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Review of Lighting Strategies for Enhancing Users' Experience and Achieving Environmental Sustainability in Art Museums

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Abstract: Art museums hold a distinct role as custodians of cultural heritage, housing a rich tapestry of artefacts that encapsulate human creativity, history, and identity. The interaction between museum displays and visitors hinges on lighting, a critical factor in enhancing user experiences and preserving ecological balance. This review paper explores the intricate relationship between lighting strategies, user satisfaction, and environmental sustainability within the context of art museums. This paper is particularly centered on achieving two intertwined objectives: enhancing the quality of user interactions and experiences, while concurrently championing principles of environmental preservation and sustainability. By reviewing relevant scholarly articles, books, conference papers, and reports, this paper explores the current state of knowledge regarding lighting strategies in art museums, their impact on users' experience, and their contribution to environmental sustainability. Using the qualitative approach, data was gathered by content analysis from relevant published works. The result was presented with text in themes with the aid of a table. The review reveals key trends, challenges, and best practices in the field, shedding light on potential avenues for further research and practical implementation. The study provided insight into various lighting strategies that are not deleterious to interior functions and artefacts in art museums. The study is useful for enhancing the knowledge of building and environment on issues relating to optimizing lighting strategies in the development of exhibition areas, especially in art museums.

Keywords: Art Museums, Artificial Lighting strategies, Daylighting strategies, Environmental Sustainability, Users' Experience, Nigeria.

1. Introduction

Art museums hold a unique position as repositories of cultural heritage, housing an array of artefacts that embody the essence of human creativity, history, and identity. Such displays in art museums communicate with visitors. As visitors seek immersive encounters with artworks that evoke emotions, provoke thoughts, and inspire connections, the quality of lighting emerges as an instrumental factor [1]. Simultaneously, the imperatives of ecological stewardship demand that the illumination systems within art museums are not only visually impactful but also energy-efficient, mindful of natural resources, and attuned to the global call for sustainability. Therefore, art museums are increasingly tasked with the dual challenge of creating spaces that captivate and enlighten visitors while minimizing their ecological footprint [2, 1, 3, 4].

Central to this engagement is the role of lighting – a fundamental aspect that shapes how visitors perceive, interact with, and appreciate the exhibited artworks. Lighting strategies within art museums not only impact the aesthetic quality of the space but also significantly influence users' experiences and the overall sustainability of these institutions [5–7]. Incorporating appropriate lighting into the design of exhibition spaces within art

museums is fundamental for cultivating sustainable display areas, particularly those dedicated to the exhibition of art materials [2, 6, 8–10]. In the discourse of architectural illumination, sustainability stands as an indispensable theme. Yet, despite the overall significance of lighting in architectural constructs, challenges arise, notably in the domain of daylighting, which is observed to present difficulties in certain architectural typologies, such as art museums [2, 11, 3]

Within these considerations, lighting emerges as a pivotal determinant, because of its requisites fluctuating in accordance with function and task dynamics [12, 13]. The specificity of museum lighting (in terms of intensity and colour) demands the conveyance of an artwork's visual intricacy and emotional resonance while concurrently safeguarding its essence and integrity for posterity [14]. In Nigeria, artificial lighting predominates in museum designs due to the limitations of daylighting, primarily the presence of ultraviolet rays with the potential to harm textiles and artefacts over time. Consequently, Architects and designers pay little or no attention to harnessing daylight potential in the design of museum buildings due to its hazardous effect on exhibited works [15].

This concern, coupled with the substantial energy demand and consumption attributed to artificial lighting raises ecological and energy efficiency apprehensions, given the significant greenhouse gas emissions associated with electricity production [16, 17]. There is, therefore, a need to navigate the complexities of available energy options, harnessing their potential while safeguarding ecological balance, functional requirements, and artefact preservation [18]. This study focuses on achieving environmental sustainability through effective and well-conceived lighting strategies, aiming to mitigate adverse environmental impacts through the judicious selection of energy sources and techniques compatible with the ecological ecosystem, interior functions, and artefact preservation.

While prior studies acknowledge the potential of daylighting in museum contexts, their implementation calls for strategic calibration, as evidenced by various research [8, 12, 13, 1, 19, 7, 4, 15]. Nonetheless, a discernible void persists in pinpointing the most fitting lighting strategy to concurrently optimize user satisfaction and environmental sustainability in the realm of art museum exhibition space development. Hence, the present study undertakes an in-depth examination of lighting strategies, poised to amplify user experiences while advancing environmental sustainability within the design and development of art museum exhibition areas. The study is driven by two central objectives: firstly, to comprehensively analyze diverse categories of lighting strategies applicable to architectural contexts, and secondly, to identify and delineate strategies optimally suited for exhibition spaces within art museums, with a dual focus on enhancing user experiences and promoting environmental sustainability.

The confluence of enhancing users' experiences and advancing environmental sustainability constitutes a critical concern in contemporary museum design and management. While extant research has delved into distinct aspects of museum lighting, such as aesthetics, conservation, and energy efficiency, a holistic exploration that intricately interweaves these facets within the context of art museums remains absent. Specifically, a substantial research gap emerges concerning the meticulous assessment of lighting strategies that not only amplify visitors' engagements but also strategically minimize environmental impact, culminating in an encompassing ecosystem that encompasses both human and planetary well-being.

Thus, the identified gap underscores the pressing need for a review that elucidates the spectrum of lighting strategies available, scrutinizes their potential to heighten users' engagement, and rigorously evaluates their efficacy in advancing environmental sustainability objectives. Bridging this gap would not only enrich the theoretical discourse but also offer insights for practitioners, designers, and policymakers aiming to craft illuminative paradigms that synergize experiential and ecological dimensions within the captivating area of art museums. Though a lot of factors contribute to user satisfaction and environmental harmony within built environments, this study confines its scope to the areas of lighting strategies, acknowledging their foundational significance in art museums.

This study is poised to serve as an invaluable resource, offering insights into effective lighting strategies for bolstering user satisfaction and attaining environmental sustainability in the design and construction of museum buildings. The synthesis of this review not only contributes to the scholarly discourse surrounding museum studies, architecture, and environmental sustainability but also serves as a practical guide for museum professionals, designers, architects, and policymakers invested in creating art museum environments that resonate with visitors and align with the principles of environmental conservation.

The study unfolds across eight distinct sections: abstract, introduction, methodology, categorization of lighting applications in built environments, lighting strategies suitable for art museum exhibition spaces, conclusion, acknowledgements, and references.

2. Materials and Methods

As the focus of the study was to identify lighting approaches best suitable in art museum display areas, a literature review was considered adequate to achieve this. The study is therefore a concise review paper that adopted qualitative research methods. The qualitative technique involved an examination of relevant literature from reputable sources to provide a broad perspective of various lighting strategies used in buildings from where those most suitable for use in display areas of art museums were identified. The research problem was drawn from the gap identified in the literature as stated in the sixth paragraph of the introduction, which led to the deduction of research purpose and focus, both of which were posited in the aim of the study.

To achieve the aim, two research objectives were derived as stated in the sixth paragraph of the introduction. Being a literature review article, secondary sources were employed for data collection. To gather the relevant literature that was used for the study, the following keywords were deployed to search on the internet: art museums, artificial lighting strategies, daylighting strategies, environmental sustainability, users' experience, and Nigeria. The search was conducted using Google Scholar, Scopus, and ScienceDirect to gather crucial information on lighting in museums. These search platforms were employed because they are popular mediums used by scholars to search for scholarly materials in any field.

To situate the study within current research in the field, 75% of the literature search with most open-access materials released in the last ten years was consulted. Based on the aforementioned selection criteria, over a hundred documents were first retrieved. After a careful content analysis of the documents, twenty of them were found useful for achieving the target of the study. The selected documents were scrutinized and relevant data for achieving the aim and objectives of the study were extracted from them. The result was presented using a thematic descriptive approach with the aid of a table to enhance understanding.

3. Results and Discussion

The design and implementation of lighting strategies in art museums represent a critical juncture where aesthetic, functional, and ecological considerations converge [4]. The objectives of enhancing users' experiences and achieving environmental sustainability in these institutions underscore the nuanced nature of this paper. The present literature review embarks on a comprehensive exploration of the diverse array of lighting strategies employed within art museums, aimed at harmonizing these dual aspirations. Lighting employed in buildings is categorised into two broad headings based on their source, namely: daylighting or natural lighting; and artificial lighting [20, 21, 7, 9].

3.1 Daylighting

Daylighting, also known as natural lighting, originates from the Sun. The Sun is the main natural source of illumination on Earth which receives its energy through nuclear

fusion [1, 7, 22]. Sunlight is important to all life forms but can only be utilized until nightfall. The use of direct or diffused sunlight to light areas in buildings contributes to a reduction in the quantity of energy required for such purposes via artificial ways, which reduces greenhouse gas emissions [10, 20, 23]. Daylighting utilises a technique that aims to efficiently bring daylight into a structure using proper space planning, redirection devices, tubular lights, exterior glazing; windows, glass blocks, skylights, panels, and openings while reducing artificial lighting requirements and saving energy [7].

Integrating daylighting when designing buildings and shaping cities is essential as it has been proven to help attain environmental sustainability and increase health and visual comfort levels for building occupants [6, 8]. Enhancing users' experience and achieving environmental sustainability in art museums can be very challenging when trying to fully utilize daylighting, as consideration must be given to, building use, sun orientation, opening sizes, number and spacing, window-to-wall ratio, proper space planning, the geometry of the building, proximity to the area of interest, location and type of opening aperture, the sky reflected components, internally and externally reflected components [5, 7, 16, 22].

3.1.1 Daylighting Strategies

To make the daylighting strategy effective, the consideration highlighted in section 3.1 should be appropriately adhered to, to ensure the maximum use of daylight while avoiding solar heat gain and glare [17]. Daylighting is said to have a high luminous output that contains high concentrations of ultraviolet rays, which can damage pieces of furniture or art materials. As a result, some strategies were found to harness daylight qualities, while mitigating damages on exhibited objects. They include the following:

(i) Direct Lighting: The most prevalent natural lighting strategy approach is known as direct lighting. Controlled light exposure falls directly into the building and on non-light-sensitive artworks through the opening apertures [19, 22]. The south window area is extended over the sun-tempered house's 7% restriction. This strategy is dependent on the following: sizing limit, glazing type and thermal mass [12]. To regulate this, drapes or blinds can be used to keep the exhibit space dark when not in use by the public.

(ii) Sunspace: Using the building orientation, opening dimensions and position, sunspace is a resolute direct-gain room on the house's south side. A common wall is a wall that divides the home from the sunspace, the wall has moveable windows and doors that are opened and closed at will, to regulate the light intensity needed. This strategy depends solely on diffused lighting, which is a lighting principle in which soft light is scattered evenly over the area from a distant source. Light diffusion may be accomplished both naturally and artificially. Sunspace strategy application in temperate regions functions well when there are little to no thermal and air restrictions and this can be achieved by the use of louvres or perforated blocks [8, 1, 7, 4].

(iii) Sun Tempering: The sun rises from the east, passes through the south and sets in the west, making the openings in the south a full receival of natural lighting. Sun tempering refers to modest increases in windows on the south side using clearstories, to avoid directly falling on artworks. This is a low-cost strategy to properly utilize natural lighting while drastically excluding heat gains and glare. In a conventional design, about a quarter of the windows face south. This equates to around 3% of the overall floor space of the house. In a sun-tempered design system, the proportion is raised to a maximum of around 7% of the floor surface. This strategy involves the intentional reduction of glare and light on the artwork [16, 1, 13].

(iv) Combined System: Direct heat gain, sunspace and sun tempering can function individually, but for better results, a combination of the two is better. Direct gain works extremely well when combined with a sunspace or sun tempering. Such combinations need a huge amount of south-facing space, as well as careful design to ensure that the systems are well-integrated with one another and with the building's mechanical system [1, 7].

3.2 Artificial Lighting

Artificial Lighting is known as human-made features with the use of technology to produce illumination for visual ability enhancement and aesthetic purposes; they require a light source to function [24]. They can be controlled to give the desired amount and direction of lighting, creating a range of effects according to the required space [12]. There are factors to be considered when choosing artificial lighting. They include the building use, geometry of the building, proximity to the area of interest, size of the opening aperture and the internally reflected components [9]. Sources of artificial lighting include incandescent, fluorescent, and light-emitting diode (LED) [20, 21]. According to Sylvania [4], artificial lighting types include ambient lighting, decorative lighting, spotlighting, accent lighting, wall washing, dimming, floodlight and beam angles. All the aforesaid artificial lighting types can be categorised under four strategies which are examined in the following section.

3.2.1 Artificial Lighting Strategies

The standard recommendation for the illuminance of sensitive objects is 50-100 lux. Therefore, to make this strategy effective, the use of timers, dimmer switches, energy-efficient lighting systems and motion sensors should be utilized to ensure that exhibited works are only illuminated when the visitors are present [25, 17].

(i) Downlighting: This is the most prevalent artificial lighting strategy, with fixtures on or recessed in the ceiling projecting light downward. This is the most conventional lighting strategy, and it is employed in most building types. Compared to an incandescent downlight or spotlight, the introduction of LED lighting has enhanced its energy efficiency by around 90%. LED lights or bulbs may now be retrofitted to substitute high-energy consumption fixtures [13, 4, 9].

(ii) Uplighting: Uplighting also known as indirect lighting is a less prevalent artificial lighting strategy that is often used to bounce light off the ceiling and back down. The diffused highlight emphasizes the object's authentic texture and hue [8]. It is utilized in lighting situation that requires minimal glare and consistent ambient illuminance levels. It offers a more consistent display of the light output while functioning. However, this strategy is entirely dependent on the surface's reflective coefficient. While Uplighting may produce a diffused and silhouette and glare-free light, it is considered an inefficient and uneconomical lighting method [4, 8].

(iii) Front Lighting: Front Lighting is also prevalent due to its significant benefit. It uniformly illuminates the object and although it tends to make the subject appear flat since it creates apparent silhouettes behind displayed works leaving an almost seamless imitation of the object [26, 13, 4, 9]. This strategy is used when simple lighting is required.

(iv) Side Lighting: This strategy uses 90° light to highlight an object, making the opposite side less prominent and lit. Although lighting from the side is less prevalent since it causes a little glare near the eye, it dramatically helps to define the shape of the displayed works in three dimensions [26, 8, 13, 4].

(v) Backlighting: Backlighting surrounding or passing through an item from behind is primarily utilized for emphasis. Backlighting is a strategy for illuminating an object with a reduced contract. This gives the display works more depth and strong backlight results in a silhouette. It can also be employed to create a more spectacular impression [26, 13].

3.3 Lighting Strategies and User Experience

Lighting in art museums is intrinsically tied to user experiences [5, 27–29]. Lighting, when wielded judiciously, can accentuate the visual appeal of artworks, evoke emotional responses, and guide visitor narratives. Optimal lighting design engenders a dynamic interplay of light and shadow, elevating the narrative potency of the exhibits while fostering immersive and memorable encounters [13]. Various lighting strategies have been ex-

plored to accentuate the visual quality of exhibited artworks and foster deeper connections between visitors and the artistic narratives they encounter. The psychological impact of lighting, however, extends beyond the aesthetic and cognitive realms to encompass visitors' perceived comfort and overall sense of well-being [5, 28].

Illumination levels, colour temperatures, and lighting quality can collectively shape visitors' comfort levels, influencing their duration of stay and overall satisfaction. Inadequate or harsh lighting conditions may lead to discomfort, visual fatigue, and reduced engagement, while well-calibrated lighting can promote relaxation, ease, and a positive sensory experience [4, 13]. This, in turn, can contribute to extended visitation times and heightened engagement, thereby fostering a more profound connection between visitors and the artistic narratives presented within the museum space. A plethora of studies delve into the nuanced effects of lighting on visual perception, emotional resonance, and cognitive engagement. Sensitive calibration of lighting variables, such as intensity, colour temperature, and directionality, plays a pivotal role in evoking desired emotional responses and intellectual reflections [28].

Studies by Kusumawardani *et al*. [5], Aderonmu *et al.* [12], Kwong [28], faith and Omale [27], Adewale *et al,* [29], illuminate the multifaceted impacts of lighting on user experiences. These studies underscored the importance of dynamic lighting schemes that can be tailored to diverse exhibits, considering factors such as artwork genre, temporal context, and intended emotional resonances.

3.4 Environmental Sustainability in Museum Lighting

The imperatives of environmental sustainability weigh heavily on modern architectural design and practice, extending their reach to art museums. Environmental sustainability in museum lighting is confronted by a unique set of challenges inherent to the preservation of delicate artifacts and artworks. Traditional lighting methodologies, while accentuating visual aesthetics, often exert undue stress on artifacts due to heat emissions and light-induced degradation. The conservation imperative, intertwined with sustainability, necessitates an intricate balance between optimal lighting conditions and the safeguarding of cultural heritage [11].

Lighting choices carry inherent implications for energy consumption, and art museums are increasingly challenged to merge their display ambitions with resource conservation. The intersection of lighting design and sustainability manifests through energy-efficient solutions, reduction of greenhouse gas emissions, and ecological consciousness. In response to these challenges, museums are increasingly embracing innovative lighting technologies and strategies that minimize ecological footprints while accentuating visual allure. Sustainability in museum lighting also encompasses the preservation of artworks and artifacts for future generations. Harmful ultraviolet (UV) and infrared (IR) radiation emitted by conventional lighting sources can cause irreversible damage to delicate materials over time [2, 6].

As an alternative, Light-emitting diodes (LEDs), characterized by their energy efficiency and controllability, have emerged as a cornerstone of sustainable museum lighting. LEDs, when calibrated to specific wavelengths, not only mitigate the emission of ultraviolet and infrared radiation but also offer flexible lighting scenarios, thereby ensuring the protection of artifacts while creating immersive experiences. Studies by Maddox [1], Wilson [6], Richardson [11], and Oyedepo *et al*. [18], underscored the criticality of adopting sustainable lighting practices within art museums.

These studies evaluated the ecological repercussions of lighting choices, offering insights into minimizing carbon footprints while retaining optimal exhibition conditions. Museums can further enhance their environmental sustainability by integrating renewable energy sources into their lighting infrastructure. Solar panels, for instance, can be strategically deployed to power lighting systems, reducing dependence on conventional energy grids. This integration of renewables not only decreases operational costs but also reinforces the museum's commitment to reducing its ecological impact.

3.5 Balancing User Experience and Environmental Sustainability

The interplay between user-centric illumination and sustainable lighting practices harbours synergies and trade-offs that necessitate meticulous navigations. Achieving optimal user experiences while adhering to sustainability tenets requires a calibrated approach [6]. Studies by Wilson [6], and Onuwe *et al.* [15], delve into the delicate equilibrium between dynamic lighting and ecological sensibilities. These aforementioned researches explored adaptive lighting strategies that respond to user presence, time of day, and artwork characteristics. Simultaneously, they scrutinize potential conflicts, such as the mitigation of ultraviolet radiation to preserve artifacts while ensuring visitor comfort and aesthetic satisfaction [12, 29].

Strategies involving daylighting, adaptive controls, and sensor-driven interventions emerge as mechanisms to strike this equilibrium. As museums continue to evolve as dynamic and transformative spaces, the implementation of sustainable lighting practices becomes an embodiment of commitment – a commitment to both the preservation of cultural legacies and the safeguarding of the planet's ecological equilibrium. Through innovative technologies, adaptive strategies, and a shared commitment to balance, museums forge a luminous path towards a future where enlightenment and sustainability coalesce in harmonious splendour [1, 19, 30].

3.6 Lighting Strategies Suitable For Display Areas Of Art Museums

From the data gathered above, Table 1 shows daylighting and artificial lighting strategies suitable for display areas of art museums.

Table 1: Daylighting and Artificial Lighting Strategies Suitable for Display Areas of Art Museums

S/N	Lighting Strategy	Characteristics of Lighting Strategy	Lighting Strategy Suitability	Possible Solution for Unsuitable Lighting Strategy
1	Direct lighting (DLS)	High UV radiation, glare, heat gains, eco-friendly	No	Use of clerestories, elongated eaves, UV-absorbing acrylic glazing, drapes, blinds
2	Sunspace (DLS)	Low UV radiation, improved visual quality, Minimal heat, eco-friendly	Yes	-
3	Sun Tempering (DLS)	High UV radiation, glare, heat gains, eco-friendly	No	Use of clerestories, shading devices, UV-absorbing acrylic glazing, drapes,
4	Combined System (DLS)	Very Low UV radiation, no glare, no heat gains, improved visual quality, eco-friendly	Yes	-
5	Downlighting (ALS)	improved visual quality, no glare, no heat	Yes	-
6	Uplighting (ALS)	Prolonged artwork shelf, improved visual quality, no glare, no heat	Yes	-
7	Front Lighting (ALS)	Heat, glare	No	Increase the distance between the object and the light source
8	Side Lighting (ALS)	Minimal glare, improved visual quality	Yes	-
9	Backlighting (ALS)	Heat, glare	No	Increase the distance between the object and the light source

*Daylighting Strategy (DLS), Artificial lighting strategy (ALS).

An evaluation of various lighting strategies in the context of their characteristics, suitability, and potential solutions for strategies deemed unsuitable as shown in Table 1. Each lighting strategy's attributes are considered in relation to factors such as UV radiation, glare, heat gains, visual quality improvement, overall eco-friendliness, each with distinct advantages and limitations. The evaluation provides insights into which strategies align with the dual goals of enhancing visitor engagement and achieving environmental sustainability within art museums. It indicates that out of the nine lighting strategies examined, five of them were discovered to be suitable for use in art museums towards enhancing users' experience and achieving environmental sustainability.

The strategies are two daylighting strategies (sunspace and combined systems) and three artificial lighting strategies (downlighting, uplighting and side lighting). However, due to the high admission of light by some daylighting strategies causing unnecessary heat gain and glare (visual discomfort), as well as damage to exhibited artworks, two daylighting strategies (direct lighting and sun tempering) are adjudged unsuitable. Also, two artificial lighting strategies (front lighting and backlighting) were found not to be suitable because of the glare they cause and the high heat they emit which will be deleterious to art materials.

However, to improve the performance of the direct lighting and sun tempering strategies in exhibition areas, the use of clearstories, elongated eaves, UV-absorbing acrylic glazing, drapes, and blinds are advised. Likewise, creating a distance between the artwork and the light source can help improve the suitability of the front lighting and backlighting strategies in exhibition display areas.

4.0 Conclusion

The primary objective of this study was to comprehensively evaluate a spectrum of lighting strategies, analysing their potential to heighten users' experiential engagement while concurrently advancing environmental sustainability. The central focus further encompassed the identification of strategies most aptly suited for implementation within the intricate design and developmental realms of art museum exhibition areas. Both natural and artificial lighting strategies came under the scrutiny of this investigation, whereby a comprehensive assessment revealed a significant cohort of strategies that exhibited compatibility. Within this spectrum, notable inclusions comprised various iterations of daylighting strategies, encompassing sunspace and combined systems, alongside artificial lighting strategies such as downlighting, up-lighting, and side lighting. Conversely, a subset of strategies was deemed less suitable, due to issues stemming from glare emissions and excessive heat dissipation.

This category encompassed two daylighting strategies, namely direct lighting and sun tempering, alongside two artificial lighting methods, specifically front lighting and backlighting. Among the diverse range of evaluated strategies, the combined system emerged as the most fitting option, notably due to its potential to mitigate the pronounced challenges often associated with excessive heat and glare. Furthermore, the intricate fusion of daylighting and artificial lighting emerged as a promising avenue, offering a synergistic approach capable of augmenting user experience while concurrently addressing environmental sustainability. This collaborative integration also presented the potential to curtail reliance on artificial lighting sources, consequently contributing to a significant reduction in electricity consumption by up to 50%, thus manifesting as a potent instrument for bolstering broader environmental sustainability initiatives.

Concurrently, the framework of environmental sustainability, as underscored by Wilson [6], and Inspire Clean Energy [10], highlights a need characterized by elevating human well-being while minimizing the adverse impact on the Earth's vital ecosystems. To successfully manifest these aspirations within the context of art museums, it is imperative to adhere to a set of paramount lighting criteria. These encompass an array of considerations, ranging from heightened visual quality and enhanced mood states to the ex-

tension of the longevity of artworks, cost-effectiveness, mitigation of light pollution, energy conservation, and the amelioration of glare and heat-related issues. It is acknowledged that the criteria used for the selection of resource materials may potentially confer certain limitations upon this study's scope.

Despite these limitations, the study furnishes valuable scholarly currency, positioned as a foundational resource for future inquiries and scholarly endeavours. It is conceivable that future explorations could expand the purview by utilizing alternative internet search engines and incorporating closed-access publications. Moreover, a prospective avenue for research might involve the aggregation and analysis of primary data sourced directly from extant art museums, thereby providing a more intimate and empirical comprehension of users' experiences within these vibrant cultural spaces.

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