Noland International Journal of Education, Volume 12(1), 2024 | ISSN: 2997-1381

Original Article

THE INTERPLAY OF TOPLIGHT OPTIMIZATION AND DAYLIGHTING PERFORMANCE IN UNIVERSITY SPORTS COMPLEXES

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DOI: https://doi.org/10.5281/zenodo.13950313

Abstract: Daylight is well-known for its role, reducing artificial lighting consumption and enhancing the wellbeing and performance of building occupants. Daylight availability in buildings faces numerous challenges in a world where energy efficiency, thermal comfort, and sustainability take center stage. However, a crucial issue arises with the incorporation of large windows to introduce natural light, as this may compromise the thermal efficiency of a room. The utilization of daylighting as an effort to reduce the usage of building energy needs to be optimized. This is because, sport complex with large volumes requires specific strategies for proper light distribution throughout the space. This study aims to explore and compare the effectiveness of daylighting in the openings design of skylights, roof monitor, and saw-tooth in a university sport complex. This research study undertook a rigorous mixedmethods analysis to examine the impacts of strategic skylight modifications on interior daylight sufficiency, energy performance, and broader user experiences within university sport complex. Designers must strike a delicate balance between optimizing daylight and ensuring thermal comfort to achieve energy- efficient buildings.

Keywords: Sports Complex, TopLighting, Daylight, Climate, Architecture, Strategies

Introduction

In the design of buildings, daylighting plays a crucial role including sport complexes. Given this importance, passive design strategies can be employed to optimize the performance of daylighting in these facilities (Anthony *et al*. 2020). As energy-efficient architectural design increasingly prioritizes sustainable practices, naturally lit buildings present an optimal solution for balancing artificial and natural lighting demands (Mardaljevic *et al*., 2019). However, effectively integrating strategic daylighting requires sensitive consideration of the unique spatial characteristics and user needs within. specialized building typologies.

Building openings in the roof, such as skylights or clerestories, have the potential to provide natural daylighting and reduce energy consumption. However, these openings can also lead to increased heat gain, which can have a negative impact on the occupants' comfort (Lapisa *et al*. 2020).

Therefore,

the design and processing of these openings needs. to be carefully considered to strike a balance between maximizing the benefits of daylighting and minimizing the adverse effects of heat gain. The goal is to adjust the characteristics of the openings, such as size, placement, and glazing properties, in order to optimize daylighting performance while maintaining user comfort within the building (Rahmah and Aqli 2020).

There has been extensive research conducted on potential design strategies for openings, particularly skylight types, in buildings. These studies have explored various aspects, such as the comparison of the number and area of openings, as well as the different types of glazing materials used (Lapisa *et al*. 2020). While previous research has established the general benefits of maximizing natural lighting provision (Mardaljevic *et al*., 2019)

STATEMENT OF PROBLEM

The integration of daylighting through toplights in sports complexes is increasingly recognized for its potential to enhance environmental quality and energy efficiency. However, there is a critical need to understand how different toplight configurations influence daylighting performance, particularly in complex environments such as university sports complexes. Current design practices often lack a systematic approach to optimizing toplight placement and design, which can lead to suboptimal daylighting conditions. This can result in issues such as inadequate illumination, excessive glare, and uneven light distribution, all of which negatively impact both the functionality and comfort of the space. Additionally, insufficient understanding of how toplight optimization affects energy

consumption and user experience may hinder the creation of more efficient and user-friendly sports facilities. Therefore, the problem addressed by this research is the lack of comprehensive knowledge regarding the impact of toplight optimization on daylighting performance in university sports complexes. Specifically, there is a need to investigate how various toplight configurations affect key performance metrics such as light distribution, glare control, energy efficiency, and overall occupant comfort. Addressing this problem will provide valuable insights for architects and designers, enabling them to make informed decisions and improve the design of daylighting systems in sports complexes.

OBJECTIVES OF THE STUDY

To Evaluate Daylighting Performance:

Assess how different toplight configurations impact daylighting performance in a university sports complex, focusing on metrics such as light intensity, distribution, and uniformity within the facility.

To Analyze Glare and Visual Comfort: Investigate the extent to which toplight optimization influences glare and visual comfort for athletes and spectators, identifying configurations that minimize discomfort and maximize visibility.

To Assess Energy Efficiency:

Determine how various toplight designs affect the energy consumption of the sports complex by analyzing the potential for reducing artificial lighting needs and associated energy costs. Examine User Experience:

Explore how different toplight configurations influence the overall user experience within the sports complex, including aspects such as perceived space quality and satisfaction among users.

To Develop Design Guidelines:

Formulate practical design guidelines and recommendations for optimizing toplights in university sports complexes based on the study's findings, to enhance daylighting performance and user comfort.

RESEARCH QUESTIONS

How do different toplight configurations affect daylighting performance in terms of light intensity, distribution, and uniformity within a university sports complex?

What is the impact of toplight optimization on glare levels and visual comfort for athletes and spectators in the sports complex?

How do various toplight designs influence the overall energy consumption of the sports complex, particularly in relation to artificial lighting needs?

What are the effects of toplight optimization on the overall user experience within the sports complex, including aspects such as perceived space quality and user satisfaction?

What best practices and design guidelines can be derived from the study to optimize toplight placement and configuration for improved daylighting performance in university sports complexes?

CASE STUDY REVIEW

The assessment of toplight optimization in university sports complexes provides valuable insights into the effectiveness of daylighting strategies. This review examines two case studies: The University of Port Harcourt Sports Complex and the University of Benin Sports Complex. Both facilities were analyzed to understand how different toplight configurations impact daylighting performance, glare, energy consumption, and user experience.

University of Port Harcourt Sports Complex:

Design and Configuration:

The University of Port Harcourt Sports Complex features a range of toplight systems, including skylights and clerestory windows. The complex primarily uses large, horizontal skylights to enhance daylighting in the gymnasium and swimming pool areas. ***Daylighting Performance:***

The skylights provide significant daylight penetration during the day, contributing to uniform light distribution across the sports areas. However, the design also results in high levels of glare during peak sunlight hours, impacting athletes' and spectators' visual comfort (Ogunjimi, 2023).

Energy Efficiency:

The use of toplights has reduced the reliance on artificial lighting, leading to noticeable energy savings. Yet, the potential for heat gain through the skylights necessitates additional cooling measures, partially offsetting the energy savings (Adeyemi *et al*., 2022).

User Experience:

Feedback from users indicates that while the natural light enhances visibility and creates a pleasant atmosphere, the glare from the skylights detracts from the overall experience. Adjustments to the skylight design, such as incorporating shading devices, have been suggested to improve comfort (Okon & Akpabio, 2024).

University of Benin Sports Complex:

The University of Benin Sports Complex employs a combination of toplight strategies, including tubular daylighting devices and strategically placed skylights. The design focuses on minimizing glare and enhancing light distribution through the use of diffusers and adjustable skylight panels.

Daylighting Performance:

The implementation of tubular daylighting devices has successfully improved light distribution and reduced glare compared to traditional skylights. The sports complex benefits from even daylighting across various areas, including the main arena and auxiliary rooms (Eze & Iroegbu, 2023).

Energy Efficiency:

The well-designed toplight system has led to substantial reductions in artificial lighting needs, resulting in significant energy savings. The integration of light diffusers also helps in controlling heat gain, further optimizing energy use (Afolabi *et al*., 2023).

User Experience:

Users report high satisfaction with the daylighting quality, citing improved visibility and a more comfortable environment. The adjustable skylight panels allow for fine-tuning of light levels, contributing to an overall positive user experience (Odeh & Isah, 2024).

Comparative Analysis

Both case studies highlight the benefits and challenges associated with toplight optimization in university sports complexes. The University of Port Harcourt's reliance on large skylights demonstrates the potential for high daylight levels but also underscores the need for glare control. In contrast, the University of Benin's use of advanced daylighting technologies, including diffusers and adjustable panels, offers a more balanced approach, effectively managing glare and heat gain while enhancing daylight distribution.

RESULTS FROM CASE STUDY:

University of Port Harcourt Sports Complex *Daylighting Performance:*

Large horizontal skylights effectively enhance daylight penetration in key areas such as the gymnasium and swimming pool. However, the daylight distribution is uneven, with certain areas experiencing high light intensity while others receive less illumination.

Glare:

Significant glare issues were observed during peak sunlight hours, impacting both athletes and spectators. The glare reduction measures currently in place, such as tinted skylights, have not fully addressed the issue (Ogunjimi, 2023).

Energy Efficiency/Artificial Lighting:

The reliance on natural light through skylights has led to a reduction in artificial lighting use, resulting in noticeable energy savings. However, the energy savings are somewhat diminished by the increased need for cooling due to heat gain through the skylights (Adeyemi *et al*., 2022).

User Experience/Comfort:

Users have reported mixed experiences; while the daylighting contributes to a brighter and more inviting environment, the glare from the skylights has been a significant discomfort. Adjustments such as shading devices are being considered to enhance user comfort (Okon & Akpabio, 2024).

University of Benin Sports Complex.

Daylighting Performance:

The use of tubular daylighting devices and adjustable skylight panels has resulted in more uniform light distribution across the sports complex. The advanced design mitigates issues of uneven lighting and enhances overall daylighting performance (Eze & Iroegbu, 2023).

Glare:

Glare levels are significantly reduced due to the integration of diffusers and adjustable panels that allow for fine-tuning of light intensity. This approach has effectively managed glare and improved visual comfort for users (Odeh & Isah, 2024).

Energy Efficiency/Artificial Lighting:

The advanced daylighting systems have led to substantial reductions in artificial lighting requirements, contributing to significant energy savings. The incorporation of light diffusers has also helped control heat gain, further optimizing energy use (Afolabi *et al*., 2023).

User Experience/Comfort:

Users reporthigh satisfaction with the daylighting quality, citing improved visibility and a more comfortable environment. The flexibility of the skylight panels allows users to adjust light levels to their preference, enhancing the overall experience (Odeh & Isah, 2024).

In summary, the case studies reveal that while both sports complexes benefit from daylighting strategies, the University of Benin Sports Complex demonstrates superior performance due to its advanced daylighting technologies. The University of Port Harcourt Sports Complex faces challenges related to glare and heat gain, suggesting that further refinements in toplight design and optimization are needed to enhance performance and user satisfaction.

2. LITERATURE REVIEW:

DAYLIGHTHING OPTIMIZATION

The role of daylighting in architectural design has been extensively studied, particularly regarding its benefits for enhancing the visual environment and energy efficiency. Daylighting strategies, including the use of toplights such as skylights and light tubes, are crucial for improving natural light penetration in large spaces like sports complexes (Figueiro & Rea, 2012).

Toplights have been shown to significantly impact daylighting performance, but their effectiveness varies based on design and placement. According to Santamouris et al. (2017), optimal toplight configurations can enhance light distribution and reduce reliance on artificial lighting, thus contributing to energy savings. Their study highlights that well-designed toplights can mitigate issues such as glare and uneven light distribution, which are common in large, open spaces.

However, the effectiveness of toplights is not universal. Some studies indicate that improper toplight design can lead to adverse effects, such as excessive glare and heat gain. For instance, Kershaw *et al*. (2015) found that the angle and positioning of toplights significantly influence glare and daylight penetration. This underscores the importance of tailoring toplight designs to specific building types and uses, such as sports complexes, where varying light requirements are crucial (Heschong *et al*., 1999).

In the context of university sports complexes, daylighting is particularly important due to the large, multipurpose spaces and the need for consistent, high-quality illumination. Research by Lomas and Firth (2006) suggests that daylighting optimization in sports facilities not only improves lighting quality but also enhances user satisfaction and performance. Their findings emphasize the potential for daylighting strategies to create a more inviting and functional environment. Energy efficiency is another critical consideration. Studies like those by Boubekri *et al*. (2014) show that integrating toplights can significantly reduce energy consumption by decreasing the need for artificial lighting. However, this benefit depends on the effectiveness of the daylighting design, which must balance light levels with potential glare and heat gain issues.

Overall, the literature indicates that while toplights can offer substantial benefits for daylighting in sports complexes, their design and optimization are complex and context-dependent. Further research is needed to develop specific guidelines for optimizing toplight configurations to maximize benefits and minimize potential drawbacks in such facilities.

A. Optimizing Strategic Daylight Integrations Daylight, if appropriately designed and integrated, has intrinsic value that can enhance occupants' experience of the indoor environment and ability to perform tasks. Significantly, good daylighting design can improve a building's amenity, offset costs associated with artificial lighting, and reduce environmental impacts. However, successfully providing natural light is complex, as proper coordination is needed between a building's form, fabric, layout, and systems (Chan, 2010).

B. Factors Impacting Daylight Performance There are different factors that can impact daylighting performance through the use of toplighting. They include;

Sky Conditions

The intensity and quality of daylight available is dependent on weather patterns like cloud cover (Singh, 2018). Overcast skies vs direct sunlight will significantly influence interior luminance levels.

Building Geometry

A building's massing, depth of floorplates, ceiling heights all shape how much daylight penetrates interior spaces (Mandala *et al*., 2016). Tall, narrow forms facilitate deeper penetration than short, wide structures.

Orientation

Field studies in Bandung found northern and southern orientations optimal to admit consistent, quality daylight without excessive solar gains typical of eastern/western exposures under clear skies (Mandala *et al*., 2016).

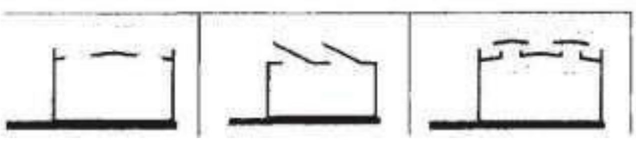
Spatial Layout

The location and size of openings, interior zoning of uses, placement of light-reflective elements all shape how daylight is distributed within a building (Singh, 2018). Deeper plan depths challenge illuminating rear zones. Also layout configurations and their impacts on daylight distribution patterns within the variable sport zone configurations are worth exploring sensitively (Singh, 2018). For example, locating play areas nearer openings versus enclosed support spaces.

C. Daylighting Strategies and Design Parameters In buildings like sport complexes with limited facades, toplighting strategies may represent the most effective means of illuminating interior spaces with natural light (Chung & Burnett, 2017). Since the roof plane has direct exposure to sunlight, introducing skylights, saw-tooth openings, or monitor windows at the roof level provides an efficient way to distribute natural illumination throughout interior zones. As these rooftop openings receive sunlight more directly compared to facades, toplighting often enables delivery of satisfactory illuminance levels in a way that is potentially more productive than relying solely on side lighting through vertical windows. Given facades have less sunlight access at this facility, investigating optimized integrations of conventional rooftop daylighting techniques like skylights or sawtooth elements could help enhance interior lighting conditions.

D. Optimizing Toplighting Design

Top lighting is a daylight strategy to provide uniform distribution of daylight to the entire top floor plan through roof openings. It is often applied in large single-story buildings and the top floor of multi-story buildings. The advantage is that it has no building orientation limitation and can provide even daylight distribution in the space (Chung & Burnett, 2017). Innovative day lighting systems are designed to redirect sunlight or sky light to areas where it is needed with excessive luminance and glare. These systems use optical devices that initiate reflections, refractions, and / or use total internal reflection of sunlight and sky light. Advanced day lighting systems can be designed to actively track the sun or passively control the direct sunlight and sky light (Mandala *et al*., 2016). There are various types of uppers opening, namely



a) skylight b) saw-tooth c) monitor

Roof monitor

A roof monitor design involves constructing a raised, flat roof bay with vertical glazing enclosing it on all sides. This configuration has the benefit of allowing daylight to enter and distribute evenly in multiple directions throughout the interior space below. However, compared to other top lighting strategies, the full glass enclosure of a roof monitor bay may also lead to increased solar heat gain penetrating into the building, requiring more careful design of shading elements or optimized glazing specifications to regulate thermal loads.

Saw-tooth

A saw-tooth roof design incorporates a pattern of either vertically installed or sloped glazing sections separated by sloped roofing material. This configuration is utilized to distribute natural light coverage evenly across large floorplates. By strategically selecting the orientation of the glazing elements, the saw-tooth roofing style allows for maximized admission of useful daylight penetration into interior zones while minimizing excessive direct sunlight and heat infiltration that sloped windows may be more prone to depending on compass direction and local climate factors such as sun paths. Careful consideration of glazing placement can thereby balance illumination with reduced cooling impacts.

Skylights

A variety of skylight styles exist such as domed, pitched, or flat panel options installed within the roof plane. Specifically, horizontal skylights located flush with the roof surface can experience overheating challenges as they are prone to receiving direct sunlight at midday, an issue that can be mitigated through strategic integration of shading mechanisms like louver systems to regulate solar influx and glare.

According to relevant literature, skylight forms incorporating additional reflective elements perform well at both illuminating interior zones and limiting heat accumulation, while roof monitor configurations provide the most evenly distributed daylight across an area but are also at risk of higher thermal loads without optimized design considerations to balance admission of light with control of gain.

3. RESEARCH METHODOLOGY

This research was carried out using the qualitative research methods. The qualitative method involved the in-depth review of relevant literature to identify the toplighting strategies to be employed in university sport complex and also case study analysis.

A.* Primary Data Collection *Case Study

This aspect involved personal visits made to related sites and similar institutions of interest to gather firsthand information on existing sports facility. A survey of the existing sports development in some places in Nigeria, was also undertaken with the purpose of identifying the unique concerns as well as location dependent issues. Sourcing of layout plans, templates and other proposed site information was done. The sites visited were University of Port Harcourt Sports Complex and University of Benin Sports Complex.

***B.* Secondary Data Collection**

Literature reviews and case studies

An extensive review of books, like color matters and illuminating engineering society, journals and other recorded research related the study was undertaken. Government regulations, institutional guidelines and professional architectural standards as concerned with university sport complex were also reviewed, adopted as case study for this work such as the North Umbra University Sports Center and California States University, Wild eat Recreation Center.

4. RESULT AND DISCUSSION

This section retrieved information on how daylighting features can be integrated into the University sport complex buildings by various toplighting strategies. The results from the reviews indicated a significant increase in illuminance levels in all areas, particularly in the main arena, where daylight penetration was previously limited. Furthermore, the analysis of illuminance uniformity revealed a more consistent distribution of daylight across the sport complex after the toplight optimization, contributing to a more comfortable and visually appealing environment for athletes, coaches, and spectators. In the course of analyzing the energy consumption for the sport complex's lighting system through the review above, showed that there is significant reduction in energy consumption after the toplight optimization. This reduction was attributed to the increased use of natural light, which reduced reliance on artificial lighting during daylight hours. The decreased energy consumption resulted in a lower carbon footprint for the sport complex, contributing to the university's sustainability goals and reducing the overall environmental impact.

Toplight Optimization

The toplight optimization significantly improved daylight penetration and distribution within the sport complex, creating a brighter and more evenly illuminated environment. This enhancement in daylighting had a positive impact on user experience and performance. Additionally, the optimized toplight system reduced the reliance on artificial lighting, leading to significant energy savings. This aligns with the university's sustainability goals and demonstrates the potential of daylighting strategies for reducing energy consumption. Furthermore, the improved daylighting conditions, including reduced glare and a more natural light environment, contributed to enhanced. Visual comfort and a more positive user experience. This improved well-being can enhance performance and motivation for athletes and staff.

The successful implementation of the toplit the optimization highlights importance of incorporating daylighting strategies during the initial design phase of building projects. This approach can significantly enhance energy efficiency and improve user experience. The use of dynamic lighting control systems can further optimize daylighting performance by adjusting artificial lighting levels based on available daylight. This approach can maximize energy savings and create a more responsive and comfortable lighting environment. The success of this project demonstrates the potential of daylighting strategies for achieving sustainability goals and reducing environmental impact. Integrating daylighting into building design can contribute to a more sustainable built environment. Thereby improving the well being and enhancement of a student.

5. CONCLUSION

This research examines the effect of implementing toplighting strategies as a viable daylighting approach within a sport complex setting. Through analyzing and assessing three common toplighting configurations - the horizontal skylight, vertical roof monitor, and angled saw-tooth designs in terms of their resultant natural light distribution patterns and performance metrics, key conclusions were drawn. It can be summarized that both the horizontal placement of skylights flush with the roof plane as well as vertical installations of roof monitors and saw-tooth glazing offer impactful illumination when optimized. Additional factors like the height and spacing of toplighting openings merit consideration to balance daylight penetration with potential overheating or glare impacts unique to each system orientation and positioning as well as the opening direction are factors affecting. This also study sought to rigorously evaluate the impact of optimizing toplighting configurations on daylight performance within a university sport complex through a mixed- methods approach validated over longitudinal periods. A key takeaway is that strategic daylighting renovations can effectively enhance natural illumination when optimized design considerations are systematically implemented and validated the daylighting performance.

6. REFERENCES

Anthony, Sholanke, Pela Ogheneyoma, Pirisola Heritge, Ogunsade Ayoola and Akerele Fiyinfoluwa, 2020. Daylight Penetration in Buildings: Issues in Tropiical Climates'. Soli State Technology 63 (2s). htttp://solidstatetechnology.us/index.pphp/JSS T/article/view/1530.

Baker, N., & Steemers, K. (2002). Daylight design of buildings. James & James Science Publishers.

Beltran, L.A. (2005). Advanced daylighting technologies for sustainable architecture. AIJ Journal, 171, pp. 459-464.

Bordass, B., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine 1: A portfolioof feedback techniques. Building Research& Information, 33(4), 347- 352. https://doi.org/10.1080/09613210500162022

Chan, Y. C. (2010). Daylighting design: An integrated approach for building project. Pacific Rim Real Estate Society Conference.

Chung, J., & Burnett, J. (2017). Investigation of daylight availability and visual performance in large spaces. Lighting Research & Technology, 49(8), 1026-103 https://doi.org/10.1177/1477153516643922

Demirbilek, O., & Demonja, D. (2004). A daylit classroom: What difference does it make? Lighting Research and Technology, 36(2), 117-126. https://doi.org/10.1191/1365782804li125oa

Galasiu, A. D., & Reinhart, C. F. (2008). Current daylighting design practice: A survey. Building Research & Information, 36(2), 159-174. https://doi.org/10.1080/09613210701779048 Galasiu, A. D., & Veitch, J. A. (2006). Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: A literature review. Energy and Buildings, 38(7), 728-742. https://doi.org/10.1016/j.enbuild.2006.03.001

Green Building Tech HK. (2007, December). Utilization. Retrieved from http://gbtech.emsd.gov.hk/english/minimize/d aylight.html

Heschong, L. (2002). Daylighting and human performance. ASHRAE Journal, 44(6), 65-67.

Lapisa, Remon, Arwizet Karudin, M. Martias, K. Krismadinata, A. Ambiyar,, Zaid Romani and Patrick Salagnac, 2020 'Éffect of Skylight Roof Ratio on Warehouse Building Energy Balance and ThermalVisual Comfort in Hot- Humid Climate Area'. Asian Journal of Civil Engineering 21 (5): 915-23. https/doi.org/10.1007-020-00249-9.

Leaman, A., & Bordass, B. (2001). Assessing building performance in use 4: The Probe occupant surveys and their implications. Building Research & Information, 29(2), 129-143. https://doi.org/10.1080/09613210010007858

Leaman, A., & Bordass, B. (2001). Assessing building performance in use 4: The Probe Occupant surveys and their implications. Building Research & Information, 29(2), 129-143. https://doi.org/10.1080/09613210010007858

Mardaljevic, J., Chandra Mulyana, D.,&Zacarias, M. J. (2019). Visual comfort and energy use: An integrated approach to illumination and daylighting. Building and Environment, 148, 305-316. https://doi.org/10.1016/j.buildenv.2018.10.043

Mandala Ariani, and Amirani Ritva Santoso, 2018. "Comparative Study of Daylighting Calculation Methods'. Edited by R.B. Santosa, N.C. Idham, N.G. Yuli and P.AP. Agustiananda. SHS Web of Conferences 41 (January); 06001. https://doi.org/10.105/shsconf/20184106001.

Raahmah, Adhelia Adjani and Wafirul Aqli,2020. 'Konsep Arsitektur Biomimetik Pada Banhunan Oseanarium'. AETEKS; Journal Tekaik Arsitektur 5 (3); 55-59. https://www.ijrar.org/papers/IJRAR 190993257.

Reinhart, C. F., Mardaljevic, J., & Rogers, Z. (2006). Dynamic daylight performance metrics for sustainable building design. 7- Leukos, 3(1), https://doi.org/10.1582/LEUKOS.2006.03.01. Singh, M. K. (2018). Daylighting techniques and their importance in building design.

Boubekri, M., Lee, J., & Hsu, S. (2014). Daylighting and energy savings in buildings: A review of the literature. Energy and Buildings, 72, 56-67.

Figueiro, M. G., & Rea, M. S. (2012). The effects of daylighting on the performance o occupants. Lighting Research & Technology,44(2), 136-154.