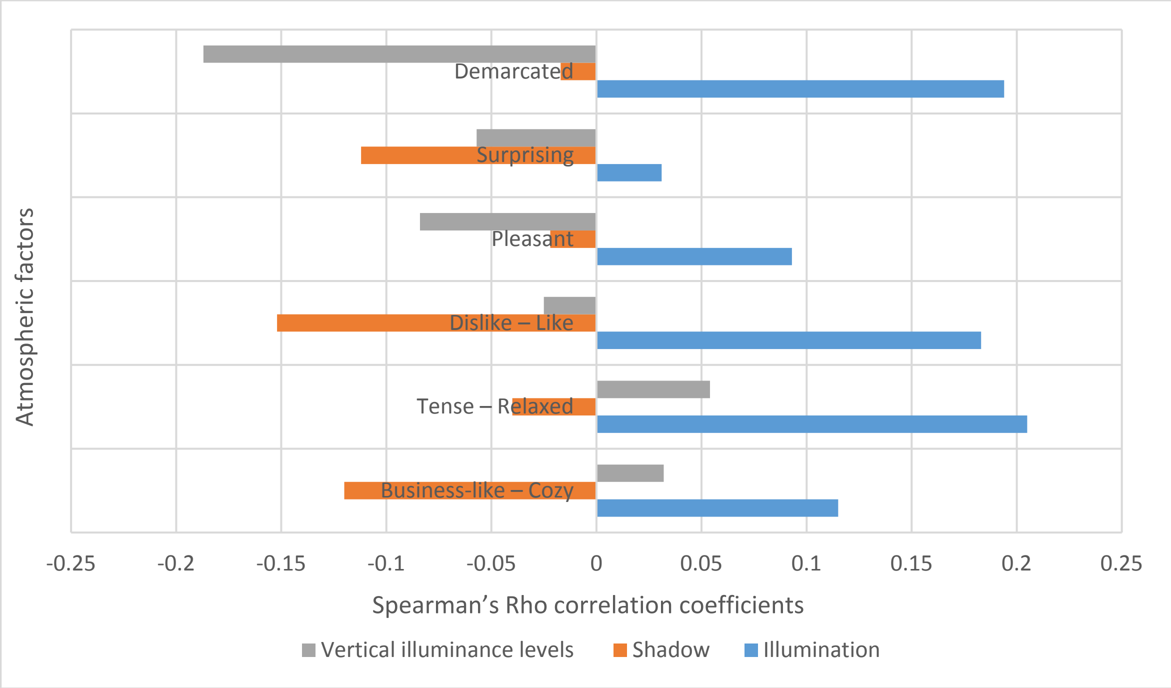


Figure 9-18 Spearman's Rho correlation coefficients of the relationship between the atmospheric factors, vertical illuminance levels and subjective daylight attributes (on a cloudy day), South-facing studios.

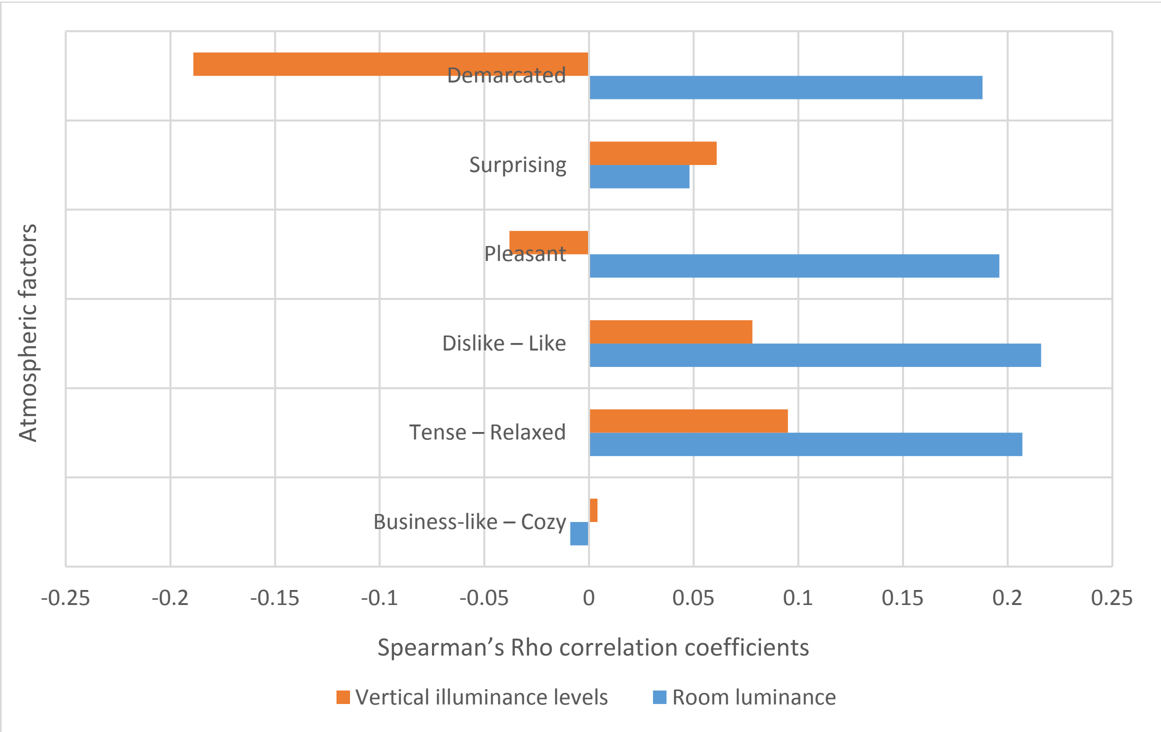


Figure 9-19 Spearman's Rho correlation coefficients of the relationship between the atmospheric factors, vertical illuminance levels and subjective daylight attributes (on a bright day), South-facing studios.

9.6 **Summary**

The aim of this chapter was to investigate the effect of façade fenestration on the daylight levels and experienced atmosphere in South-facing studios in Glasgow and Aberdeen, from a subjective perspective. The investigated studios have two design typologies (double-volume open plan studio and ordinary open-plan studio) and not all studios had a skylight. The subjective ratings of the windows from the perspective of providing sufficient daylight levels to the studios during cloudy and bright days have been examined in relation to the guidelines, which recommends daylight levels between 500-700 lux. The findings showed that the subjective ratings for the functionality of windows in providing sufficient daylight levels in studios with or without skylight did not support the objective measurement during cloudy days, because students evaluated windows as being ‘adequate’ in providing sufficient daylight levels, whereas the objective measurements (mean illuminance levels) registered less than 400 lux. On bright days, students’ ratings supported the objective measurements in the studios with a skylight, where the mean of the measured illuminance levels was more than 500 lux and students rated windows as ‘very efficient’ in providing sufficient daylight levels. However, in the studios with no skylight, students rated windows as being ‘efficient’ even though the mean illuminance levels were less than 200 lux. Accordingly, the Kruskal-Wallis H test revealed that the presence of a skylight has no statistically significant effect on subjective responses for sufficient daylight on cloudy and bright days.

The effect of façade window characteristics on the subjective ratings of different façade window descriptions was investigated, with factors such as providing sufficient daylight levels on cloudy and bright days, providing an attractive outside view, helping to create a significant spatial experience, contributing positively to the studio’s aesthetics and adding character to the studio. The Kruskal-Wallis H test results revealed that there is no statistically significant effect ($p>0.05$) of window-to-wall area ratio, window-to-floor area ratio, window area, windowsill height, window arrangements, the presence of skylight and type of view on providing sufficient daylight levels to the studio during cloudy and bright days. However, they have a statistically significant effect ($p<0.05$) only on providing an attractive outside view. As such, none of the façade characteristics were found to have a statistically significant effect on creating spatial experience, contributing positively to the studio's aesthetics or adding character to the studio.

In terms of window arrangement, as the students have occupied in studios both with and without skylights, the Kruskal-wallis H test displayed a no statistically significant effect for the presence of skylight on students' preferences for a particular window arrangement. Regardless of their studio, students revealed a preference for type I as the one that would make the most of the daylight in their studios. This result corresponds with the students located in North-oriented studios, who also preferred the type I window arrangement. In addition, the Wilcoxon Signed-Rank revealed that there is no statistically significant difference between choosing the preferred window arrangement (type I) and the existing façade window in studios A1, A2 and GSInu. In contrast, although students evaluated the current studios' windows for GSPo and GSP as being 'efficient' in providing sufficient daylight levels, the Wilcoxon test showed a significant difference ($p<0.05$) between choosing the preferred window arrangement (type I) and the existing facade window. This result also agreed to the one obtained from studios oriented to the north.

For the part relating to subjective responses to the effect of façade windows on experienced atmosphere (studios with skylight vs without), factor analysis revealed that the factor contributing most to the perceived atmosphere was *furniture arrangements – proximity*. The variables that are significant to this factor are: 'daylight on a bright day', 'temperature in winter, 'acoustics', 'air quality', 'spaciousness' and 'overlooking view'. This factor explains 26.71% of the variance.

The Kruskal-Wallis H test revealed that the window-to-floor area ratio is the only factor that has a statistically significant effect ($p<0.05$) on daylight on a bright day as being perceived either as positive or negative stimuli, while none of the other façade characteristics showed a statistically significant effect on either daylight or façade windows. This finding confirms with the previous analysis regarding the subjective response to different descriptions of façade window, in which none of the characteristics of façade fenestration were found to have a statistically significant effect on descriptions related to spatial experience, a studio's character and aesthetics. On the other hand, this result contradicts the one obtained from studios oriented to the north, where window-to-wall area ratio, window-to-floor area ratio, window area, external obstructions and layers of view were each found to have a statistically significant effect ($p<0.05$) on the creation of a spatial experience, contribute to the studio's aesthetics and add a character to the studio (see section 8.3.1). Furthermore, window-to-wall area ratio and studios' design typology were each found to have a statistically significant effect ($p<0.05$) on façade windows to be perceived as positive or negative stimuli (see section 8.4).

The state of atmosphere was rated by the SD scale, in which sixteen items were reduced to three factors: *Dislike-like, Business-like – cosy and Tense – relaxed*. Accordingly, the Kruskal-Wallis H test revealed that window arrangement had a statistically significant effect ($p<0.05$) on rating 'tense-relaxed' and 'dislike-like' factors, while window-to-floor area ratio had a statistically significant effect ($p<0.05$) only on rating 'business-like – cosy' factor. Meanwhile, window-to-wall area ratio, windowsill height, window area, the presence of skylight and type of view had no statistically significant effect on any of the identified atmospheric factors.

In evaluating the experienced atmosphere (Likert scale), factor analysis determined three factors: *Pleasant, Surprising* and *Demarcated*. The Kruskal-Wallis H test results revealed that the window arrangement had a statistically significant effect ($p<0.05$) on 'pleasant', 'surprising' and 'demarcated' factors. Meanwhile, the window area had no statistically significant effect on any of the atmospheric factors. Furthermore, window-to-wall area ratio, window-to-floor area ratio, windowsill height, skylight and layers of view were each found to have a statistically significant effect ($p<0.05$) only on the 'demarcated' factor.

In terms of the subjective attribute of daylight, two factors were identified on a cloudy day: *Illumination* and *Shadow*. Whereas, the *Room luminance* was the only identified factor on a bright day. The Kruskal-Wallis H test results showed that on a cloudy day, the 'shadow' had a statistically significant effect on experience the 'business-cosy' factor. Meanwhile, the room luminance on a bright day had no significantly effects on the atmospheric factors. However, the ‘brightness’ factor was found to have a statistically significant effect on experience the ‘tense-relaxed’ and ‘pleasant’ factors of atmosphere.

Finally, the Spearman’s Rho correlation test revealed a weak association between façade windows characteristics, daylight attributes and atmospheric factors. Accordingly, the second hypothesis has been rejected as it suggested there to be a strong association between the façade fenestration characteristics and experienced atmosphere.

9.7 **Discussion**

This chapter discusses the paper-based questionnaire designed to examine the subjective appraisal to the effect of façade windows characteristics on daylight levels and the experienced atmosphere. The characteristics of façade windows were window area, windowsill height, window-to-wall area ratio, window-to-floor area ratio, window arrangement as well as other factors, such as external obstructions and type of view. Some of studios (GSp, GSPo, GSInu) have a skylight in addition to vertical windows. Therefore, it was important to include the skylight as a factor in the analysis. Previous studies, such as a study by Treado et al. (1984) found that skylights are the most effective daylight source, in which South-facing clerestories are more effective than North-facing ones. Similarly, a study by Acosta et al. (2012) reported that lightscoop skylights provide homogeneous lighting over the horizontal plane in overcast sky conditions. However, the findings from subjective appraisal revealed that the skylight factor had no statistically significant effect on rating the functionality of façade windows in terms of daylight sufficiency, while it had a significant effect on view provision.

Similarly, in terms of the experienced atmosphere, the findings revealed that skylights had no significant effect on atmospheric factors, except on ‘demarcated’ factor. The finding maybe useful to architects in that a skylight affects the functional dimension of daylight but has on impact on atmospheric dimensions, such as cosiness (pleasant, intimate) and liveliness (stimulating, lively, exciting). Additionally, the factor analysis revealed that *furniture arrangements - proximity* contribute the most to the atmosphere being experienced as positive or negative stimuli in comparison with façade windows and daylight. This result is in line with Ne'Eman & Hopkinson's (1970, p. 25) study, which found that subjective appraisal cannot be related simply and directly to any single parameter.

On the other hand, students occupying the studios with skylights preferred window arrangement type I for making the most of daylight in their studios, an attitude similar to the students' choice in studios with no skylight or studios orientated to the North. By this, it is clear that type I is the students' preferred, regardless of the studios' size, orientation and typology. Furthermore, the windowsill height in studios orientated to the South was found only to have a statistically significant effect on providing an attractive outside view, similar to the studios orientated to the North, where sill height also effects on outside view. In this study, four types of window arrangements orientated to the South were investigated: continuous strip windows, punched windows, side windows, central and side windows (see Figure 9-10). However, the findings revealed that window arrangement has no statistically significant effect on daylight (cloudy and bright days) to be perceived as positive or negative stimuli, while it has a significant effect on overlooking view. Nevertheless, in terms of the experienced atmosphere, the window arrangement was found to have a significant effect on the 'tense-relaxed', 'pleasant', 'surprising' and 'demarcated' atmospheric factors.

In terms of façade windows characteristics, the results are in contrast with those results obtained from North-oriented studios, in which the window area has no significant effect on providing sufficient daylight levels to the studio during cloudy and bright days. This could be due to the nature of the penetrating daylight from South-oriented windows, which tends to be direct sunlight. Similarly, the window area has no significant effect on the experienced atmosphere. This result is in line with those factor analysis results that determined *furniture arrangements - proximity* is the most stimuli that contribute to the perceived atmosphere. Furthermore, the Spearman's Rho test computed a weak association between window area, window-to-wall area ratio, window-to-floor area ratio, windowsill height and window arrangement with atmospheric factors. As a result of this, the second hypothesis in this study has been rejected.

Although the types of views in this phase of study are buildings and trees that have similar heights and distances from the studios, the findings recommend that more attention should be paid to artificial lighting while working on the concept of atmosphere, especially that view has a statistically significant effect on artificial light being considered to be either positive or negative stimuli, which in return effects on the ‘demarcated’ atmospheric factor.

Finally, although the mean daylight levels were registered at less than 400 lux on cloudy days for studios with or without skylight, students tended to evaluate the functionality of windows in providing sufficient daylight levels as being ‘adequate’. In contrast with the studios orientated to the North, an agreement was found between the subjective responses to the windows’ efficiency in providing sufficient daylight levels, with objective measurements that were assessed using the guidelines which recommend daylight levels between 500-750 lux for art schools. Yet, during bright days, students’ ratings supported the objective measurement in studios with a skylight, where the mean illuminance levels were registered at more than 500 lux and students rated windows as ‘very efficient’ in providing sufficient daylight levels.

The study recommends further investigations into the function of skylights in design studios, as only one type of skylight located in the Glasgow studios was available for investigation. More types of rooflights, such as clearstory, monitors, sawtooths and lightscoops, are recommended to be investigated in terms of their functionality in providing sufficient daylight levels and if they would be considered strong stimuli for students to have a positive attitude toward the experienced atmosphere. In addition, further practical investigation for the preferred window arrangement that could be optimum for daylight admittance is recommended through the use of different methods, such as physical models, simulation or virtual reality.

Chapter 10

General conclusion

10.1 Summary

The current study investigates the effects of façade fenestration on daylight levels and experienced atmosphere under an overcast sky within various design studios in three Scottish cities: Glasgow, Edinburgh and Aberdeen. The aim of this study is to assess the characteristics of façade fenestration in various typologies of design studios, in line with the nature of areas where there is a shortage of daylight, with dark and gloomy conditions for most of the year. This requires careful design and well-placed fenestrations to enhance the daylight levels and experienced atmosphere. The following research questions were addressed in this study:

- *How does façade fenestration design affect the daylight levels in different studios typologies under overcast sky conditions?*

- What is the impact of façade fenestration and the resultant daylight level on the experienced atmosphere?

Various rules of thumbs have had a vital impact in shaping the design of façade fenestration and daylight levels overtime. Accordingly, the study tested the following hypotheses and analysed the relationships between variables from previous fieldworks, theories and guidelines: Hypothesis 1: *'The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines.'* Hypothesis 2: *The characteristics of facade fenestration (window –to- floor area ratio, window –to- wall area ratio, window area, windowsill height) are strongly associated with the experienced atmosphere'*.

In that respect, this study adopted the longitudinal quantitative research design method, in which the field measurements consisted of an analysis of different types of façade fenestration for the selected studios. The main investigated studios' typologies were the double-volume open plan studios, mezzanine studios and ordinary open-plan studios. The measurement of the daylight levels and their distribution was achieved by locating light meters in the studios, both vertically and horizontally. Subjective consideration was gleaned through issuing a questionnaire that was completed by the user of the space where the daylight and experienced atmosphere were being evaluated. The total number of participants was 279 students. The data gathered both from daylight measurements and from the questionnaires was analysed statistically using SPSS (Statistical Package for the Social Sciences), whereby various design parameters and orientations (i.e. North facades vs South) were considered. The main significance and contributions of this study are presented in the introduction chapter (see section 1.4). The first part of this chapter presents the key findings obtained from various analyses and summarises them in section 10.2. The second part then presents the research achievements with their practical implication. The limitations of this study are then outlined, especially with regards to the practical side, before presenting opportunities for further research and any final thoughts about how to develop the present work.

10.2 Research findings

This section presents the main findings obtained from the analysis of the daylight levels and experienced atmosphere in different design typologies under an overcast sky. It is important to mention that different design typologies do not necessarily mean different activities. Within this context, it refers to different physical dimensions or characteristics, specifically the height of the studio and the number of floor levels that divide the same space. The next sections of the study go on to present the key findings for the two phases: Glasgow – Edinburgh and Glasgow – Aberdeen.

10.2.1 First phase (Glasgow-Edinburgh)

The first phase of the study aimed to investigate the studios orientated to the North, which included six studios in Glasgow (GNC, GNCm, GNIn, GNPL, GNPm, GNJm) and two studios in Edinburgh (E1, Em). The studios have similar typology characteristics, a double-volume open plan studio with a mezzanine studio above. However, the nature of the penetrating daylight in the different zones within the same studio was experienced differently. The analysis began then by dividing each studio into three zones: zone one related to the area in the double-volume open studio that is not covered by the mezzanine above, zone two related to the area in the double-volume open studio that is covered by the mezzanine above and zone three related to the mezzanine studio.

Accordingly, a group of measuring points (light meters) were placed inside the studios, from the window wall, to the middle, to the furthest point of each studio horizontally, and in the middle of every wall vertically (Appendix G. 1, Appendix G. 2, Appendix G. 3). Regarding the vertical measuring points (VMPs) that were placed at two levels: at the students' eye level while seated (1.20m) and above eye level (1.60m). The findings revealed there to be a non-statistically significant difference between the VMPs situated at eye level and those above eye level in studios with low daylight levels, such as in studio Em and studio GNJm (covered zone). On the other hand, there was found to be a statistically significant difference ($p<0.05$) between the VMPs at eye level and those above eye level in the rest of the studios, even though they had a window-to-wall area ratio of more than 50%. With this in mind, the results revealed there to be no statistically significant effect on the position of window in the centre of the wall on the variation of illumination levels between VMPs at eye level vs. above. Meanwhile, there was found to be a statistically significant effect ($p<0.05$) of the window-to-wall area ratio and window-to-floor area ratio on the variation of illumination levels between VMPs at eye level vs above. In addition, it was found that the direction of VMPs has a more significant effect on the registered illuminance levels than the distance from the window.

The findings from the analysis of the illuminance levels registered by the VMPs and HMPs in zone 1(see section 6.3.3) revealed that studio GNIn registered the highest illuminance levels for most of the measurement period, followed by studio GNPL with a marginal difference in studio GNIn. Meanwhile, both the VMPs and HMPs in studio E1 registered the lowest illuminance levels throughout the measurement period. Further analysis indicated that the main differences in the illuminance levels between studios resulted from the external obstructions (buildings and trees) and from the studios being located at higher or lower levels in the building. Therefore, the highest illumination levels were registered in studios that were located on the higher levels from the ground where the sky is more visible and there were fewer external obstructions to block the daylight from penetrating inside. In terms of zone 2 (see section 6.3.3.1), the highest illuminance levels registered by the VMPs were in studio GNJm for most of the measurement period, along with studio GNPL. Meanwhile, the highest illuminance levels registered by the HMPs were in studio GNPL for most of the measurement period. The lowest illuminance levels registered by the VMPs and HMPs happened to be in studio E1 throughout the measurement period. According to zone 3 (see section 6.3.3.2), the highest illuminance levels registered by the VMPs and HMPs were in studio GNJm for most of the measurement period, along with studio GNCm (the two separated by a marginal difference). Meanwhile, studio Em registered the lowest illuminance levels throughout the measurement period. It is important to mention that the external obstruction is not the only factor that played a role in the variation of illuminance levels, but also the window head height. In studio Em, the window head height was notably lower than the eye height while seated, which led to a major reduction to the penetrated daylight in the studio.

To sum up, zone 3 (the mezzanine studio) registered the highest illuminance levels throughout the measurement period, as the window was designed and placed in alignment with the studios' mezzanine levels. Meanwhile, zone 2 (the area in the double-volume studio that is covered by the mezzanine above) registered the lowest illuminance levels throughout the measurement period, even though the window was placed in alignment with its floor level in studio E1. Although there was no significant difference in illumination levels based on the HMPs in zone 2, the vertical ones revealed significant results in the following months: April, June, July and August. Furthermore, the findings demonstrated that both the VMPs and HMPs revealed significantly different illumination levels between the studios in zone 1 and zone 3. This result could be related to the window location, distance and direction of the measuring points from the window, the studio floor level from the ground or any external obstructions. With this in mind, further suggestions as to how the studios' activities and lighting requirements could be adjusted to the different zones that registered different illuminance levels in the same studio are mentioned in section 10.3 .

The main factors assumed to impact the significant differences in illumination levels between studios in the previous findings were the studio floor level and the presence of external obstructions (section 6.2.1). These were mainly found to have a significant effect on the registered illuminance levels in zone 1 and zone 3. Also, the study found that the inclined window had a considerable effect on the penetrated daylight, and made the following predictions in case of two studios have the same orientation (North), W/W%, window area, floor level from the ground, obstructions factor and weather conditions (excluding area covered by mezzanine floor above):

1- For inclined windows, the less windowsill height, the more daylight levels will register at the area close to the window. Whereas the more windowsill height, the more daylight levels will register in the middle and back of the studio.

2- For inclined vs vertical windows, the inclined window will penetrate more daylight levels for the total studio than the vertical window, no matter of windowsill height. Yet, the consideration of providing a view for aesthetic and psychological needs should be taken into considerations.

The performance of daylight inside the studios was assessed based on the SLL code published by the Society of Light and Lighting in the UK (Raynham et al., 2012) and by the British recommendations (British Standards Institution. et al., 2019) leading to hypothesis 1 being formulated as follows: '*The facade fenestration (transparent windows without external shading), if encompassing a glazing area which is ≥ 20% of the floor area, will secure a well-lit space, considered to be between 500-750 lux of illuminance, by lighting guidelines*'. The findings revealed that studios with a window-to-floor area ratio of over 20% supported the hypothesis. However, this applied only in zones that are not covered by the mezzanine floor above and not for the entire measurement period, like in October and February. With regards to the daylight factor, studios with less than 20% of window-to-floor area ratio registered DF_{avg} in February at less than 2%, which meant that supplementary artificial light was needed. Whereas studios with a window-to-floor area ratio of over 20% registered DF_{avg} in February at over 5%. However, this does not apply in zone 2, which is covered by the mezzanine floor, and registered a DF_{avg} in February of less than 2%. Moreover, even though DF_{avg} registered over 5%, the artificial light in all studios was turned on based on the researcher observations in February.

Regarding the subjective appraisal, the results revealed that the subjective responses in rating the functionality of windows in providing sufficient daylight levels during both cloudy and bright days supported the objective measurements in all the studios, except in studio E1, where students evaluated the studios' windows as being 'efficient' in providing sufficient daylight levels. Accordingly, the guidelines recommendations for illuminance levels between 500-750 lux from the SLL code and British standards can be adapted to North-facing design studios. Moreover, the results indicated that studio design typology has no effect on students' preferences for a particular window arrangement, as students in all the investigated studios preferred one particular window arrangement (type I, see Table 8-8). In addition to this, the characteristics of façade fenestration, such as window-to-wall area ratio, window-to-floor area ratio, window area, design typology, external obstructions and layers of views, each have an effect on the subjective response to windows descriptions, mainly on daylight levels during cloudy and bright days. Meanwhile, windowsill height was found to only has an effect on providing an attractive outside view.

According to the experienced atmosphere, it was found that the factor *spaciousness - furniture arrangements* contribute most to the experienced atmosphere inside the studios. Variables like 'furniture proximity', 'acoustics', 'air quality', 'façade windows', 'temperature in summer', 'overlooking view', 'artificial light' and 'daylight on cloudy and bright days' are significant to this factor. For the effect of façade fenestration on the experienced atmosphere, it was found that window-to-wall area ratio and studios' design typology each had a statistically significant effect on façade windows perceived as being either positive or negative stimuli. Meanwhile, for daylight conditions, window-to-wall area ratio, window-to-floor area ratio, window area, design typology, external obstructions and layers of views were each found to have a statistically significant effect on daylight being perceived as positive or negative stimuli. As a result, it was found that the windowsill height has a no effect on daylight stimuli, which contradicts the results obtained from the objective measurements but confirms the subjective responses. In double-volume studios with outside obstructions, the analysis results revealed on the statistically significant effect of the windowsill height on the penetrated daylight levels (see section 6.4.1).

In investigating the effect of façade fenestration characteristics on atmospheric factors, the findings revealed that the window-to-wall area ratio had a significant effect on rating the following atmospheric factors: 'dislike-like', 'formal-intimate' and 'terrifying-pleasant'. The window-to-floor area ratio had a significant effect only on rating the 'formal-intimate' and 'dislike-like' atmospheric factors. Window area, external obstructions and layers of views had significant effects on rating 'formal-intimate' factor. Meanwhile, windowsill height and design typology were found to have no significant effects on any of atmospheric factors. Further analysis indicated that the window-to-wall area ratio and window area had a significant effect on rating 'pleasant' and 'simple' factors, while window-to-floor ratio, external obstructions and layers of view only had significant effects on rating the 'simple' factor.

Finally, the relationship between the objective measurement of facade fenestration and subjective response attributes which formed the basis of the second hypothesis '*The characteristics of facade fenestration (window-to-floor area ratio, window-to-wall area ratio, window area, windowsill height) are strongly associated with the experienced atmosphere*' was rejected as the correlation test revealed a weak linear association between the characteristics of façade fenestration and atmospheric factors. The same result applied to the effect of daylight attributes, as the correlation test revealed a weak association between the daylight attributes, such as brightness and colour (yellowish & grey), objective measurements of daylight (vertical illuminance levels) and atmospheric factors.

10.2.2 Second phase (Glasgow- Aberdeen)

The second stage of the study aimed to investigate the impact of South orientation on daylight levels and to this end, the study chose four studios in Glasgow (GSInm, GSInu, GSPo, GSp) and two studios in Aberdeen (A1, A2). However, studio (GSInm) was excluded from the analysis because it has two east-facing windows that had an impact on the penetrated daylight. The investigated studios had two typology variations: double-volume open plan studios and ordinary open-plan studios. Similar to the studios orientated to the North, all studios had comparable student tasks, furniture design and colour, orientation and overcast sky conditions. A group of measuring points (light meters) were placed inside the studios. From the window wall, to the middle, to the furthest point of each studio horizontally, and in the middle of every wall vertically (Appendix O. 3). Regarding the vertical measuring points (VMPs) that were placed at two levels: at the students' eye level while seated (1.20m) and above eye level (1.60m). In contrast with the studios orientated to the North, the findings revealed windows located in the centre of the wall to have a significant effect on the variation of illumination levels between VMPs at eye level and those above eye level. Furthermore, it was found that the window–to–floor area ratio and window–to–wall area ratio had a significant effect on the illuminance variation between the VMPs at eye level vs above.

The findings related to the analysis of illuminance levels registered by the VMPs and HMPs revealed that studio GSp registered the highest illuminance levels throughout the measurement period, while studio A2 registered the lowest illuminance levels throughout the measurement period. Regarding the effect of façade fenestration characteristics, it was found that the studio typology, the presence of a skylight, the windowsill height, W/W%, and W/F% each had a significant effect on the registered illuminance levels at all distances from the window and throughout the measurement period. Accordingly, in the comparative analysis between the studios, the findings revealed that the studio with vertical windows and a skylight would register more daylight levels than studios with vertical windows, even if they have a higher window–to-wall area ratio.

In terms of testing the suggested hypothesis, studios with vertical windows with no skylight, such as studio A1 and studio A2, only confirmed the hypothesis in June, despite having a W/F% above 20%. Meanwhile, studios with vertical windows (no sill height) and a skylight confirmed the hypothesis throughout most of the measurement period, except in February, March and October. Meanwhile, studios with vertical windows (sill height = 2m) and a skylight confirmed the hypothesis throughout the measurement period.

With regards to the subjective responses and in contrast with the studios orientated to the North, the results revealed that the subjective ratings for the functionality of windows in providing sufficient daylight levels did not confirm the objective measurement during the cloudy days. At these points, students evaluated the studios' windows as being 'adequate' in providing sufficient daylight levels while the objective measurements (mean illuminance levels) registered less than 400 lux in all studios, except studio GSp. For the bright days, students' ratings confirmed the objective measurements in the studios with a skylight, where the mean illuminance levels registered more than 500 lux and students rated windows as 'very efficient' in providing sufficient daylight levels. However, in the studios without skylights, students rated the windows as being 'efficient' even though the mean illuminance levels registered less than 200 lux. Consequently, it was found that the presence of a skylight has no significant effect on the subjective responses regarding sufficient daylight on cloudy and bright days. This result contradicts the one obtained from the objective measurement, which found that the skylight had a significant effect on the registered illuminance levels at different distances from the window and throughout the measurement period. Moreover, it was found that there to be no significant effect of the presence of skylight on students' preferences of a particular window arrangement. Regardless of their studio, students revealed a preference for type I as the one that would make the most of the daylight in their studios (see Table 9-7). This result corresponds with the students located in studios oriented to the North, who also preferred the type I window arrangement.

In addition to this, the results revealed that there is no statistically significant effect of window-to-wall area ratio, window-to-floor area ratio, window area, windowsill height, window arrangements, skylight and type of view on providing sufficient daylight levels to the studio during cloudy and bright days. The windowsill height was found only to have a significant effect on providing an attractive outside view. Accordingly, none of the façade characteristics were found to have significant effect on creating spatial experience, contributing positively to the studio's aesthetics or adding character to the studio. In addition, similar to the result obtained from studios oriented to the North, it was found that the façade windows have a significantly weak association with the daylight on cloudy and bright days. However, the façade windows have a significantly moderate relationship with the overlooking view.

According to the experienced atmosphere, the analysis revealed that the variables contributing most to the perceived atmosphere were *furniture arrangements – proximity*. For the effect of façade windows' characteristics on studios' stimuli, the results revealed that none of the windows characteristics have a significant effect on either daylight or façade windows, except for the window-to-floor area ratio where is the only factor that has a significant effect on daylight on a bright day perceived as being either a positive or negative stimuli. This result is in line with the previous result regarding the subjective response to different descriptions of façade window, in which none of the characteristics of façade fenestration were found to have a significant effect on descriptions related to spatial experience, a studio's character and aesthetics. However, this result contradicts the one obtained from studios oriented to the North, where window-to-wall area ratio, windowsill height, studios' design typology, external obstructions and layers of views were each found to have a significant effect on façade windows being perceived as positive or negative stimuli.

In investigating the effect of façade fenestration characteristics on atmospheric factors, the findings revealed that the window arrangement has a significant effect on rating most atmospheric factors, while the presence of a skylight and windowsill height have only a significant effect on rating the 'demarcated' factor. On the other hand, the window area has no statistically significant effect on any of the atmospheric factors. Whereas for the window-to-floor area ratio, it was found to have a significant effect on rating the following factors: 'business-like – cosy' and 'demarcated' factors. Meanwhile, the window-to-wall area ratio and type of view have a significant effect on rating the atmospheric factor 'demarcated'.

Finally, the relationship between the objective measurement of facade fenestration and subjective response attributes, which comprised the second hypothesis, has been rejected as the correlation test revealed a weak association between the characteristics of façade fenestration, daylight attributes and atmospheric factors, such as 'business-like-cosy' and 'surprizing'.

10.2.3 Findings in relation to architectural theory

Further interpretations of the findings in relation to architectural theory indicate that the investigated studios have been built based on the concept known as "form follow function". The concept is associated with industrial design and is a consequence of the machine age, when a building was primarily modelled based on its function or purpose. This concept has been supported by many architectural theorists, including Adolf Loos, in his well-known essay 'Ornament and Crime'. In the essay, Loos argues that damage can be done by ornament when it is no longer an expression of culture or even linked to the world order. His extreme manifesto presented ornament as a crime that brings an 'unaesthetic effect' to the modern man and contributes neither to the current cultural level nor the cultural evolution of nations (Conrads, 1998, p. 21). Loos' essay in support of the eradication of ornament led to dramatic change in the faces of buildings (façades). Ultimately, he helped to define the ideology of modern architectural movement, including practices that are seen in the international style.

However, Norberg-Schulz argued that 'the international architecture was a dominant tendency in the twenties, and for the first time architecture lost its regional and local traits' ((Norberg-Schulz, 1996). The Nordic lands presented as an example in his argument are victims of the international style that has led to the 'contemporary loss of place'. Therefore, international modernism failed and northern regionalism rose in importance. Norberg-Schulz employed the term "domestication" to refer to the interaction between the special, local, and general factors, placing the emphasis on rooted and universal architecture. Norberg-Schulz also highlighted the concepts of "Folk architecture", "National romanticism" and "Regionalism" to accommodate buildings within a local context, where they assume identities in interaction with the place to which it belongs (the locality). Even though buildings that are isolated from where they belong might work functionally, their surroundings become fragmented, meaningless, and characterless.

The Nordic art of building means living poetically under Nordic conditions, where the qualitative identity of the environment is appreciated. As a vital condition, light gives the environment its primary character. The Nordic light that filters through an overcast sky creates a ‘space of moods’, where the mood belongs to the environment and is absorbed by its inhabitants ((Norberg-Schulz, 1996). Hence, if it is the light that determines the “Nordic character”, it is necessary to understand the qualitative aspects of the climate ((Norberg-Schulz, 1996).

Likewise, Hawkes et al. (2002, p. 21) highlighted the fundamental importance of context in terms of the regional dimension and climatic regionalism. However, as the authors argued, the geography of architecture has received little attention from architects, with architectural practices becoming international and architects working in different places away from their own native environments. This could be controlled, the authors argued, if the relationship between climate and building becomes a priority that can be sustained by vernacular buildings. Furthermore, the authors noted the importance of ‘selective design’, a concept that focuses on climatic conditions to maintain comfort, and on reducing the use of artificial lighting and energy consumption (Hawkes et al., 2002, p. 123).

The vernacular tradition as a response to climatic parameters was also examined by Baker & Steemers (2002). The authors argued that, although ‘high’ architecture presents power and levels of sophistication, traditional design is more concerned with people’s needs and views, and, consequently, is ‘an unselfconscious expression of the society and its culture’ (Baker & Steemers, 2002, p. 5). Architects like Gunnar Asplund and Alvar Aalto are considered vernacular or romantic modernists whose work involved an explicit awareness of climatic and cultural context, as well as an understanding of the power and meaning of natural light (Baker & Steemers, 2002, p. 23).

Hawkes noted that Charles Mackintosh’s building designs are the best manifestations of a deep sensibility of the climatic conditions of Glasgow and the west of Scotland, and the area’s engineering culture (2006, p. 19). Mackintosh’s greatest building, The Glasgow School of Art, is the embodiment of his understanding of ‘technological conservatism’, as shown in its structure, materials, and environmental arrangements. In addition, Mackintosh supplemented the building's heating and ventilating systems with traditional fireplaces more as a symbolic traditional element than a functional one (Hawkes, 2006, p. 23). This relates to the concepts of National romanticism and Regionalism discussed in Norberg-Schulz's writings.

Meanwhile, Porteous emphasises the concept of "architectural interiority" (2019, p. 143) as a means of expressing the societal and spatial connectivity between the inside of the building and its outside environment. The different modes of activity, transition, and response require different environmental control regimes. For example, climatic, geographic, and topographic conditions have a great impact on social and cultural atmosphere. Similarly, Baker & Steemers (2002, p. 36) refer to the daylight available at a site as the 'daylight microclimate'. The overall daylight microclimate is affected by local conditions and site properties, such as pollution, fog, haze, and obstructions, as well as latitude, cloudiness, building function, and occupancy period.

In this study, however, the investigated studios clearly showed a general absence of ornaments, aesthetic features, and national romanticism, mainly due to the adopting of principles of international design explained by Norberg-Schulz. Here, I would argue that the current architectural priority is to highlight the power of steel and glass as symbolic of rejecting the past and welcoming the future. Aesthetic considerations in buildings are becoming luxuries rather than necessities. Consequently, educational buildings, in general, are starting to mimic the form of factories, with their façades dominated by aluminium panels and glass openings to reflect new technology; hence, they present a "factory facade". This would not be a dilemma if, during design processes, deep considerations were made of the physical manifestations of façade fenestration, climatic factors, educational theories, and culture interest.

Norberg-Schulz, on the other hand, emphasised the 'environmental character' of buildings, i.e. the essence of place, which is determined by how things are and how they are made. The 'totality' of material substance, shape, texture, colour, and technical realisation are the concrete elements that define the 'formal constitution of the place' ((Norberg-Schulz, 1980). Yet, the character of a place is also a function of time, the changes in seasons, the course of the day, and the weather, all of which determine light conditions, which in turn create varieties in atmosphere ((Norberg-Schulz, 1980). In that context, as Nikolopoulou & Steemers (2003) argued, the physical environment and psychological adaptation complement, rather than contradict, each other. Naturalness, expectations, experience, and time of exposure are evidence of how psychological adaptation affects how we perceive a space.

Based on the students' ratings of the studios, furniture arrangements and approximates are the factors that contribute most to the experienced atmosphere. This key result confirms two psychological functions: orientation and identification. Orientation means knowing where one is, while identification means becoming "friends" with a particular environment ((Norberg-Schulz, 1980). The concrete objects of identification form the basis for developing a sense of belonging. The "meaning" of any object consists of its relationships to other objects; that is, it consists of what the object "gathers". 'A thing is a thing by virtue of its gathering. "Structure", instead, denotes the formal properties of a system of relationships. Structure and meaning are hence aspects of the same totality' ((Norberg-Schulz, 1980).

Nevertheless, the investigated studios are reflections of "cosmic architecture" – an integrated logical system distinguished by rationality, abstractness, and a lack of atmosphere. The limited number of basic characters is aimed at 'necessity rather than expression' ((Norberg-Schulz, 1980). Meanwhile, for creative spaces (studios), 'romantic architecture' is the aim. Romantic architecture is an intimate, idyllic, and mysterious system distinguished by multiplicity, variety, and a strong atmosphere with a live and dynamic character. Its forms are a result of "growth" rather than organisation. In other words, 'Romantic space is topological rather than geometrical' ((Norberg-Schulz, 1980).

In Chapter 3, atmosphere was interpreted as a collection of auras that merge based on their electromagnetic fields and frequency. However, identifying cosmic architecture as a place that lacks atmosphere does not correspond with the aforementioned interpretation. Rather, the researcher would argue that there is in fact an atmosphere in a cosmic place, but a "powerless" and "prosaic" one. On a separate note, the relation between atmosphere and light is relative. The main reasons identified for the significant differences in illumination levels between studios were studio floor level and external obstructions. This was also found in the results obtained from the subjective evaluation of the atmospheric stimuli between studios. Even though all studios reflect a cosmic architecture, which is associated with a lack of atmosphere, the results show significant variations in ratings of studio atmosphere in relation to daylight (cloudy and bright days), façade windows, and overlooking view. Furthermore, significant differences were found between studios in rating the various states of atmosphere for the two orientations.

'To reach the quality without a name we must then build a living pattern language as a gate' (Alexander. 1979, p. 155). Tregenza & Loe (1998, p. 47) argue that the character of a room is affected by the patterns of lightness and darkness on room surfaces, as well as by people's feelings and judgments based on the culture and climate of the surroundings. The present study's findings align closely with Tregenza & Loe's observation. In double-volume studios with a mezzanine floor, it was found that the daylight levels are significantly lower under the mezzanine floor, creating spaces characterised by darkness, while the area in the double-volume is well day-lit during good weather conditions. This contrast between the two areas within the same space creates a special character; a special typology that has been examined within the analysis of daylight and experienced atmosphere. However, the darkness was not accepted as an entity that needs certain processing; rather, artificial lights randomly covered the area to provide the illuminance levels needed for functional tasks. With this in mind, understanding the surrounding climate and culture is a fundamental step in designing spaces, regardless of the architectural style to be applied.

The window is an important spatial structure that relates to the light and where the *genius loci* is focused and explained (Norberg-Schulz, 1980). However, the findings reject the second hypothesis: *The characteristics of facade fenestration (window–to-floor area ratio, window–to-wall area ratio, window area, windowsill height) are strongly associated with the experienced atmosphere*. This result confirms the researcher's new definition of atmosphere and provokes a new argument. Linear associations (x & y) do not address the relationship between atmosphere and stimuli as they eliminate context.

Atmosphere is not a single variable, but a collection of variables or a system. Hence, the relationship is more complex. As the atmosphere exists within an invisible physical sphere, then it can be said to have a form within a fifth-dimensional sphere. As Alexander notes, ‘The greatest clue to the inner structure of any dynamic process lies in its reaction to change’ (1964, p. 43). Thus, the process of form-making for any entity requires a deep understanding of the surrounding forces (stimuli), directions, patterns, and power. The analysis methods used in this study, including Semantic Differential Scale (SD), have helped to translate the occupants’ thoughts into numeric evaluations. In some points, this has provided a general picture of the power of stimuli in the experienced space. Factor analysis, on the other hand, has facilitated the identification of patterns and variability among observed stimuli. The next challenging task, however, is to examine the direction of stimuli, so as to decipher the form of atmospheric spaces by paying close attention to their qualitative modes.

10.1.1 Researcher experience

Through observing and documenting the daylight in these studios over a two-year period, the researcher noted that the nature of daylight was very changeable throughout the day and year. In the North-facing studios and on cloudy days, the researcher noticed that students tend to turn on the artificial lights constantly in order to support their functional needs. This observation was supported by the weather data, whereby Glasgow and Edinburgh were each found to have 8 oktas of cloud coverage (sky completely cloudy) as the most frequent amount of cloud coverage throughout the study period (see section 5.5.3). On the other hand, in particular typologies, such as the double-volume studios with a mezzanine above, students tended to turn on the artificial lights constantly during both cloudy and bright days when the areas located under the mezzanine and close to the window wall, where the windowsill height was 4m with external obstructions. Although windows that are located higher on a wall allow more natural light to penetrate deeper into a space, it would be more successful if they had been combined with windows at the students’ seating levels for view considerations.

The colour of the daylight tended to be grey, similar to the studios’ own finishing colours, such as grey concrete floors (except for studio GNPm), so contributing to a duller experience. The white walls were good for reflecting light; however, the colour composition of the daylight and the studios' furnishings, like the white furniture and grey concrete floor, resulted in there being no boundaries in visual perception, as in the Figure-Ground phenomenon. Tregenza & Loe (1998, p. 88) express a similar view, as visual contrasting is needed to distinguish an object from its background. This contrast could be produced by altering objects' brightness, colour, patterns, or movement.

For a similar case, but with no external obstructions, the penetrated daylight tends to be higher, however, artificial lights were still needed in the area near to the window wall and in the area under the mezzanine floor. The absence of outside views in most of the studios generated feelings of being cramped. Therefore, it is crucial to have a windowsill height below the students' eye level, despite the overlooking view being obstructed. This was also highlighted by many students who had occupied the studios for a longer time. Appendix W. 1 presents more comments and opinions from students in the North-facing studios.

For the South-facing studios, cloudy days also produced a dull experience, with both Glasgow and Aberdeen having 8 oktas of cloud coverage (sky completely cloudy) as their most frequent amount of cloud coverage throughout the study period. However, during bright days, the sunlight was strong in the studios, no matter what the size or window arrangement was. Students tended to cover the windows using blinds, even when the windows had external shading devices. This occurred during the period of afternoon until sunset. The colour of the natural light had more yellow tones which added a cheerful brightness. The presence of a skylight in some studios were detached from the vertical windows and seemed to have different languages from each other. Nevertheless, they made a significant impact on the penetrated daylight. Appendix W. 2 shows the students' comments and opinions regarding daylight/artificial light, façade layout and experienced atmosphere inside their studios.

It is important to mention that the undergraduate students, and some of the postgraduate students, had probably experienced cloudier days than bright ones, as the academic year normally runs from September to May. In addition to this, students tend to work in the studios almost all day until closure time (10 p.m.), due to design preparation (such as sketching and model-making) taking a long time to be achieved. Accordingly, artificial lighting is a crucial element that should be considered along with the daylighting design. However, the researcher noticed that most of the installed lighting was not positioned according to the students' tasks and studio requirements. The intensity of the light was harsh in some studios and did not blend well with the daylight nor with the studios' objects and furnishings. Some zones needed a particular type, colour, flow and direction of lighting, such as task lighting (lamps) on the students' desks, while other zones needed more ambient lighting. Finally, although it is a challenging task for the architect and designer to tackle the inconsistency in the environmental conditions, there are effective solutions that have succeeded in overcoming many environmental issues that should be learned from. This is proof that the impact of research in architectural practice is feeble.

10.3 Research implications

The daylight levels have been investigated by many researchers, particularly regarding the Mackintosh Building at Glasgow School of Art. These researchers include Hanna (2002) and Lawrence (2014). This experimental study is the first to deal with the effect of various façade fenestrations and studios' typologies on the daylight levels and experienced atmosphere in real-life settings in Scotland. The findings obtained from the joint investigations of objective measurements (daylight levels) and subjective responses (students' perspectives) have shaped the relevant practical implications and recommendations presented in the following section:

10.3.1 Practical implications

The theory of creative spaces within educational buildings is based on a qualitative user research that determined various criteria and characteristics, which were developed later into a typology. However, the effect of environmental factors on the emerged typologies still require empirical investigations. This study therefore contributes to the body of knowledge with regards to the effect of façade fenestration on the daylight levels and experienced atmosphere within different typologies of the design studios.

First of all, the findings obtained from the double-volume open plan studio with the mezzanine studio above revealed new insights into the spatial design and daylight scenario for this particular typology. As the daylight levels differed significantly from one zone to another (i.e. zone 1 vs zone 2 vs zone 3), the different kind of activities that can be carried out in the creative studio should align with the daylight levels available in the various zones of the studios. A similar argument was demonstrated in Vartiainen et al.'s (2000) study, which suggests that areas near the window could be used for tasks that require accurate vision, while the areas in the back of the room could be used for tasks with fewer lighting requirements. Likewise, the presence of the mezzanine level in the studio design opens new possibilities to implement a certain activity that matches the design's lighting and spatial quality. Accordingly, the study recommends that the computer lab or the presentation space be positioned in zone 2 (the area located under the mezzanine level), where low daylight levels, shadow and darkness are the driving forces.

From another perspective, large obstructions were found to have a major effect on the availability of daylight, in that they stopped light from reaching areas away from the window (The Society of Light and Lighting, 2014). Therefore, the study recommends that some solutions should be adopted which can enhance the distribution of daylight, such as a light tube or daylight duct system which use reflective materials, such as mirrors or aluminium, to send light to indoor spaces. Moreover, louvers and reflectors mirrors would be useful for assisting the natural light to penetrate inside (Sharp et al., 2014), as they can be used in multi-level buildings where a roof light is not possible.

In terms of the studios' orientations, the results indicated the importance of the windowsill height in the studios, particularly those orientated to the North, where daylight is diffused and has a greyish colour. Therefore, large glazed windows are welcome when facing the North because of the uniform daylight throughout the day and year and the less associated problems of direct sunlight, such as uncomfortable glare (Barrett et al., 2015, p. 15). Furthermore, for the

North-facing studios, the study recommends the implementation of inclined windows with a windowsill height of less than the eye level of the students while seated, or vertical windows attached to an inclined clerestory for the studios located on the highest floor levels. Skylights are also considered a valuable option for improving daylight levels inside studios, especially if they are orientated to the North. However, if a skylight is improperly installed, water or thermal leaks may occur from the skylight curb (Sharp et al., 2014, p. 468). This was a matter previously noted in Hanna's (2002) study survey, whereby students complained about the rainwater leakage from the horizontal clearstory. As such, Hanna (2002) recommends using an inclined clerestory or inclined skylight as an effective option to move the water away by gravity.

For the South-facing studios (section 7.2.1), although the students evaluated the daylight levels as being efficient, the issue of uncomfortable glare was experienced in the studios. The SLL code for Light and Lighting recommended few options that could be used to reduce the glare (Raynham et al., 2012), such as using translucent blinds, curtains and splaying the window reveals for more intermediate brightness between the outside and the window wall. Furthermore, the study recommends using angled reveals so that the outside light can be diffused and reflected, thus reducing the glare. A skylight can also be used to achieve more diffused daylight if it is North-facing. Smart façade (intelligent facade) can be considered as well, which defined as the use of environmental control system, such as solar radiation and airflow in react to change in external conditions (Moloney, 2006) & (Ahmed, Abel-Rahman, & Ali, 2015). It is a high-tech option that adapts to the environmental conditions simultaneously by using weather control panels.

Investigating daylight levels under overcast weather conditions throughout nine months of the year served as a reminder that daylight is extremely changeable during the day and between seasons. As mentioned in the weather considerations section (see section 5.5.3), the factor of cloud coverage considerable affects the daylight availability as well as the change in seasons. To illustrate this, in most of Scotland's major cities, the sunrise in February is at around 8:00 a.m. and the sunset is at around 16:45 p.m., whereby the total daylight hours are 8:27 hrs, 8:37 hrs and 8:38 hrs for Aberdeen, Edinburgh and

Glasgow, respectively. On the other hand, some students tend to work in the studios for around 14 hours a day, usually from the early morning until 10 p.m. (studio closure). Therefore, the artificial lights are hugely important regardless of the window size. An argument previously stated by many researchers, such as Barrett et al. (2015), is that while natural daylighting should always be the main source of lighting in schools, it will need to be supplemented by electric light when the daylight fades. Nevertheless, some of the students raised concerns about the artificial lights in the studios, explaining that the light pollution can cause headaches. Therefore, this study recommends putting greater attention into designing artificial lights that meet the functional, psychological and aesthetical requirements of design studios. One of the lighting schemes that can be implemented is the one that can balance the warmth and coolness of light in order to adjust the intensity, colour temperature and angle of the light. This allows for an even tone of light that works with the required activity or with the subjective preferences for the case of using desk lamps, as the students suggested.

From the results related to the experienced atmosphere, the effect of cloudy conditions can be tackled by relying more on other factors, such as darkness, artificial light, spaciousness and furniture design, to create a certain atmospheric factor. This was previously implemented in Mackintosh's design of the Art School building, whereby light (daylight and artificial), darkness, colour and furniture all worked smoothly as one entity. Atmosphere is becoming an important factor in designing interior spaces and has significantly developed from a theoretical concept to being fully integrated into empirical research. The study recommends that certain guidelines be set for seeking the required atmosphere within studios. For example, based on this study's results, if the aim is to have a pleasant and stimulating atmosphere, then designers must work on the window-to-wall area ratio being over 50% to enhance this need, as well as considering the layers of views when positioning the window. It is important to mention that the façade characteristics should be alongside other factors as atmosphere is affected by many of them. For example, the furniture arrangement should be adjusted with façade characteristics to achieve a particular atmosphere.

10.4 Limitations

This study adopted the longitudinal design research method, whereby the daylight levels were measured for nine months (February - October). It was originally intended to measure the daylight levels for the full year; however, campuses closing for the winter break and the access restrictions for the studios during submission time (whereby projects were presented inside the studios for examination) made it difficult to proceed with the measurements in November, December and January. This limitation did not affect the study's reliability regarding time and season, due to meteorological data, such as cloud coverage and daylight hours, being successfully gained. As such, a general picture of the nature of daylight inside the studios during the missed period of time can be assumed.

For conducting the daylight field measurement, it is recommended that the measuring points be placed in a grid that covers the full space horizontally. This can be achieved if the field measurement is conducted in a controlled environment, such as in a lab. It can also be achieved if the measurements are taken for once time as in cross-sectional studies. However, due to the adoption of the longitudinal design research method, whereby daylight levels were measured for nine months (six days per month, 5-min interval time), the measuring points were placed in the most critical locations that would give sufficient information about the penetrated daylight levels and distributions inside the studios. Furthermore, following the tutors' instructions, the measurement points had to be aligned with students' activities so that the meters would not cause any distractions to their work.

Another practical limitation encountered in this study concerned the inability to consider occupants' use of shadings. The presence of external shading devices was only found in the Aberdeen studios, while internal movable shadings, such as blinds, were found in all three case studies. Although blinds are very effective at reducing glare but they also reduce the daylight available indoors.

Developing a typology for creative spaces in higher education has moved from a speculative exercise to reality. In support of the previous studies discussed in the literature review, the present research has opened up an avenue for further experimental investigation involving physical elements, such as various façade fenestrations and typologies, along with special elements like daylight and experienced atmosphere. However, creative spaces consist of complex sets of physical and spatial elements, designs, and configurations, which are not covered in their entirety in this study.

The study's questionnaire includes questions related to demographic information, students' sitting areas, and reasons for choosing current seating positions, to provide layers of views that can contribute to understanding the studios' spatial experience. The survey also investigated the best time to occupy the studio (winter/summer), and evaluates artificial lighting and its effect in the studio. It explores spaciousness and the factors that make a studio appear more or less spacious. It examines the stability of atmosphere over time during the course of a day and in different seasons. Suggestions (drawings) are gathered from students about the most appropriate window arrangement for making the most of the daylight and gaining the best view. However, given that the investigation is limited to the proposed hypothesis and addresses only the research questions, the analysis and results presented in this thesis are limited to the effect of daylight (on cloudy and bright days) and façade fenestration on the experienced atmosphere.

Similarly, objective data related to humidity and temperature have been measured, although not presented in the thesis, as they fall outside of the study's scope. Other atmospheric factors, such as acoustics, air quality, furniture design, and previous events and experiences, have not been examined. Hence, further investigation of all of the aforementioned points is crucial for a holistic investigation into the experienced atmosphere.

Finally, it was intended for this study to evaluate the experienced atmosphere during different seasons of the year and at different times of the day with an aim to investigate whether it would change with the daylight variability during the day and throughout the year from a subjective perspective. Yet, the practical considerations in terms of students' availabilities and the study's financial constraints limited the intended process, in that students evaluated the experienced atmosphere in their studios only for one time.

10.5 Future work / further research

This study covers four factors that mainly impacted the studios'-built environments: studio typology, façade fenestration, daylight levels and experienced atmosphere. Accordingly, the findings of this study determined the possibility for several pieces of future work within the following areas of interests:

10.5.1 Façade fenestration

When making objective measurements (daylight and façade fenestration), scientific generalisation requires a large number of samples to be able to statistically generalise the findings of a research study; the generalisability of findings will not be improved by increasing the number of data points for a single case (Mills et al., 2012). Therefore, even though the sample in this study (13 studios) is representative of Scotland and provides generalisability in theory, a larger sample size is highly recommended to reduce the potential for error in the conclusions.

In the study's literature, it was noted that social, economic, political and climatic factors, along with educational theories, shaped the design of façade fenestration, hence the daylighting system in creative spaces. However, this study dealt with façade fenestration in relation to daylighting under overcast skies. Therefore, it is crucial that further investigations be conducted into the effect of the mentioned factors with different research approaches on the design of façade fenestration.

Considering the subjective responses obtained from all the investigated studios, it was revealed that window arrangement type (I) was the preferred option for providing sufficient daylight levels inside the studios. It would be a promising step into the optimisation of facade fenestration within studios if this particular window arrangement was to be further examined in relation to the different studios' typologies and other different façade characteristics, such as W/W%, W/F%, window area and windowsill height. Likewise, it could be beneficial to investigate how window arrangement type (I) could affect the experienced atmosphere.

In the second stage of the study, the findings revealed the statistically significant effect of the skylight on the registered illuminance levels between studios orientated to the South. This is because in overcast skies, the light level at the zenith is three times higher than the horizon (VELUX, 2020). An unobstructed skylight usually provides three times more light in comparison to an unobstructed side-window with both having the same area. Accordingly, it would be insightful to investigate the effect of the different types, sizes and locations of the rooflights (such as clearstory, sawtooth, monitor and light scoops) on the daylight levels inside the studios. Rasmussen (1959, p. 208), for example, argued that sawtooth roofs represent a good option for allowing light into all rooms, as opposed to skylights, which lead to light becoming too diffused to produce the shadows required to see form and texture clearly. Neither side lights alone due to the lack of light penetration.

Likewise, it would be significant to further investigate the effect of the vertical window that connects to the horizontal or inclined clearstory on the daylight levels inside the different studios' typologies. This type of combined window was used in the Mackintosh Building studios. On the other hand, this study asked students to evaluate the vertical windows only in terms of their effect on the experienced atmosphere, so it would be useful to consider the skylight in further investigations.

10.5.2 Studio typology

The design studio, as a creative space, accommodates various activities that may be conducted simultaneously and may require different levels of daylight (intensity and direction). It is therefore recommended to investigate these activities and their alignment with physical characteristics and spatial qualities of the studio, in order to fulfil the occupants' functional and psychological needs. Three types of studio typologies were identified and investigated within this study. Nonetheless, identifying and investigating more typologies in terms of their physical characteristics and the spatial qualities they offer would be beneficial for developing the theory of creative space from the perspective of the built environment. Moreover, the study's findings revealed differences in daylight levels and distributions among different zones within the same typology, which was more closely related to the window location. Further investigations into the studios' activities and lighting requirements that could be adjusted to the different zones in the same typology are recommended, particularly for studios that are already established and are facing this challenge.

10.5.3 Experienced atmosphere

The findings obtained from the subjective responses revealed that furniture arrangements, proximity and spaciousness each contributes most highly to the experienced atmosphere. Accordingly, further investigations are recommended to tackle the effects of these dimensions, as well as the effects of the external view, artificial lighting, acoustics and air quality. Also, this study recommends that a comparative investigation be conducted into the different contexts that are geographically similar to Scotland cities, such as Copenhagen or Stockholm. Moreover, it would be interesting to examine the effect of ethnic differences on evaluating the façade fenestration and experienced atmosphere.

Finally, this study heavily relied upon the lighting guidelines in order to evaluate the daylight performance inside the North and South orientated studios throughout the year. However, considerable development of the guidelines is essential, in order to determine the required illuminance levels inside the design studios in higher educational buildings. Moreover, the study findings noted that the guidelines for illuminance levels in places which have over 20% of window-to-floor area ratio do not apply in October and February. As such, it would be effective to update the guidelines based on the orientation, weather and seasonal considerations.

10.6 Final thoughts

This study represents the first systematic research investigation to collect, assess, and use field data (objective & subjective), and statistical methods to test relationships between variables of facade fenestration, daylight levels, and the human dimensions of experienced atmosphere in real-world settings of design studios in Scotland. This thesis opens up an avenue in higher education for experimental investigation into creative spaces. Although it was extremely challenging to conduct the study, as many factors needed to be controlled or avoided, the unique dataset of daylight measurements taken from real places under real sky conditions are very useful and helpful for validating simulation programmes that require real measurements from real conditions. In light of the above, the researcher will share some thoughts about issues encountered during the study:

- From reading different works on phenomenology, psychology, sociology, and environmental studies, it is evident that there is a very large body of theoretical content. However, there is a need for more practical studies of built environments. One area that attracted the researcher's attention is the subject of product design or product design engineering. It was noticed that in this subject, theory and practicality are studied side by side in what is known as "a usability test" (Kuniavsky, 2012). This technique involves the systematic observing of the user experience to evaluate a product by testing it on users, then trying to resolve the encountered issues to meet the intended purposes.

  Regarding this practice in the field of architecture, pioneers like Steen Rasmussen note that 'architecture is not produced simply by adding plans and sections to elevations. It is something else and something more' (Rasmussen, 1959, p. 2). An example of architecture being tested to its fullest is the Basilica of the Sagrada Familia designed by Antoni Gaudi in Barcelona, Spain. The architect tested his extraordinary personal interpretation by producing multiple versions of plans and models, and building real mock-ups until achieving a final design. The same can be observed in the city of Petra in Jordan. The Nabateens built many replicas of the main façade (Al-Khazneh) until the final one was complete. This process of testing architectural design is extremely challenging in both financial and practical terms. But what if architects and designers followed the "usability test" path, or what is known in research as "environmental appraisal", to improve and develop future projects?

- The second point concerns knowing exactly who is going to be using the product. This critical step in product design is known as identifying the target audience. The designer familiarises him/herself with the terminology, tools, and techniques that people are likely to use (Kuniavsky, 2012). In architecture, this is a form of contextual inquiry, aimed at understanding people's environment and revealing their needs. It represents a crucial way of measuring any community, given the great difference between occupants' needs and architects' desires.

The researcher recommends future studies pursue the relationship between daylight and atmosphere to consider the qualitative aspects of daylight, with emphasis on darkness and shadow factors, which are mostly neglected entities in creative spaces built in an international style. Returning to the Victorian art schools and considering the design principles they implemented would represent a first step for overcoming the pressures of international trends to break up national identity and dissolve the sense of belonging to a cultural community (Lefebvre, 2008). Furthermore, creating user experience narrations is highly recommended so as to examine subjective interiority. This might involve asking questions such as what picture have users built in a particular place? And what are they looking for?

Adaptation to the surrounding environment is a determining factor that differentiates human appraisals from those conducted via instrument measurements, as noted by Parpairi (cited in Steemers & Steane, 2004, p. 182). Therefore, it is necessary to consider the vital role of adaptation in daylight and atmospheric investigation within creative spaces. For example, is there a significant difference between environmental appraisals at the beginning of the academic term and at the end, or between the beginning of a particular season or the end of it?

In addition, presenting domestic elements in institutional building, as can be found in Mackintosh's designs (Hawkes, 2006) and described in the literature review (e.g. Paoli & Ropo, 2017), can contribute a method for characterising creative workplaces. There is an urgent need to examine the effects of such elements on "national romanticism" and, thus, on the experienced atmosphere.

Finally, understanding the mechanisms of the brain is a highly complex subject that has attracted the attention of many researchers, such as Foster and Kreitzman (2014). Connecting the brain's processes as a system with daylight-atmospheric factors will help to remove some of the ambiguity surrounding this area and bring promising outcomes to research.

Appendix A

Appendix A. 1 Data collection timeline

Stage Type Key Stage 1 Stage 2

February **Objective Measurments Timeline** **2019**

Stage	Fri 1	Sat 2	Sun 3	Mon 4	Tue 5	Wed 6	Thu 7	Fri 8	Sat 9	Sun 10	Mon 11	Tue 12	Wed 13	Thu 14	Fri 15	Sat 16	Sun 17	Mon 18	Tue 19	Wed 20	Thu 21	Fri 22	Sat 23	Sun 24	Mon 25	Tue 26	Wed 27	Thu 28	Total Days
Stage 1																													6
Stage 2																													6
February Total																													12

Stage Type Key Stage 1 Stage 2

March **2019**

Stage	Fri 1	Sat 2	Sun 3	Mon 4	Tue 5	Wed 6	Thu 7	Fri 8	Sat 9	Sun 10	Mon 11	Tue 12	Wed 13	Thu 14	Fri 15	Sat 16	Sun 17	Mon 18	Tue 19	Wed 20	Thu 21	Fri 22	Sat 23	Sun 24	Mon 25	Tue 26	Wed 27	Thu 28	Fri 29	Sat 30	Sun 31	Total Days
Stage 1																																6
Stage 2																																6
March Total																																12

Stage Type Key Stage 1 Stage 2

April **2019**

Stage	Mon 1	Tue 2	Wed 3	Thu 4	Fri 5	Sat 6	Sun 7	Mon 8	Tue 9	Wed 10	Thu 11	Fri 12	Sat 13	Sun 14	Mon 15	Tue 16	Wed 17	Thu 18	Fri 19	Sat 20	Sun 21	Mon 22	Tue 23	Wed 24	Thu 25	Fri 26	Sat 27	Sun 28	Mon 29	Tue 30	31	Total Days
Stage 1																																6
Stage 2																																6
April Total																																12

Stage Type Key Stage 1 Stage 2

May **2019**

Stage	Wed 1	Thu 2	Fri 3	Sat 4	Sun 5	Mon 6	Tue 7	Wed 8	Thu 9	Fri 10	Sat 11	Sun 12	Mon 13	Tue 14	Wed 15	Thu 16	Fri 17	Sat 18	Sun 19	Mon 20	Tue 21	Wed 22	Thu 23	Fri 24	Sat 25	Sun 26	Mon 27	Tue 28	Wed 29	Thu 30	Fri 31	Total Days
Stage 1																																6
Stage 2																																6
May Total																																12

Stage Type Key Stage 1 Stage 2

June **2019**

Stage	Sat 1	Sun 2	Mon 3	Tue 4	Wed 5	Thu 6	Fri 7	Sat 8	Sun 9	Mon 10	Tue 11	Wed 12	Thu 13	Fri 14	Sat 15	Sun 16	Mon 17	Tue 18	Wed 19	Thu 20	Fri 21	Sat 22	Sun 23	Mon 24	Tue 25	Wed 26	Thu 27	Fri 28	Sat 29	Sun 30	31	Total Days
Stage 1																																6
Stage 2																																6
June Total																																12

Stage Type Key Stage 1 Stage 2

July **2019**

Stage	Mon 1	Tue 2	Wed 3	Thu 4	Fri 5	Sat 6	Sun 7	Mon 8	Tue 9	Wed 10	Thu 11	Fri 12	Sat 13	Sun 14	Mon 15	Tue 16	Wed 17	Thu 18	Fri 19	Sat 20	Sun 21	Mon 22	Tue 23	Wed 24	Thu 25	Fri 26	Sat 27	Sun 28	Mon 29	Tue 30	Wed 31	Total Days
Stage 1																																6
Stage 2																																6
July Total																																12

Stage Type Key	Stage 1	Stage 2

August 2019

	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Days
Stage 1																																7
Stage 2																																5
August Total																																12

Stage Type Key	Stage 1	Stage 2

September 2019

	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon		
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Days
Stage 1																																6
Stage 2																																6
September Total																																12

Stage Type Key	Stage 1	Stage 2

October 2019

	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Days
Stage 1																																6
Stage 2																																6
October Total																																12

Stage Type Key	Stage 1	Stage 2

November 2019

	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat		
Stage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Days
Stage 1																																0
Stage 2																																0
November Total																																

Appendix B

Appendix B. 1

Time		Sun altitude (in °)		Azimuth	
		Glasgow	Edinburgh	Glasgow	Edinburgh
1st January	8:00 a.m.	-6.03	-5.58	122.92	123.85
	12:00 p.m.	11.1	11.06	175.24	176.34
	5:00 p.m.	-8.32	-8.88	240.92	241.86
1st February	8:00 a.m.	-2.15	-1.63	117.83	118.8
	12:00 p.m.	16.81	16.79	172.41	173.59
	5:00 p.m.	-1.9	-2.51	242.07	243.03
1st March	8:00 a.m.	6.11	6.61	113.12	114.13
	12:00 p.m.	26.29	26.28	171.92	173.22
	5:00 p.m.	6.07	5.49	247.29	248.28
1st April	8:00 a.m.	9.25	9.83	108.41	109.47
	12:00 p.m.	36.19	36.36	173.35	174.85
	5:00 p.m.	22.93	22.36	255.67	256.67
1st May	8:00 a.m.	18.83	19.43	103.65	104.73
	12:00 p.m.	46.81	46.99	174.75	176.49
	5:00 p.m.	31.04	30.45	263.33	264.31
1st June	8:00 a.m.	24.39	24.99	98.8	99.88
	12:00 p.m.	53.47	53.68	173.75	175.71
	5:00 p.m.	36.87	36.27	267.68	268.63
1st July	8:00 a.m.	24.42	25.02	96.73	97.8
	12:00 p.m.	54.03	54.27	171.08	173.07
	5:00 p.m.	38.51	37.91	267.07	268.02
1st August	8:00 a.m.	20.02	20.61	99.7	100.77
	12:00 p.m.	49.03	49.25	170.92	172.74
	5:00 p.m.	34.63	34.04	263.05	264.03
1st September	8:00 a.m.	12.98	13.56	107.12	108.19
	12:00 p.m.	40.08	40.25	174.26	175.84
	5:00 p.m.	25.57	24.99	258.43	259.43
1st October	8:00 a.m.	4.99	5.53	115.7	116.75
	12:00 p.m.	29.44	29.54	178.04	179.41
	5:00 p.m.	14.38	13.82	254.25	255.23
1st November	8:00 a.m.	3.94	4.38	122.7	123.7
	12:00 p.m.	19.76	19.67	179.88	181.08
	5:00 p.m.	-3.65	-4.25	249.47	250.44
1st December	8:00 a.m.	-3.22	-2.78	125.21	126.16
	12:00 p.m.	12.41	12.33	178.61	179.73
	5:00 p.m.	-9.16	-9.74	244.39	245.32

Table B. 1 **Sun altitude and azimuth for Glasgow and Edinburgh throughout the year 2019 (NOAA Global Monitoring Laboratory, 2020)**

Appendix B. 2

Month	Edinburgh		Glasgow		Edinburgh	Glasgow
	Sunrise (hour)	Sunset (hour)	Sunrise (hour)	Sunset (hour)	Day length (hour)	Day length (hour)
January	08:43	15:48	08:47	15:53	7:05:19	7:06:28
February	08:07	16:45	08:11	16:49	8:37:23	8:38:07
March	07:05	17:46	07:09	17:50	10:41:14	10:41:31
April	06:44	19:50	06:48	19:54	13:05:50	13:05:38
May	05:29	20:51	05:34	20:55	15:21:17	15:20:36
June	04:35	21:46	04:40	21:50	17:10:50	17:09:39
July	04:31	22:01	04:36	22:04	17:30:03	17:28:45
August	05:16	21:20	05:21	21:24	16:04:16	16:03:23
September	06:16	20:07	06:20	20:12	13:51:32	13:51:10
October	07:14	18:48	07:19	18:53	11:34:00	11:34:05
November	07:18	16:33	07:22	16:37	9:14:18	9:14:52
December	08:18	15:44	08:22	15:49	7:25:38	7:26:40

Table B. 2 Sunrise, sunset and day length for Glasgow and Edinburgh (Thorsen, 2020).

Appendix B. 3

Edinburgh		
cloud coverage as fraction	*Frequency*	*Percent(%)*
0	205	15.8
1	66	5.1
2	36	2.8
3	35	2.7
4	38	2.9
5	48	3.7
6	63	4.9

Glasgow		
cloud coverage as fraction	*Frequency*	*Percent(%)*
0	214	16.5
1	63	4.9
2	38	2.9
3	54	4.2
4	40	3.1
5	35	2.7
6	58	4.5

Table B. 3 Frequencies of Glasgow and Edinburgh cloud coverage

Appendix B. 4

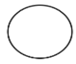
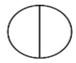
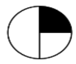
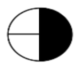
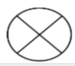
Oktas	Description	Symbol
0	Sky completely clear	
1	From a trace of cloud up to 1/8	
2	More than 1/8 but not more than 2/8	
3	More than 2/8 but not more than 3/8	
4	More than 3/8 but not more than 4/8	
5	More than 4/8 but not more than 5/8	
6	More than 5/8 but not more than 6/8	
7	More than 6/8 but not total coverage i.e. if there is any sky visible then use 7/8	
8	Sky completely overcast (no breaks or openings)	
9	Sky obstructed from view	

Table B. 4 Cloud amount estimation as fraction of sky (oktas) (Bureau of Meteorology Training Centre, n.d.)

Appendix B. 5

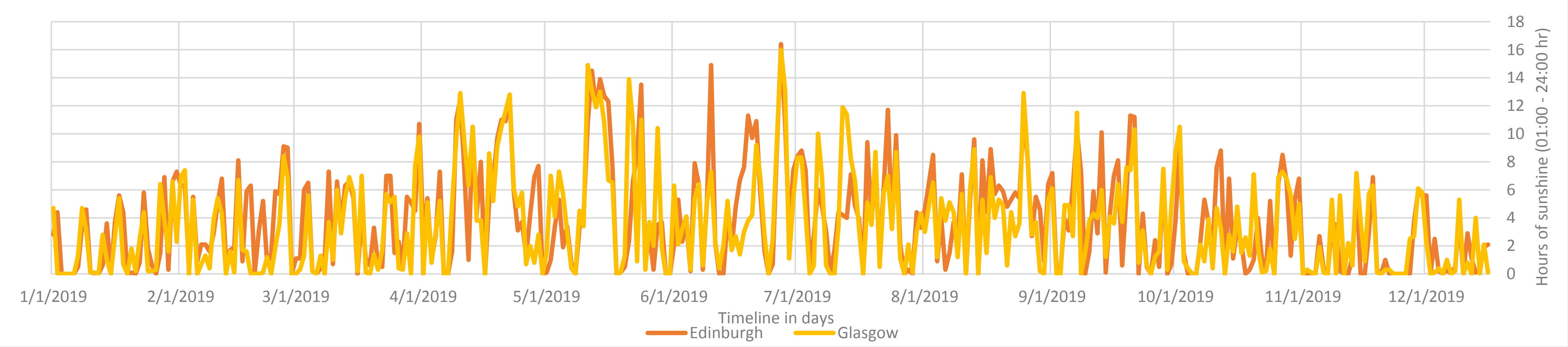


Figure B.5. 1 **Daily total sunshine for Edinburgh and Glasgow (Jan-Dec, 2019).**

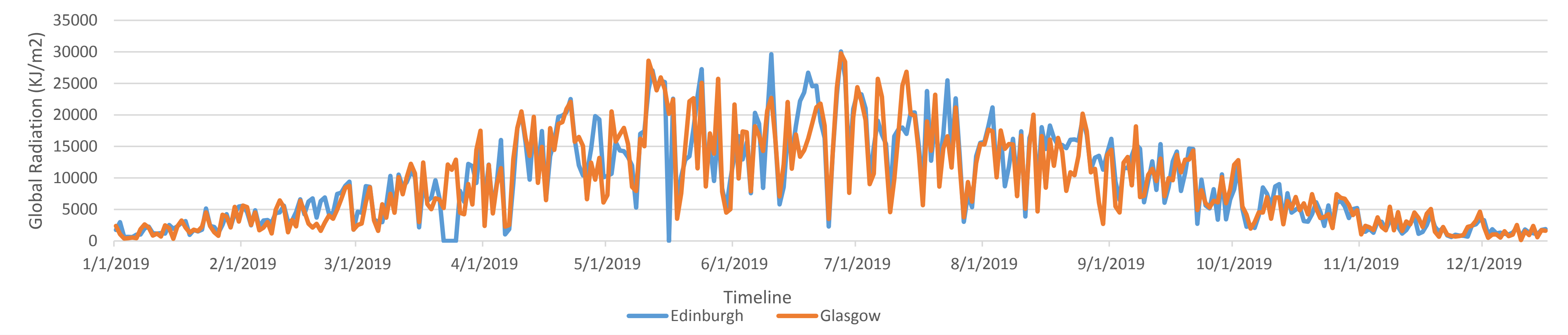


Figure B.5. 2 Global radiation for Edinburgh and Glasgow (Jan-Dec, 2019).

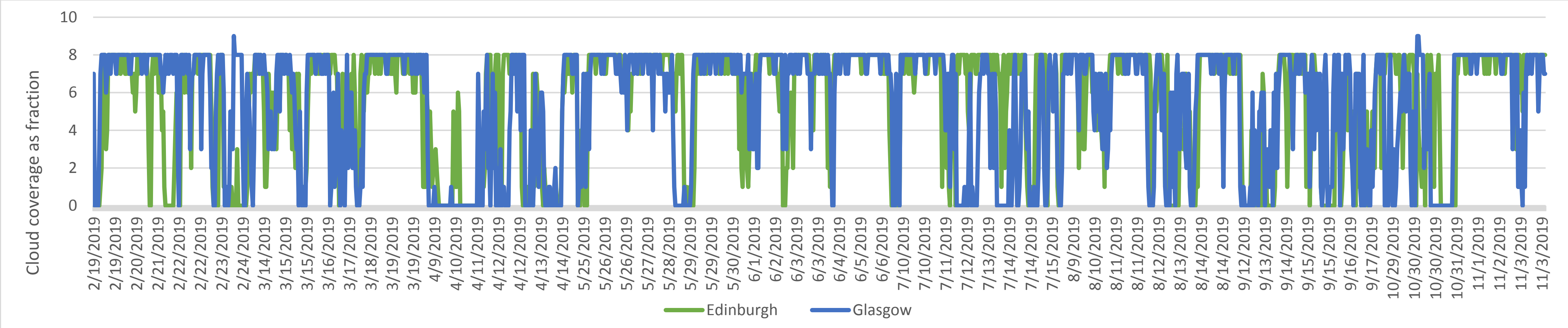


Figure B.5. 3 Cloud coverage for Glasgow and Edinburgh (Feb-Nov, 2019).

Appendix B.6

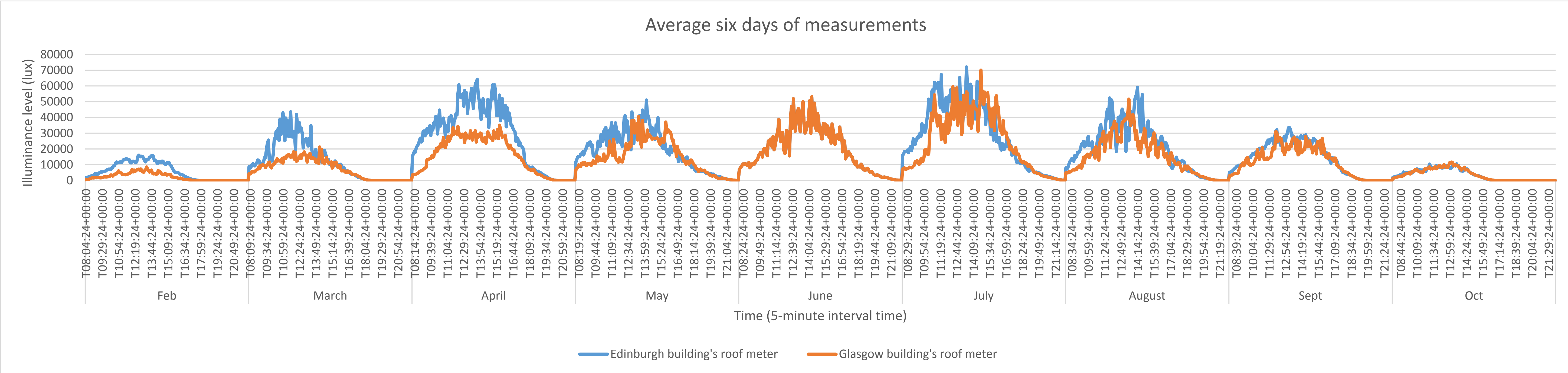


Figure B.6 Average illuminance levels registered under unobstructed sky (Glasgow & Edinburgh).

Appendix C

Appendix C. 1

Time		Sun altitude (in °)		Azimuth	
		Glasgow	Aberdeen	Glasgow	Aberdeen
1st January	8:00 a.m.	-6.03	-5.72	122.92	124.54
	12:00 p.m.	11.1	9.91	175.24	177.23
	5:00 p.m.	-8.32	-9.97	240.92	242.77
1st February	8:00 a.m.	-2.15	-1.61	117.83	119.57
	12:00 p.m.	16.81	15.67	172.41	174.55
	5:00 p.m.	-1.9	-3.61	242.07	243.82
1st March	8:00 a.m.	6.11	6.65	113.12	115.1
	12:00 p.m.	26.29	25.16	171.92	174.31
	5:00 p.m.	6.07	4.52	247.29	248.94
1st April	8:00 a.m.	9.25	10.27	108.41	97.62
	12:00 p.m.	36.19	35.49	173.35	157.66
	5:00 p.m.	22.93	21.29	255.67	243.67
1st May	8:00 a.m.	18.83	19.97	103.65	93.07
	12:00 p.m.	46.81	46.14	174.75	156.85
	5:00 p.m.	31.04	29.49	263.33	251.19
1st June	8:00 a.m.	24.39	25.63	98.8	88.59
	12:00 p.m.	53.47	52.89	173.75	154.05
	5:00 p.m.	36.87	35.39	267.68	255.54
1st July	8:00 a.m.	24.42	25.7	96.73	86.63
	12:00 p.m.	54.03	53.53	171.08	151.34
	5:00 p.m.	38.51	37.02	267.07	254.84
1st August	8:00 a.m.	20.02	21.24	99.7	89.28
	12:00 p.m.	49.03	48.48	170.92	152.63
	5:00 p.m.	34.63	33.08	263.05	250.78
1st September	8:00 a.m.	12.98	14.04	107.12	96.28
	12:00 p.m.	40.08	39.38	174.26	157.85
	5:00 p.m.	25.57	23.96	258.43	246.5
1st October	8:00 a.m.	4.99	5.81	115.7	104.71
	12:00 p.m.	29.44	28.58	178.04	163.41
	5:00 p.m.	14.38	12.74	254.25	242.92
1st November	8:00 a.m.	3.94	4.21	122.7	124.57
	12:00 p.m.	19.76	18.46	179.88	182.05
	5:00 p.m.	-3.65	-5.22	249.47	251.34
1st December	8:00 a.m.	-3.22	-3.02	125.21	126.88
	12:00 p.m.	12.41	11.14	178.61	180.63
	5:00 p.m.	-9.16	-10.78	244.39	246.29

Table C. 1 Sun altitude and azimuth for Glasgow and Aberdeen throughout the year 2019 (NOAA Global Monitoring Laboratory, 2020)

Appendix C. 2

Month	Aberdeen		Glasgow		Aberdeen	Glasgow
	Sunrise (hour)	Sunset (hour)	Sunrise (hour)	Sunset (hour)	Day length (hour)	Day length (hour)
January	08:47	15:36	08:47	15:53	6:48:50	7:06:28
February	08:08	16:36	08:11	16:49	8:27:00	8:38:07
March	07:02	17:39	07:09	17:50	10:37:20	10:41:31
April	06:38	19:47	06:48	19:54	13:08:45	13:05:38
May	05:20	20:51	05:34	20:55	15:31:10	15:20:36
June	04:22	21:50	04:40	21:50	17:28:04	17:09:39
July	04:17	22:06	04:36	22:04	17:48:53	17:28:45
August	05:05	21:22	05:21	21:24	16:16:47	16:03:23
September	06:09	20:06	06:20	20:12	13:56:42	13:51:10
October	07:11	18:43	07:19	18:53	11:32:39	11:34:05
November	07:18	16:24	07:22	16:37	9:06:01	9:14:52
December	08:21	15:32	08:22	15:49	7:10:40	7:26:40

Table C. 2 Sunrise, sunset and day length for Glasgow and Aberdeen (Thorsen, 2020).

Appendix C. 3

Glasgow		
cloud coverage as fraction	*Frequency*	*Percent(%)*
0	214	16.5
1	63	4.9
2	38	2.9
3	54	4.2
4	40	3.1
5	35	2.7

Aberdeen		
cloud coverage as fraction	*Frequency*	*Percent(%)*
0	164	12.7
1	43	3.3
2	36	2.8
3	43	3.3
4	49	3.8
5	36	2.8

Table C. 3 Cloud amount estimation as fraction of sky (oktas) (Bureau of Meteorology Training Centrer, n.d.)

Appendix C. 4

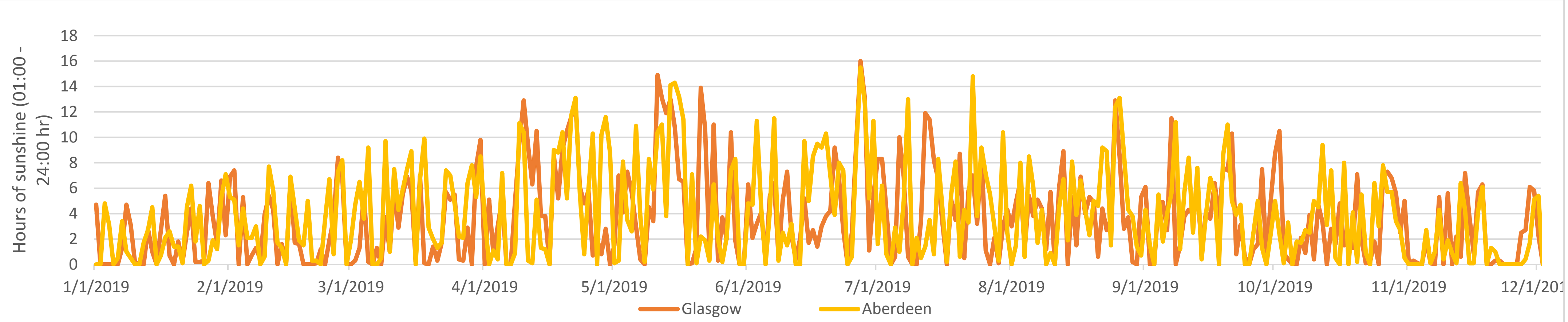


Figure C.4. 1 Daily total sunshine for Glasgow and Aberdeen (Jan-Dec, 2019).

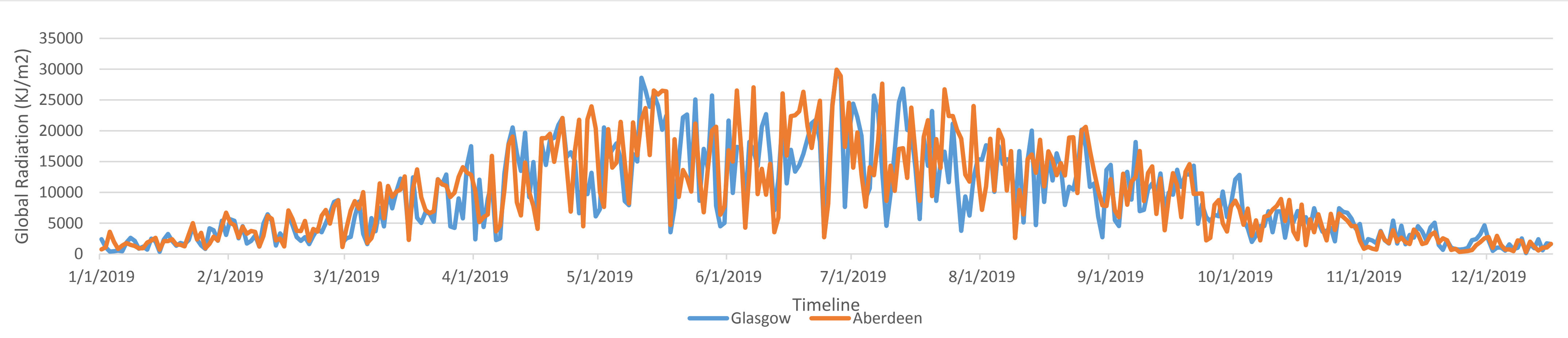


Figure C.4. 2 Global radiation for Glasgow and Aberdeen (Jan-Dec, 2019).

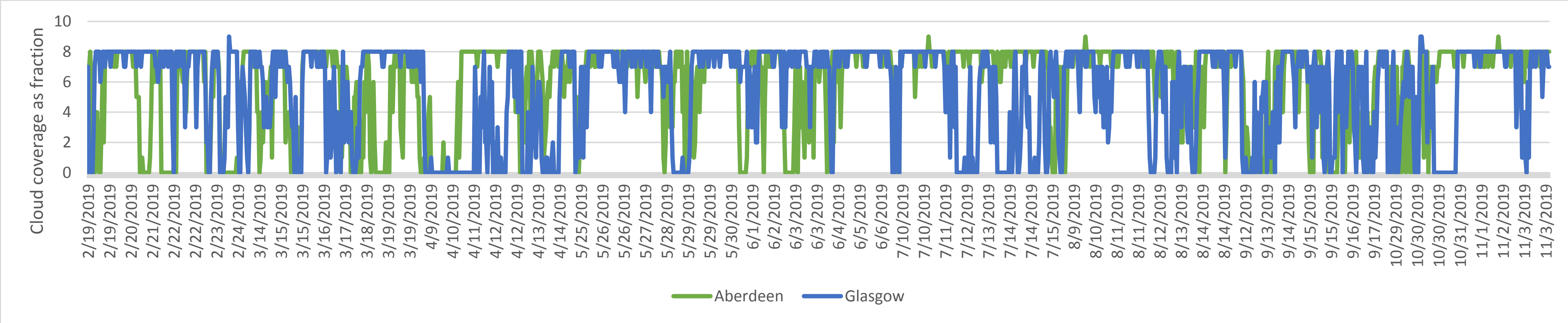


Figure C.4. 3 Cloud coverage for Glasgow and Aberdeen (Feb-Nov, 2019).

Appendix C.5

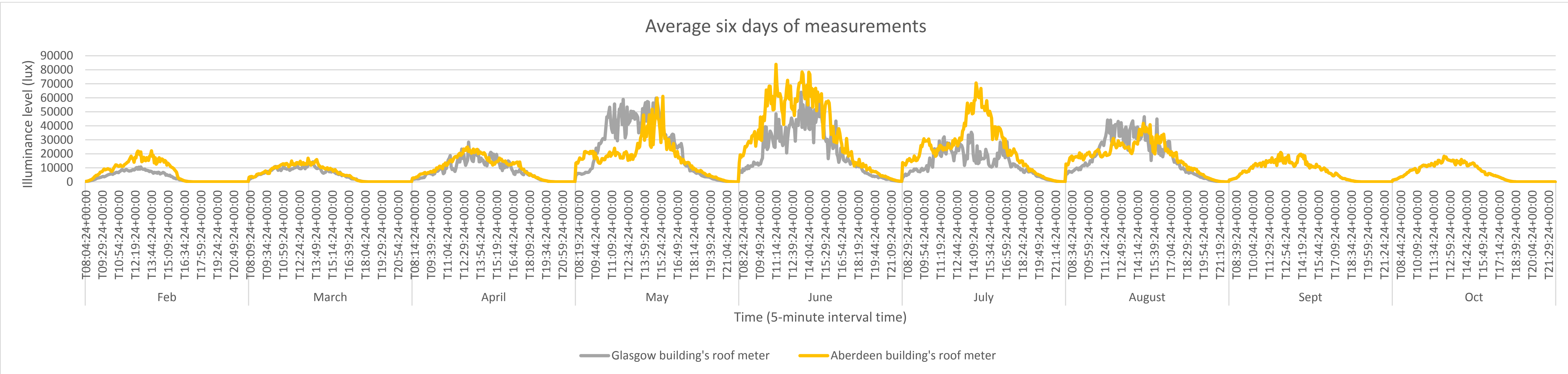


Figure C.5 Average illuminance levels registered under unobstructed sky (Glasgow & Aberdeen).

Appendix D

Appendix D. 1

PARTICIPANT INFORMATION SHEET

GSoA

Title of study

The optimisation of studio façade design for daylighting and experienced atmosphere under overcast

Invitation Paragraph

The design of daylighting systems is crucial to providing health benefits to humans and promoting the experienced atmosphere within a built environment. The increasing cost of fossil fuels and general desire for a greater quality of life makes it a vital consideration. Within architectural envelopes, the careful implementation of façade configuration and daylighting systems can optimise the interaction between outdoor and indoor spaces, with window openings reducing the need for artificial lighting. This way, the outside is connected with the inside, allowing daylight to enter buildings and provide a pleasant environment.

I would like to invite you to participate in a PhD research study, which is conducted in your studio space. Please take time to read the information provided. Do not hesitate to ask any questions if anything is unclear or if you would like further information. You are welcome to take time to decide whether or not to be involved.

What is the purpose of the study?

Over the last two decades, remarkable façades have been conceived and built. Yet, the role of façade configuration has often not been aptly addressed within the design processes. From this perspective, this study investigates the impact of façade design on daylighting levels, and experienced atmosphere on design studio space under overcast sky conditions.

Why have I been invited to take part?

I am asking you to join because the research study will be conducted in your studio, which you have occupied for enough time to make your contribution to this study significant. I would like you to consent to be involved in the study as a student; your participation would be vital to the fields of daylighting and atmosphere in Scotland.

Do I have to take part?

Your participation in the study is voluntary and, as such, you are free to withdraw at any time without providing an explanation. I would advise your participation as I believe that you can make a crucial contribution to the research. However, if you do not wish to be involved, you may ignore this request.

What will happen to me if I take part?

Should you choose to take part, you may begin by reading through the form and contacting me if you have any questions which are unanswered by the information sheet. Once your knowledge is sound, please sign and return the consent form. After confirming your participation, the researcher will contact you to fill the questionnaire.

PARTICIPANT INFORMATION SHEET

What are the possible benefits and risks of taking part?

All questions are concerned with the topics of daylight and experienced atmosphere in your studio. No sensitive topics will be asked for. All responses to the questionnaire will be kept anonymous, and all information provided by you will remain confidential at all times.

As I mentioned above, your participation will help to add value and contribution to the existing knowledge in the fields, and you will be part of enhancing the façade design in studio spaces.

Will my taking part be kept confidential?

All information you provide will be kept confidential. The only person who will be able to access it is the researcher herself.

What will happen to the results of the study?

The data gathered both from measurement and from the questionnaires will be analysed statistically using SPSS (Statistical Package for the Social Sciences) whereby various design parameters and orientations (i.e. north facades vs. south) will be correlated with levels of daylighting. The results and findings will be presented in the main dissertation, academic journals and as part of the conference presentation.

Who should I contact for further information?

If you require more information, please contact me on my email.
e.mayah1@student.gsa.ac.uk

What if I have further questions, or if something goes wrong?

If this study has harmed, you in any way or if you wish to make a complaint about the conduct of the study you can contact GSA using the details below for further advice and information:

Supervisors:

Dr. Raid Hanna	Professor Tim Sharp
r.hanna@gsa.ac.uk	t.sharpe@gsa.ac.uk

Bourdon Building, Scott St, Glasgow G3 6RQ

Head of Research, The Glasgow School of Art, 167 Renfrew Street, G3 6RQ; research@gsa.ac.uk

Thank you for reading this information sheet and for considering taking part in this research. Please keep this sheet for future reference

Appendix D. 2

Research Consent Form

Research Project Title: [The investigation of façade fenestration for daylighting and experienced atmosphere in design studios under overcast sky]

Lead Researcher: [Eman Mayah]

Contact Details: [e.mayah1@student.gsa.ac.uk]

Please initial boxes

1. I confirm that I have read and understand the participant information sheet for the above study; ☐
2. I have had an opportunity to consider the information, ask questions and have had these answered satisfactorily; ☐
3. I agree to complete the anonymized questionnaire as part of the research and understand that these will be kept anonymous; ☐
4. I agree to the anonymized results being made public available in publications, presentations, reports or examinable format (dissertation or thesis) for the purposes of research and teaching – I understand that these will remain anonymous. ☐
5. I agree to the results being used for *future* research or teaching purposes; ☐
6. I agree to take part in the above study. ☐
7. I am happy to be contacted about any future studies and agree that my personal contact details can be retained in accordance with the Data Protection Act 1998 ☐

Name of participant	Date	Signature
Name of person taking consent **(if different from researcher)**	Date	Signature
Researcher	Date	Signature

Complaints about the conduct of this research should be raised with: [Raid Hanna r.hanna@gsa.ac.uk]

Appendix D. 3

Thank you for agreeing to answer the following questions about the effects of façade design on daylight levels and the experienced atmosphere inside the studio. Your answers will be kept confidential.

感谢您同意回答以下有关平面设计对工作室内的日光水平和氛围感受的影响的问题。 您的答案将被保密。

Definitions you may need:

您可能需要的定义

Brightness: is a function of the amount of light received at the eye.

亮度：是眼睛接收到的光的总量的物理量

Color appearance (rendering): The effect which the spectral characteristics of a light have on the appearance of colored objects illuminated by it.

外观颜色： 光的光谱特性对其照射的彩色物体的外观的影响

Flickering: moving or shining irregularly or unsteadily

闪烁 ： 不规则或不稳定地移动或发亮

Glare: to shine with a harsh uncomfortably high brightness, which there is a reduction in the ability to see significant objects due to extreme contrasts.

眩光：是指视野中由于不适宜亮度分布，或在空间或时间上存在极端的亮度对比，以致引起视觉不舒适和降低物体可见度的视觉条件。

Illumination: The spread of light over a surface

光照：光在表面上的扩散

Room luminance: The property of source to emit light in a given direction.

室内亮度:光源在给定方向上发光的特性

sensorial stimuli: The way that we obtain information from our environment through our senses (sight, hearing, touch, taste and smell).

感觉刺激：我们通过感官（视觉，听觉，触觉，味觉和嗅觉）从我们的环境中获取信息的方式。

Uniformity: lighting levels are stable with no sudden break and drops.

均匀性：照明水平稳定，没有突然中断和下降。

Visual comfort: is a subjective reaction to the quantity and quality of light within any given space at a given time.

视觉舒适度：是在特定的时间，特定的空间内对光线的数量和质量的主观反应。

1

Demographic information

个人信息

Date and Time of the survey: …………………………………………

调查的日期和时间：…………………………………………

1. Your gender? 你的性别是？

- ○ Female 女性
- ○ Male 男性
- ○ Other (if you would like to mention, please do in the box)
- ○ 其他 （如果你想提及，请在括号中填写）
- ○ Prefer not to say 不愿告知

2. Your age? 你的年龄是？

- ○ 17 or below 17 岁及 17 岁以下
- ○ 18-21
- ○ 22-25
- ○ 26 and above 26 岁及 26 岁以上

3. Residency: Which of the following categories best describes your original type of residency? 住处：以下哪类最能说明您的原居住类型？

- ○ UK resident 英国居民
- ○ European resident 欧洲居民
- ○ South-East Asia resident 东南亚居民
- ○ Other (please specify) 其他（请具体说明）
- ○

Your sitting area in your studio

您在工作室的座位区

4. How long have you been using the studio? 你已经使用这个工作室多久了？

- ○ 1 month or less 少于 1 个月
- ○ 2-6 months 2-6 个月
- ○ 7-12 months 7-12 个月
- ○ More than a year 超过 1 年

2

5. On average, how many days do you spend inside the studio? 平均而言，您在工作室内度过了多少天？

o A day or less 少于 1 天

o 2-4 days 2-4 天

o 5-7 days 5-7 天

6. On average, how many hours per day do you spend inside the studio? 平均而言，你每天在工作室里花多少小时？

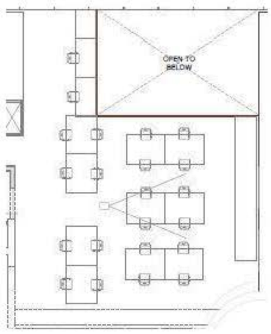
o 1 hour or less 少于 1 小时

o 2-5 hours 2-5 个小时

o 6-9 hours 6-9 个小时

o 10-14 hours 10-14 个小时

7. Use the drawing and please mark your seating position in relation to your studio's windows? 请在下面的平面图上根据窗户的位置标记您的座位？



Product Design Engineering Studio

8. Which of the following reasons make you choose your current seating position? (choose all that are relevant) 以下哪个原因让您选择您当前的座位？（选择所有相关的选项）

o Close to the window to get more daylight and view 靠近窗户以获得更多的日光和视野

o Far from the window to avoid excessive daylight 远离窗户以避免过度的日光

o In the middle 在中间的位置

o I have been asked to set here. 我被要求坐在这里

o Because of the type of performing task 由于自身任务的类型

o No specific reason to choose my current seating area 没有特殊的原因让我选择目前的座位区

o Other, please specify 其他，请具体说

9. Based on your seating position in your studio, what layers of views do you get from your studio's window(s)? (choose all that are relevant) 根据您在工作室中的座位位置，您可以透过工作室的窗口观察到什么层次的风景？（选择所有相关的）

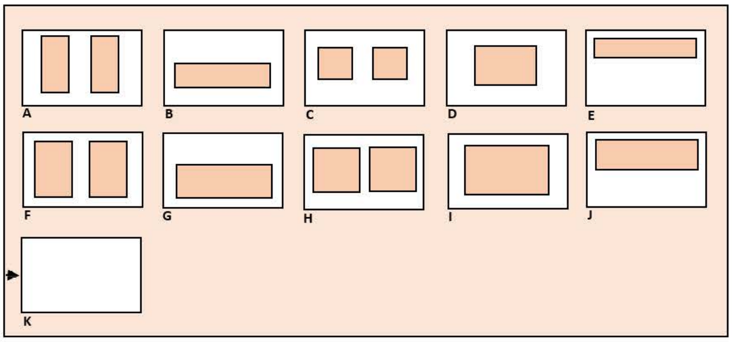
- Upper – only sky
  上部 - 只有天空

- Upper (distant)– the sky down to the natural or man-made skyline
  上部（远处） -天空到自然或人造天际线这一区间

- Middle – natural or man-made objects such as fields, trees, hills and buildings.
  中间 - 自然或人造物体，如田野，树木，丘陵和建筑物。

- Lower (close) – the foreground, for example plants and paving.
  下部或更低（近处） - 前景，例如植物和铺路。

10. Based on your seating position in your studio, which of the following window arrangements in elevations would capture the best of the view in your studio? (If the arrangements below are inappropriate, please draw a different arrangement in space K below). (choose all that are relevant) 根据您在工作室中的座位位置，以下哪些窗户布置可以捕捉您工作室中最佳的视野？（如果以下的窗户布置不合适，请在下面的方框 K 中画出您认为的最佳形状）。（选择所有相关的）



4

11. Please tick the number that best describes your opinion about <u>the contribution of outside view to your studio's spatial experience.</u>

请勾选最能描述您对外部景色对工作室空间体验贡献的看法的数字。

	Not applicable at all	根本不适用				非常适用	***Very applicable***
	1	2	3	4	5	6	7
Too many surrounding buildings, which impacts negativity on my studio. **周围的建筑太多，对我的工作室产生了负面影响**	○	○	○	○	○	○	○
Natural connection with pleasant views outside including trees and sky. **宜人的窗外景色与大自然的联系，包括树木和天空**	○	○	○	○	○	○	○
Adds more aesthetic quality to the interior 为室内环境增添更多美感	○	○	○	○	○	○	○
Adds more dynamic rhythm and varieties to my perception including changes on time, weather and people's movement 为我的感知添加更多动态的节奏和变化，包括时间，天气和人的运动的变化	○	○	○	○	○	○	○
Provides a distracting view, including the activities of people. **提供令人分心的视野，包括人的活动。**	○	○	○	○	○	○	○

5

12. Please tick the number that best describes your view point about the windows in your studio. **请勾选最能描述您对工作室窗户的看法的数字。**

	Not applicable at all	根本不适用				非常适用	***Very applicable***
	1	2	3	4	5	6	7
They provide sufficient daylight levels to the studio on a cloudy day **冬天的时候，它们能为工作室提供充足的日光**	○	○	○	○	○	○	○
They provide sufficient daylight levels to the studio on a bright day **夏天的时候，它们能为工作室提供充足的日光**	○	○	○	○	○	○	○
They provide attractive outside view *窗户能让人欣赏到窗外的美景*	○	○	○	○	○	○	○
The outside sound is not distracting **外面的声音不会分散注意力**	○	○	○	○	○	○	○
They enhance the thermal comfort **它们提高了室内的保温舒适度**	○	○	○	○	○	○	○
They help to create a significant spatial experience. **它们有助于创造重要的空间体验。**	○	○	○	○	○	○	○
The façade windows contribute positively to the studio's aesthetics **立面的窗户为工作室的美**	○	○	○	○	○	○	○

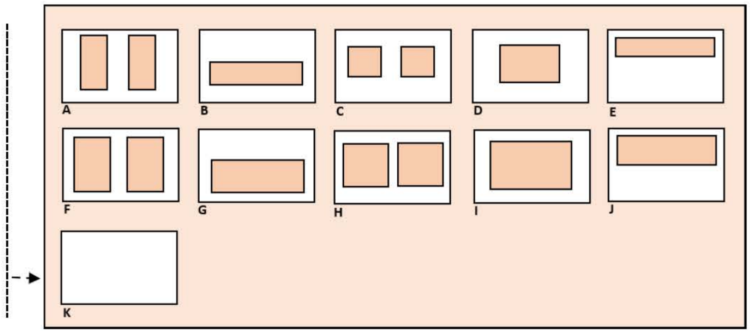
6

学做出了积极贡献							
They add a character to the studio 他们为工作室添加了一个角色	○	○	○	○	○	○	○

Daylight 日 光

➢ *Daylight is a combination of direct and indirect sunlight, and diffused cloud cover during the daytime.* 日光是阳光直射和间接照射的结合，在白天会被云层分散

13. Based on your seating position in your studio, which of window arrangements in the following elevations do you think would makes the most of the daylight in your studio? (If the arrangements below are inappropriate, please draw a different arrangement in space K below). (choose all that are relevant) **根据您在工作室中的座位位置，您认为以下平面图中哪些窗户布置可以充分利用您工作室的日光？（如果下面的布置不合适，请在下面的空格 K 中画出不同的安排）。（选择所有相关的）**



14. From the perspective of adequate daylight, what is the best time for you to occupy your studio in the winter? (Choose all that are relevant) 从充足的日光角度来看，你在冬天使用工作室的最佳时间是什么时候？（选择所有相关的）

- ○ In the morning (8-12) a.m. **在上午（8-12）点的时候**
- ○ In the afternoon (1-5) p.m. **在下午（1-5）点的时候**
- ○ In the evening (6-10) p.m. **在晚上（6-10）点的时候**
- ○ Neither **一个也不是**
- ○ I have not experienced winter season yet **我还没有经历过冬季**

15. From the perspective of adequate daylight, what is the best time for you to occupy your studio in the summer? (Choose all that are relevant)
从充足的日光角度来看， 你在夏天使用工作室的最佳时间是什么时候？ （选择所有相关的）

- In the morning (8-12) a.m. 在上午（8-12） 点的时候
- In the afternoon (1-5) p.m. 在下午（1-5） 点的时候
- In the evening (6-10) p.m. 在晚上（6-10） 点的时候
- Neither 一个也不是
- I have not experienced summer season yet 我还没有经历过夏季

16. Please tick the number that best describes your view point about <u>the importance of daylight in your studio's spatial experience.</u> 请勾选最能描述您关于<u>日光在您工作室空间体验中的重要性</u>的观点的数字

	Not applicable at all 根本不适用					非常适用	***Very applicable***
	1	2	3	4	5	6	7
Daylight stimulates my visual experience in my studio 日光刺激了我在工作室的视觉体验	○	○	○	○	○	○	○
Daylight provides high illuminance, color and variability in my studio 日光在我的工作室中提供了高照度，色彩和可变性	○	○	○	○	○	○	○
Daylight provides uncomfortable solar glare in my studio 日光在我的工作室里产生了令人不舒服的太阳眩光	○	○	○	○	○	○	○
Daylight provides a psychological comfort to me in my studio 日光为我提供了心理上的安慰	○	○	○	○	○	○	○

8

Daylight creates a productive environment as it brings less stress and discomfort than artificial light in my studio 日光创造了一个富有成效的环境，因为它比我工作室中的人造光带来更少的压力和不适	○	○	○	○	○	○	○
Daylight is insufficient in my studio, which impacts regarding on my productivity 我工作室的日光不足，影响了我的工作效率	○	○	○	○	○	○	○
During the daytime, I complete my studio work at different places rather than my usual location in studio? 在白天，我在工作室不同的地方完成我的工作而不是在常用位置？	○	○	○	○	○	○	○
After sunset, I continue working on my studio at night. 日落之后，我晚上会继续在我的工作室工作。	○	○	○	○	○	○	○

Artificial lighting 人工照明

17. Please tick the best that describes your view point about the following statements regarding the artificial light in your studio. **请勾选**以下最能**描述您对**工作室中人造光的**陈**述的**观**点。

	Strongly disagree 非常不同意					非常同意	***Strongly agree***
	1	2	3	4	5	6	7
Crucial to supplement daylight and extend working time **最重要的是**补**充日光并延**长**工作**时间	○	○	○	○	○	○	○
Increases safety at night **提高了在夜晚的安全性**	○	○	○	○	○	○	○
Increases concentration **增**强**了注意力**	○	○	○	○	○	○	○
Creates an atmospheric environment 营造一个有氛围的环境	○	○	○	○	○	○	○
It increases my productivity **它提高了我的生**产**力**	○	○	○	○	○	○	○
Bring a visual comfort 带来视觉上的舒适感	○	○	○	○	○	○	○
It causes eye strain **它会**导**致眼睛疲**劳	○	○	○	○	○	○	○
It causes headache and fatigue **它会**导**致头痛和疲**劳	○	○	○	○	○	○	○

18. On scale from 1-7 (1= **Strongly** disagree, 7= **Strongly** agree), please evaluate the artificial light in your studio? 从 1-7 的范围中（1 =非常不同意，7 =非常同意），**请评估**工作室中的人造光？

	Strongly disagree	非常不同意				非常同意	***Strongly agree***
	1	2	3	4	5	6	7
Adequate illumination **充足的照明**	○	○	○	○	○	○	○
Uniformity* **均匀性***	○	○	○	○	○	○	○
Glare* **眩光***	○	○	○	○	○	○	○
Flickering* 闪烁*	○	○	○	○	○	○	○
Good color appearance* **良好的外观颜色***	○	○	○	○	○	○	○
High visual comfort **高视觉舒适度**	○	○	○	○	○	○	○
Creates shadows 创造阴影	○	○	○	○	○	○	○
Lack of control **缺乏控制**	○	○	○	○	○	○	○

19. In your opinion, which of the following rating scales best describe the effect of artificial light in your studio. 在您看来，以下哪个**评级**量表最能描述工作室中人造光的效果。

	1	2	3	4	5	6	7	
Hazy 朦胧的	○	○	○	○	○	○	○	Clear 清晰的
Complex 复杂的	○	○	○	○	○	○	○	Simple 简单的
Tense 紧张的	○	○	○	○	○	○	○	Relaxed 轻松的
Dim 昏暗的		○	○	○	○	○	○	Bright 明亮的
Visually cool 冷色调		○	○	○	○	○		Visually warm 暖色调
Ordinary 普通的		○	○	○	○	○		Special 特殊的
Non-functional 无功能性的	○	○	○	○	○	○	○	Functional 功能性的
Unpleasant 讨厌的	○	○	○	○	○	○	○	Pleasant 舒适的
Frustrating 令人沮丧的	○	○	○	○	○	○	○	Satisfying 令人满意的

20. Are you using artificial light while you are taking part in this survey?

您在参加本次调查时是否正在使用人造光？

- ○ Yes 是
- ○ No 否

Spaciousness 空间感

➢ *Spaciousness is the sense of visual freedom, which relates to the feeling that an interior provides the sense of being open or enclosed, it is also considered as an index for the visual environment.*

空间感是一种视觉自由的感觉，是指给人一种在室内开放或封闭的感觉，也被认为是视觉环境的一个指标。

21. From your point of view, please evaluate <u>the spaciousness</u> in your studio. 从您的角度来看，请评估您工作室的空间感。

	1	2	3	4	5	6	7	
Small 小的	○	○	○	○	○	○	○	Large 大的
Short 短的	○	○	○	○	○	○	○	Long 长的
Cramped 狭窄的	○	○	○	○	○	○	○	Spacious 宽敞的

22. In your opinion, which of the following indicators make your studio appear spacious, or otherwise? 在您看来，以下哪个指标会使您的工作室显得宽敞，或者其他指标？

	Strongly disagree 非常不同意					非常同意	***Strongly agree***
	1	2	3	4	5	6	7
Ceiling height 天花板的高度	○	○	○	○	○	○	○
The area or depth of floor plan 平面图的面积或深度	○	○	○	○	○	○	○
Furniture compactness 家具紧密度	○	○	○	○	○	○	○
Studio shape (rectangular, square,etc.) 工作室形状（矩形，方形等）	○	○	○	○	○	○	○
The studio's walls and ceiling colour 工作室墙壁和天花板的颜色	○	○	○	○	○	○	○
Window size 窗户的尺寸	○	○	○	○	○	○	○
Window arrangement 窗户的布置	○	○	○	○	○	○	○
Overlooking view 远眺景色	○	○	○	○	○	○	○
The amount of daylight 日光量	○	○	○	○	○	○	○

The quality of artificial light 人造光的质量	○	○	○	○	○	○	○

Atmosphere in relation to the light: 与光有关的氛围：

- *Atmosphere is the first impression that you get from the perception of the surrounding environment in relation to our internal sensation, which affects our experience of a space.* 氛围是您对周围环境的感知与我们内在的感觉之间的关系所产生的第一印象，它会影响我们对空间的体验。

23. Were you aware of the concept of atmosphere in architectural spaces before? 您之前是否意识到建筑空间内的氛围概念？

- ○ Yes 是
- ○ No 否

24. Do you think the interior space could have sensorial stimuli*? 你认为内部空间可能有感觉刺激*吗？

- ○ Yes 有
- ○ Maybe 也许有
- ○ No 没有

25. In your opinion, which factors do contribute to the atmosphere being perceived as a positive or negative stimuli in your studio? 在您看来， 哪些因素确实有助于将氛围视为您在工作室中的积极或消极刺激？

	Strongly negative stimuli 非常消极的刺激					非常积极的刺激 ***Strongly positive stimuli***	
Factor 因素	1	2	3	4	5	6	7
Daylight on a cloudy day 冬天的日光 (if you experienced it) （如果你经历过的话）	○	○	○	○	○	○	○
Daylight on a bright day 夏天的日光 (if you experienced it) （如果你经历过的话）	○	○	○	○	○	○	○

Artificial light 人造光源	○	○	○	○	○	○	○
Temperature in winter 冬天的温度 (if you experienced it) （如果你经历过的话）	○	○	○	○	○	○	○
Temperature in summer 夏天的温度 (if you experienced it) （如果你经历过的话）	○	○	○	○	○	○	○
Acoustics 声音	○	○	○	○	○	○	○
Air quality 空气质量	○	○	○	○	○	○	○
Furniture arrangements 家具布置	○	○	○	○	○	○	○
Furniture compactness 家具紧密度	○	○	○	○	○	○	○
Spaciousness 空间感	○	○	○	○	○	○	○
Façade windows 立面窗户	○	○	○	○	○	○	○
Overlooking view 远眺景色	○	○	○	○	○	○	○

26. From your point of view, which of the following best describe <u>the state of atmosphere</u> in your studio. 从您的角度来看， 以下哪一项最能描述您工作室的<u>氛围状况</u>。

	1	2	3	4	5	6	7	
Business-like 商业化的	○	○	○	○	○	○	○	Cozy 舒适的
Formal 正式的	○	○	○	○	○	○	○	Intimate 随意的
Dull 无趣的	○	○	○	○	○	○	○	Stimulating 刺激的
Terrifying 骇人的	○	○	○	○	○	○	○	Pleasant 令人愉快的
Dispirited 死气沉沉的	○	○	○	○	○	○	○	Lively 活泼的
Tense 紧张的	○	○	○	○	○	○	○	Relaxed 放松的
Public 开放的	○	○	○	○	○	○	○	Private 私人的
Boring 让人无聊的		○	○	○	○	○	○	Exciting 令人激动的
Unattractive 不吸引人的	○	○	○	○	○	○	○	Attractive 吸引人的
Inconvenient 不方便的	○	○	○	○	○	○	○	Convenient 方便的
Passive 消极的	○	○	○	○	○	○	○	Active 积极的
Hostile 有敌意的	○	○	○	○	○	○	○	Friendly 友好的
Unsociable 不爱交际的	○	○	○	○	○	○	○	Sociable 好交际的
Monotonous 单调的	○	○	○	○	○	○	○	Interesting 有趣的
Dislike 厌恶	○	○	○	○	○	○	○	Like 喜欢
Frustrating 令人沮丧的	○	○	○	○	○	○	○	Satisfying 让人满意的

27. In your opinion, please evaluate <u>the experience of atmosphere</u> in your studio based on the following dimensions. 请以您的角度，根据以下几个方面评估工作室<u>氛围的体验</u>。

	Not applicable at all 根本不适用					非常适用 ***Very applicable***	
	1	2	3	4	5	6	7
Stimulating 刺激的	○	○	○	○	○	○	○
Pleasant 愉快的	○	○	○	○	○	○	○
Secure 安全的	○	○	○	○	○	○	○
Lively 活跃的	○	○	○	○	○	○	○
Subdued 冷清的	○	○	○	○	○	○	○
Demarcated 划定的	○	○	○	○	○	○	○
Airy 轻快的	○	○	○	○	○	○	○
Masculine 阳刚的	○	○	○	○	○	○	○
Feminine 阴柔的	○	○	○	○	○	○	○
Simple 简单的	○	○	○	○	○	○	○
Complex 复杂的	○	○	○	○	○	○	○
Aged 年老的	○	○	○	○	○	○	○
Modern	○	○	○	○	○	○	○

*现代*的							
New 新的	○	○	○	○	○	○	○
Surprising 令人惊喜的	○	○	○	○	○	○	○
Ordinary 普通的	○	○	○	○	○	○	○

28. Please evaluate the contribution of daylight in your studio's atmosphere on a cloudy day? **请评估在冬季，日光对于你的工作室氛围的贡献？**

	Very low 非常低						***Very high*** 非常高
	1	2	3	4	5	6	7
Brightness* 亮度*	○	○	○	○	○	○	○
Illumination* 光照*	○	○	○	○	○	○	○
Uniformity* 均匀性*	○	○	○	○	○	○	○
Room luminance* 室内亮度*	○	○	○	○	○	○	○
Distribution of daylight 日光的分布	○	○	○	○	○	○	○
Color- Gray 颜色-灰色	○	○	○	○	○	○	○
Color- Yellowish 颜色-淡黄色	○	○	○	○	○	○	○
Shadow 阴影	○	○	○	○	○	○	○

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Darkness 黑暗	○	○	○	○	○	○	○
Glare from daylight 日光造成的眩光	○	○	○	○	○	○	○
Visual comfort*视觉舒适度*	○	○	○	○	○	○	○
Lack of control - blinds 缺乏控制-盲目	○	○	○	○	○	○	○

29. Please evaluate the contribution of daylight in your studio's atmosphere on a bright day? 请评估在夏季，日光对于你的工作室氛围的贡献？

	Very low 非常低						*Very high* 非常高
	1	2	3	4	5	6	7
Brightness* 亮度*	○	○	○	○	○	○	○
Illumination* 光照*	○	○	○	○	○	○	○
Uniformity* 均匀性*	○	○	○	○	○	○	○
Room luminance* 室内亮度*	○	○	○	○	○	○	○
Distribution of daylight 日光的分布	○	○	○	○	○	○	○
Color- Gray 颜色-灰色	○	○	○	○	○	○	○

Color-Yellowish 颜色-淡黄色	○	○	○	○	○	○	○
Shadow 阴影	○	○	○	○	○	○	○
Darkness 黑暗	○	○	○	○	○	○	○
Glare from daylight 日光造成的眩光	○	○	○	○	○	○	○
Visual comfort*视觉舒适度*	○	○	○	○	○	○	○
Lack of control 缺乏控制	○	○	○	○	○	○	○

30. Please tick the number that best describes how stable the atmosphere is in your studio.
请勾选最能说明工作室内氛围稳定程度的数字。

	Strongly disagree 非常不同意						***Strongly Agree*** 非常同意
	1	2	3	4	5	6	7
It varies from time to time during the day 它在白天不时变化	○	○	○	○	○	○	○
It varies from one weather season to another 它因天气季节而异	○	○	○	○	○	○	○
It's changing and causing a change in any stimuli inside studio 它正在改变并引发工作室内任何刺激的变化	○	○	○	○	○	○	○

31. Would you recommend your studio to a friend, in terms of the following? 您会根据以下内容向朋友推荐您的工作室吗？

	YES 会	*MAYBE* 也许会	*NO* 不会
Adequate daylight 充足的日光	○	○	○
Experienced a positive atmosphere related to the daylight 体验了与日光相关的积极的氛围	○	○	○

Additional comments 附加意见

Please add any other comments you deem necessary that the survey does not cover regarding: 请添加您认为必要的但本调查问卷中未涵盖的任何其他意见：

Your experienced atmosphere inside the studio (Positive and negative points): 您在工作室内的经历过的氛围（正面和负面）

Daylight levels / Artificial light inside your studio (issues such as, quantity and quality of light, direction, glare, discomfort): 工作室内的日光水平/人造光（诸如光线的数量和质量，方向，眩光，不适等问题）：

The façade layout from inside your studio: 工作室内的立面布局：

Thank you for your time. You have helped to create a more pleasing atmosphere inside studio
感谢您宝贵时间。您帮助创造了一个更令人愉快的工作室氛围

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Appendix E

Appendix E. 1

Population size													
Case study	Glasgow										Edinburgh		Aberdeen	
Orientation	North						South				North		South	
Studio	GNC	GNCm	GNIn	GNPL	GNPm	GNJm	S7	S8	S9	S10	E1	Em	A1	A2
Student's numbers	42	28	47	21	50	71	55	26	45	30	40	24	30	44
Total student's numbers	● 259 students						● 156 students				● 64 students		● 74 students	
	415 students													

Table E. 1 **Population size**

- ● First phase (North orientation)
- ● Second phase (South orientation)

Appendix E. 2

City	Studio	Total students in each studio	population size for the case study	sample size for each case study	Minimum student's sample size for each studio	Number of student's response	Response percentage %
Glasgow	GNC	42	415	170	17	15	88%
	GNCm	28			11.4 = 12	12	100%
	GNIn	47			19	24	100%
	GNPL	21			8.6 = 9	13	100%
	GNPm	50			20.4 = 21	20 / ● 20	100%
	GNJm	71			29	22	76%
	GSInm	55			22.5 = 23	12 / ● 25	100%
	GSInu	26			10.6 = 11	7	70%
	GSPo	45			18.4 = 19	22	100%
	GSP	30			12	26	100%
Total response rate for Glasgow							100%
Edinburgh	E1	40	64	26	16	31	100%
	Em	24			10	16	100%
Total response rate for Edinburgh							100%
Aberdeen	A1	30	74	30	12	17	100%
	A2	44			17.8 = 18	38	100%
Total response rate for Aberdeen							100%

Table E. 2 Sample size information

● Student's numbers based on the pilot study

Appendix F

Appendix F. 1

Characteristics	Glasgow						Edinburgh	
	GNC	GNCm	GNIn	GNPL	GNPm	GNJm	E1	Em
Design type	Double-volume with mezzanine	Mezzanine floor	Double- volume open plan	Double- volume with mezzanine	Mezzanine floor	Mezzanine floor	Double- volume with mezzanine	Mezzanine floor
Studio floor level (m)	+4.375 First floor	+8.375 Second floor	+18.525 Fourth floor	+18.525 Fourth floor	+22.40 Mezzanine floor	+22.40 Mezzanine floor	+5 m	+7.5 m Mezzanine floor
Dimension (m) W*L*H	15*10*8	15*7*4	14.65*11*8	5*7*8	8*11*4	8*11*4	16*11*5	9*9*2.5
Floor Area (m^2)	146.5 m^2	102.5 m^2	161 m^2	42 m^2	88 m^2	88 m^2	288 m^2	99 m^2
Wall Area (m^2)	117 m^2	60 m^2 (window placed in entire wall)	North: 117 m^2 South: 117 m^2	56 m^2	North: 32 m^2 South: 28 m^2	North: 32 m^2 South: 20 m^2	90 m^2	22.5 m^2
Window Area (m^2)	60 m^2		North: 51 m^2 South: 51 m^2	21 m^2	North: 32 m^2 South: 28 m^2	North: 24 m^2 South: 10 m^2	6 m^2 each/ 48 m^2 for total.	1 m^2/ 4 m^2 for total
No. of windows	1	1	2	1	2	2	8	4
Window elevation	North							
Window dimension (m)	15*4 (60 m2, the window is shared with two studios)		North & South: 14.65*3.5	6*3.5	North: 8*4 South: 7*4	North: 8*3 South: 4*2.5	2*3 (48 m^2 for total)	2*0.5 (1 m^2 for total)
window sill height (m)	4	0	North & South: 4	4	North & South: 0	North: 1 South: 1.50	1	0
Window/ Floor ratio	40%	57%	32%	50%	North: 36% South: 32%	North:27% South:18%	16.6% total	4 %
Window/Wall ratio	50%	100%	North & South: 44%	50%	North & South: 100%	North: 75% South: 50%	53.3% total	18%
Obstructions (Type, Height, Distance)	Residential building, 5.5 m distance, and 22 m height.		No obstructions	No obstructions	No obstructions	No obstructions	Trees, 5m distance and 6m high. Tenement building, 16m distance and 13 m height.	Limited access to window

Table F. 1 Studios' characteristic's in Glasgow & Edinburgh.

Appendix G

Appendix G. 1

Edinburgh case							
	Studio E1			Studio Em			
Horizontal / Vertical location of reference points	Reference points inside E1 studio	Distance from the window wall (m)	Height from the ground level	Horizontal / Vertical location of reference points	Reference points inside Em studio	Distance from the window wall	Height from the ground level
Horizontal reference point	59	At window step	1 m	Horizontal reference point	51	2 m	0.74 m
	60	2 m	0.74 m		42	2 m	
	57	4 m			44	4 m	
	52	4 m			49	4 m	
	53	6 m			48	4 m	
	58	8 m			43	6.5 m	
Vertical reference point	55	window wall	1.60 m above eye level & 1.20 m at eye level.		45	7 m	
	61	6 m		Vertical reference point	46	2 m	1.20 m
	54	7 m			47	6.5 m	1.20 m
	56	11 m			50	11 m	1.20 m
	68	11 m					

Table G. 1 light meters information inside Edinburgh studios

Appendix G. 2

Glasgow Case

Studio GNC

Horizontal / Vertical location of reference points	Reference points inside GNC studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	8	0.38	0.74 m
	11	1.20	
	10	2	
	7	0.38	
	69	2	
	5	4	
	6	3	
	67	5	
	9	8.30	
	66	8.70	
Vertical reference point	2	1.10	1.60 m above eye level & 1.20 m at eye level.
	1	On window wall	
	3	1.20	
	4	10	

Studio GNCm

Horizontal / Vertical location of reference points	Reference points inside GNCm studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	15	3	1 m
	14	3	
	16	4	0.74 m
	17	4	
	19	3.5	
	18	7	
	21	3.5	
	22	5.50	
	Test 2	9	
Vertical reference point	12	5	1.60 m above eye level & 1.20 m at eye level.
	13	9	

Studio GNIn

Horizontal / Vertical location of reference points	Reference points inside GNIn studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	28	0.30	0.74 m
	27	4.50	
	29	0.30	
	30	4.50	
	63	10.50	
	31	On window step	
Vertical reference point	24	2	1.60 m above eye level & 1.20 m at eye level.
	23	On window wall	
	62	On window wall	
	25	2.50	
	65	10.5	
	26	10.5	

Table G. 2 light meters information inside Glasgow studios (GNC, GNCm, GNIn).

Appendix G. 3

<table>
<tr><th colspan="14">Glasgow Case</th></tr>
<tr><th colspan="4">Studio GNPL</th><th colspan="5">Studio GNPm</th><th colspan="5">Studio GNJm</th></tr>
<tr><th>Horizontal / Vertical location of reference points</th><th>Reference points inside GNPL studio</th><th>Distance from the window wall (m)</th><th>Height from the ground level</th><th>Horizontal / Vertical location of reference points</th><th>Reference points inside GNPm studio</th><th>Distance from the window wall (m) -North-</th><th>Distance from the window wall (m) -South-</th><th>Height from the ground level</th><th>Horizontal / Vertical location of reference points</th><th>Reference points inside GNPL studio</th><th>Distance from the window wall (m) -North-</th><th>Distance from the window wall (m) -South-</th><th>Height from the ground level</th></tr>
<tr><td rowspan="6">Horizontal reference point</td><td>36</td><td>0.85</td><td rowspan="6">0.74 m</td><td rowspan="7">Horizontal reference point</td><td>45</td><td>6</td><td>7</td><td rowspan="5">0.74 m</td><td rowspan="7">Horizontal reference point</td><td>60</td><td>2.5</td><td>-</td><td rowspan="5">0.74 m</td></tr>
<tr><td>41</td><td>2</td><td>46</td><td>9</td><td>4.5</td><td>59</td><td>5.5</td><td>-</td></tr>
<tr><td>40</td><td>4</td><td>47</td><td>11.5</td><td>1.5</td><td>57</td><td>2.5</td><td>-</td></tr>
<tr><td>37</td><td>3.5</td><td>50</td><td>7</td><td>7</td><td>58</td><td>5.5</td><td>-</td></tr>
<tr><td>38</td><td>6</td><td>51</td><td>11</td><td>2.5</td><td>61</td><td>10</td><td>3.5</td></tr>
<tr><td>39</td><td>7</td><td>44</td><td>On window step</td><td>-</td><td>1.40</td><td>52</td><td>On window step</td><td>-</td><td>1.12</td></tr>
<tr><td rowspan="5">Vertical reference point</td><td>32</td><td>On window wall</td><td rowspan="5">1.60 m above eye level & 1.20 m at eye level.</td><td>48</td><td>-</td><td>On window step</td><td>1.50</td><td>54</td><td>-</td><td>On window step</td><td>1.55</td></tr>
<tr><td>34</td><td>3.50</td><td rowspan="4">Vertical reference point</td><td>43</td><td>7</td><td>7</td><td rowspan="4">1.60 m above eye level & 1.20 m at eye level.</td><td rowspan="4">Vertical reference point</td><td>53</td><td>3.5</td><td>-</td><td rowspan="4">1.60 m above eye level & 1.20 m at eye level.</td></tr>
<tr><td>33</td><td>3.50</td><td>42</td><td>8</td><td>6</td><td>69</td><td>8.5</td><td>-</td></tr>
<tr><td rowspan="2">35</td><td rowspan="2">8</td><td rowspan="2">49</td><td rowspan="2">12</td><td rowspan="2">1</td><td>55</td><td>10</td><td>3.5</td></tr>
<tr><td>56</td><td>11.5</td><td>1.10</td></tr>
</table>

Table G. 3 light meters information inside Glasgow studios (GNPL, GNPm, GNJm).

Appendix H

Appendix H. 1

Studio	Double-volume open plan studio		Mezzanine studio
	Vertical measuring points at Zone 1 (not covered)	Vertical measuring points at Zone 2 (Covered)	Vertical measuring points at mezzanine zone
E1	55, 54, 56	68, 61	Em
Em	-	-	46, 47, 50
GNC	2, 1, 3	4	GNCm
GNCm	-	-	12, 13
GNIn	64, 23, 62, 25, 65, 26	-	-
GNPL	32, 34, 33	35	GNPm
GNPm	-	-	43, 49, 42
GNJm	-	56, 55	53, 69

Table H. 1 **Vertical measuring points grouped for three zones in Glasgow and Edinburgh studios.**

Studio	Double-volume open plan studio		Mezzanine studio
	Horizontal measuring points at Zone 1 (not covered)	Horizontal measuring points at Zone 2 (Covered)	Horizontal measuring points at mezzanine zone
E1	60, 57, 53, 58	52	Em
Em	-	-	51, 42, 44, 48, 49, 43, 45
GNC	8, 10, 11, 7, 69	5, 6, 67, 9, 66	GNCm
GNCm	-	-	14, 15, 16, 19, 17, 18, 21, 22, test2
GNIn	28, 27, 29, 30, 63	-	-
GNPL	36, 41, 37, 40	38, 39	GNPm
GNPm	-	-	44, 45, 46, 47,50, 51, 48
GNJm	-	61	60, 59, 57, 58

Table H. 2 **Horizontal measuring points grouped for three zones in Glasgow and Edinburgh studios.**

Appendix I

Appendix I. 1

Zone	Month	df	F	Sig.
Zone 1	Feb	3,11	8.026	.004
	Mar	3,11	9.921	.002
	Apr	3,11	14.070	.000
	May	3,11	10.456	.001
	Jun	3,11	11.697	.001
	Jul	3,11	7.700	.005
	Aug	3,11	8.391	.003
	Sep	3,11	10.079	.002
	Oct	3,11	28.734	.000
Zone 2	Feb	3,2	328.529	.003
	Mar	3,2	29.966	.032
	Apr	3,2	7.191	.125
	May	3,2	1310.483	.001
	Jun	3,2	2.222	.325
	Jul	3,2	4.084	.203
	Aug	3,2	3.082	.255
	Sep	3,2	61.877	.016
	Oct	3,2	7354.572	.000
Zone 3	Feb	3,6	9.106	.012
	Mar	3,6	17.719	.002
	Apr	3,6	236.867	.000
	May	3,6	533.855	.000
	Jun	3,6	12.002	.006
	Jul	3,6	16.788	.003
	Aug	3,6	8.410	.014
	Sep	3,6	12.737	.005
	Oct	3,6	110.258	.000

Table I. 1 Results of the ANOVA test investigating the significant difference of the illuminance levels between studios registered by VMP throughout the measurement period.

Appendix I. 2

Zone	Month	df	F	Sig.
Zone 1	Feb	3,14	14.913	.000
	Mar	3,14	28.905	.000
	Apr	3,14	79.892	.000
	May	3,14	6.672	.005
	Jun	3,14	4.273	.024
	Jul	3,14	24.176	.000
	Aug	3,14	7.246	.004
	Sep	3,14	57.997	.000
	Oct	3,14	35.394	.000
Zone 2	Feb	3,5	1.348	.359
	Mar	3,5	4.058	.083
	Apr	3,5	3.714	.096
	May	3,5	.586	.650
	Jun	3,5	.394	.763
	Jul	3,5	.721	.581
	Aug	3,5	.475	.713
	Sep	3,5	.462	.721
	Oct	3,5	1.957	.239
Zone 3	Feb	3,21	7.608	.001
	Mar	3,21	9.249	.000
	Apr	3,21	26.361	.000
	May	3,21	8.058	.001
	Jun	3,21	7.314	.002
	Jul	3,21	9.144	.000
	Aug	3,21	4.711	.011
	Sep	3,21	13.422	.000
	Oct	3,21	3.643	.029

Table I. 2 Results of the ANOVA test investigating the significant difference of the illuminance levels between studios registered by HMP throughout the measurement period.

Appendix I. 3

Month	Vertical / Horizontal measuring points	significant difference ($P<0.05$)	No significant difference ($P>0.05$)
Feb	V	-Studio GNIn with E1 and GNC for all time	-Studio GNC and E1. -studio GNPL with the rest of studios.
	H	-Studio GNIn with E1 and GNC for all time -studio GNPL with E1 and with GNIn (afternoon).	-Studio GNC and E1. - studio GNPL with GNC.
Mar	V	- Studio E1 with GNPL and GNIn. -Studio GNPL with all studios, yet results were fluctuated form significant to non-significant along the day with studio GNIn.	- Studio GNC and E1.
	H	-Studio E1 with all studios. -Studio GNPL with all studios, yet results were fluctuated form significant to non-significant along the day with studio GNIn.	- Studio GNC and GNIn.
Apr	V	- Studio E1 and GNC with Studios GNPL and GNIn.	- Studio GNC and E1. -Studio GNPL and GNIN.
	H	- Studio E1 and GNC with Studios GNPL and GNIn. -Studio GNPL and GNIN.	- Studio GNC and E1.
May	V	- Studio GNIn with E1 and GNC for all time.	- Studio GNC and E1. - Studio GNPL with the rest of studios, with significant difference with studio GNIn in morning time only.
	H	-Studio E1 with GNIn and GNPL. fluctuated results from significant to non-significant along the day with studio GNC.	- Studio GNPL and GNIN. -
Jun	V	-Studio GNIn with E1 and GNC for all time. -Studio GNPL and GNIN.	- Studio GNC and E1.

	H	-Studio E1 with GNIn and GNPL.	- Studio GNC and E1. -Studio GNPL and GNIn.
Jul	V	- Studio GNIn with the rest of studios.	- Studio GNC and E1.
	H	-Studios E1 and GNC with GNIn and GNPL.	- Studio GNC and E1. -Studio GNPL and GNIn.
Aug	V	- Studio GNIn with the rest of studios.	-Studio GNC, E1 and GNPL.
	H	-Studio E1 with GNIn and GNPL. -Studio GNC with GNIn -Fluctuation difference between Studio E1 and GNC.	--Studio GNPL and GNIn.
Sep	V	-Studio GNIn with E1 and GNC for all time - Fluctuations of significant difference between GNIn and GNPL along the day.	- Studio GNC and E1.
	H	Significant difference between all studios.	-
Oct	V	-Studios GNIn and GNPL with E1 and GNC for all time. -Studio GNPL and GNIN.	- Studio GNC and E1.
	H	Significant difference between all studios.	-

Table I. 3 Summary for the post hoc test (Tukey HSD) for multiple comparisons between studios (vertical and horizontal measuring points in zone 1).

Appendix J

Appendix J. 1

Zone	Month	df	F	Sig.
Zone 1	Feb	1,13	16.873	**.001**
	Mar	1,13	12.941	**.003**
	Apr	1,13	47.540	**.000**
	May	1,13	16.299	**.001**
	Jun	1,13	16.793	**.001**
	Jul	1,13	13.467	**.003**
	Aug	1,13	5.929	**.030**
	Sep	1,13	12.425	**.004**
	Oct	1,13	53.910	**.000**
Zone 2	Feb	1,4	.908	.395
	Mar	1,4	2.904	.164
	Apr	1,4	17.589	**.014**
	May	1,4	4.396	.104
	Jun	1,4	9.009	**.040**
	Jul	1,4	9.596	**.036**
	Aug	1,4	4.363	.105
	Sep	1,4	11.678	**.027**
	Oct	1,4	1.292	.319
Zone 3	Feb	1.8	6.016	**.040**
	Mar	1.8	11.904	**.009**
	Apr	1.8	2.717	.138
	May	1.8	2.878	.128
	Jun	1.8	23.841	**.001**
	Jul	1.8	54.648	**.000**
	Aug	1.8	8.124	**.021**
	Sep	1.8	21.134	**.002**
	Oct	1.8	9.666	**.014**

Table J. 1 The ANOVA test results of the effect of external obstruction on the illuminance levels registered by the vertical measuring points in zone 1, 2 and 3.

Appendix J. 2

Zone	Month	df	F	Sig.
Zone 1	Feb	1,16	21.114	.000
	Mar	1,16	7.921	.012
	Apr	1,16	36.612	.000
	May	1,16	8.787	.009
	Jun	1,16	3.765	.070
	Jul	1,16	73.385	.000
	Aug	1,16	4.476	.050
	Sep	1,16	62.682	.000
	Oct	1,16	22.027	.000
Zone 2	Feb	1,7	.776	.408
	Mar	1,7	3.056	.124
	Apr	1,7	11.930	.011
	May	1,7	.009	.928
	Jun	1,7	.070	.799
	Jul	1,7	.236	.642
	Aug	1,7	.285	.610
	Sep	1,7	.190	.676
	Oct	1,7	1.418	.273
Zone 3	Feb	1,23	2.160	.155
	Mar	1,23	6.142	.021
	Apr	1,23	8.444	.008
	May	1,23	3.269	.084
	Jun	1,23	16.197	.001
	Jul	1,23	25.919	.000
	Aug	1,23	9.928	.004
	Sep	1,23	19.465	.000
	Oct	1,23	6.005	.022

Table J. 2 The ANOVA test results of the effect of external obstruction on the illuminance levels registered by the horizontal measuring points in zone1, 2 and 3.

Appendix K

Appendix K. 1

Zone	Month	df	F	Sig.
VMPs	Feb	1,4	582.862	.000
	Mar	1,4	34.934	.004
	Apr	1,4	.310	.607
	May	1,4	35.956	.004
	Jun	1,4	39.221	.003
	Jul	1,4	220.346	.000
	Aug	1,4	44.023	.003
	Sep	1,4	17.481	.014
	Oct	1,4	66.006	.001
HMPs	Feb	1,7	14.606	.007
	Mar	1,7	9.413	.018
	Apr	1,7	1.692	.235
	May	1,7	5.764	.047
	Jun	1,7	4.796	.065
	Jul	1,7	5.572	.050
	Aug	1,7	12.372	.010
	Sep	1,7	10.103	.016
	Oct	1,7	3.300	.112

Table K. 1 The ANOVA test results of the effect of windowsill height, W/F % and window area on the mean illuminance levels registered by vertical and horizontal measuring points in studio E1 and GNC (zone 1)

Appendix K. 2

Month	Close to window (zero-0.38 m)										2m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation			Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 59		Meter 8								Meter 60		Meter 10							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	1532	628	224	91	24.33	103	**.00**	104	.89	.00	79	28	661	299	-21.61	103	**.00**	104	.91	.00
Mar	1567.99	599.30	277.64	82	26.29	117	**.00**	118	.83	.00	194.95	71.35	864.42	264.56	-33.40	117	**.00**	118	.73	.00
April	4032.04	2311.60	277.66	77.94	19.34	139	**.00**	140	.21	.01	619.22	333.83	727.73	211.09	-3.66	139	**.00**	140	.23	.00
May	2255.64	922.43	463.06	257.08	30.08	153	**.00**	154	.78	.00	366.95	212.42	2366.93	1410.40	-19.16	153	**.00**	154	.59	.00
Jun	2951.37	1527.13	275.45	214.55	24.05	164	**.00**	165	.51	.00	367.43	237.42	2092.39	1818.66	-15.78	164	**.00**	165	.54	.00
Jul	3773.03	2002.82	515.35	203.60	23.02	167	**.00**	168	.84	.00	626.99	1225.70	1225.70	562.89	-19.76	167	**.00**	168	.79	.00
Aug	2189.45	1045.95	364.66	188.94	25.41	162	**.00**	163	.73	.00	285.03	122.21	1008.04	568.23	-18.74	162	**.00**	163	.68	.00
Sept	2220.46	1176.86	303.24	145.57	22.02	144	**.00**	145	.89	.00	229.60	156.59	899.71	449.28	-22.58	144	**.00**	145	.70	.00
Oct	742.28	385.97	172.07	71.07	18.77	110	**.00**	111	.94	.00	269.84	158.10	523.07	255.47	-20.17	110	**.00**	111	.90	.00

Month	4m distance from window										8m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation			Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 57		Meter 6								Meter 58		Meter 9							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	59	21	166	89	-16.31	103	**.00**	104	.86	.00	24	10	60	30	-13.94	103	**.00**	104	.57	.00
Mar	83.34	38.81	266.17	83.14	-28.26	117	**.00**	118	.54	.00	39.46	20.13	77.40	27.73	-16.38	117	**.00**	118	.48	.00
April	203.39	94	201.29	56.07	.248	139	**.00**	140	.17	.03	101.80	46.51	71.08	21.95	6.55	139	**.00**	140	-.20	.01
May	129.62	61.70	811.22	501.61	-17.83	153	**.00**	154	.49	.00	70.63	31.01	256.25	160.74	-13.89	153	**.00**	154	-.07	.38
Jun	119.18	76.35	553.53	431.11	-14.08	164	**.00**	165	.53	.00	62.56	32.05	176.95	137.84	-10.93	164	**.00**	165	.22	.00
Jul	154.02	89.09	1002.25	474.80	-25.97	167	**.00**	168	.64	.00	60.27	27.36	93.27	69.17	-8.50	167	**.00**	168	.79	.00
Aug	101.76	48.72	957.22	511.01	-23.04	162	**.00**	163	.78	.00	39.61	19.53	123.12	67.03	-20.19	162	**.00**	163	.79	.00
Sept	100.99	62.76	556.77	267.81	-25.64	144	**.00**	145	.88	.00	32.51	19.97	116.93	73.10	-17.90	144	**.00**	145	.86	.00
Oct	48.79	26.67	256.34	145.93	-17.79	110	**.00**	111	.88	.00	15.08	8.24	74.51	39.68	-19.30	110	**.00**	111	.90	.00

Table K. 2 The Paired-Samples T- test results for the difference in the illuminance levels between studio GNC and studio E1.

N= measurements registered from 8 a.m. until sunset

Appendix L

Appendix L. 1

Zone	Month	df	F	Sig.
VMPs	Feb	1,7	2.553	.154
	Mar	1,7	4.870	.063
	Apr	1,7	.270	.620
	May	1,7	4.917	.062
	Jun	1,7	5.759	.047
	Jul	1,7	3.427	.107
	Aug	1,7	8.547	.022
	Sep	1,7	6.179	.042
	Oct	1,7	4.717	.066
HMPs	Feb	1,7	4.867	.063
	Mar	1,7	55.694	.000
	Apr	1,7	37.151	.000
	May	1,7	.051	.827
	Jun	1,7	.047	.834
	Jul	1,7	.050	.829
	Aug	1,7	.141	.719
	Sep	1,7	17.051	.004
	Oct	1,7	21.623	.002

Table L. 1 ANOVA test result of the effect of W/F % and window area on the average illuminance levels registered by vertical and horizontal measuring points in studio GNIn and GNPL (zone 1)

Appendix L. 2

Month	Close to window (0.30m-0.85m)									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 28		Meter 36							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	1650.10	930.90	876.23	465.71	16.30	103	**.00**	104	.97	.00
Mar	456.28	179.95	1136.90	497.87	-21.95	117	**.00**	118	.93	.00
April	2104.67	1134.37	4170.15	2229.75	-22.23	139	**.00**	140	.99	.00
May	2969.48	1840.73	2588.80	1604.75	20.01	153	**.00**	154	1.00	.00
Jun	2299.27	1688.76	2004.50	1472.26	17.48	164	**.00**	165	1.00	.00
Jul	3352.06	2530.79	2922.20	2206.25	17.16	167	**.00**	168	1.00	.00
Aug	905.30	702.06	688.70	534.09	16.46	162	**.00**	163	1.00	.00
Sept	1453.64	763.29	1137.67	693.55	11.42	144	**.00**	145	.90	.00
Oct	826.07	496.17	1229.04	750.89	-16.12	110	**.00**	111	.99	.00

Month	3.5m-4.5m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 27		Meter 37							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	2441.39	1369.71	987.67	523.85	17.17	103	**.00**	104	.97	.00
Mar	727.32	285.35	1327.57	558.82	-21.55	117	**.00**	118	.94	.00
April	2867.09	1533.01	4033.84	2156.87	-22.12	139	**.00**	140	1.00	.00
May	3871.97	2400.17	2393.50	1483.69	20.01	153	**.00**	154	1.00	.00
Jun	2998.09	2202.03	1853.29	1361.20	17.48	164	**.00**	165	1.00	.00
Jul	4370.69	3299.86	2701.75	2039.81	17.16	167	**.00**	168	1.00	.00
Aug	1029.17	798.12	636.76	493.81	16.46	162	**.00**	163	1.00	.00
Sept	1329.33	801.72	1051.88	641.25	12.37	144	**.00**	145	.95	.00
Oct	552.56	313.05	1936.15	1182.91	-16.70	110	**.00**	111	.99	.00

Month	6m-10m distance from window (mezzanine effect)									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 63		Meter 38							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	770.47	428.52	447.45	250.34	18.33	103	**.00**	104	.99	.00
Mar	245.87	94.95	1260.85	530.74	-24.94	117	**.00**	118	.94	.00
April	1077.51	576.14	2905.65	1553.63	-22.12	139	**.00**	140	1.00	.00
May	1455.16	902.03	429.97	266.53	20.01	153	**.00**	154	1.00	.00
Jun	1126.73	827.56	332.90	244.50	17.48	164	**.00**	165	1.00	.00
Jul	1642.57	1240.14	485.31	366.40	17.16	167	**.00**	168	1.00	.00
Aug	385.50	298.96	114.37	88.70	16.46	162	**.00**	163	1.00	.00
Sept	1645.53	805.09	188.91	115.16	24.86	144	**.00**	145	.88	.00
Oct	336.69	185.57	716.02	437.46	-15.72	110	**.00**	111	.99	.00

Table L. 2 The Paired-Samples T- test results for the difference in the illuminance levels between studio GNIn and studio GNPL.

N= measurements registered from 8 a.m. until sunset

Appendix M

Appendix M. 1

Zone	Month	df	F	Sig.
VMPs	Feb	1,3	6.433	.085
	Mar	1,3	15.222	.030
	Apr	1,3	14.996	.030
	May	1,3	18.677	.023
	Jun	1,3	17.030	.026
	Jul	1,3	51.371	.006
	Aug	1,3	47.178	.006
	Sep	1,3	21.232	.019
	Oct	1,3	131.428	.001
HMPs	Feb	1,14	36.443	.000
	Mar	1,14	17.116	.001
	Apr	1,14	6.465	.023
	May	1,14	14.030	.002
	Jun	1,14	11.428	.004
	Jul	1,14	11.162	.005
	Aug	1,14	15.397	.002
	Sep	1,14	15.788	.001
	Oct	1,14	26.795	.000

Table M. 1 ANOVA test result of the effect of W/F %, W/W %, window area and window head height on the average illuminance levels registered by vertical and horizontal measuring points in studio GNCm and Em (zone 3)

Appendix M. 2

Month	2m-3m distance from window										4m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation			Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 51		Meter 15								Meter 48		Meter 21							
	Mean	**SD**	**Mean**	**SD**	**t**	**df**	**Sig.**	**N**	**r**	**Sig.**	**Mean**	**SD**	**Mean**	**SD**	**t**	**df**	**Sig.**	**N**	**r**	**Sig.**
Feb	91.89	33.79	221.55	86.19	-23.34	103	**.00**	104	.92	.00	32.03	12.09	232.61	8.07	-28.20	103	**.00**	104	.83	.00
Mar	124.26	53.35	275.17	87.20	-27.07	117	**.00**	118	.72	.00	37.97	18.38	250.05	83.09	-31.66	117	**.00**	118	.63	.00
April	233.50	93.93	286.55	77.66	-6.05	139	**.00**	140	.28	.00	95.87	49.78	181.30	55.86	-14.38	139	**.00**	140	.11	.16
May	86.34	34.67	1228.53	678.51	-21.76	153	**.00**	154	.79	.00	27.68	11.11	257.78	156.93	-19.02	153	**.00**	154	.63	.00
Jun	89.51	44.66	1763.50	1218.21	-18.13	164	**.00**	165	.73	.00	36.71	26.11	305.48	211.55	-17.84	164	**.00**	165	.72	.00
Jul	123.31	80.89	361.39	164.19	-23.60	167	**.00**	168	.61	.00	72.35	71.58	315.79	149.27	-29.09	167	**.00**	168	.73	.00
Aug	79.08	66.06	299.84	182.36	-17.13	162	**.00**	163	.43	.00	47.02	42.19	251.12	127.93	-24.49	162	**.00**	163	.63	.00
Sept	147.10	89.16	282.51	131.18	-25.07	144	**.00**	145	.89	.00	39.71	24.21	145.98	74.32	-23.83	144	**.00**	145	.89	.00
Oct	31.07	18.14	158.98	101.47	-15.39	110	**.00**	111	.80	.00	12.96	7.52	140.56	91.32	-15.65	110	**.00**	111	.74	.00

Month	5.5m-6.5m distance from window										7m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation			Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 43		Meter 22								Meter 45		Meter 18							
	Mean	**SD**	**Mean**	**SD**	**t**	**df**	**Sig.**	**N**	**r**	**Sig.**	**Mean**	**SD**	**Mean**	**SD**	**t**	**df**	**Sig.**	**N**	**r**	**Sig.**
Feb	7.39	3.03	151.40	65.57	-22.89	103	**.00**	104	.49	.00	5.06	2.15	110.21	35.79	-31.10	103	**.00**	104	.63	.00
Mar	9.12	5.04	127.98	46.13	-29.69	117	**.00**	118	.56	.00	5.50	3.12	104.03	41.08	-27.30	117	**.00**	118	.62	.00
April	20.73	10.98	158.09	46.69	-37.96	139	**.00**	140	.45	.00	13.40	5.83	131.40	40.01	-35.72	139	**.00**	140	.23	.00
May	9.01	3.65	262.86	138.28	-23.22	153	**.00**	154	.73	.00	5.52	2.22	164.72	91.81	-21.83	153	**.00**	154	.60	.00
Jun	11.47	7.94	258.89	185.11	-17.68	164	**.00**	165	.69	.00	6.75	4.57	209.79	148.19	-17.99	164	**.00**	165	.71	.00
Jul	21.82	21.87	212.37	104.92	-27.12	167	**.00**	168	.69	.00	12.83	12.83	200.98	99.98	-26.73	167	**.00**	168	.71	.00
Aug	13.83	12.35	143.21	69.87	-26.77	162	**.00**	163	.71	.00	8.31	7.60	152.93	77.40	-25.53	162	**.00**	163	.69	.00
Sept	17.35	10.17	112.85	51.78	-26.88	144	**.00**	145	.90	.00	12.78	7.81	123.53	57.05	-26.50	144	**.00**	145	.87	.00
Oct	3.84	2.15	56.14	34.33	-16.97	110	**.00**	111	.87	.00	2.51	1.41	74.33	61.72	-12.45	110	**.00**	111	.69	.00

Table M. 2 The Paired-Samples T- test results for the difference in the illuminance levels between studio GNCm and studio Em.

N= measurements registered from 8 a.m. until sunset

Appendix N

Appendix N 1

Zone	Month	df	F	Sig.
VMPs	Feb	1,3	7.279	.074
	Mar	1,3	7.002	.077
	Apr	1,3	271.192	.000
	May	1,3	944.789	.000
	Jun	1,3	.139	.734
	Jul	1,3	.072	.806
	Aug	1,3	4.510	.124
	Sep	1,3	2.979	.183
	Oct	1,3	71.790	.003
HMPs	Feb	1,7	3.716	.095
	Mar	1,7	5.680	.049
	Apr	1,7	17.467	.004
	May	1,7	5.882	.046
	Jun	1,7	.817	.396
	Jul	1,7	.195	.672
	Aug	1,7	.987	.354
	Sep	1,7	4.009	.085
	Oct	1,7	.967	.358

Table N. 1 ANOVA test result of the effect of W/F %, W/W % and window area on the mean illuminance levels registered by vertical and horizontal measuring points in studio GNPm and GNJm (zone 3).

Appendix N 2

Month	5.5m-6m distance from window									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 45		Meter 59							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	164.02	91.77	99.49	55.66	18.22	103	**.00**	104	1.00	.00
Mar	264.81	111.47	242.38	102.03	25.80	117	**.00**	118	1.00	.00
April	36.09	19.30	2367.59	1265.94	-22.12	139	**.00**	140	1.00	.00
May	307.91	190.87	403.62	250.20	-20.01	153	**.00**	154	1.00	.00
Jun	1454.13	1068.02	648.28	131.53	10.33	164	**.00**	165	.55	.00
Jul	1083.99	818.41	744.50	258.37	6.69	167	**.00**	168	.71	.00
Aug	255.94	198.48	1021.03	888.78	-13.73	162	**.00**	163	.91	.00
Sept	749.69	457.02	961.57	548.55	-15.79	144	**.00**	145	.96	.00
Oct	362.64	221.56	64.69	39.26	17.14	110	**.00**	111	.98	.00

Month	9m-10m distance from window (height effect)									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 46		Meter 61							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	91.77	51.34	45.61	25.52	18.22	103	**.00**	104	1.00	.00
Mar	109.07	45.91	92.21	38.81	25.80	117	**.00**	118	1.00	.00
April	198.64	106.21	1108.46	592.69	-22.12	139	**.00**	140	1.00	.00
May	195.17	120.98	164.63	102.05	20.02	153	**.00**	154	1.00	.00
Jun	1018.76	748.25	445.57	210.80	12.80	164	**.00**	165	.86	.00
Jul	756.54	571.19	353.18	154.17	11.49	167	**.00**	168	.81	.00
Aug	118.16	91.63	339.37	231.15	-16.78	162	**.00**	163	.79	.00
Sept	195.17	118.98	441.42	288.27	-15.86	144	**.00**	145	.90	.00
Oct	94.39	57.66	29.55	18.04	16.74	110	**.00**	111	.95	.00

Month	10m-11.5m									
	Paired samples statistics				Pair sample test			Paired samples correlation		
	Meter 47		Meter 61							
	Mean	SD	Mean	SD	t	df	Sig.	N	r	Sig.
Feb	85.00	48.17	45.61	25.52	17.63	103	**.00**	104	.99	.00
Mar	121.34	51.07	92.21	38.81	25.80	117	**.00**	118	1.00	.00
April	44.44	23.76	1108.46	592.69	-22.12	139	**.00**	140	1.00	.00
May	407.09	252.35	164.63	102.05	20.01	153	**.00**	154	1.00	.00
Jun	2673.05	1963.30	445.57	210.80	16.04	164	**.00**	165	.86	.00
Jul	1434.55	1083.8	353.18	154.17	14.57	167	**.00**	168	.81	.00
Aug	126.45	98.06	339.37	231.15	-16.48	162	**.00**	163	.79	.00
Sept	1746.06	1064.44	441.42	288.27	19.35	144	**.00**	145	.90	.00
Oct	844.66	516.06	29.55	18.04	17.21	110	**.00**	111	.95	.00

Table N. 2 The Paired-Samples T- test results for the difference in the illuminance levels between studio GNPm and studio GNJm.

N= measurements registered from 8 a.m. until sunset

Appendix O

Appendix O. 1

Characteristics	Glasgow						Aberdeen	
	GSInu		GSpo		GSp		A1	A2
Design type	Double-volume open plan		Double-volume open plan		Double-volume open plan		Ordinary open-plan	Ordinary open-plan
Studio floor level (m)	+17.395 Fourth floor		+17.395 Fourth floor		+17.395 Fourth floor		+30.00 Fourth floor	+30.00 Fourth floor
Dimension (m) W*L*H	14.65*8*7		14.65*6*7		14*7*7		26*8*4	12*8*4
Floor Area (m^2)	117 m^2		88 m^2		98 m^2		208 m^2	96 m^2
Wall Area (m^2)	102.55 m^2		102.55 m^2		98 m^2		104 m^2	48 m^2
Window Area (m^2)	Vertical	9 m^2	Vertical	29.3 m^2	Vertical	6 m^2 20 m^2	**Total** = 87.5 m^2	**Total** = 22.7 m^2
	Skylight	14.65 m^2	Skylight	14.65 m^2	Skylight	14.65 m^2		
	Total= 23.65 m^2		**Total**= 43.95 m^2		**Total**= 40.65 m^2			

Table O. 1 Studios characteristic's in Glasgow and Aberdeen.

Appendix O. 2

<table>
<tr><th rowspan="2">City</th><th rowspan="2">Studio</th><th rowspan="2">No. of windows</th><th rowspan="2">Window orientation</th><th rowspan="2">Window dimension (m)</th><th rowspan="2">window sill height (m)</th><th rowspan="2">Window/ Floor ratio</th><th rowspan="2" colspan="2">Window/Wall Ratio (each window)</th><th colspan="3">Obstructions</th></tr>
<tr><th>Type</th><th>Height</th><th>Distance</th></tr>
<tr><td rowspan="7">Glasgow</td><td rowspan="2">GSInu</td><td rowspan="2">2</td><td>South</td><td>4.5*2</td><td>0</td><td rowspan="2">V: 8%
Total: 20.21%</td><td>Vertical (south)= 8.77%</td><td rowspan="2">Total=21.29%
Mean= 10.64%</td><td rowspan="2" colspan="3">Mackintosh building, 10 m distance, and 22.40 m height.</td></tr>
<tr><td>Skylight</td><td>14.65*2</td><td>5</td><td>Skylight= 12.52%</td></tr>
<tr><td rowspan="2">GSpo</td><td rowspan="2">2</td><td>South</td><td>14.65*2</td><td>0</td><td rowspan="2">V: 33%
Total: 49.94%</td><td>Vertical= 28.57%</td><td rowspan="2">Total= 45.21%
Mean= 22.60%</td><td rowspan="2" colspan="3">Mackintosh building, 10 m distance, and 22.40 m height.</td></tr>
<tr><td>Skylight</td><td>14.65*2</td><td>5</td><td>Skylight= 16.64%</td></tr>
<tr><td rowspan="3">GSp</td><td rowspan="3">3</td><td>South</td><td>3.70*2</td><td>0</td><td rowspan="3">V: 27%
Total: 41.47%</td><td rowspan="2">Vertical= 26.53%</td><td rowspan="3">Total= 41.47 %
Mean= 20.73%</td><td rowspan="3" colspan="3">Mackintosh building, 10 m distance, and 22.40 m height.</td></tr>
<tr><td>South</td><td>4.5*4</td><td>2</td></tr>
<tr><td>Skylight</td><td>14.65*2</td><td>5</td><td>Skylight= 14.94%</td></tr>
<tr><td rowspan="3">Aberdeen</td><td>A1</td><td>5</td><td>South</td><td>5*3.5</td><td>0.50</td><td>42%</td><td colspan="2">84.13%</td><td colspan="3">Trees, 10 distance and 30m high.</td></tr>
<tr><td rowspan="2">A2</td><td rowspan="2">2</td><td rowspan="2">South</td><td>5*3.5</td><td rowspan="2">0.50</td><td rowspan="2">23.64%</td><td rowspan="2" colspan="2">47.29%</td><td rowspan="2" colspan="3">Trees, 10 distance and 30m high.</td></tr>
<tr><td>2.60*2</td></tr>
</table>

Table O. 2 Window characteristic's in Glasgow and Aberdeen.

Appendix O. 3

Glasgow Case			
Horizontal / Vertical location of reference points	Studio GSInu		
	Reference points inside GNCm studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	28	2m	0.74 m
	30	5m	
	29	2m	
	23	5m	
	24	2m	
	25	5m	
	26	2m	
	65	5m	
Vertical reference point	64	Window wall	1.60 m above eye level & 1.20 m at eye level.
	63	3m	
	27	7.5m	
	62	Window wall	
	22	5m	

Glasgow Case

Horizontal / Vertical location of reference points	Studio GSPo		
	Reference points inside GNC studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	18	Window step	0
	12	1m	0.74 m
	14	1m	
	13	1m	
	19	6m	
	16	6m	
	15	6m	
Vertical reference point	4	4m	1.60 m above eye level & 1.20 m at eye level.
	21	4m	
	20	7m	

Horizontal / Vertical location of reference points	Studio GSP		
	Reference points inside GNCm studio	Distance from the window wall (m)	Height from the ground level
Horizontal reference point	10	Window step	0
	9	3m	0.74 m
	66	5m	
	8	2m	
	5	5m	
	11	2m	
	67	4m	
	3	Window step	2m
Vertical reference point	7	4m	1.60 m above eye level & 1.20 m at eye level.
	1	Window wall	
	6	3m	
	2	11m	

<table>
<tr><th colspan="8">Aberdeen case</th></tr>
<tr><th rowspan="2">Horizontal / Vertical location of reference points</th><th colspan="3">A2</th><th colspan="4">A1</th></tr>
<tr><th>Reference points inside E1 studio</th><th>Distance from the window wall (m)</th><th>Height from the ground level</th><th>Horizontal / Vertical location of reference points</th><th>Reference points inside Em studio</th><th>Distance from the window wall</th><th>Height from the ground level</th></tr>
<tr><td rowspan="5">Horizontal reference point</td><td>58</td><td>At window step</td><td>0.48 m</td><td rowspan="7">Horizontal reference point</td><td>42</td><td>3m</td><td rowspan="6">0.74 m</td></tr>
<tr><td>56</td><td>2m</td><td rowspan="4">0.74 m</td><td>44</td><td>6m</td></tr>
<tr><td>61</td><td>5m</td><td>48</td><td>3m</td></tr>
<tr><td>55</td><td>2</td><td>43</td><td>6m</td></tr>
<tr><td>54</td><td>5</td><td>46</td><td>6m</td></tr>
<tr><td rowspan="7">Vertical reference point</td><td>53</td><td>3</td><td rowspan="7">1.60 m above eye level & 1.20 m at eye level.</td><td>47</td><td>3m</td></tr>
<tr><td>57</td><td>10</td><td>45</td><td>At window step</td><td>0.48 m</td></tr>
<tr><td>52</td><td>Window wall</td><td rowspan="5">Vertical reference point</td><td>50</td><td>Window wall</td><td rowspan="5">1.60 m above eye level & 1.20 m at eye level.</td></tr>
<tr><td>68</td><td>10m</td><td>49</td><td>10m</td></tr>
<tr><td rowspan="3">Test 2</td><td rowspan="3">Window wall</td><td>59</td><td>10m</td></tr>
<tr><td>60</td><td>Window wall</td></tr>
<tr><td>51</td><td>7m</td></tr>
</table>

Table O. 3 light meters information inside Glasgow and Aberdeen studios

Appendix P

Appendix P. 1

Zone	Month	df	F	Sig.
VMPs	Feb	4,17	14.92	**.000**
	Mar	4,17	18.77	**.000**
	Apr	4,17	21.08	**.000**
	May	4,17	49.81	**.000**
	Jun	4,17	16.33	**.000**
	Jul	4,17	10.35	**.000**
	Aug	4,17	47.68	**.000**
	Sep	4,17	33.49	**.000**
	Oct	4,17	11.08	**.000**
HMPs	Feb	4,25	23.30	**.000**
	Mar	4,25	25.89	**.000**
	Apr	4,25	47.55	**.000**
	May	4,25	64.01	**.000**
	Jun	4,25	11.25	**.000**
	Jul	4,25	30.58	**.000**
	Aug	4,25	35.57	**.000**
	Sep	4,25	28.13	**.000**
	Oct	4,25	15.19	**.000**

Table P. 1 Results of the ANOVA test investigating the significant difference of the illuminance levels between South-facing studios registered by VMPs and HMPs throughout the measurement period.

Appendix Q

Appendix Q. 1

Effect		Month	df	F	Sig.
Studio typology, the skylight presence and windowsill height	**VMPs**	Feb	1,20	41.92	.000
		Mar	1,20	15.64	.001
		Apr	1,20	12.51	.002
		May	1,20	17.30	.000
		Jun	1,20	32.49	.000
		Jul	1,20	25.84	.000
		Aug	1,20	201.74	.000
		Sep	1,20	53.47	.000
		Oct	1,20	25.44	.000
	HMPs	Feb	1.28	66.16	.000
		Mar	1.28	34.38	.000
		Apr	1.28	17.95	.000
		May	1.28	18.45	.000
		Jun	1.28	36.98	.000
		Jul	1.28	120.24	.000
		Aug	1.28	156.65	.000
		Sep	1.28	122.89	.000
		Oct	1.28	55.54	.000

Table Q. 1 ANOVA test results present the effects of studio typology, the skylight presence and windowsill height on the registered illuminance levels for South-facing studios

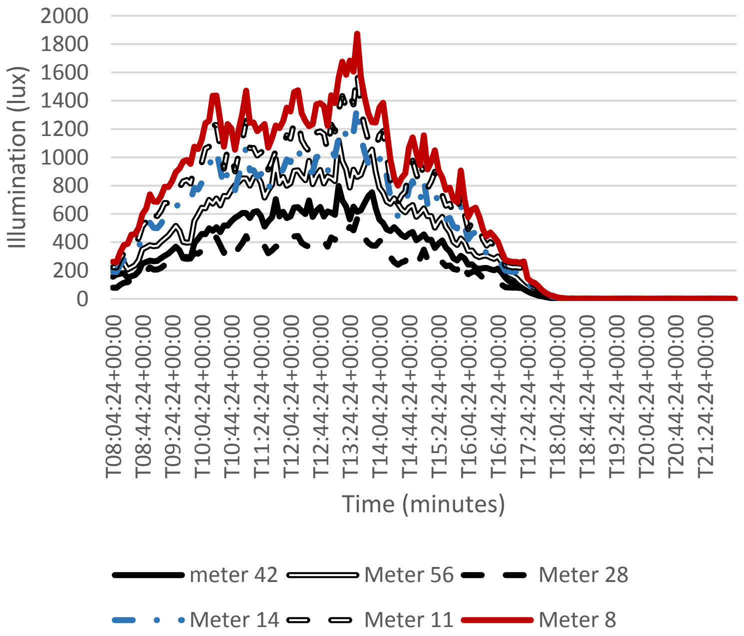
Appendix Q. 2

Effect		Month	df	F	Sig.
Window area, W/F% and W/W%	**VMPs**	Feb	4,17	14.92	.000
		Mar	4,17	18.77	.000
		Apr	4,17	21.08	.000
		May	4,17	49.81	.000
		Jun	4,17	16.33	.000
		Jul	4,17	10.35	.000
		Aug	4,17	47.68	.000
		Sep	4,17	33.49	.000
		Oct	4,17	11.08	.000
	HMPs	Feb	4,25	23.30	.000
		Mar	4,25	28.89	.000
		Apr	4,25	47.55	.000
		May	4,25	64.01	.000
		Jun	4,25	11.25	.000
		Jul	4,25	30.58	.000
		Aug	4,25	35.57	.000
		Sep	4,25	28.13	.000
		Oct	4,25	15.19	.000

Table Q. 2 **ANOVA test results present the effects of window area, W/F% and W/W% on the registered illuminance levels for South-facing studios.**

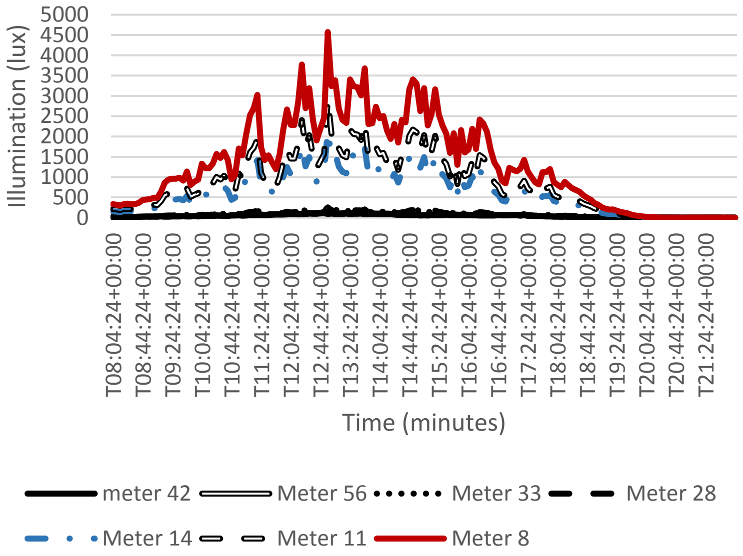
Appendix R

Appendix R. 1

	1m-2m distance from the window
Mar	

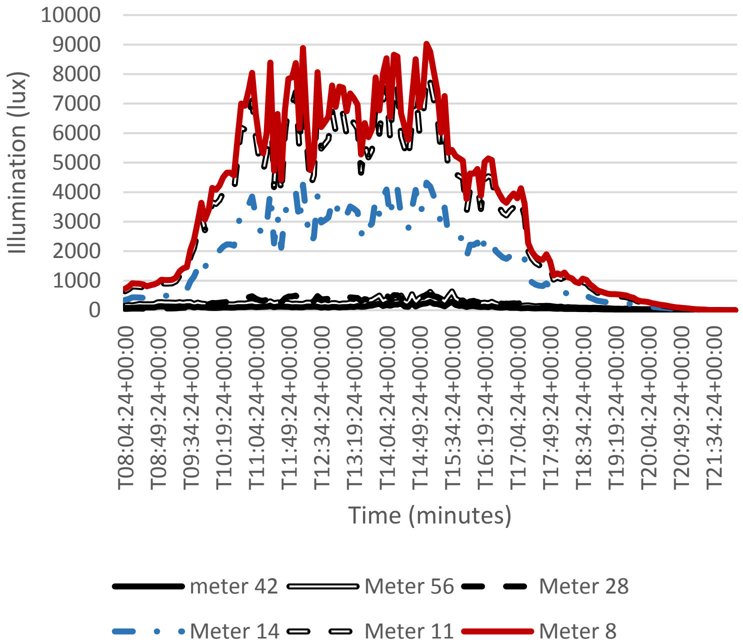
Interpretation

Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		**Mean**	**Std.dv**	**t**	**df**	**Sig.**	**N**	**r**	**Sig**
Pair 1	Meter 14	698.31	300.43	21.28	114	.00	115	.93	.00
	Meter 42	417.80	189.90						
Pair 2	Meter 14	698.31	300.43	11.03	114	.00	115	.93	.00
	Meter 56	585.38	266.06						
Pair 3	Meter 14	698.31	300.43	24.93	114	.00	115	1.00	.00
	Meter 28	288.99	124.33						
Pair 4	Meter 14	698.31	300.43	-24.93	114	.00	115	1.00	.00
	Meter 11	819.19	352.44						
Pair 5	Meter 14	698.31	300.43	-24.93	114	.00	115	1.00	.00
	Meter 8	957.88	412.11						
Pair 6	Meter 42	417.80	189.90	-22.84	114	.00	115	.93	.00
	Meter 11	819.19	352.44						
Pair 7	Meter 56	585.38	266.06	20.27	114	.00	115	.93	.00
	Meter 28	288.99	124.33						

Apr		
		

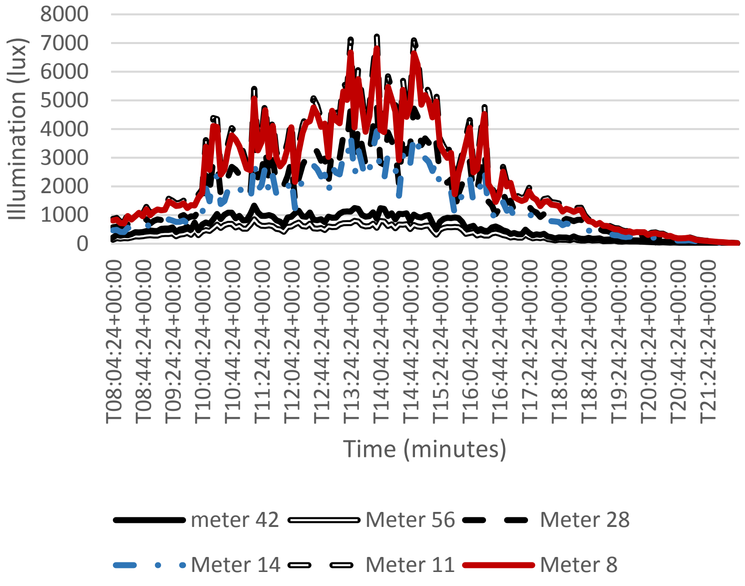
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. Deviation	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	744.22	462.24	18.68	139	.00	140	.84	.00
	Meter 42	51.59	28.26						
Pair 2	Meter 14	744.22	462.24	18.62	139	.00	140	.84	.00
	Meter 56	58.88	32.25						
Pair 3	Meter 14	744.22	462.24	19.05	139	.00	140	1.00	.00
	Meter 28	87.88	54.58						
Pair 4	Meter 14	744.22	462.24	-19.05	139	.00	140	1.00	.00
	Meter 11	1013.48	629.48						
Pair 5	Meter 14	744.22	462.24	-19.05	139	.00	140	1.00	.00
	Meter 8	1590.89	988.12						
Pair 6	Meter 42	51.59	28.26	-18.78	139	.00	140	.84	.00
	Meter 11	1013.48	629.48						
Pair 7	Meter 56	58.88	32.25	-10.62	139	.00	140	.84	.00
	Meter 28	87.88	54.58						

May



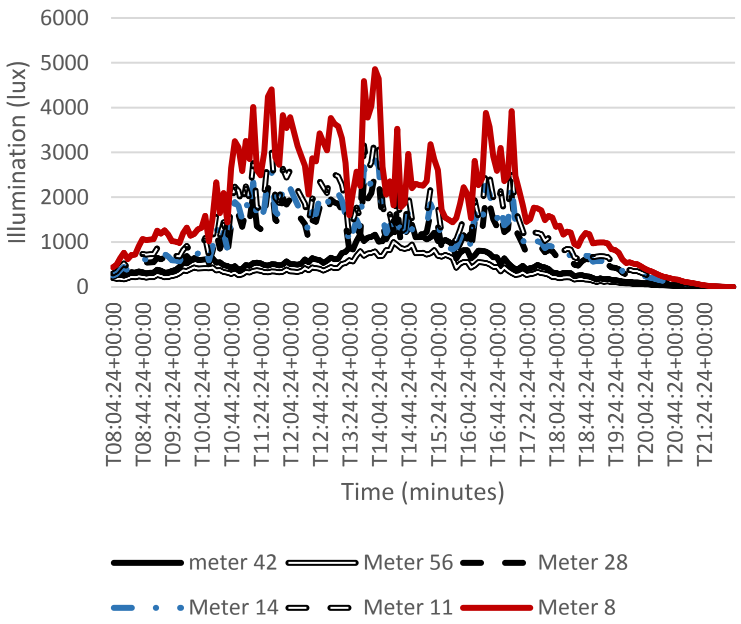
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. Deviation	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	1886.48	1350.43	16.87	152	.00	153	.72	.00
	Meter 42	99.41	56.45						
Pair 2	Meter 14	1886.48	1350.43	16.32	152	.00	153	.72	.00
	Meter 56	217.78	123.66						
Pair 3	Meter 14	1886.48	1350.43	17.27	152	.00	153	1.00	.00
	Meter 28	232.68	166.56						
Pair 4	Meter 14	1886.48	1350.43	-17.27	152	.00	153	1.00	.00
	Meter 11	3478.46	2490.04						
Pair 5	Meter 14	1886.48	1350.43	-17.27	152	.00	153	1.00	.00
	Meter 8	3939.30	2819.93						
Pair 6	Meter 42	99.41	56.45	-17.06	152	.00	153	.72	.00
	Meter 11	3478.46	2490.04						
Pair 7	Meter 56	217.78	123.66	-1.59	152	.12	153	.72	.00
	Meter 28	232.68	166.56						

Jun



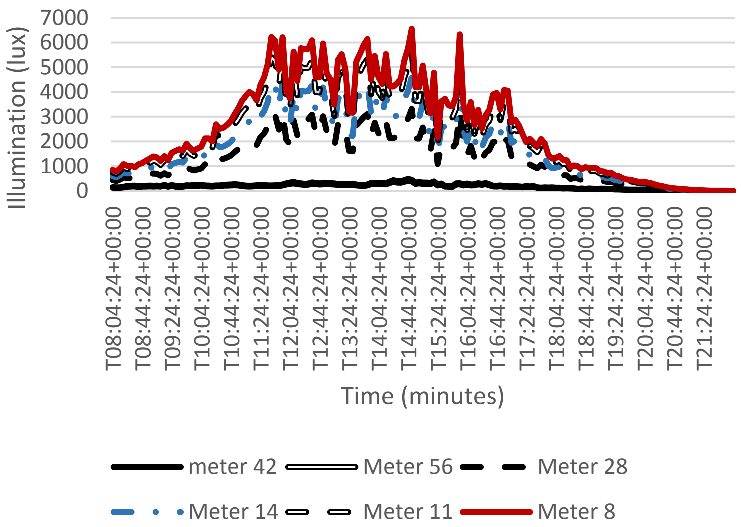
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. Deviation	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	1346.01	1011.12	14.16	164	.00	165	.86	.00
	Meter 42	562.74	375.67						
Pair 2	Meter 14	1346.01	1011.12	15.60	164	.00	165	.86	.00
	Meter 56	359.87	240.24						
Pair 3	Meter 14	1346.01	1011.12	-17.10	164	.00	165	1.00	.00
	Meter 28	1660.38	1247.27						
Pair 4	Meter 14	1346.01	1011.12	-17.10	164	.00	165	1.00	.00
	Meter 11	2498.63	1876.96						
Pair 5	Meter 14	1346.01	1011.12	-17.10	164	.00	165	1.00	.00
	Meter 8	2340.63	1758.27						
Pair 6	Meter 42	562.74	375.67	-15.91	164	.00	165	.86	.00
	Meter 11	2498.63	1876.96						
Pair 7	Meter 56	359.87	240.24	-15.95	164	.00	165	.86	.00
	Meter 28	1660.38	1247.27						

July



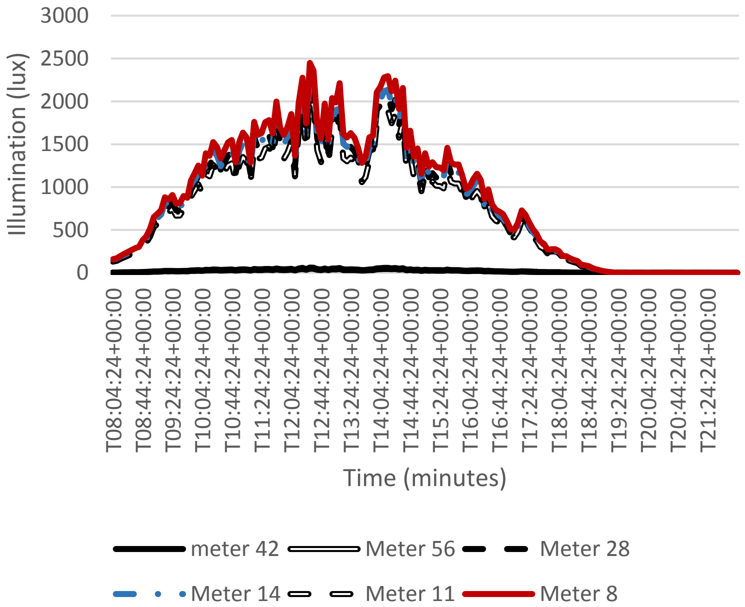
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. Deviation	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	1045.72	696.48	13.01	166	.00	167	.65	.00
	Meter 42	505.14	356.28						
Pair 2	Meter 14	1045.72	696.48	15.95	166	.00	167	.65	.00
	Meter 56	343.15	242.03						
Pair 3	Meter 14	1045.72	696.48	19.40	166	.00	167	1.00	.00
	Meter 28	931.76	620.58						
Pair 4	Meter 14	1045.72	696.48	-19.40	166	.00	167	1.00	.00
	Meter 11	1237.61	824.29						
Pair 5	Meter 14	1045.72	696.48	-19.04	166	.00	167	1.00	.00
	Meter 8	1799.09	1198.26						
Pair 6	Meter 42	505.14	356.28	-14.54	166	.00	167	.65	.00
	Meter 11	1237.61	824.29						
Pair 7	Meter 56	343.15	242.03	-15.28	166	.00	167	.65	.00
	Meter 28	931.76	620.58						

Aug



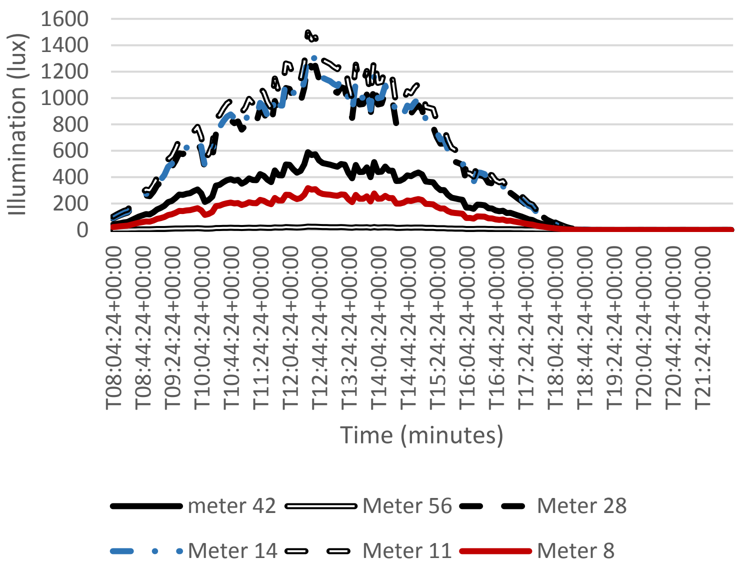
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	1906.09	1307.86	17.54	158	.00	159	.81	.00
	Meter 42	205.37	106.19						
Pair 2	Meter 14	1906.09	1307.86	17.67	158	.00	159	.81	.00
	Meter 56	174.43	90.19						
Pair 3	Meter 14	1906.09	1307.86	18.37	158	.00	159	1.00	.00
	Meter 28	1372.85	941.98						
Pair 4	Meter 14	1906.09	1307.86	-18.37	158	.00	159	1.00	.00
	Meter 11	2355.77	1616.41						
Pair 5	Meter 14	1906.09	1307.86	-18.37	158	.00	159	1.00	.00
	Meter 8	2715.42	1863.18						
Pair 6	Meter 42	205.37	106.19	-17.71	158	.00	159	.81	.00
	Meter 11	2355.77	1616.41						
Pair 7	Meter 56	174.43	90.19	-17.37	158	.00	159	.81	.00
	Meter 28	1372.85	941.98						

Sep



Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std.dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	1068.60	592.48	20.56	129	.00	130	1.00	.00
	Meter 42	22.69	12.58						
Pair 2	Meter 14	1068.60	592.48	20.56	129	.00	130	1.00	.00
	Meter 56	28.59	15.85						
Pair 3	Meter 14	1068.60	592.48	20.56	129	.00	130	1.00	.00
	Meter 28	1034.90	573.79						
Pair 4	Meter 14	1068.60	592.48	20.56	129	.00	130	1.00	.00
	Meter 11	946.87	524.98						
Pair 5	Meter 14	1068.60	592.48	-20.56	129	.00	130	1.00	.00
	Meter 8	1148.21	636.61						
Pair 6	Meter 42	22.69	12.58	-20.56	129	.00	130	1.00	.00
	Meter 11	946.87	524.98						
Pair 7	Meter 56	28.59	15.85	-20.56	129	.00	130	1.00	.00
	Meter 28	1034.90	573.79						

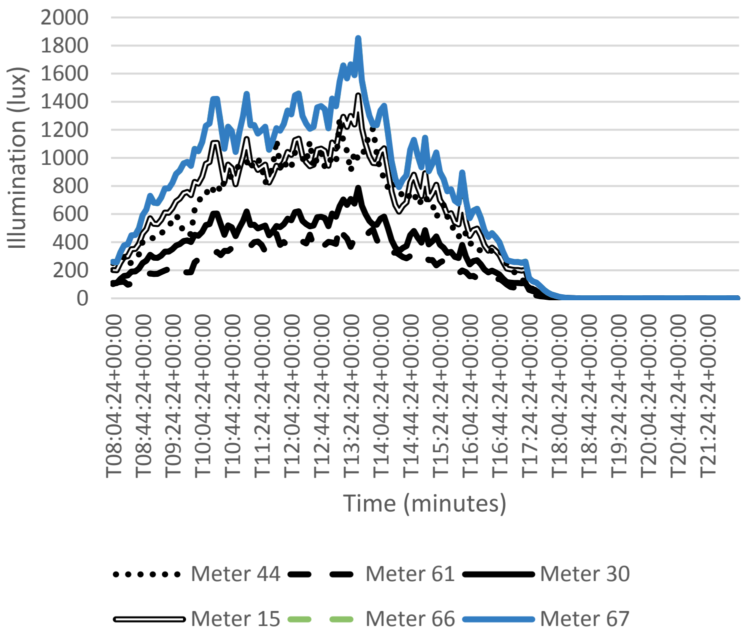
Oct



Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 14	649.04	368.11	19.79	125	.00	126	1.00	.00
	Meter 42	285.20	161.76						
Pair 2	Meter 14	649.04	368.11	17.79	125	.00	126	1.00	.00
	Meter 56	12.19	6.92						
Pair 3	Meter 14	649.04	368.11	19.79	125	.00	126	1.00	.00
	Meter 28	617.93	350.46						
Pair 4	Meter 14	649.04	368.11	-19.79	125	.00	126	1.00	.00
	Meter 11	724.77	411.06						
Pair 5	Meter 14	649.04	368.11	19.79	125	.00	126	1.00	.00
	Meter 8	153.44	87.03						
Pair 6	Meter 42	285.20	161.76	-19.79	125	.00	126	1.00	.00
	Meter 11	724.77	411.06						
Pair 7	Meter 56	12.19	6.92	-19.79	125	.00	126	1.00	.00
	Meter 28	617.93	350.46						

Table R. 1 **The Paired-Samples T- test results for the difference in the illuminance levels between studios at 1m-2m distance from the window.**

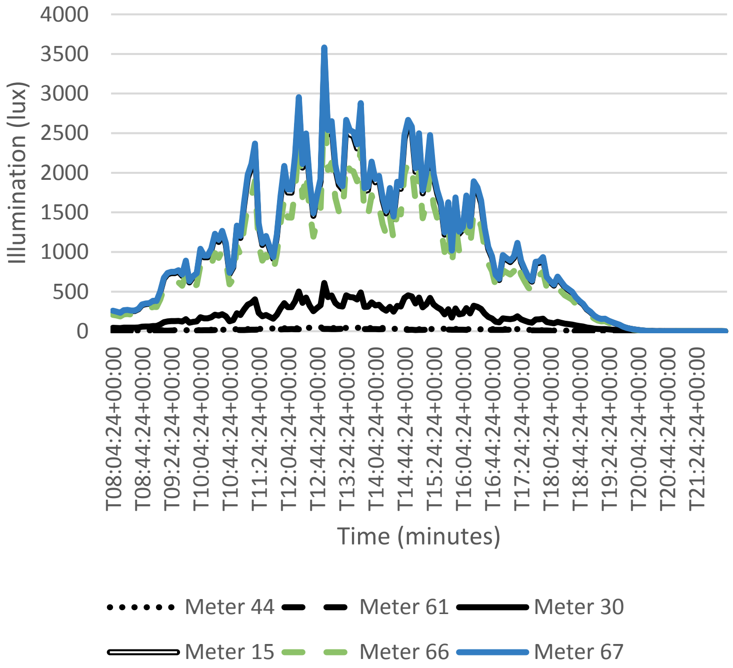
Appendix R. 2

	5m-6m distance from the window
Mar	

Interpretation

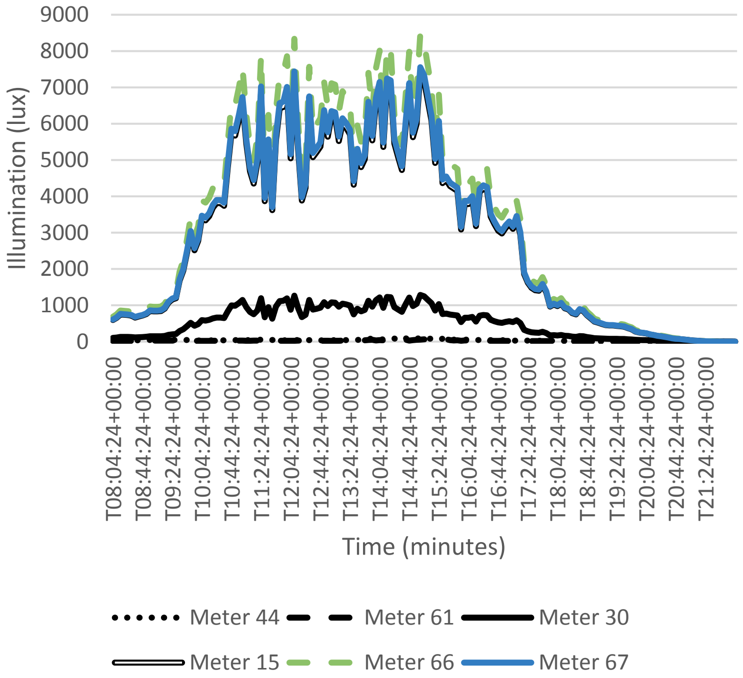
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 15	738.74	317.83	6.25	114	.00	115	.93	.00
	Meter 44	671.40	305.16						
Pair 2	Meter 15	738.74	317.83	24.11	114	.00	115	.93	.00
	Meter 61	272.60	123.90						
Pair 3	Meter 15	738.74	317.83	24.92	114	.00	115	1.00	.00
	Meter 30	402.55	173.19						
Pair 4	Meter 15	738.74	317.83	-24.92	114	.00	115	1.00	.00
	Meter 67	947.75	407.75						
Pair 5	Meter 15	738.74	317.83	-24.92	114	.00	115	1.00	.00
	Meter 66	948.11	407.91						
Pair 6	Meter 44	671.40	305.16	-17.88	114	.00	115	.93	.00
	Meter 67	947.75	407.75						
Pair 7	Meter 61	272.60	123.90	-19.05	114	.00	115	.93	.00
	Meter 30	402.55	173.19						

Apr



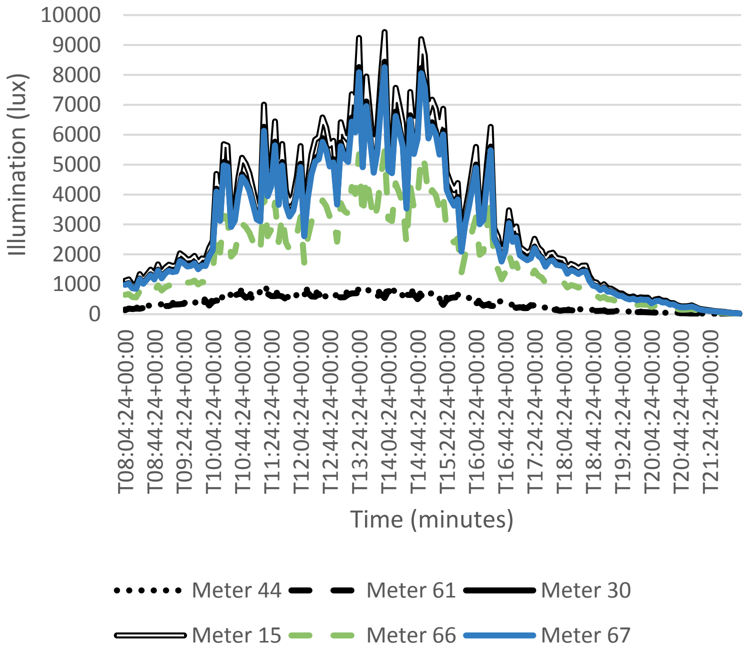
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 15	1218.95	757.11	18.95	139	.00	140	.84	.00
	Meter 44	23.41	12.82						
Pair 2	Meter 15	1218.95	757.11	18.98	139	.00	140	.84	.00
	Meter 61	15.74	8.62						
Pair 3	Meter 15	1218.95	757.11	19.05	139	.00	140	1.00	.00
	Meter 30	211.85	131.58						
Pair 4	Meter 15	1218.95	757.11	-19.05	139	.00	140	1.00	.00
	Meter 67	1245.88	773.83						
Pair 5	Meter 15	1218.95	757.11	19.05	139	.00	140	1.00	.00
	Meter 66	999.33	620.69						
Pair 6	Meter 44	23.41	12.82	-18.95	139	.00	140	.84	.00
	Meter 67	1245.88	773.83						
Pair 7	Meter 61	15.74	8.62	-18.65	139	.00	140	.84	.00
	Meter 30	211.85	131.58						

May



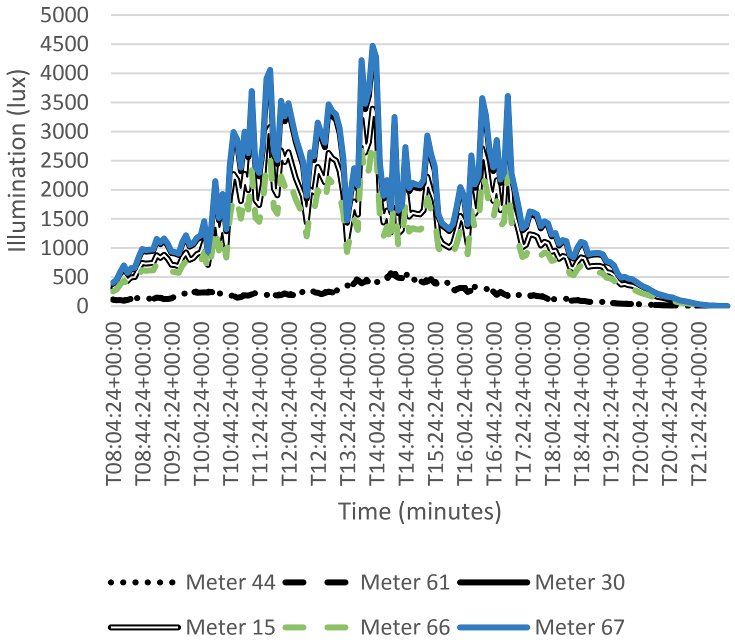
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 15	3226.53	2309.69	17.19	152	.00	153	.72	.00
	Meter 44	38.33	21.76						
Pair 2	Meter 15	3226.53	2309.69	17.22	152	.00	153	.72	.00
	Meter 61	22.90	13.01						
Pair 3	Meter 15	3226.53	2309.69	17.27	152	.00	153	1.00	.00
	Meter 30	560.84	401.47						
Pair 4	Meter 15	3226.53	2309.69	-17.27	152	.00	153	1.00	.00
	Meter 67	3297.79	2360.71						
Pair 5	Meter 15	3226.53	2309.69	-17.27	152	.00	153	1.00	.00
	Meter 66	3696.53	2646.14						
Pair 6	Meter 44	38.33	21.76	-17.19	152	.00	153	.72	.00
	Meter 67	3297.79	2360.71						
Pair 7	Meter 61	22.90	13.01	-16.96	152	.00	153	.72	.00
	Meter 30	560.84	401.47						

Jun



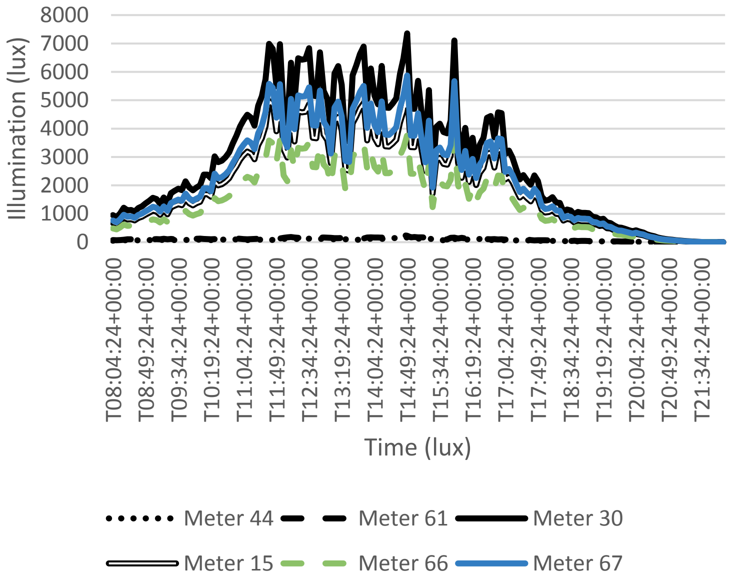
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. dv	t	df	Sig.	N	r	Sig
Pair 1	Meter 15	3239.36	2433.39	16.51	164	.00	165	.86	.00
	Meter 44	409.87	273.62						
Pair 2	Meter 15	3239.36	2433.39	16.61	164	.00	165	.86	.00
	Meter 61	351.27	234.50						
Pair 3	Meter 15	3239.36	2433.39	17.10	164	.00	165	1.00	.00
	Meter 30	2899.19	2177.86						
Pair 4	Meter 15	3239.36	2433.39	17.10	164	.00	165	1.00	.00
	Meter 67	2836.07	2130.45						
Pair 5	Meter 15	3239.36	2433.39	17.10	164	.00	165	1.00	.00
	Meter 66	1874.78	1408.33						
Pair 6	Meter 44	409.87	273.62	-16.42	164	.00	165	.86	.00
	Meter 67	2836.07	2130.45						
Pair 7	Meter 61	351.27	234.50	-16.54	164	.00	165	.86	.00
	Meter 30	2899.19	2177.86						

Jul



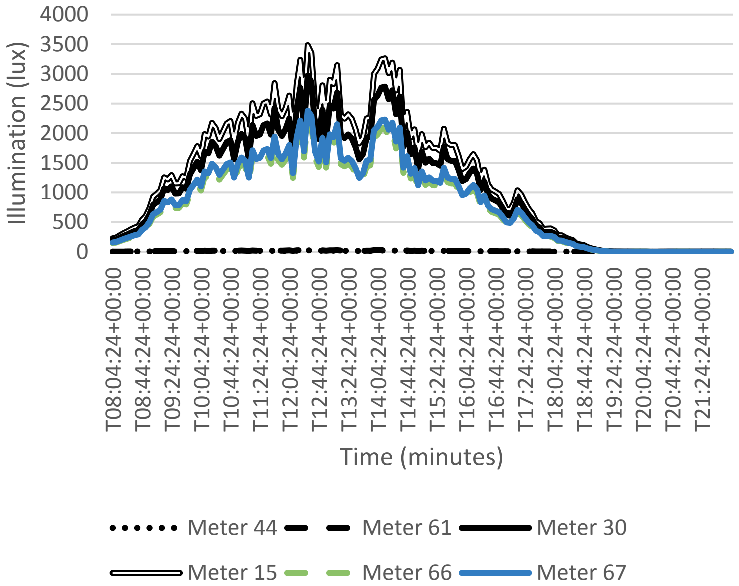
Pair		Paired samples statistics: Mean	Std. Deviation	Pair sample test: t	df	Sig.	Paired samples correlation: N	r	Sig
Pair 1	Meter 15	1256.66	836.98	18.08	166	.00	167	.65	.00
	Meter 44	207.11	146.08						
Pair 2	Meter 15	1256.66	836.98	18.18	166	.00	167	.65	.00
	Meter 61	194.49	137.18						
Pair 3	Meter 15	1256.66	836.98	-19.40	166	.00	167	1.00	.00
	Meter 30	1611.96	1073.62						
Pair 4	Meter 15	1256.66	836.98	-19.40	166	.00	167	1.00	.00
	Meter 67	1656.56	1103.32						
Pair 5	Meter 15	1256.66	836.98	19.40	166	.00	167	1.00	.00
	Meter 66	1046.76	697.18						
Pair 6	Meter 44	207.11	146.08	-18.47	166	.00	167	.65	.00
	Meter 67	1656.56	1103.32						
Pair 7	Meter 61	194.49	137.18	-18.51	166	.00	167	.65	.00
	Meter 30	1611.96	1073.62						

Aug



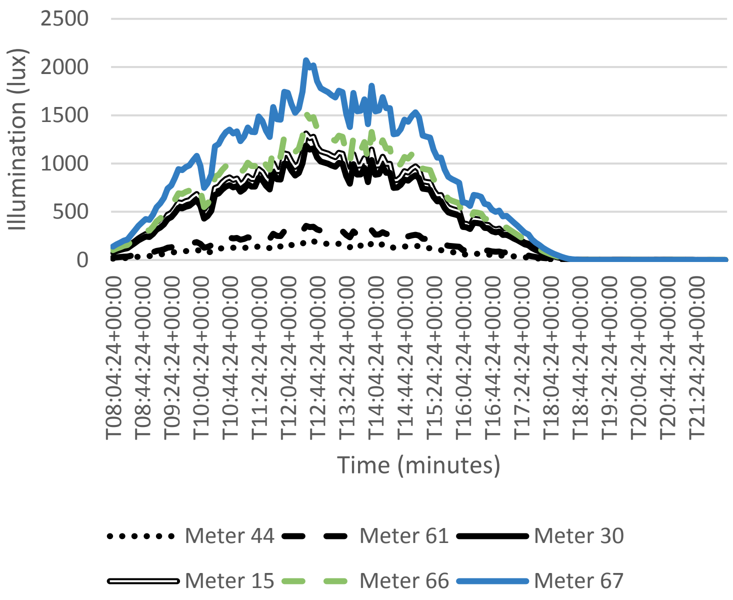
Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		Mean	Std. Deviation	t	df	Sig.	N	r	Sig
Pair 1	Meter 15	2168.73	1488.07	18.12	158	.00	159	.81	.00
	Meter 44	75.28	38.92						
Pair 2	Meter 15	2168.73	1488.07	18.02	158	.00	159	.81	.00
	Meter 61	104.69	54.13						
Pair 3	Meter 15	2168.73	1488.07	-18.37	158	.00	159	1.00	.00
	Meter 30	3047.87	2091.29						
Pair 4	Meter 15	2168.73	1488.07	-18.37	158	.00	159	1.00	.00
	Meter 67	2433.27	1669.58						
Pair 5	Meter 15	2168.73	1488.07	18.37	158	.00	159	1.00	.00
	Meter 66	1563.42	1072.74						
Pair 6	Meter 44	75.28	38.92	-18.15	158	.00	159	.81	.00
	Meter 67	2433.27	1669.58						
Pair 7	Meter 61	104.69	54.13	-18.12	158	.00	159	.81	.00
	Meter 30	3047.87	2091.29						

Sep



Paired samples statistics				Pair sample test			Paired samples correlation		
Pair		**Mean**	**Std. Deviation**	**t**	**df**	**Sig.**	**N**	**r**	**Sig**
Pair 1	Meter 15	1633.48	905.67	20.56	129	.00	130	1.00	.00
	Meter 44	10.61	5.89						
Pair 2	Meter 15	1633.48	905.67	20.56	129	.00	130	1.00	.00
	Meter 61	13.40	7.43						
Pair 3	Meter 15	1633.48	905.67	20.56	129	.00	130	1.00	.00
	Meter 30	1394.13	772.96						
Pair 4	Meter 15	1633.48	905.67	20.56	129	.00	130	1.00	.00
	Meter 67	1115.77	618.63						
Pair 5	Meter 15	1633.48	905.67	20.56	129	.00	130	1.00	.00
	Meter 66	1046.74	580.35						
Pair 6	Meter 44	10.61	5.89	-20.56	129	.00	130	1.00	.00
	Meter 67	1115.77	618.63						
Pair 7	Meter 61	13.40	7.43	-20.56	129	.00	130	1.00	.00
	Meter 30	1394.13	772.96						

Oct



Pair		Paired samples statistics: Mean	Std. Deviation	Pair sample test: t	df	Sig.	Paired samples correlation: N	r	Sig
Pair 1	Meter 15	634.28	359.74	19.79	125	.00	126	1.00	.00
	Meter 44	96.43	54.69						
Pair 2	Meter 15	634.28	359.74	19.79	125	.00	126	1.00	.00
	Meter 61	171.11	97.05						
Pair 3	Meter 15	634.28	359.74	19.79	125	.00	126	1.00	.00
	Meter 30	574.69	325.94						
Pair 4	Meter 15	634.28	359.74	-19.79	125	.00	126	1.00	.00
	Meter 67	1001.87	568.22						
Pair 5	Meter 15	634.28	359.74	-19.79	125	.00	126	1.00	.00
	Meter 66	735.58	417.19						
Pair 6	Meter 44	96.43	54.69	-19.79	125	.00	126	1.00	.00
	Meter 67	1001.87	568.22						
Pair 7	Meter 61	171.11	97.05	-19.79	125	.00	126	1.00	.00
	Meter 30	574.69	325.94						

Table R. 2 **The Paired-Samples T- test results for the difference in the illuminance levels between studios at 5m-6m distance from the window.**

Appendix S

Appendix S. 1

	Variables	Daylight in winter	Daylight in summer	Artificial light	Temperature in winter	Temperature in summer	Acoustics	Air quality	Furniture arrangements	Furniture proximity	Spaciousness	Façade windows	Overlooking view
Correlation coefficient	Daylight in cloudy day	1.000	.282**	.247**	.369**	.215**	.212**	.050	.184*	.208**	.288**	.253**	.287**
	Daylight in bright day	.282**	1.000	.156*	.055	.374**	.186*	.016	.119	.074	.261**	.133	.094
	Artificial light	.247**	.156*	1.000	.063	.069	.195*	.082	.146	.201**	.194*	.159*	.076
	Temperature in winter	.369**	.055	.063	1.000	.167*	.150	.114	.112	.155*	.097	.061	.136
	Temperature in summer	.215**	.374**	.069	.167*	1.000	.345**	.383**	.360**	.262**	.322**	.163*	.054
	Acoustics	.212**	.186*	.195*	.150	.345**	1.000	.425**	.532**	.454**	.505**	.265**	.276**
	Air quality	.050	.016	.082	.114	.383**	.425**	1.000	.539**	.485**	.485**	.247**	.121
	Furniture arrangements	.184*	.119	.146	.112	.360**	.532**	.539**	1.000	.770**	.663**	.306**	.316**
	Furniture proximity	.208**	.074	.201**	.155*	.262**	.454**	.485**	.770**	1.000	.638**	.298**	.235**
	Spaciousness	.288**	.261**	.194**	.097	.322**	.505**	.485**	.663**	.638**	1.000	.480**	.379**
	Façade windows	.253**	.133	.159*	.061	.163*	.265**	.247**	.306**	.298**	.480**	1.000	.531**
	Overlooking view	.287**	.094	.076	.136	.054	.276**	.121	.316**	.235**	.379**	.531**	1.000

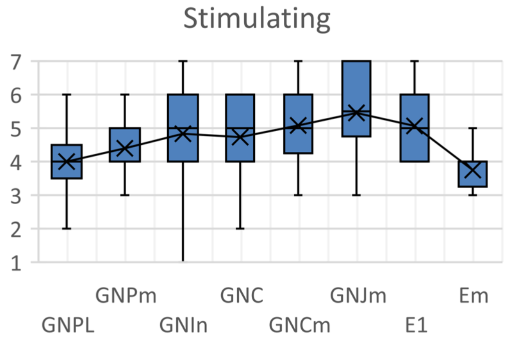
Table S. 1 Correlation matrix for variables (stimuli) contributing to the atmosphere in Glasgow & Edinburgh studios.

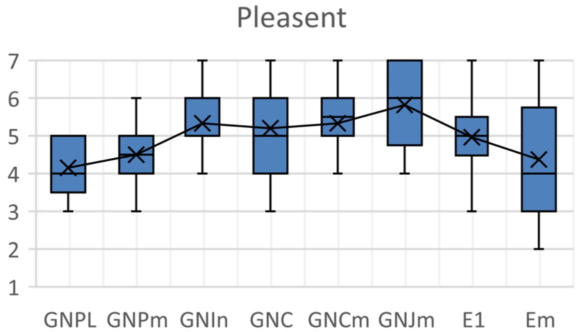
a. Determinant = .017

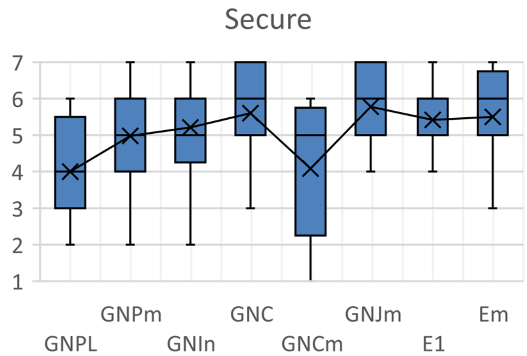
*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

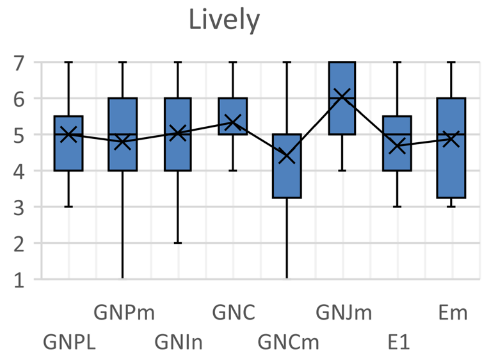
Appendix T

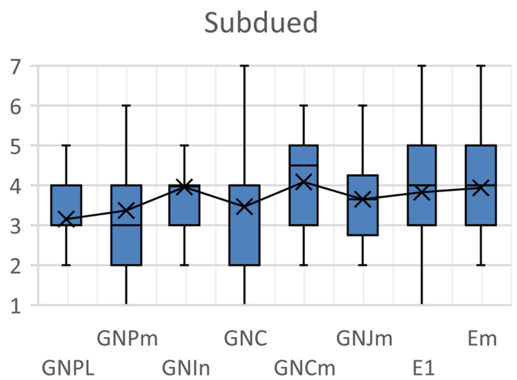
Appendix T. 1

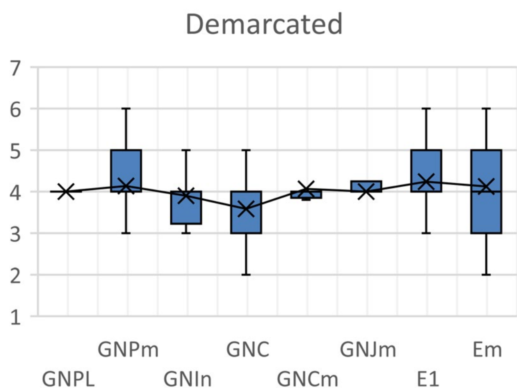


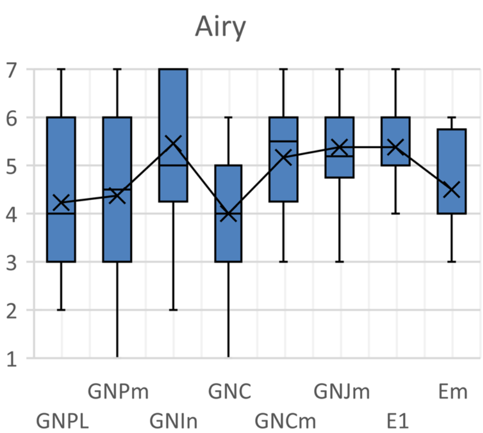


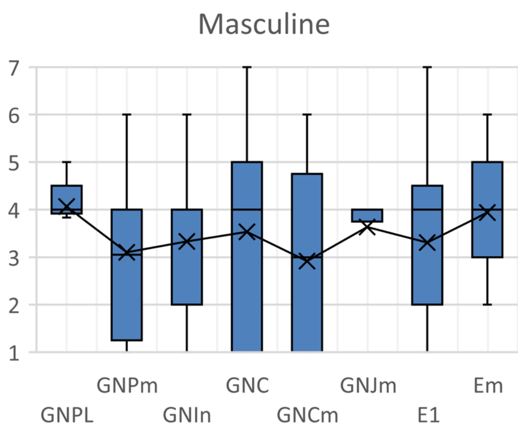












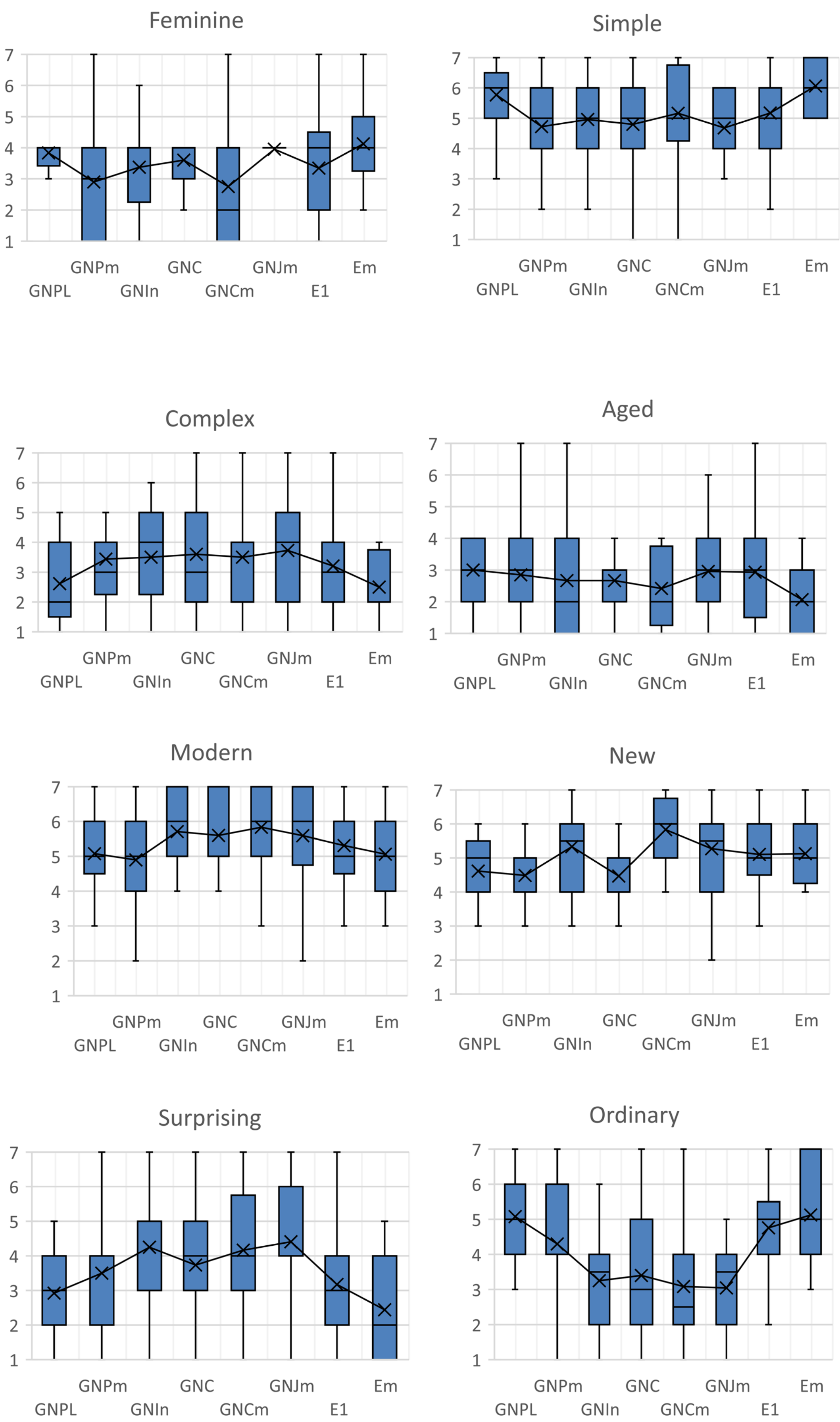


Figure T. 1 Mean subjective ratings for different dimensions of atmosphere in Glasgow & Edinburgh studios. Ratings from 1 (not applicable at all) to 7 (very applicable).

Appendix T. 2

Dimension	df	F	Sig.
Stimulating	7,163	3.959	.001
Pleasant	7,163	4.578	.000
Secure	7,163	4.202	.000
Lively	7,163	3.008	.005
Subdued	7,163	1.091	.372
Demarcated	7,163	.640	.722
Airy	7,163	3.961	.001
Masculine	7,163	1.155	.331
Feminine	7,163	2.189	.038
Simple	7,163	2.650	.013
Complex	7,163	1.532	.160
Aged	7,163	.860	.539
Modern	7,163	1.858	.080
New	7,163	2.886	.007
Surprising	7,163	3.505	.002
Ordinary	7,163	6.491	.000

Table T. 2 ANOVA test results of the effect of studio differences on the atmospheric dimensions.

Appendix U

Appendix U. 1

	Variables	Daylight in winter	Daylight in summer	Artificial light	Temperature in winter	Temperature in summer	Acoustics	Air quality	Furniture arrangements	Furniture proximity	Spaciousness	Façade windows	Overlooking view
Correlation coefficient	Daylight in winter	1	**.469****	-.083	**.193***	**.336****	.069	.078	.100	-.007	-.103	.130	-.013
	Daylight in summer	**.469****	1	.057	.161	**.340****	.142	**.220***	.055	.002	-.086	**.315****	**.275****
	Artificial light	-.083	.057	1	**.261****	-.046	**.268****	.020	.149	.155	-.066	-.064	.056
	Temperature in winter	**.193***	.161	**.261****	1	**.246***	**.267****	.114	.164	**.254****	.052	**.198***	.149
	Temperature in summer	**.336****	**.340****	-.046	.246*	1	.065	.168	.078	.101	-.031	.066	-.141
	Acoustics	.069	.142	**.268****	**.267****	.065	1	**.436****	**.355****	**.306****	**.204***	-.104	.158
	Air quality	.078	**.220***	.020	.114	.168	**.436****	1	**.535****	**.396****	**.367****	**.229***	**.466****
	Furniture arrangements	.100	.055	.149	.164	.078	**.355****	**.535****	1	**.670****	**.580****	-.039	.158
	Furniture proximity	-.007	.002	.155	**.254****	.101	**.306****	**.396****	**.670****	1	**.620****	.056	**.245***
	Spaciousness	-.103	-.086	-.066	.052	-.031	**.204***	**.367****	**.580****	**.620****	1	.097	.136
	Façade windows	.130	**.315****	-.064	**.198***	.066	-.104	**.229***	-.039	.056	.097	1	**.518****
	Overlooking view	-.013	**.275****	.056	.149	-.141	.158	**.466****	.158	**.245***	.136	**.518****	1

Table U. 1 Correlation matrix for variables (stimuli) contributing to the atmosphere in Glasgow & Aberdeen studios.

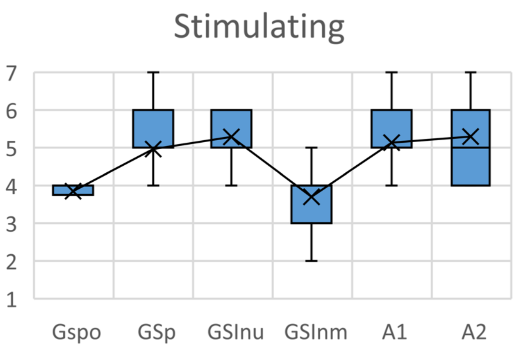
a. Determinant = .022

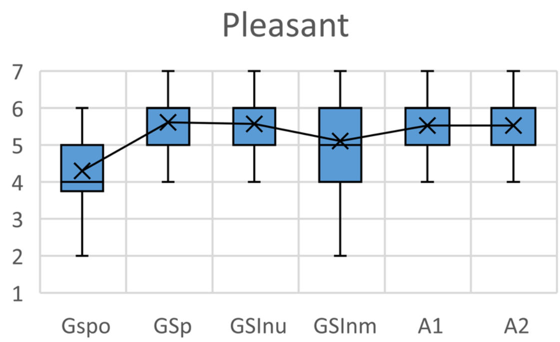
*Correlation is significant at the 0.05 level (2-tailed).

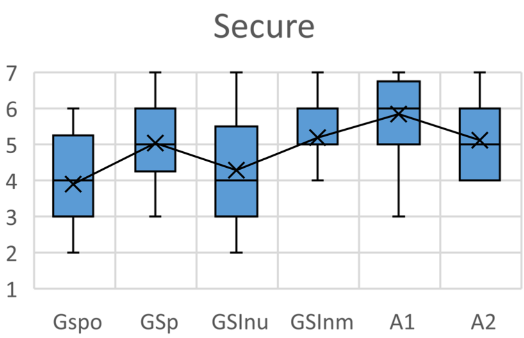
**Correlation is significant at the 0.01 level (2-tailed).

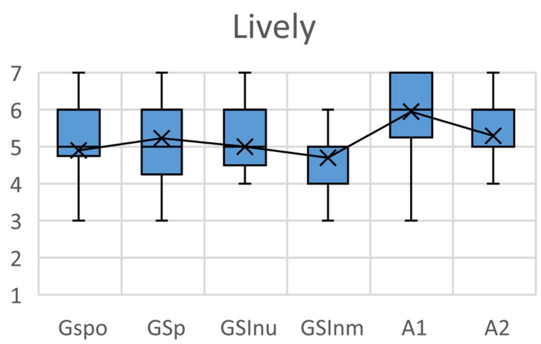
Appendix V

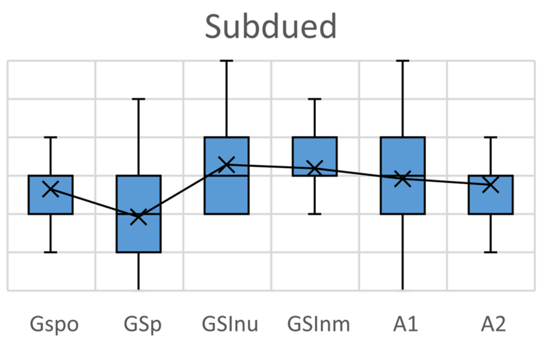
Appendix V. 1

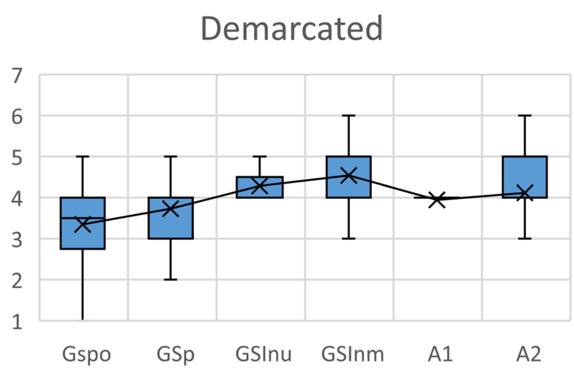


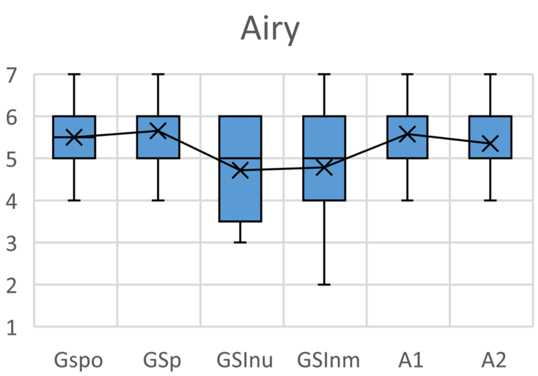


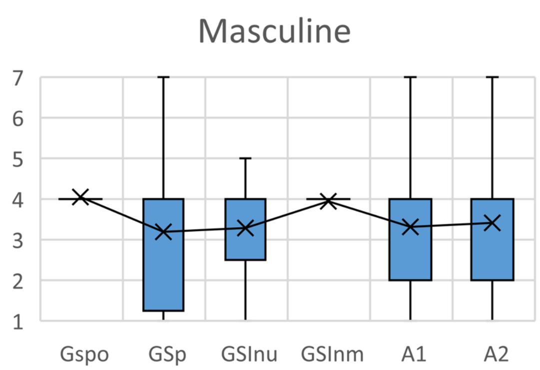












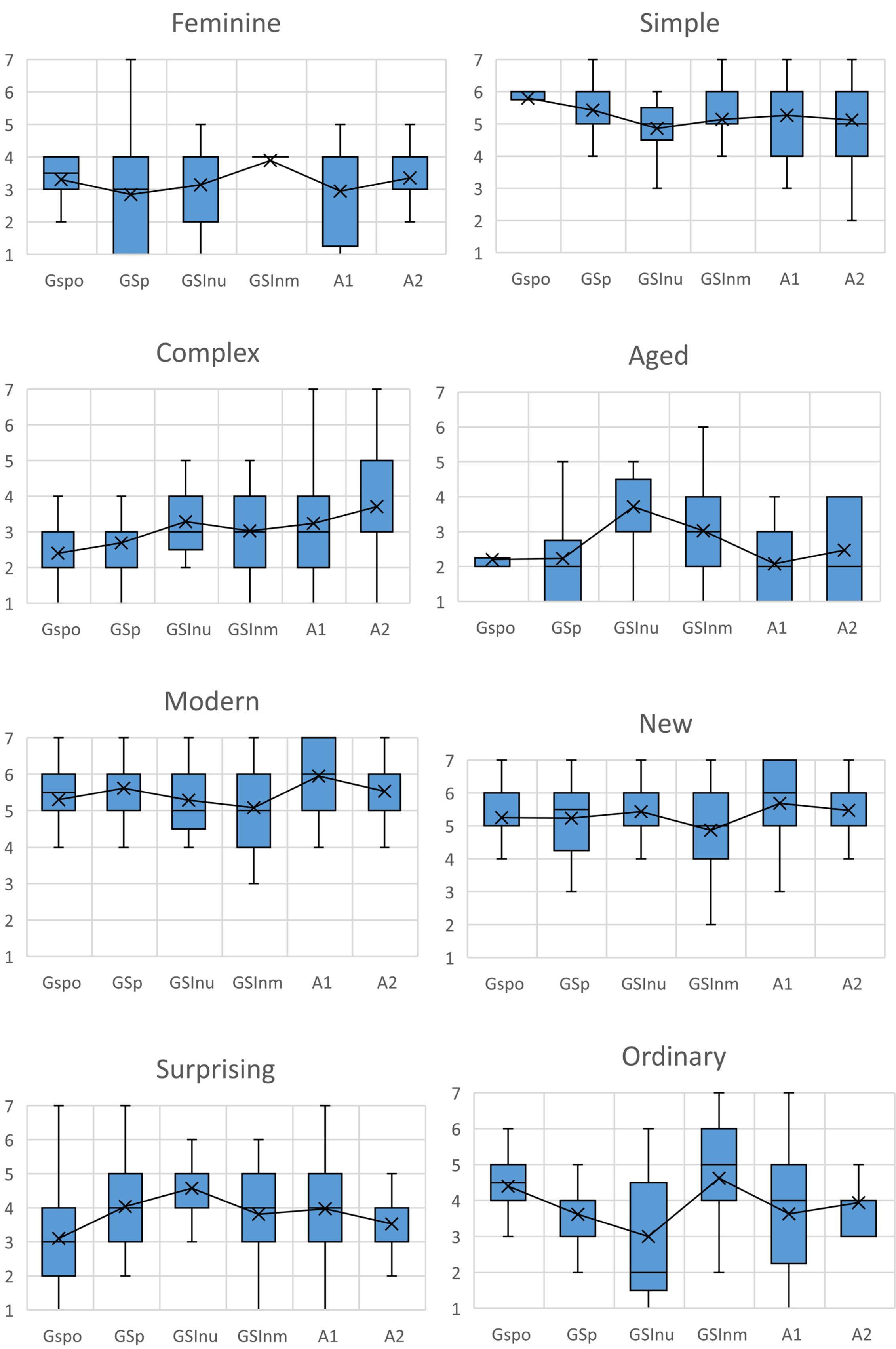


Figure V. 1 Mean subjective ratings for different dimensions of atmosphere in Glasgow & Aberdeen studios. Ratings from 1 (not applicable at all) to 7 (very applicable).

Appendix W

Appendix W. 1

Additional students' comments and opinions that the survey do not cover regarding experienced atmosphere, daylight levels/artificial lights and façade layouts from inside studios. North-facing studios.

E1 studio:

- 'Can be echoy'

- 'Quite dark towards side of room away from windows, very basic artificial light, minimal control and windows could be bigger (higher up)/ extended further'.

- 'Although, daylight positive stimuli, daylight reflecting on 'white' surfaces of the studio- cold atmosphere'.

- 'Good to allow me to work well. No issues, all is well and façade windows are good'.

- 'Too cold'

- 'Very dark winters-light changes very quickly. A lot of lights under mezzanine level. More required lower studio especially in the winter. Façade windows are repetitive'.

Em studio:

- 'The artificial light is too strong on the mezzanine causing glare and discomfort. However, good when working downstairs'.

- 'The mezzanine sits higher than the windows and from my seating position. I barely notice the change of daylight and artificial light is always needed'.

- 'I cannot see out of any windows from the mezzanine so mostly artificial light and lighting does not change much up in the mezzanine'.

- 'During winter the artificial light can be uncomfortable and unwelcoming. In the summer we get lot of daylight. In the winter barely any due to being .... Need better lighting. ... different types for different occasions. Bright white for working and drawings and warmer for computer work or meetings. The window layout does not affect me in anyway. The yellow/white fluorescent lights can give me a headache when the light outside is low'.

- 'The lights are on a timer/sensor. If you are studying/working at night alone they go off very frequently 20 min and its very dark. As using mezzanine my opinion of the facade has changed as very minimum view is now present'.

- 'Being on the mezzanine floor allows for no daylight/ you become unaware of time passing'.

- 'The studio is usually a bright and light place to work. It is spacious also. Lights on the mezzanine are too bright for how close they feel. Gives headache'.

- 'Mezzanine does not get much daylight which is sad, and can't see windows. Same as light. Artificial lights aren't on. They are good for working. More could be arranged to put light to the top of room.

- 'Where I sit in the studio has no views of the window whatsoever. Making it quite dark most of the time. The light switch control groups together a number of lights in the studio. there isn't much ventilation'.

<u>GNC studio:</u>

- 'I think the darkness is more due to Glasgow climate than to the building. Very big windows but poor view due to dwelling surroundings and the first flown position'.

- '*Layout, third year desk was under. The mezzanine and the shadow in that section made me come in ley*'.

- '*Atmosphere is positive when people are in it. Atmosphere could be improved with better lighting, the window is high up and gives a grey feeling*', '*Artificial light is uncomfortable, needs to be less blue, it fiches and its very strong intrusive light* and *window is too high up feels you are submerged in the studio*'.

- '*Unusual interior solutions create active atmosphere dynamic, light enough* and *like the form of windows*'.

- '*Not much visual stimuli (white walls) could use some plants. Can get quite stuffy,* light *inequality dispersed, artificial light become tiring* and *no view of outside stimuli*'.

- '*Very low light in winter, get so dark after 3 p.m., fluorescent lights make my eye hurt, yellow plastic instead of white. When I was at the back of the room last year, there was almost no natural light, the table lights were always on and I had always had a headache and... a headache. Put a mirror in the second floor to reflect the view and the light*'.

- '*Based on where I am sitting feel underground* and *façade layout is adjustable*'.

<u>GNCm studio:</u>

- *'The atmosphere from natural light is very positive. However, I find the artificial light, once the daylight is inadequate, off-putting difficult to work in'.*

- *'Can barely see the windows.*

- *'Neg: air feels stale-not enough airflow. Pos: good energy, good daylight. daylight is good but when it gets dark, I did like the artificial light more. Façade is nice but the view is blocked by the mezzanine to my desk'.*

- *'Good lighting until 3 each day, and then it becomes a tiring light'.*

- 'I love the large window and abundance of natural light. I prefer when the lights are off to save energy and stain on my eyes. I am much happier in my new dark which does more face a wall. Quality of light is good, large windows and white wall open the space, illuminating the room'.

<u>GNPL studio:</u>

- 'I don't think that daylight crossed my mind during my time here, probably a good thu'.

- 'A bright space, although too cramped'

- 'Nice and bright, not probably in the winter season yet so have not experienced darkness in late afternoon but expect it not to be as nice to work in artificial light compared to sunlight and have to look up to see out the window but can only see clouds or sky'.

- 'Flickery, warm, artificial is very annoying and we can only see the sky, good lighting but no view'.

- 'light good for working in and taking photos, but does not level space'

- 'It's a good area for taking photos and working in due to the daylight'.

- 'especially when using laptops there can be glare'.

- 'View would much atmos. Feel better and the light is better than most classrooms (e.g. Glasgow Uni are pretty bad) but not as good as the GSA lunch hall for example'.

- 'Other studios have better views. Ours is much of a cell. Cramped, daylight bigger than artificial in all seasons. Less daylight later into the evenings in winter and façade layout is minimalistic. I like it'.

- 'This space is quite compact, and only suitable for around 20 people at most and the artificial lighting is actually significantly yellow-ish: bad for taking pictures'.

GNPm studio:

- 'Lack of light when rainy. Great view of the city'.

- 'It can be very loud, cramped. This is because there are a lot of people. I imagine this would be worse if we didn't have the windows, however they reflect sound quite a lot. Because of the table arrangement there is sometimes a glare when the sun gets lower in the afternoon. window is obstructed on my side (the side I face)'.

- 'Negative: too many people, not big enough. Positive: I love the big windows. Lots of glare. No issues with natural daylight. Very small and light'.

- 'The biggest issue is the temperature control (usually too hot) unrelated to daylight'.

- 'Too hot inside when getting sunshine'.

- 'Feels comfortable. Sometimes there is glare when blinds are down. Where I sit, view is less attractive than on opposite side'.

- 'The window will make the people feel dizzy in Sunday especially in summer. A few uncomfortable'.

- 'Bright, well lit'.

- 'Too many people, it's very crowded and stuffy'.

- 'Positive: activity. Negative: the sunlight hurt my eyes when I sit in studio, and it makes the studio so warm. daylight levels: glare, discomfort. Artificial light: warm. Crowded'.

- 'Positive= size of the window. Negative=Lack of fresh air, daylight. Quality of light'.

- 'Temperature control sucks, always too hot. Usually good, sometimes get glare on bright days'.

- 'The air is not very fresh. In summer it is too hot and too bright. In outside, it is hard to see the top façade design'.

- 'It gets way too hot and stuffy in the summer. Light feels old, sometimes lamps don not work properly. Weird heading terrace, windows look good'.

- 'Overall good atmosphere based on longer views, design and lighting. Sometimes lights from sun too intense. Windows layout is great as is studio mezzanine possible views and sunlight'.

- 'It's a nice studio, but do to the temperature I prefer to use the studio downstairs, it's far too hot up here'.

- 'Negative mainly due to temperature not light'.

- 'The windows do not open meaning the room gets far too hot in the summer in which it less comfortable to work in. I prefer cloudless days so I notice the reduce hot in light when its cloudy. The room much darker despite the large windows'.

- 'It gets hot in summer. I like it but other people do not'.

- 'The biggest factor that influenced me this year was airflow and air quality in the studio, window did not allow a sufficient amount to enter or fans were very useful'.

- 'I like the bright, airy, open spaces. Noise was a problem often, but the lack of divisions provided better interactions. Glare was sometimes a problem, but the mount of light was overall a positive'.

- 'I like the fact that we have windows unlike other studios. Light is adequate. Not much of façade going on'.

- 'Tidiness, messiness had an effect. Secluded, get there is noise coming from the floor below. During the summer, it is basically a greenhouse (glass all around rising heat from the rest of the building. Closing the shades will cover the open windows, trade-off between getting shade or getting fresh air'.

- 'Too hot from sunlight in summer, no control'.

- 'Feel stressed when I am working with other people, so the atmosphere is not important to me. The quality is good, but it's too hot in summer. The arrangements of furniture's are depressing; it will be better for larger space'.

- 'The arrangement of furniture in this studio is a bit boring, does not take a great advantage of this space and the daylight. It would be better if we can control the amount of daylight coming through. simple layout, for taking exhibition than use as a studio for independent study? Maybe- more suitable'.

<u>GNIn studio:</u>

- 'There are large windows and it covers a lot of studio, it is usually pleasant and does not feel restricting. It is a good atmosphere'.

- 'Positive: we have good light from the window. Daylight is good, the artificial lights are okay could be better. Nice, does the job'.

- 'In the evening lamps would be nice'.

- 'Very welcoming due to huge windows, amount of daylight. Artificial light during day seem unnaccany. Good eco-friendly, less electricity used? the composition of windows great, huge. Amount of natural light from both sides of studio!'.

- 'The main aspect to me in the studio is daylight, natural light and the way the windows have been placed we get a lovely light all day'.

GNJm studio:

- *'I love this studio, it's so lively. During high daylight, can be difficult to see torch flame. During night, bench lights are very good. Slightly cramped, I trip over chairs quite a lot. But generally, a very good layout'.*

- *'It supports my work when I needed. The artificial light sometimes will turn itself off in the evening if I am working alone and late in studio (around 7 p.m-10p.m). It is quite creative and interesting for people to study in It'.*

- *'Bright, open and spacious. Terie has an effect on light and we can't really control it, artificial is needed'.*

- *'Sun glare. Orange light. Best windows'.*

- *'Consistently having lights go out when working in winter evenings. North facing studio, split level often not enough light down stairs. However, too much light at other times effects ability to solder for example. Fine for top level of studio. lower levels can be too dull'.*

- *'Positive: nice and light, stimulating. Negative: no blinds to cover light. Daylight is very adequate later in day, artificial light is needed but can give headaches. No blinds so can't control. It contributes to overall visual pleasuring-ness of room'.*

- *'Temperature control lacking. On a nice day daylight levels very good. Night time (city lights). Façade is Good'.*

- *'Significant glare on computer screens in afternoon'.*

- *'Glare in afternoon on computers. Too bright-artificial light'.*

Appendix W. 1

South-facing studios

A1 studio:

- *'Big, airy and spacious. Welcoming'.*

- *'Atmosphere is good. Glare can be strong and the heat can be bad. Façade windows it looks good'*

- *'Lighting are Lack of control and complex. Façade windows Can be overpowering with amount of light'.*

- *'Too much, blinds often used'*

- *'Can feel cold sometimes. Façade windows definitely highlight the best views'.*

- *'Control of blinds makes the studio comfortable'.*

- *'Feel there may be a difference in atmosphere in different seasons but never notice it. In summer the light does gives me a sere lead shortening my studio hours'.*

- *'The high daylight comes at the cost of severe overheating during summer. High glare during winter, lack of shading. South facing does not work for a studio'.*

- *'Atmosphere is positive'*

- *'Summer sun produces a lot of direct rays which is annoying. Good that there is so much window space to allow light in, but the blinds are almost always down and in-use every day to reduce glare and direct sunlight'.*

- *'If sunny causes lots of uncomfy glare'.*

- *'Nice and open. Always have the shades down, too much light/heat/ Glare at times'.*

A2 studio:

- 'Lots of light an easy place to work. Windows layout are good'.

- 'Atmosphere is positive. Could have a little less artificial light. Windows layout are positive'.

- 'Messy but nice studio (Human factors). Lighting and façade layout are good'.

GSInu studio:

- 'Table lamps with warm light would create cosier environment in the evenings'.

- 'Automatic switch-off for artificial lights are frustrating on quite evenings and doesn't provide enough light'.

- 'I'd prefer to be sat nearer a window for the view outside. The atmosphere is good, light levels even'.

'I don't get glare where I sit as I have no direct sunlight which is good'.

'Very bright, cosy, perfect artificial quality, excellent use of brightness. Very good lighting. Façade layout is fine'.

'Really bright open space. no walls and void= noise from other studio and ref. Artificial light has a harsh contrast compared to natural. From my seat I enjoy the facade layout as it gives me a calming view'.

GSpo studio:

- 'Comfort during bad weather, nice to see lashing rain. Façade windows are good, like the panorama, would be nice to have a few high window columns also'.

- 'Modular furniture, can create diff arrangement and good for group work. sometimes lack of privacy'.

- 'I love sitting next to windows, but I do sometimes get glare from other windows (that aren't next to me) and I always feel redundant to shut the blinds (that aren't next to me), cos afraid that other people...'

-'.. may want the blind open. I wished we could have different facade for summer/winter'.

- 'Too crowded for the number of people in the studio'.

- 'Glare from natural light on laptop. Quite yellow at night. Chair/table space not used effectively- studio is large'.

- 'There are so of us crammed into 1 studio-lighting is good but almost irrelevant when the studio is pached'.

GSp studio:

- 'It is a very bright and happy atmosphere. Right amount of artificial light, artificial light is a good colour (close to sun light). Façade windows are good'.

- 'Atmosphere is Lively, inspiring, collaborative. Façade windows are pleasant yet not distracting'.

- 'Light, spacious. Good place to work. Artificial lighting is quite bright but this can be useful. Very good and brings daylight to room'.

- 'The feasibility of rebuild, the windows will re-design. limit the imagination'.

- 'Have ADHD so ratings of distraction/ comfort in open space studio are mildly biased'.

- 'The artificial lighting cause extreme discomfort to me personally. I get really bad headache after a long day at art school'.

- 'Very bright, people sometimes need to wear sunglasses because of it, artificial lights cause bad headache'.

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