

## Behavioral dimensions of user movement in daylight library spaces: a review

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### Abstract:

This paper analyzes literature on user movement in libraries within the context of daylighting studies, highlighting its significance for library design in relation to daylighting. The objective is to analyze how library user movement has been addressed in daylighting research. The methodology involves a review of literature utilizing the Scopus and Web of Science (WOS) databases focusing on 'library' and 'daylight'. It identifies four main categories of user movement in daylighting studies: User Experience and Spatial Utilization, Dynamic User Positions and Spatial Locations, Walking and Transition, and Occupation Over Time. This approach enhances the understanding of user dynamics in libraries, informing design strategies to optimize user experience. The relationship between user movement and daylighting includes parameters like spatial utilization, dynamic positions, walking patterns, and temporal occupation. It identifies a research gap: insufficient studies on physical interactions with daylighting elements and their potential disruptive effects within libraries. The study concludes by defining library user movement in daylighting studies, identifying spatial exploration, user location choices, movement of others, and temporal movement evolution, impacting user satisfaction, visual comfort, and interactions within library spaces.

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### Keywords:

daylighting, user movement, library, architecture, space

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## 1. Introduction

Over time, libraries have continuously evolved, adapting to changing societal roles, current trends and styles in architecture, and user needs (Fig. 1). As a result, both daylight and the movement of people within library spaces have grown in significance, directly influencing how users interact with their environment. Moreover, the user in the built space is affected by multiple variables and stimuli that shape their spatial experience. Among these factors, one significant variable is the dynamic impact of sunlight within the built space.

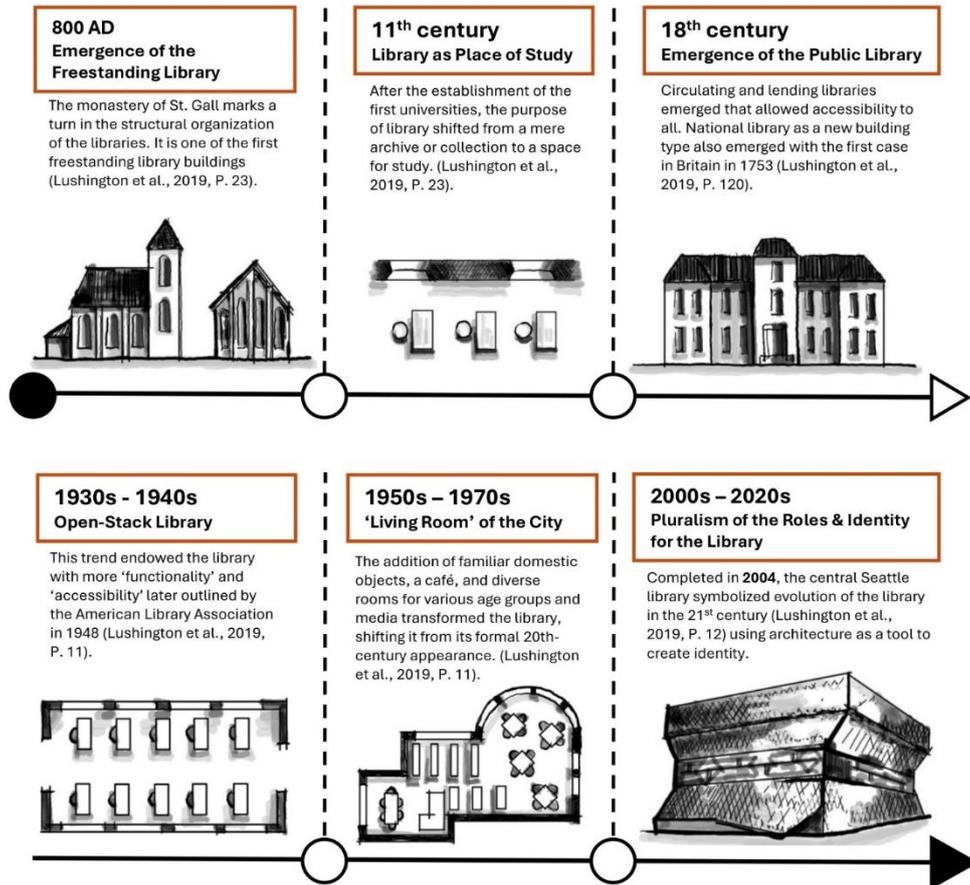
Libraries are sometimes compared to “cathedrals, “shopping malls, or “casinos” [2] because they have this duty to invite people to come in, move around, and motivate them to return. This inviting nature of libraries is further enhanced by architectural elements, such as the use of light, which can draw people in and guide their movement. This idea is reflected in places that “physically connect with light and recall pedestrian movement in a shopping mall” [3] (Fig. 2). Each of these spaces – cathedrals, stores, and libraries – possesses distinct characteristics that shape the unique patterns of movement and interaction within them. In libraries, this takes the form of four stages: scanning, selecting, borrowing/purchasing, and reading materials [4] during the browsing experience.

There are research endeavors to identify different types of users in a library. For example, focusing on the browsing activity

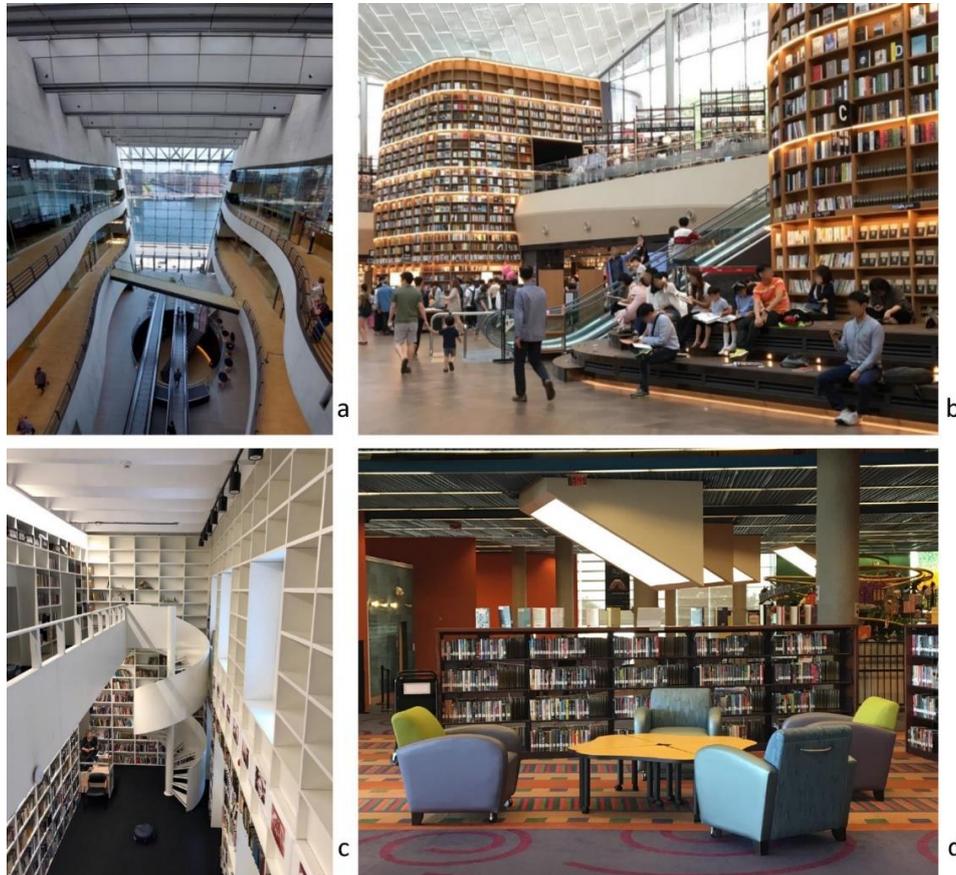
McKay et al. [5] in their research recognized 6 different types of users in a library according to the browsing type in terms of serendipity, information need, search, and book availability; These users could be identified as Grab-and-go, Satisficing, Opportunistic browsing, Search seeding, Location seeding, and Wandering users. However, a distinct methodological approach appears requisite for identification of the types of user movements during daylight hours and by consideration of daylighting literature.

In other words, the exploration of user types and space usage patterns within libraries provides valuable insights for enhancing the design and layout of these environments. However, to better understand the role of library space, especially one that relates to both user movement patterns and daylighting, more research is needed.

Building on efforts to categorize library user behaviors, such as those by McKay et al. [5], this study focuses on understanding how user movement is defined in daylight-related architectural research. To achieve this, it is crucial to first explore how 'user movement' has been addressed in studies linking 'library' and 'daylighting.' This review categorizes various interpretations and applications of user movement within the context of daylighting in architecture, offering insights into the relationship between spatial experience and natural light in libraries. Accordingly, the review seeks to answer the following key question: How is library user movement defined in daylight-related research?



**Fig. 1.** Timeline of library development highlighting periods where daylight and user movement could have influenced design (Source: Authors adapted from Lushington et al. 2019) Source: [1]. (Source of images: Authors)



**Fig. 2.** Det Kongelige Bibliotek in Copenhagen by Schmidt Hammer Lassen Architects (a). Starfield Library, Seoul by Gensler (b). Library of the Krzysztof Kieślowski Film School in Katowice by firma BAAS Architecture & Design (c). ImaginOn: The Joe & Joan Martin Center in Charlotte by Gantt Huberman Architects and Holzman Moss Bottino Architecture (d). Source of images: authors

Aiming to group and provide a structured framework for further study, focusing on understanding library user movement in relation to daylighting, the objectives of this review are:

1. Review of the existing literature, including the keywords of 'library' and 'movement', and categorization of the interpretations of user movement:  
To categorize how different studies define and analyze user movement concerning daylighting in libraries, focusing on the impact of natural light on movement patterns.
2. Examination of the user movement and daylighting:  
To explore how user movement is addressed in studies linking libraries and daylighting, examining the interplay between movement, natural light, and architectural design.

### 1.1. Definitions

- User behavior: The patterns of human activity, including desires, motivations, and feelings, that both shape and are shaped by the built environment [76]. In this study, user behavior refers to goal-oriented or exploratory strategies that library users adopt, which are inferred through observable movement patterns within the library space.
- Library user: A library user or visitor who engages with the library's resources and services. Users may scan, select, borrow, purchase, or read materials during their browsing, working, or studying experience within the library.
- Movement: Movement refers to the dynamic interactions and physical activity of library users within a space. In the context of this review, it involves the locations, patterns, and pathways library users take as they navigate and

interact with the library environment, particularly how these patterns are influenced by daylighting.

- Daylighting: The use of natural light to illuminate the interior of a building, affecting both the visual and spatial experience of users.

In this paper, the terms user behavior and user movement are closely related but not interchangeable. User behaviors refer to the underlying intent or browsing strategy of library users, while user movement describes the observable spatial behaviors through which these behaviors could be expressed.

### 2. Review methodology

The methodology of this study consists of a structured literature review conducted using the Web of Science (WoS) and Scopus databases. These databases were selected for their broad, interdisciplinary coverage of peer-reviewed research in architecture, engineering, and related fields. The review was conducted in two phases and included all records indexed in both databases up to January 2025 (Fig. 3).

In the first phase that was Identification and Initial Filtering, a comprehensive search was performed using the primary keywords "daylight" (including daylighting) and "library." applied across both databases. This initial search yielded 266 records in total. To refine the results, built-in database filters were applied. In Scopus, the search was restricted to TITLE-ABS-KEY, while in WoS the Topic field was used. This refinement reduced the dataset to 106 records. The retrieved studies spanned multiple disciplinary categories, including Architecture, Art, and Urban Studies (WoS) and Engineering, Energy, Social Sciences, Arts and Humanities, and Psychology (Scopus).

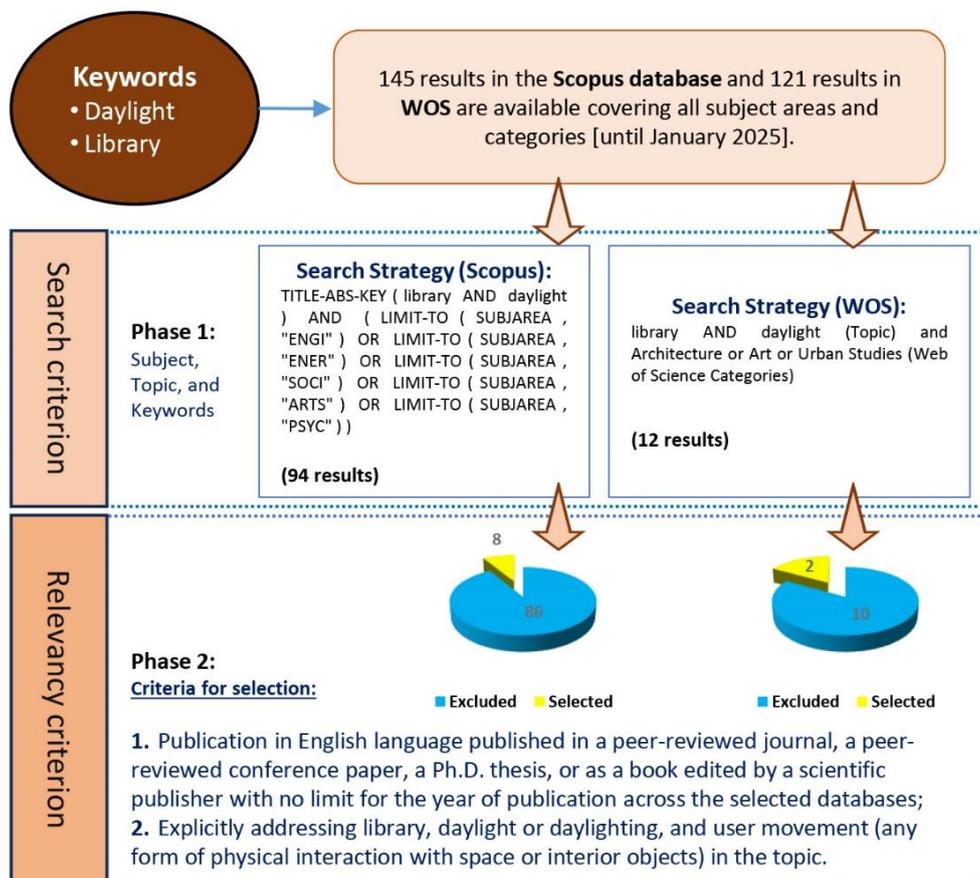


Fig. 3. The search strategy of the review. Source: authors

In the second phase (screening), the titles, abstracts, and keywords of the 106 records were screened in detail according to the predefined inclusion and exclusion criteria (see Fig. 3). Studies were included only if they explicitly addressed user movement in relation to daylight within library buildings. Papers that focused solely on daylighting performance without reference to movement, or on movement without daylight considerations, were excluded.

Following this screening process, 10 studies met all inclusion criteria and were selected for in-depth qualitative analysis. The selected studies were systematically analyzed and coded to identify how movement was conceptualized and investigated in relation to daylight. The extracted data were synthesized into thematic categories, enabling the identification of patterns, research emphases, and gaps in the literature.

This study aims to classify research studies into distinct categories. To achieve this, an initial analysis was conducted (refer to Annex 1), identifying six categories. However, research on library buildings reveals that only four of these categories have been explored. These four main categories originate from a broader analysis encompassing various building types and focusing on movement in daylight research (Annex 1). Table 1

depicts the coding process for grouping the studies. This categorization is based on thematic convergence observed during the analysis of the selected studies in this paper and Annex 1, ensuring alignment with the key focus areas of existing research and providing a structured framework for further review. The criteria for grouping the studies, based on the relationship between movement, space, and daylight, are as follows:

- Similarity or uniqueness in terminology (General criterion): Categorizing studies based on linguistic or terminological similarities used to describe various types of movement or interactions.
- Intention of movement: Grouping studies according to the purpose or goal behind the movement, such as whether it is driven by necessity, the choice of a specific destination, or simply exploration.
- Scale and time of movement: Categorizing based on the spatial scale (e.g., individual movement within a specific area versus group movement spanning larger spaces or zones) and the temporal aspect (e.g., immediate movement as short-term actions versus prolonged movement as long-term or continuous behavior).

**Table 1.** Category coding. Source: authors

Category	Scope	Inclusion	Exclusion
1. User Experience and Spatial Utilization	How daylight influences spatial experience, perceived comfort, spatial efficiency, and integration of daylight with activities and movement	<ul style="list-style-type: none"> <li>• Perceived spatial quality related to daylight</li> <li>• How users use or navigate spaces based on daylight</li> <li>• behavioral and activity patterns influenced by daylight</li> </ul>	<ul style="list-style-type: none"> <li>• Seating/location decisions (Cat. 2)</li> </ul>
2. Occupants' Positions and Choice of Spatial Locations	Where people choose to sit, stand, work, or position themselves in relation to daylight	<ul style="list-style-type: none"> <li>• Seat/desk choice and window proximity</li> <li>• Attraction/avoidance patterns</li> <li>• Spatial clustering linked to illuminance</li> </ul>	<ul style="list-style-type: none"> <li>• Circulation/movement (Cat. 3)</li> <li>• Temporal occupancy cycles (Cat. 4)</li> </ul>
3. Walking and Transition	Movement flows within or between indoor/outdoor spaces where daylight affects navigation, transitions, or circadian responses	<ul style="list-style-type: none"> <li>• Circulation in Pedestrian pathways, corridors and transitional zones</li> <li>• Daylight as a cue for navigation/orientation</li> <li>• Perceptual or visual transitions along daylighted paths</li> </ul>	<ul style="list-style-type: none"> <li>• Static seating/location behavior (Cat. 2)</li> <li>• Longitudinal occupancy or temporal usage patterns (Cat. 4)</li> </ul>
4. Occupation Over Time	Temporal patterns of occupancy, including duration, frequency, and alignment with daylight cycles	<ul style="list-style-type: none"> <li>• Duration of occupancy</li> <li>• Time-of-day patterns</li> <li>• Longitudinal occupancy trends</li> <li>• Circadian alignment</li> </ul>	<ul style="list-style-type: none"> <li>• Single-moment seating choices (Cat. 2)</li> <li>• Transitional movement (Cat. 3)</li> </ul>
5. Physical Interaction	Physical manipulation or adjustment of daylighting systems and other adaptive behaviors responding to daylight	<ul style="list-style-type: none"> <li>• Manual control of blinds/shades</li> <li>• Lighting on/off switching</li> <li>• Adjustment of activities to daylight conditions</li> <li>• Adaptive/stochastic user behavior related to light use</li> </ul>	<ul style="list-style-type: none"> <li>• Comfort or perception without physical interaction (Cat. 1)</li> </ul>
6. Disruptive User–Space Interaction	Behaviors where daylight or thermal/light conditions trigger disruptive reactions, maladaptive responses, escape/migration, or indirect physiological shifts	<ul style="list-style-type: none"> <li>• Occupant escape/migration due to lighting discomfort</li> <li>• Delayed manual control leading to discomfort</li> <li>• User interaction with lighting/cooling systems in response to discomfort</li> <li>• Disruptive or abrupt movement patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Normal or adaptive manual control (Cat. 5)</li> <li>• Intentional, comfortable transitions (Cat. 3)</li> <li>• Regular seating adjustments (Cat. 2)</li> </ul>

### 3. Results

After reviewing the titles, abstracts, keywords, methodology, and conclusions of all selected papers in Phase 1 (see Fig. 3), 10

papers were chosen for in-depth analysis. These papers met the selection criteria outlined in Phase 2 (see Fig. 3).

According to the analysis of the reviewed studies, these ten research elements can be categorized into the following four

general categories in the next subsections. These four main categories stem from a broader analysis covering all building types that link the study of movement in daylight studies (refer

to Annex 1). The research sample studied could be listed in the table below (Table 2).

**Table 2.** The analysis of the samples Source: authors

Reference	Spatial Characters Under Study	Elements related to daylight	Methods related to daylight	Elements related to movement description	Methods related to movement
[12]	Study areas; Furniture arrangement; Spatial orientation; Interior materials and objects	Window location; Solar gain; Indirect daylight	Direct observation and description; Questionnaire; Photography; Schematic simulation	Users' physical behavior; Table selection; User activity; Use of study area	Literature review; Questionnaire
[6]	Dark and light areas; Library interior	Visiting experience; Lighting experience to attract users; User attractors	Experiment: participants entering and walking through the space	Visiting experience; Lighting experience to attract users; User attractors	Experiment: participants entering and walking through the space
[8]	Glass curtain; walls	-	Daylight Simulation	Spatial experience	-
[13]	Shading systems	-	Daylight Simulation	User position in the room	-
[10]	Daylit and non-daylit areas	-	Questionnaire; Experiment	Seat selection	Seat selection
[15]	Furniture layout	-	Daylight Simulation; Environmental measurements	Presence and Movement of people	-
[9]	Physical environment	Feelings toward daylight	Review	Circulation area; seating layout	-
[16]	Architectural elements	Hollow prismatic light guides		User behavior	Monitoring with a datalogger
[11]	Library space	-	Survey	Choice of seat; Circulation guidance; Crowding	Observation
[7]	Spatial openness	-	Comparative case studies	Democratic and physical openness	-

### 3.1. User experience and spatial utilization in the library setting

Spatial experience in the library connotes the user's attendance and exploration of the space, involving movement through the literature of the study. Jørgensen et al. [6] conducted a study investigating user experience regarding brightness, dark-to-light variation, and luminance, aiming to understand the impact of daylight strategies on user perceptions. Data collection methods included subjective evaluations through questionnaires administered after users entered and moved through the libraries, HDR (High Dynamic Range) photography, and luminance mapping. Additionally, daylight factor (DF) measurements were employed to assess the effectiveness of daylighting strategies. The study, conducted across three public libraries in Denmark, provided valuable insights into the design implications of daylighting strategies for user experience. The libraries reflect distinct strategies:

- Gentofte emphasized meticulous daylight planning with intuitive design,
- Albertslund prioritized flexibility and functional lighting with engineering input,
- and Frederiksberg used dramatic light staging but faced thermal issues, highlighting a trade-off between artistic vision and practical considerations.

Daylight shapes spatial experiences, creating ambience while supporting functional needs like reading and visibility. Successful designs balance aesthetic goals with practical

requirements, as seen in Albertslund's efficient lighting and Frederiksberg's impactful yet uneven skylight strategy.

Enhancing the user experience in the library – or, more specifically, facilitating user movement – has been one of the aspects of library design and trends research. For example, Edwards [7] investigated new trends in library design focusing on physical openness, democratic openness, transparency, and view-out elements. Using comparative case studies, the research examined how these design features contribute to sustainable practices within library environments. By exploring these aspects, the study aimed to highlight green innovative approaches to library design that promote sustainability and enhance user experiences through openness, transparency, and connections to the surrounding environment. This research contributes valuable insights into the evolving landscape of 21st century library architecture by signifying the return of library design to the modernist Scandinavian concepts such as 'high levels of daylight' and 'social harmony.' Moreover, one of the most recent studies, Liu et al. [8] explores the integration of building simulation techniques with architectural design principles to optimize lighting performance, particularly in libraries. While this study does not directly explore user behavior, it emphasizes the use of glass curtain walls to achieve optimal lighting conditions, aiming to improve spatial experience and minimize issues related to sun exposure and glare within library spaces. In addition, in another study to increase 'library space utilization', Mortazae and Haron [9] conducted a review focusing on the impacts of daylight on luminous comfort in

libraries. The study examined various aspects of the physical environment, such as floor level and interior design elements, including circulation area and seating layout, that directly impact satisfaction with daylight. This review paper investigated user perceptions towards daylight, satisfaction with daylight, and overall luminous comfort in library settings. By reviewing these factors, the study aimed to enhance users' motivation to utilize library spaces through improved luminous comfort considerations. This review contributes valuable insights into optimizing library environments to promote user satisfaction and well-being related to daylighting conditions.

All in all, these studies define movement as user attendance and spatial exploration within the library, encompassing navigation and interactions with the environment. They highlight the influence of daylight strategies on user perceptions, assessed through evaluations and luminance mapping, and emphasize the role of daylight integration in enhancing satisfaction and well-being.

General solid design recommendations and daylight treatments to increase space utilization identified in the research include: to optimize library space, bookshelves should be positioned perpendicular to windows to maximize daylight use and reduce glare. Circulation paths should also be aligned perpendicularly to study carrels to control daylight exposure in work areas. Placing individual study carrels near windows with low partitions provides controlled daylight and exterior views, enhancing user satisfaction and performance. Spatial layouts that provide higher daylight availability in seating areas are associated with higher space utilization [9] (See Fig. 4).

Additionally, architectural vision should not be prioritized over practical daylight distribution and thermal comfort. More specifically, the study recommends that architectural daylight strategies should be formulated at the design stage to ensure they are effectively experienced by users. Strategies that incorporate spatial considerations – such as even daylight distribution – receive more positive evaluations [6] (See Fig. 5).

### 3.2. Occupant's positions and choice of spatial locations

To study daylight performance, occupant movement can be categorized into three scales [75]. This section focuses on changes in position (movement of the joints within a specific location) and changes in location (movement of the entire body through space) (Figs. 6B and 6C). The figure below illustrates all three movement scales (Fig. 6).

In the review, existing literature has primarily focused on the concept of 'occupant's choice of location', particularly 'seat selection' as studied by Izmir Tunahan et al. [10] within this category. This research specifically investigates how movement and daylight relate within a library setting. One of their findings indicates that seat preferences in a library are primarily influenced by daylight availability, followed by privacy, outdoor views, quietness, and minimal interaction with others, with subjective daylight ratings aligning closely but not perfectly with actual conditions. However, there was another study done on how users choose their seats in a library. Kilic and Hasirci [11] conducted a study focusing on the examination of the various factors related to user experience, including seat selection, circulation guidance, privacy, personal space, territoriality, and crowding, in the context of daylight appraisal. The study investigated how users choose their seats based on daylight perception and environmental factors influenced by seating distance. Data collection methods included observation and surveys conducted within library settings. By exploring these aspects, the study aimed to understand the impact of daylighting on user satisfaction and seating behavior in university library environments, providing insights to optimize library design and enhance the user experience and well-being. More specifically, visual comfort and environmental processes should be prioritized when designing university library spaces to enhance user experience in terms of visual comfort, privacy, personal space, territoriality, and crowd management.

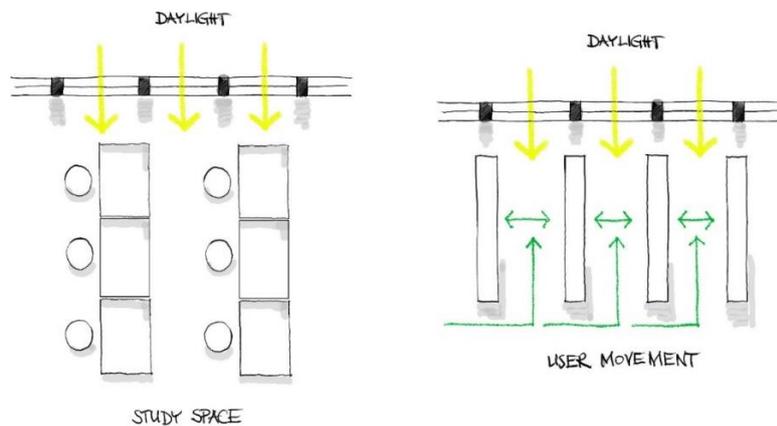


Fig. 4. Arrangement of library shelving and study areas considering daylight (perpendicular to the direction of light through the windows). Source: authors

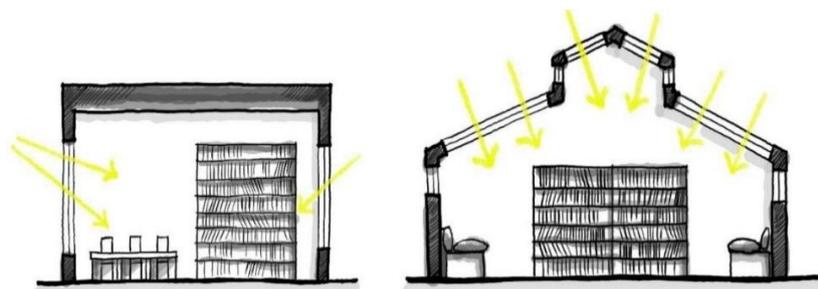
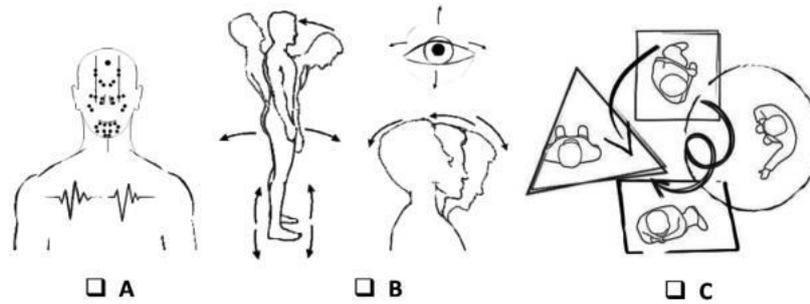


Fig. 5. Even daylight distribution in the library. Source: authors



**Fig. 6.** Movement scales. Movement of the facial muscles and heart (A), Movement of the joints and eye (B), and Movement of the body through the space (C). Source: [75]

Not only was seat selection examined in the research on the library research on daylighting, but table selection was also investigated. Aram and Alibaba [12] conducted a study investigating the effects of daylight in a university library. The research focused on users' psychological behavior, table selection, and user activities in relation to daylight glare, intensity, window location, and solar gain. The study aimed to understand both the positive and negative impacts of daylight on user mood and physiological behavior within the library environment. Data collection methods included direct observation and description, photography, and schematic simulation to assess solar radiation and solar gain. By exploring factors like window location, glare, solar gain, and furniture arrangement, the study provides insights into optimizing daylighting strategies in university libraries to enhance user experience and well-being, showing that indirect daylight improves energy and comfort, while excessive glare and solar heat gain can cause discomfort and reduce productivity. Designers can optimize study spaces by adjusting building orientation, window size, and shading to manage these challenges and enhance functionality.

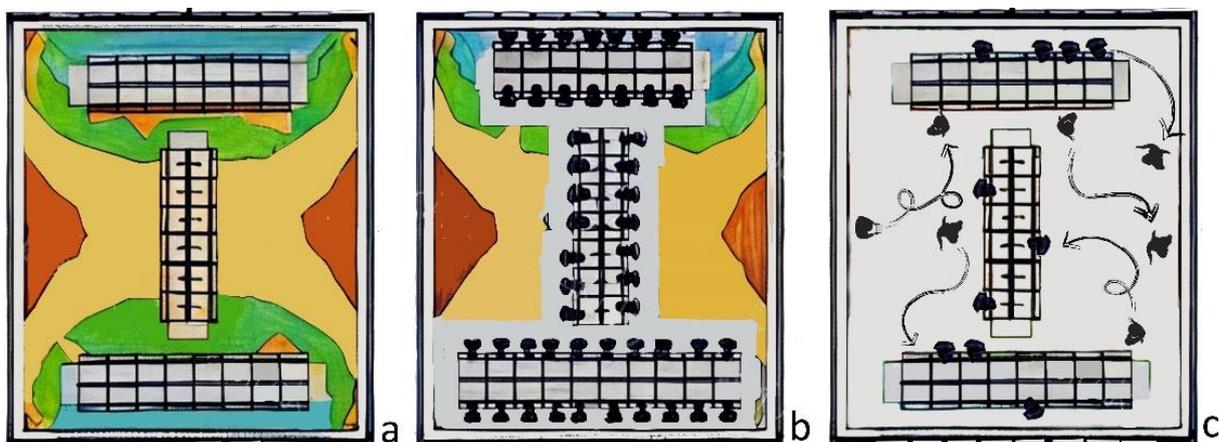
All in all, these studies aim to find the optimal user location and positions within the library space. More specifically, Dabaj et al. [13] focused on recommending optimal user positions corresponding to different types of shading devices to mitigate glare issues. By employing simulation techniques specific to reading room environments, the research highlights the importance of strategically placing users relative to the shading devices to enhance visual comfort and daylight utilization within such spaces.

Movement in this context is defined as the “occupant’s choice of location within the library,” with a focus on seat and

table selection influenced by daylight. Research explores how users select seats based on daylight perception and environmental conditions, using methods such as observations, surveys, and simulations. The goal is to optimize seating arrangements for better visual comfort and efficient daylight utilization, while addressing challenges such as glare and solar heat gain.

### 3.3. Walking and transition

The presence of the movement of other people apart from the user itself has been an interesting phenomenon to study since it might impact the learning process in a library setting as well. As in the library buildings, Nasrollahi and Shokry [15] conducted a study investigating the impact of various factors, including furniture layout, and ‘presence and movement of people’ in the study spaces. On the other hand, the parameters related to daylighting aspects in the study were window form and position, uniformity, daylight factor, and reflectivity on daylighting, visual comfort, and electrical energy performance. The study developed an optimized architectural model using simulation techniques and environmental measurements to enhance the quality of study spaces in libraries. It highlights how strategic adjustments to design elements, such as furniture layout, can improve daylight distribution and energy efficiency while ensuring visual comfort for users. One scenario with people in the simulation showed that their presence had minimal impact on the uniformity rate and daylight factor, which stayed within the standard range, maintaining optimal daylight distribution and visual comfort (Fig. 7). In this category, daylighted environments are examined in relation to users’ walking, presence, and transitional movement patterns within the library.



**Fig. 7.** Visualization of the impact of the presence of movement on the daylight distribution for three scenarios of without users (a), with static users (b), and with dynamic users (c). Source: authors

### 3.4. Occupation over time

Time is integral to understanding movement in both physics and architecture. In daylighting design for the libraries, it is crucial to consider how user movements change throughout the day, across seasons, under varying daylight conditions, and to adapt spaces to support these dynamic patterns. One study that considers movement as an occupation over time was conducted by Omar et al. [16]. They conducted a study that investigated user behavior and daylight utilization through lighting simulation and occupancy pattern monitoring to propose optimal daylighting strategies. By examining daylight conditions and energy performance, the study aimed to enhance energy efficiency in the library environment. The research involved monitoring with dataloggers to gather data on user behavior and daylighting patterns within the library setting, providing valuable insights into effective daylighting strategies for energy conservation.

In this category, movement is defined as the 'evolution of people's movements over time' within the library space, influenced by varying daylight conditions. This includes examining user behavior and daylight utilization through lighting simulations and occupancy pattern monitoring. Studies aim to propose optimal daylighting strategies to enhance energy efficiency and adapt to shifting mobility patterns and activities.

## 4. Discussions

The movement-related categories introduced in this paper are derived from studies across multiple building types and are subsequently applied to the library context. In daylighting research, atriums have received considerably more attention than libraries in terms of space utilization and experiential quality. Studies highlight how atriums influence architectural space dynamics and emotional engagement, often functioning as vibrant and interactive hubs depending on building function, location, and design [17,18]. Similarly, Ma and Yang [19] examined atriums as activity centers, emphasizing daylight-driven architectural strategies to optimize spatial efficiency and accommodate diverse activities. Although these studies do not explicitly measure user movement, they implicitly address movement through patterns of use, engagement, and spatial occupation. More broadly, research on passive design [20] demonstrates how spatial layout, activity distribution, and illuminance levels collectively shape building utilization. Biophilic design, as a form of passive design, has been associated with active behavior [72], defined as purposeful physical movement stimulated by spatial and daylighting conditions, particularly in healthcare environments. Comparable findings are reported in indoor sports research [73,74], where natural light influences physiological states such as alertness, directly affecting movement intensity and performance. Together, these studies support the User Experience and Spatial Utilization category by illustrating how daylight indirectly shapes exploratory and activity-based movement patterns. Research on smart buildings [21] and traditional architectural design [22] further reinforces the role of atriums in enhancing spatial experiences through integrated daylighting strategies. In library contexts, atriums also offer opportunities to support user-centered goals, enabling more integrated movement patterns alongside natural lighting.

Regarding Occupants' Positions and Choice of Spatial Locations, research beyond library settings has extensively addressed movement in relation to daylight. As underscored by research [14], there is a close interconnection between perception and action. Urban studies [23] document behavioral adaptations

in city squares, particularly resting and positioning behaviors influenced by daylight exposure. Zeibo et al. [24] further advanced this understanding by predicting pedestrian movement at urban intersections based on location and speed parameters. In interior environments, studies integrating daylight analysis with user movement [25] have enabled forecasts of illuminance levels for lighting control, while earlier work [26] demonstrated reductions in energy consumption through the identification of actual activity patterns and daylight presence. Hosseini et al. [27] expanded this approach using parametric simulations focused on users' fields of vision and dynamic attraction points. Occupant position selection has also been central to spatial design evaluation and energy optimisation. Previous studies [28] mapped occupants' choice of location to improve energy performance, while others examined visual comfort through movable views in office buildings [29], glare mitigation strategies based on occupant location [30], and blind control systems informed by occupant position and activity [31]. Earlier work by Atzeri et al. [32] proposed comfort metrics incorporating occupant position and reaction at early design stages. Collectively, these findings reinforce the relevance of dynamic positions and locations as a key daylight-responsive behavior extending well beyond library environments.

The Walking and Transition category similarly aligns with extensive research across urban and interior contexts. De Montigny et al. [33] observed pedestrian walking habits in relation to environmental conditions, identifying correlations between weather, daylight, and movement. Earlier studies [34,35] examined how daylight and street-level movement patterns affect microclimatic conditions, including usage intensity and shade availability. More recent work by Liu et al. [36] integrated user movement, lighting comfort, and daylight to optimize lighting solutions, while other studies modelled daylight behavior in historic streets [37] and analyzed design strategies for creating inviting walking environments [38]. Indoor-focused research further highlights the coupling of perception and movement, including studies on historic interiors [39], safe movement transitions [40], sensorial perception and light dynamics [41], experiential enhancement in interior design [42], and synchronization between human movement and circadian rhythms [43].

With respect to Occupation Over Time, daylighting research has traditionally concentrated on office buildings and working hours rather than libraries. However, as libraries increasingly serve as multifunctional workplaces, temporal occupancy patterns are becoming increasingly relevant. Studies by Jens and Khoudi [44] examined occupancy duration alongside daylight presence using post-occupancy evaluations, while Hunt's pioneering work [45] emphasized occupation cycles as a fundamental factor in lighting and energy research. Subsequent studies [46] explored occupancy duration and manual control behavior in relation to energy use, leading to broader attention to space occupation hours in daylighting research. Temporal mapping approaches [47] have been used to optimize design strategies, while further studies examined space occupation hours [48], daylight usage duration [49], and passive daylighting systems in relation to energy conservation and visual comfort [50,51,52]. In library settings, prolonged stationary occupancy is common, as illustrated in Fig. 8, where extended periods of static presence are observed in study areas. These patterns demonstrate that movement in libraries often manifests as temporal occupation rather than continuous physical circulation, reinforcing the relevance of time-based movement categories in daylight-focused research.



**Fig. 8.** Maly Kack Library in Gdynia. User occupancy over time, representing periods of extended stationary presence in the library without frequent movement or browsing. *Source:* authors

Despite these insights, this review identified a notable research gap: the limited consideration of physical interaction with daylighting elements and disruptive user–space interactions within library environments. While such behaviors have been examined in other building types under terms such as user action, interaction, and reaction [53-58], usage behavior [54,57,58], user customs, habits, and adaptive behavior [59-65], their application to libraries remains scarce. Similarly, disruptive responses - including parasitic energy consumption [66], delayed manual control [67], user escape [68], and migratory living patterns [69] – have been explored outside library contexts but are largely absent from library-focused daylighting studies.

Overall, the reviewed literature demonstrates consistent patterns of movement categorization across spatial utilization, positional behavior, walking and transition, and occupation over time. In library contexts, these patterns intersect with user experience, seating and table selection, circulation, and prolonged occupancy, highlighting the importance of integrating daylighting strategies with movement-sensitive design. However, a deeper understanding of library user movement also requires consideration of user diversity and library typologies. Kim and Choi [70] identify four primary library types – public, special, school, and academic – consistent with classifications proposed by the Illuminating Engineering Society [71]. Recognizing these distinctions is essential for interpreting movement behaviors and daylight sensitivity across different library environments.

Last but not least, a nuanced relationship can be observed between McKay’s six library user behaviors and the movement categories proposed in this review. As illustrated in Fig. 9, behaviors such as Wandering, Opportunistic Browsing, and Location Seeding appear to be the most strongly influenced by daylighting conditions. These behaviors are characterized by exploratory, visually driven, and nonlinear movement patterns, where users respond to spatial cues, visibility, and perceived ambience rather than following a fixed, goal-oriented path. In these cases, daylight plays an active role in shaping movement by enhancing spatial legibility, encouraging serendipitous exploration, and fostering positive associations with locations within the library. In contrast, more goal-driven behaviors such as Grab-and-Go, Satisficing, and Search Seeding demonstrate a more limited sensitivity to daylighting. These behaviors prioritize efficiency, proximity to target items, or predefined search strategies, resulting in movement patterns that are primarily function-driven and less dependent on environmental qualities. While daylight may still support visibility and

orientation in these cases, it is not the primary determinant of user movement. Together, these distinctions support the applicability of the proposed movement framework by demonstrating how different types of library user behavior align with varying degrees of daylight influence. However, the relationships identified here remain interpretative and indicative rather than conclusive. Further empirical behavioral research – such as observational tracking, movement mapping, and longitudinal studies – is required to validate and refine the connections between specific daylighting conditions and library user behaviors.

## 5. Conclusions

This review proposes a movement-oriented conceptual framework for understanding daylighting research, synthesizing six movement-related categories that capture the reciprocal relationship between daylight and human behavior. Rather than treating movement solely as physical displacement, the framework conceptualizes movement as a combination of spatial experience, positional choice, circulation, interaction, disruption, and temporal occupation. Across these categories, movement is understood both as a response to daylight – shaping user actions, perceptions, and behavioral adaptation - and as an active modifier of daylight conditions through occupancy patterns, spatial positioning, and interaction with building systems.

When applied to library buildings, this framework reveals a notably limited body of research. Only ten studies were found to explicitly address user movement in relation to daylighting, highlighting a clear research gap. Within these studies, movement in libraries is primarily conceptualized through four categories. First, User Experience and Spatial Utilization associate movement with user presence, engagement, and exploratory behavior, emphasizing how daylight influences comfort, satisfaction, and perceived spatial quality. Second, Occupants’ Positions and Choice of Spatial Locations frames movement through seat and table selection, demonstrating how users actively position themselves in relation to daylight conditions. Third, Walking and Transition interpret movement through circulation and the perceived presence of others, influencing awareness, learning processes, and social dynamics within library spaces. Fourth, Occupation Over Time understands movement as a temporal phenomenon, reflecting how user behavior evolves throughout the day in response to changing daylight conditions.

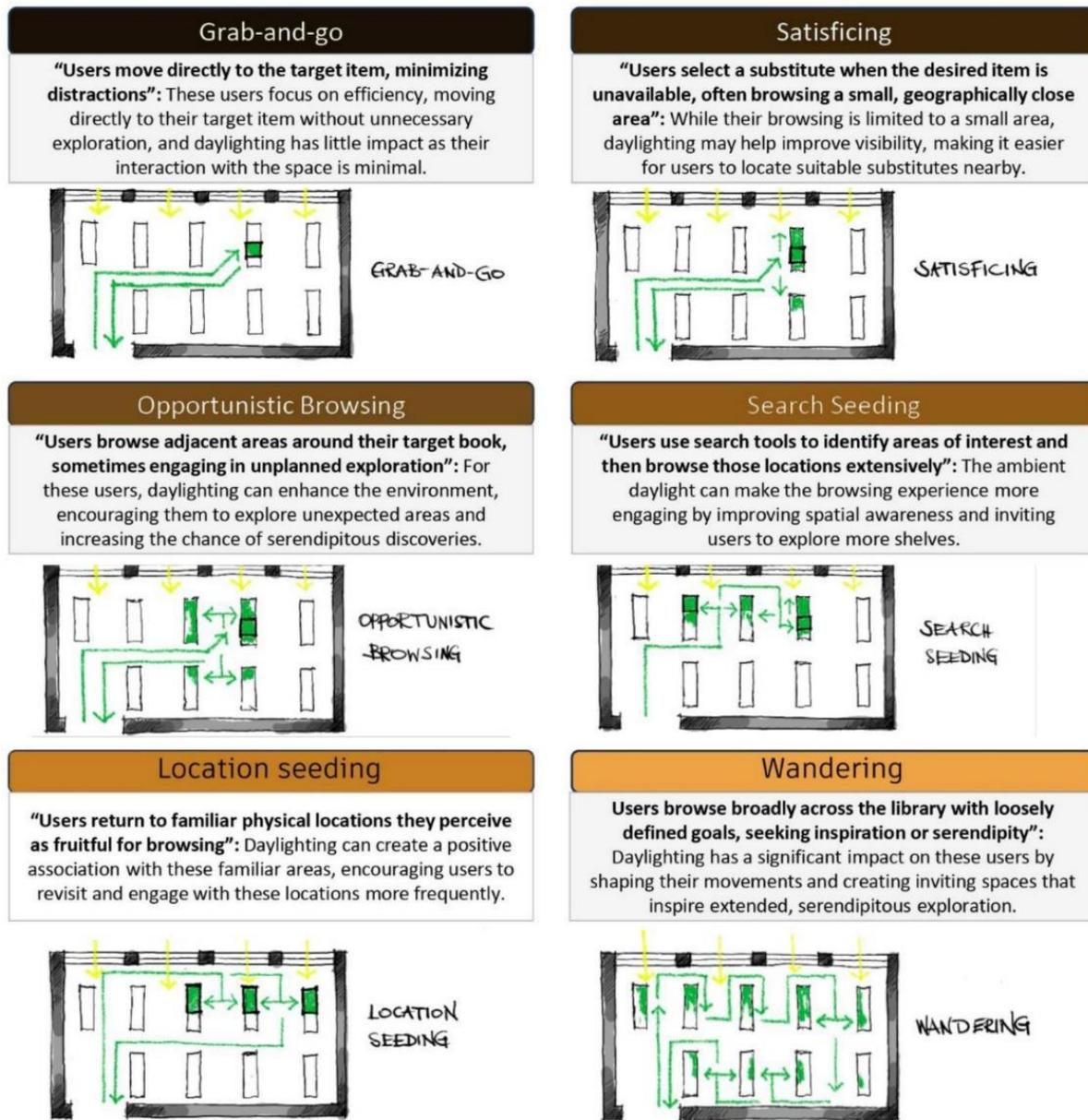
Collectively, these findings show that movement in library daylighting studies is largely indirect, expressed through

positional behavior, visual perception, and prolonged occupancy rather than frequent physical circulation. Notably, none of the reviewed studies address physical interaction with daylighting systems – such as manual blind adjustment – or disruptive user-space interactions, despite their documented importance in other building types. This absence represents a significant gap in both behavioral and daylighting research within library contexts.

The review further demonstrates that library user behavior – particularly seat and table selection, spatial preference, and sensitivity to the presence and movement of others – plays a critical role in shaping daylight perception and comfort. These

behaviors vary across library types and user groups, underscoring the importance of accounting for functional diversity in both research and design.

Future research should adopt empirical behavioral methods, including observational tracking, movement mapping, and longitudinal studies, to examine how multiple movement categories operate simultaneously in libraries. Greater attention to user interaction with daylighting systems and to disruptive or adaptive behaviors will be essential for developing more responsive, user-centred, and daylight-sensitive library environments.



**Fig. 9.** The likelihood of daylighting’s impact on the Six Library User Behaviors through an abductive analysis. The definitions shown in bold format are (adapted from [5]). Possible movement patterns in the library space, considering the Six Library Users Behaviors, the location of the desired target, and daylighting. Source: authors

**Conflict of interest**

The authors declare no conflict of interest.

**Data Availability Statement**

All data supporting the findings of this study are provided in the main manuscript and the annex.

**References**

- [1] Lushington N., Rudorf W., Wong L., *Libraries - A design manual*, 1st ed. Birkhäuser, 2019.
- [2] Lushington N., Rudorf W., Wong L., *Libraries - A design manual*, 1st ed. Birkhäuser, 2019, 167, 145, 18.
- [3] Lushington N., Rudorf W., Wong L., *Libraries - A design manual*, 1st ed. Birkhäuser, 2019, p. 167.

- [4] Lushington N., Rudolf W., Wong L., *Libraries - A design manual*, 1st ed. Birkhäuser, 2019, p. 100.
- [5] McKay D., Chang S., Smith W., Buchanan G., The things we talk about when we talk about browsing: an empirical typology of library browsing behavior. *Journal of the Association for Information Science and Technology* 70(12) (2019) 1383–1394. <https://doi.org/10.1002/asi.24200>
- [6] Jørgensen M., Iversen A., Jensen L.B., Investigation of architectural strategies in relation to daylight and integrated design: a case study of three libraries in Denmark. *Journal of Green Building* 7(1) (2012) 40–54. <https://doi.org/10.3992/jgb.7.1.40>
- [7] Edwards B.W., Sustainability as a driving force in contemporary library design. *Library Trends* 60(1) (2011) 190–214. <https://doi.org/10.1353/lib.2011.0030>
- [8] Liu Q., Han X., Yan Y., Ren J., A parametric design method for the lighting environment of a library building based on building performance evaluation. *Energies* 16(2) (2023) 832. <https://doi.org/10.3390/en16020832>
- [9] Mortazae S., Haron S.H., A review of daylight impacts on luminous comfort in libraries. In: Bin Meor Razali A. M. M. F., Awang M., Emamian S. S. (eds) *Advances in Civil Engineering Materials*. Lecture Notes in Civil Engineering, vol 139. Springer, Singapore. [https://doi.org/10.1007/978-981-33-6560-5\\_1](https://doi.org/10.1007/978-981-33-6560-5_1)
- [10] Izmir Tunahan G., Altamirano H., Teji J.U., Ticleanu C., Evaluation of daylight perception assessment methods. *Frontiers in Psychology* 13 (2022) 805796. <https://doi.org/10.3389/fpsyg.2022.805796>
- [11] Kilic D.K., Hasirci D. Daylighting concepts for university libraries and their influences on users' satisfaction. *The Journal of Academic Librarianship* 37(6) (2011) 471–479. <https://doi.org/10.1016/j.acalib.2011.07.003>
- [12] Aram R., Alibaba H.Z., Investigation of the effects of daylight in a university library. *Journal of Architectural and Planning Research* 35(4) (2018) 343–356. <https://www.jstor.org/stable/26893777>
- [13] Dabaj B., Rahbar M., Fakhr B.V., Impact of different shading devices on daylight performance and visual comfort of a four opening sides' reading room in Rasht. *Journal of Daylighting* 9(1) (2022) 97–116. <https://doi.org/10.15627/jd.2022.7>
- [14] Jelić A., Tieri G., de Matteis F., Babiloni F., Vecchiato G., The enactive approach to architectural experience: a neurophysiological perspective on embodiment, motivation, and affordances. *Frontiers in Psychology* 7 (2016) 481. <https://doi.org/10.3389/fpsyg.2016.00481>
- [15] Nasrollahi N., Shokry E., Parametric analysis of architectural elements on daylight, visual comfort, and electrical energy performance in the study spaces. *Journal of Daylighting* 7(1) (2020) 57–72. <https://doi.org/10.15627/jd.2020.5>
- [16] Omar O., García-Fernández B., Fernández-Balbuena Á.Á., Vázquez-Moliní D., Optimization of daylight utilization in energy saving application on the library in faculty of architecture, design and built environment, Beirut Arab University. *Alexandria Engineering Journal* 57(4) (2018) 3921–3930. <https://doi.org/10.1016/j.aej.2018.10.006>
- [17] Yunus J., Ahmad S.S., Zain-Ahmed A., Analysis of atrium's architectural aspects in office buildings under tropical sky conditions. 2010 International Conference on Science and Social Research (CSSR 2010), 2010, 536–541. <https://doi.org/10.1109/CSSR.2010.5773836>
- [18] Hourani M.M., Hammad R.N., Impact of daylight quality on architectural space dynamics. *Renewable and Sustainable Energy Reviews* 16(6) (2012) 3579–3585. <https://doi.org/10.1016/j.rser.2012.02.074>
- [19] Ma J., Yang Q., Optimizing annual daylighting performance for atrium-based classrooms of primary and secondary schools in Nanjing, China. *Buildings* 13(1) (2022) 11. <https://doi.org/10.3390/buildings13010011>
- [20] Ouahrani D., Assessment of climate adaptation of youth club in Tozeur, south of Tunisia. *Energy Procedia* 30 (2012) 1205–1215. <https://doi.org/10.1016/j.egypro.2012.11.133>
- [21] Kaiwen C., Kumar A., Xavier N., Panda S. K., An intelligent home appliance control-based on WSN for smart buildings. in 2016 IEEE International Conference on Sustainable Energy Technologies (ICSET), 2016, 282–287. <https://doi.org/10.1109/ICSET.2016.7811796>
- [22] Manurung P., Daylighting and architectural concept of traditional architecture: The Tongkonan in Toraja, Indonesia. *A/Z: ITU Journal of Faculty of Architecture* 14(1) (2017) 111–126. <https://doi.org/10.5505/ituja.2017.65487>
- [23] Krüger E.L., Paskowy N.A., Moro J., Minella F.O., Identifying solar access effects on visitors' behavior in outdoor resting areas in a subtropical location: a case study in Japan Square in Curitiba, Brazil. *International Journal of Biometeorology* 63(3) (2019) 301–313. <https://doi.org/10.1007/s00484-018-01664-z>
- [24] Zeibo J., Mishra M.K., Panda A.R., Mishra B.S.P., Mallick P.K., Pedestrian trajectory prediction in crowd scene using deep neural networks. In: Priyadarshi N., Padmanaban S., Ghadai R. K., Panda A. R., Patel R. (eds) *Advances in Power Systems and Energy Management*. ETAEERE ETAEERE 2020, 2020. Lecture Notes in Electrical Engineering, vol 690. Springer, Singapore. [https://doi.org/10.1007/978-981-15-7504-4\\_27](https://doi.org/10.1007/978-981-15-7504-4_27)
- [25] Park S., Byun J., Kang B., Jeong D., Lee B., Park S., Design of an energy-aware LED light system (EA-LLS) for energy saving and user satisfaction through daylight, space and user movement analysis in buildings. *IEICE Transactions on Information and Systems* E98.D(10) (2015) 1861–1865. <https://doi.org/10.1587/transinf.2014EDL8124>
- [26] Parise G., Martirano L., Cecchini G., Design and energetic analysis of an advanced control upgrading existing lighting systems. 49th IEEE/IAS Industrial Commercial Power Systems Technical Conference, 2013, 1–8. <https://doi.org/10.1109/ICPS.2013.6547337>
- [27] Hosseini S.M., Mohammadi M., Schröder T., Guerra-Santin O., Integrating interactive kinetic façade design with colored glass to improve daylight performance based on occupants' position. *Journal of Building Engineering* 31 (2020) 101404. <https://doi.org/10.1016/j.jobee.2020.101404>
- [28] Pan W., Du J., Effects of neighbourhood morphological characteristics on outdoor daylight and insights for sustainable urban design. *Journal of Asian Architecture and Building Engineering* 21(2) (2022) 342–367. <https://doi.org/10.1080/13467581.2020.1870472>
- [29] Bian Y., Leng T., Ma Y., A proposed discomfort glare evaluation method based on the concept of 'adaptive zone'. *Building and Environment* 143 (2018) 306–317. <https://doi.org/10.1016/j.buildenv.2018.07.025>
- [30] Huang T.Y., Huang P.Y., Tsai H.Y., Automatic design system of optimal sunlight-guiding micro prism based on genetic algorithm. *Developments in the Built Environment* 12 (2022) 100105. <https://doi.org/10.1016/j.dibe.2022.100105>
- [31] Montaser Koohsari A., Heidari S., Subdivided venetian blind control strategies considering visual satisfaction of occupants, daylight metrics, and energy analyzes. *Energy and Buildings* 257 (2022) 111767. <https://doi.org/10.1016/j.enbuild.2021.111767>
- [32] Atzeri A.M., Cappelletti F., Tzempelikos A., Gasparella A., Comfort metrics for an integrated evaluation of buildings performance. *Energy and Buildings* 127 (2016) 411–424. <https://doi.org/10.1016/j.enbuild.2016.06.007>
- [33] de Montigny L., Ling R., Zacharias J., The effects of weather on walking rates in nine cities. *Environment and Behavior* 44(6) (2012) 821–840. <https://doi.org/10.1177/0013916511409033>
- [34] Zacharias J., Stathopoulos T., Wu H., Microclimate and downtown open space activity. *Environment and Behavior* 33(2) (2001) 296–315. <https://doi.org/10.1177/0013916501332008>
- [35] Zacharias J., Stathopoulos T., Wu H., Spatial behavior in San Francisco's plazas: the effects of microclimate, other people, and environmental design. *Environment and Behavior* 36(5) (2004) 638–658. <https://doi.org/10.1177/0013916503262545>
- [36] Liu J., Zhang W., Chu X., Liu Y., Fuzzy logic controller for energy savings in a smart LED lighting system considering

- lighting comfort and daylight. *Energy and Buildings* 127 (2016) 95–104. <https://doi.org/10.1016/j.enbuild.2016.05.066>
- [37] Almayyah S., Elkadi H., Study on the visual performance of a traditional residential neighborhood in old Cairo. *Journal of Urban Technology* 19(4) (2012) 59–86. <https://doi.org/10.1080/10630732.2011.649913>
- [38] Tafahomi R., Revitalization of cultural values in urban landscape through street trees design. *METU Journal of the Faculty of Architecture* 39(1) (2022) 215–236. <https://doi.org/10.4305/METU.JFA.2022.1.10>
- [39] Panahiazar S., Matkan M., Qualitative and quantitative analysis of natural light in the dome of San Lorenzo, Turin. *Frontiers of Architectural Research* 7(1) (2018) 25–36. <https://doi.org/10.1016/j.foar.2017.11.005>
- [40] Lasagno C. M., Pattini A.E., Rodriguez R.G., Colombo E.M., Developing a modelling factor index for transition spaces: a case study approach. *Architectural Science Review* 54(3) (2011) 215–224. <https://doi.org/10.1080/00038628.2011.590058>
- [41] Nasybullina R., Slastenin P., Fadeev A., Designing lightspace in contemporary architecture. *E3S Web of Conferences* 110 (2019) 01013. <https://doi.org/10.1051/e3sconf/201911001013>
- [42] Kristo S., Kristo X., Architectural atmospheres: from interior towards exterior. in *Handbook of Research on Methodologies for Design and Production Practices in Interior Architecture*, IGI Global, 2021, 343–367. <https://doi.org/10.4018/978-1-7998-7254-2.ch016>
- [43] Andersen M., Gochenour S.J., Lockley S.W., Modelling ‘non-visual’ effects of daylighting in a residential environment. *Building and Environment* 70 (2013) 138–149. <https://doi.org/10.1016/j.buildenv.2013.08.018>
- [44] Jens K., Khoudi A., Using computer-vision sensors to study the impact of window views on occupancy and self-assessed productivity in flexible working environments: an intervention study. *Intelligent Buildings International* 15(2) (2023) 78–90. <https://doi.org/10.1080/17508975.2022.2084012>
- [45] Hunt D.R.G., The use of artificial lighting in relation to daylight levels and occupancy. *Building and Environment* 14(1) (1979) 21–33. [https://doi.org/10.1016/0360-1323\(79\)90025-8](https://doi.org/10.1016/0360-1323(79)90025-8)
- [46] Chiogna M., Frattari A., Lighting control system: energy efficiency and users’ behavior in office buildings. *BSA 2013, the 1st IBPSA-Italy Conference on Building Simulation Applications*, 2013, 131–139. <https://publications.ibpsa.org/conference/?id=bsa2013>
- [47] Guan Y., Yan Y., Daylighting design in classroom based on yearly-graphic analysis. *Sustainability* 8(7) (2016) 604. <https://doi.org/10.3390/su8070604>
- [48] Moazzeni M., Ghiabaklou Z., Investigating the influence of light shelf geometry parameters on daylight performance and visual comfort, a case study of educational space in Tehran, Iran. *Buildings* 6(3) (2016) 26. <https://doi.org/10.3390/buildings6030026>
- [49] Kamaruzzaman S.N., Edwards R., Zawawi E.M.A., Che-Ani A.I., Achieving energy and cost savings through simple daylighting control in tropical historic buildings. *Energy and Buildings* 90 (2015) 85–93. <https://doi.org/10.1016/j.enbuild.2014.12.045>
- [50] Lolli N., Haase M., Consequences of energy retrofitting on the daylight availability in Norwegian apartments. *Energy Procedia* 132 (2017) 903–908. <https://doi.org/10.1016/j.egypro.2017.09.713>
- [51] Nezamdoost A., Mahic A., van den Wymelenberg K., A human factors study to update a recently proposed manual blind use algorithm for energy and daylight simulations. *IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society*, 2018, 789–794. <https://doi.org/10.1109/IECON.2018.8591835>
- [52] Nezamdoost A., van den Wymelenberg K., Mahic A., Assessing the energy and daylighting impacts of human behavior with window shades, a life-cycle comparison of manual and automated blinds. *Automation in Construction* 92 (2018) 133–150. <https://doi.org/10.1016/j.autcon.2018.03.033>
- [53] Konis K., The influence of occupant behavior on facade solar transmission: discrepancies between observed shade control behavior and simulation-based shade control models. *ASHRAE Papers CD*, (2013) M1–M8.
- [54] Katsanou V.N., Alexiadis M.C., Labridis D.P., An ANN-based model for the prediction of internal lighting conditions and user actions in non-residential buildings. *Journal of Building Performance Simulation* 12(5) (2019) 700–718. <https://doi.org/10.1080/19401493.2019.1610067>
- [55] Hammes S., Weninger J., Measurement data on the window opening behavior and climate in a strongly daylight office building. *Data in Brief* 46 (2023) 108794. <https://doi.org/10.1016/j.dib.2022.108794>
- [56] Wang N., Boubekri M., Design recommendations based on cognitive, mood and preference assessments in a sunlit workspace. *Lighting Research Technology* 43(1) (2011) 55–72. <https://doi.org/10.1177/1477153510370807>
- [57] Zhang Y., Barrett P., Factors influencing occupants’ blind-control behavior in a naturally ventilated office building. *Building and Environment* 54 (2012) 137–147. <https://doi.org/10.1016/j.buildenv.2012.02.016>
- [58] van den Wymelenberg K., Patterns of occupant interaction with window blinds: A literature review.” *Energy and Buildings* 51 (2012) 165–176. <https://doi.org/10.1016/j.enbuild.2012.05.008>
- [59] Amorim C.N.D., Vasquez N.G., Matusiak B., Kanno J., Sokol N., Martyniuk-Peczek J., Sibilio S., Koga Y., Ciampi G., Waczynska M., Lighting conditions in home office and occupant’s perception: An international study. *Energy and Buildings* 261 (2022) 111957. <https://doi.org/10.1016/j.enbuild.2022.111957>
- [60] Lim G.H., Keumala N., Ghafar N.A., Energy saving potential and visual comfort of task light usage for offices in Malaysia. *Energy and Buildings* 147 (2017) 166–175. <https://doi.org/10.1016/j.enbuild.2017.05.004>
- [61] Rakha T., Chen Y., Reinhart C., Do office buildings ‘save’ energy in the united states due to daylight saving time (DST)? A 50-state simulation-based study. *2018 Building Performance Analysis Conference and SimBuild*, 2018, 21–28.
- [62] Gunay H.B., O’Brien W., Beausoleil-Morrison I., Gilani S., Development and implementation of an adaptive lighting and blinds control algorithm. *Building and Environment* 113 (2017) 185–199. <https://doi.org/10.1016/j.buildenv.2016.08.027>
- [63] Bournas I., Dubois M.C., Residential electric lighting use during daytime: a field study in Swedish multi-dwelling buildings. *Building and Environment* 180 (2020) 106977. <https://doi.org/10.1016/j.buildenv.2020.106977>
- [64] Martirano L., Manganelli M., Parise L., Sbordone D.A., Design of a fuzzy-based control system for energy saving and users comfort. *2014 14th International Conference on Environment and Electrical Engineering*, 2014, 142–147. <https://doi.org/10.1109/EEEIC.2014.6835853>
- [65] Fieldson R., Sodagar B., Understanding user satisfaction evaluation in low occupancy sustainable workplaces. *Sustainability* 9(10) (2017) 1720. <https://doi.org/10.3390/su9101720>
- [66] Aghemo C., Blaso L., Pellegrino A., Building automation and control systems: A case study to evaluate the energy and environmental performances of a lighting control system in offices. *Automation in Construction* 43 (2014) 10–22. <https://doi.org/10.1016/j.autcon.2014.02.015>
- [67] Perwita Sari D., Chiou Y., Energy saving potential from shading design for residential house in rural area. *MATEC Web of Conferences* 164 (2018) 1007. <https://doi.org/10.1051/mateconf/201816401007>
- [68] Rezaee R., Vakilinejad R., Shahzadeh M., The ‘Shavadun’ as an ecological solution for architecture in a hot climate. *WIT Transactions on Ecology and the Environment* 120 (2009) 303–313. <https://doi.org/10.2495/SDP090301>
- [69] Sakarellou-Tousi N., Lau B., The vernacular dwellings of Mount Pelion in Greece: a migratory living pattern. *PLEA2009-26th Conference on Passive and Low Energy Architecture*, 2009, 794–799.
- [70] Kim G.Y., Choi Y.H., A suggestion of criteria for categorizing libraries into types: Linking between library and information. *Journal of the Korean Society for Information Management* 29(1) (2012) 395–404. <https://doi.org/10.3743/KOSIM.2012.29.1.395>

- [71] Illuminating engineering society IES RP-4-20 Recommended practice: lighting library spaces, includes errata 1. New York, NY, 2020. ISBN: 9780879953874.
- [72] Maghlakelidze M., Mesa A., Sawyer A.O., Morad M.G., Ben-Alon L., Biophilic design elements and natural materials in healthcare environments. *Journal of Green Building* 19(3) (2024) 1–39. <https://doi.org/10.3992/jgb.19.3.3>
- [73] Chen W., Liu Y., Song J., Yu G., Effects of dynamic natural lighting variables on melanopic daylight illuminance in ice stadiums: Measurements and simulations for movement conditions. *Journal of Building Engineering* 104 (2025) 112124. <https://doi.org/10.1016/j.jobe.2025.112124>
- [74] Turrin M., Yang D., D'Aquilio A., Sileryte R., Sun Y., Computational design for sport buildings. *Procedia Engineering*, 147 (2016) 878-883. <https://doi.org/10.1016/j.proeng.2016.06.285>
- [75] Ahmadi M., Language of movement for building assessment: A review of the evaluation methods of the human movement in the built space. *Proceedings of the PLEA 2024 – (RE)THINKING RESILIENCE. PLEA 2024*.
- [76] Rapoport A., *House form and culture*. Prentice-Hall. P. 16, 1969.