

# Moonlight vs. Artificial Light: A Comparative Study on Visitors' Experiences of Nightscape Within Urban Green Spaces

Jingwei ZHAO\*, Dongyu LIU, Shuhui DENG

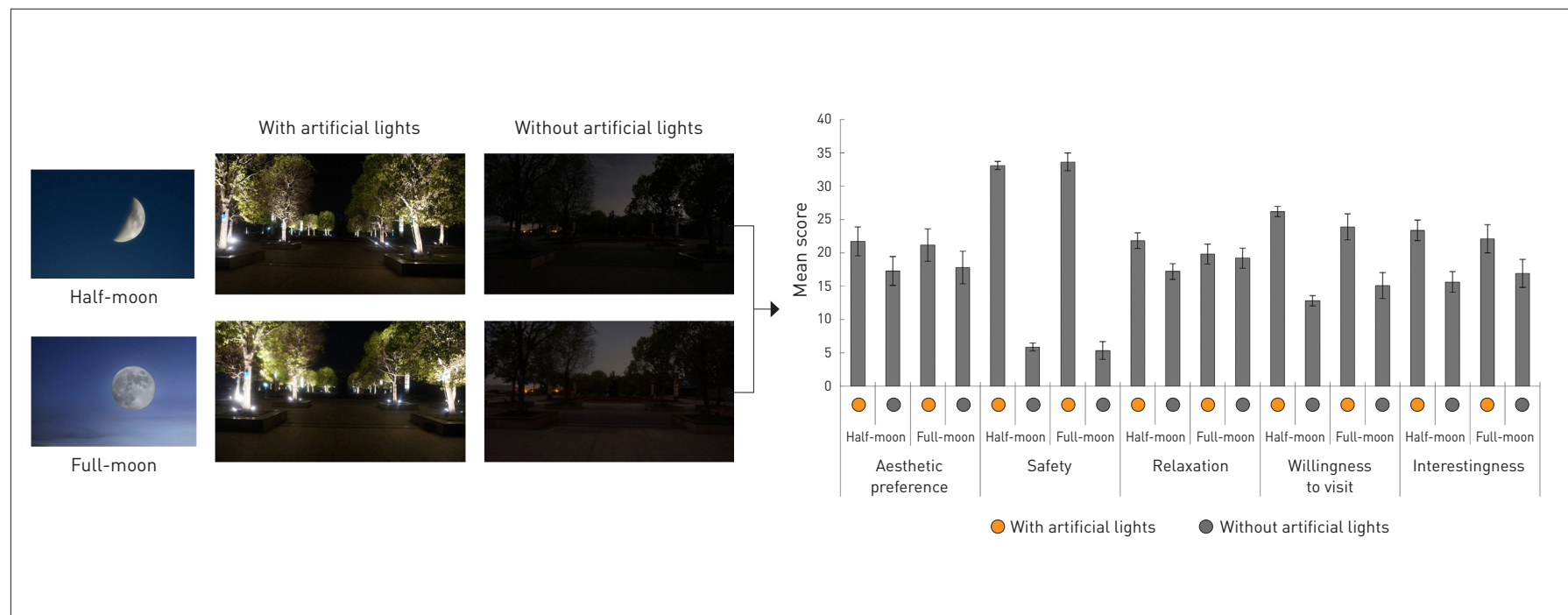
School of Architecture and Design, China University of Mining and Technology, Xuzhou 221116, China

\*CORRESPONDING AUTHOR

Address: No.1 University Road, Xuzhou, Jiangsu,  
221116, China

Email: 4365@cumt.edu.cn

## GRAPHICAL ABSTRACT



## HIGHLIGHTS

- A comparative study on differences in visitors' experiences of nightscapes within urban green spaces between artificial light and moonlight conditions
- At half-moon night, there is no significant difference in aesthetic preference between artificial light and moonlight conditions
- At full-moon night, there is no significant difference in aesthetic preference, relaxation, and interestingness between artificial light and moonlight conditions
- It is promising to introduce moonlight into nightscapes of urban green spaces as a partial substitute for artificial illumination

## KEYWORDS

Urban Green Space;  
Nightscape;  
Artificial Light;  
Moonlight;  
Visitors' Experience;  
Light Pollution;  
Comparative Study

Enhancing the nighttime environment of urban green spaces to improve visitor's experiences plays a pivotal role in realizing the full functional potential of these spaces and promoting the health and well-being of residents. However, the predominant focus of designers tends to be on artificial illumination within nightscapes, often overshadowing the consideration of natural lights such as moonlight. In this study, a total of 44 photographs of nightscapes with and without artificial lights at half- and full-moon nights respectively were taken using digital cameras at 11 sample sites of urban green spaces. Scored by college students, these photographs were assessed according to visitors' experience in five dimensions. The results indicated that at both half- and full-moon nights, the average scores of the five experience dimensions in artificial lights were higher compared with moonlight conditions. However, at

full-moon night, no significant difference in aesthetic preference, relaxation, and interestingness between artificial light and moonlight conditions was found; whereas, in terms of safety and willingness to visit, the scores under artificial light condition were significantly higher than those under moonlight. At half-moon night, there was no significant difference in aesthetic preference between artificial light and moonlight conditions, but the other four experience dimensions were significantly higher under the artificial light condition. These findings provide a theoretical basis to support the reintroduction of moonlight into urban green spaces.

EDITED BY Tina TIAN, Ying WANG  
 TRANSLATED BY Jingwei ZHAO, Tina TIAN

## 1 Introduction

Urban green spaces serve as important places for urban residents where people can connect with nature and unwind. Visiting urban green spaces can significantly improve visitors' physical health<sup>[1]</sup> and relieve mental stress<sup>[2]-[4]</sup>. As the pace of contemporary life accelerates and social competition heightens, nighttime hours become residents' main timeframe to use green space, particularly for most youth and the middle-aged because of their busy daytime schedules<sup>[5]</sup>. Therefore, exploring people's nighttime experiences within green spaces plays an important role in maximizing the multifaceted functions of urban green spaces and enhancing urban residents' satisfaction of life.

Since the invention of incandescent lamp in 1879, nighttime artificial illumination has undergone rapid development. For urban green spaces, its role has transcended from simply lighting toward a myriad of contemporary services, including spatial zoning, ambient enhancement, and traffic guidance<sup>[6]</sup>. However, the proliferation of artificial illumination also brings an array of adverse effects on human well-being and ecosystems, such as light pollution, which is defined as the unwanted or excessive artificial lights<sup>[7]</sup>. Light pollution is a recent environmental pollution in addition to air, water, waste, and noise pollution problems, which may inhibit plant

growth<sup>[8]</sup> and interfere with animal behavior<sup>[9]</sup>, thus threatening the biodiversity and ecological balance within a region<sup>[10]</sup>. Light pollution also causes a large amount of energy waste and carbon emissions, exacerbating the degradation of the global environment and leading to the disappearance of beautiful night sky—the fact is that more than one-third of global population cannot see the Milky Way anymore in their daily lives<sup>[11]</sup>. Beyond its ecological ramifications, light pollution is also harmful to urban residents' physical and mental health, causing the onset of various diseases<sup>[10][12][13]</sup>.

Existing studies have evidenced the therapeutic efficacy of natural environments as healing spaces. Compared with built environments, natural environments can more effectively contribute to relieving individuals' mental stress<sup>[14][15]</sup>. As a natural element, the significance of moonlight in relation to human physical and mental health, as well as its impact on visitors' experiences at night has been long neglected in both theoretical and practical contexts. Reintroducing moonlight into urban nightscapes holds the potential to extend residents' visual and psychological horizons, and effectively reduce the health risks associated with light pollution and circadian disruption. The natural charm of a moonlit sky would contribute to the therapeutic role of urban landscapes<sup>[16]</sup>. Moonlight is usually

regarded as an important element in the composition of nightscapes in traditional Chinese gardens<sup>[17]</sup>. However, with the advent of artificial illumination, the role of moonlight in the nightscape of urban green spaces has gradually faded from the considerations of designers. Questions pertaining to the effectiveness of moonlight integration into urban green spaces, its influence on nighttime visiting experiences, and the feasibility of its partial substitution for artificial lights remain unanswered in existing literature. This knowledge gap has hindered the efforts of introducing moonlight into urban green spaces. This study compared visitors' nighttime experiences within urban green spaces with and without artificial lights, aiming to provide a theoretical basis for the introduction of moonlight into urban nightscapes.

## 2 Research Methods

### 2.1 Sample Sites

By the end of 2021, the area of urban green spaces in Xuzhou City, Jiangsu Province, reached 17,749 hm<sup>2</sup>, with a green coverage rate of 43.3% in urban areas, and the green space per capita amounted to 17.7 m<sup>2</sup>.<sup>[18]</sup> The city has various types of green spaces, including urban parks, botanical gardens, forest parks, scenic areas, wetlands, and post-industrial reclamation parks. In this study, three parks within the Yunlong Lake Scenic Area were selected, namely Yunlong Park (built in 1958, covering an area of 30.7 hm<sup>2</sup>), Binhu Park (built in 2001, covering an area of 53.3 hm<sup>2</sup>), and Jinshan Park (built in 1993, covering an area of 2.1 hm<sup>2</sup>). Each of these parks enjoys a local renown for its unique features and attractions. Based on a comprehensive survey on the nightscapes of these parks, this study selected a total of 11 sample sites (5 in Yunlong Park, 4 in Binhu Park, and 2 in Jinshan Park), using the stratified random sampling method. The sample sites cover three landscape types that are popular by visitors at night—waterfront (2 sites), recreational plazas (5 sites), and pathways and trails (4 sites)—and all of them are equipped with lighting facilities.

### 2.2 Photographs

When conducting on-site surveys, numerous uncontrollable factors such as ambient sounds and the presence of other visitors would significantly affect individuals' experiences<sup>[19][20]</sup>. Meanwhile, there would be disparities between illuminated and non-illuminated conditions—urban sounds and the number of visitors would largely decrease when lights are off. Another fact is that in some green spaces, artificial lights are often turned off after midnight, which may bring potential risks to respondents. In

addition, the need for each respondent to enter sample sites alone, to avoid interactions between respondents, might also raise ethical concerns. Therefore, this study used photographs as proxies of real nightscapes. Although this method has limitations, such as the inability to fully reflect the real nightscape experience, and the inconsistent quality of photographs by different photographers and photographic devices<sup>[21][22]</sup>, it has advantages of high efficiency, cost-effectiveness, and the facilitation for comparative evaluations<sup>[21]</sup>. This method has been successfully applied in nightscape evaluations<sup>[23]</sup>.

The sample sites were photographed at nights on April 7 (half-moon) and April 27 (full-moon), 2021, which were both working days with clear weather. Photographs were taken from 20:00 to 01:00 of the next day (artificial lights were turned off at 22:00 in Yunlong Park and at 00:00 in Binhu Park and Jinshan Park), using a Sony digital camera (Sony NEX 3N, 35 mm for focal length). The camera was configured in the automatic night mode with an aspect ratio of 3:2, at an average height of viewing in nightscapes (1.70 m). Photographers should take photos from the same position and camera angle at both half- and full-moon nights within each sample site, and no human figure should be included in these photographs (Fig. 1). A total of 44 photographs were taken (4 for each sample site, including one for the half-moon night with artificial lights, one for the half-moon night without artificial lights, one for the full-moon night with artificial lights, and one for the full-moon night without artificial lights).

### 2.3 Survey Process

This study recruited a total of 78 college students of different majors from China University of Mining and Technology as respondents, who were divided into two groups, 39 students for each. Gender ratios of respondents in these two groups were nearly the same (21 males and 18 females in the first group, 20 males and 19 females in the second group). According to Andrew Lothian, in subjective assessment, reliable results can be achieved with the minimum respondents of 30<sup>[24]</sup>. Thus, the respondent size ensured the reliability of this study.

The 44 photographs were named half-moon group and full-moon group. The 22 photographs comprised in each group were presented by 11 slides, exhibiting the images with and without artificial lights taken on the same sample site. The two parallel photographs on each slide, named A and B, were displayed in a randomized order projected on a white screen measuring 1.6 m × 1.2 m. Respondents were asked to vote for the preferred image in five dimensions of visiting experience:

|              |                | Half-moon              |                           | Full-moon              |                           |
|--------------|----------------|------------------------|---------------------------|------------------------|---------------------------|
|              |                | With artificial lights | Without artificial lights | With artificial lights | Without artificial lights |
| Yunlong Park | Sample site 1  |                        |                           |                        |                           |
|              | Sample site 2  |                        |                           |                        |                           |
|              | Sample site 3  |                        |                           |                        |                           |
|              | Sample site 4  |                        |                           |                        |                           |
|              | Sample site 5  |                        |                           |                        |                           |
| Jinshan Park | Sample site 6  |                        |                           |                        |                           |
|              | Sample site 7  |                        |                           |                        |                           |
| Binhu Park   | Sample site 8  |                        |                           |                        |                           |
|              | Sample site 9  |                        |                           |                        |                           |
|              | Sample site 10 |                        |                           |                        |                           |
|              | Sample site 11 |                        |                           |                        |                           |

1. Photographs taken at 11 sample sites with and without artificial lights at half- and full-moon nights.

aesthetic preference, safety, relaxation, willingness to visit, and interestingness (Table 1). Respondents made their selections based on their personal perceptions. The next slide was shown only when all respondents had completed their selection of the current slide.

## 2.4 Data Analysis

If Photograph A was voted for a particular question, it was assigned a value of 1, and Photograph B assigned a score of 0. Each photo might obtain a score ranging from 0 to 39 for each dimension of visiting experience. All collected data were statistically analyzed using SPSS 17.0. The results of normal distribution, assessed through the Shapiro–Wilk’s test, and the homogeneity of variance via Levene’s test showed that, except for the dimension of relaxation under the condition of no artificial light at full-moon night ( $p = 0.035, < 0.05$ ), all the other data conformed to the normal distribution ( $p = 0.509 \sim 0.894, > 0.05$ ) and all passed the homogeneity of variance test ( $p = 0.287 \sim 0.776, > 0.05$ ). Thus, one-way ANOVA was used to compare visitors’ experiences with and without artificial lights during the same moon phase.

## 3 Results

### 3.1 Comparison of Visitors’ Experiences With and Without Artificial Lights at Half-moon Night

For the half-moon group, the average scores of the five experience dimensions with artificial lights were higher than that without artificial lights (Fig. 2). The result of one-way ANOVA showed that, except for the aesthetic preference, the scores of the

**Table 1: Visitors’ experience questionnaire**

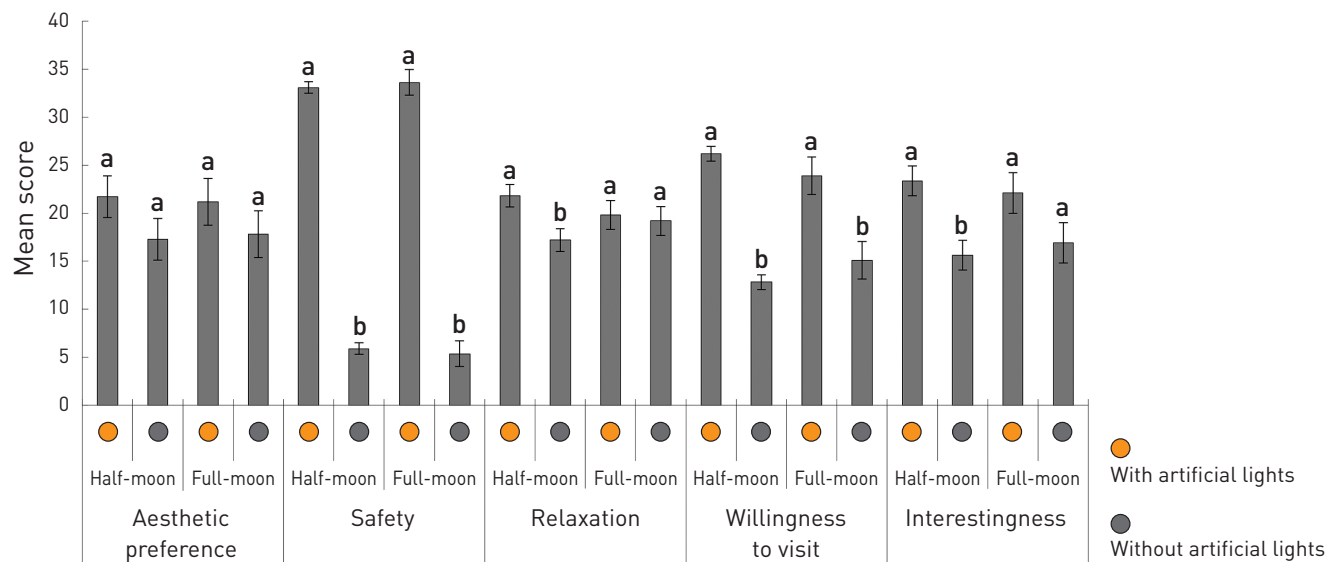
Please carefully compare the two photos A and B, and answer the following five questions  
(tick “v” in the corresponding option)

| Questions   | Options                    |                            |
|---|----------------------------|----------------------------|
| 1. Which photo do you think is more beautiful?                                  | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 2. Which photo makes you feel safer?  | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 3. Which photo makes you feel more relaxed?                                     | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 4. Which of the landscapes represented by the photos would you prefer to visit? | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 5. Which photo is more interesting to you?                                      | A <input type="checkbox"/> | B <input type="checkbox"/> |

other four dimensions with artificial lights were all significantly higher compared with those without artificial lights (Table 2).

### 3.2 Comparison of Visitors’ Experiences With and Without Artificial Lights at Full-moon Night

Consistent with the results of half-moon group, the average scores of the five experience dimensions with artificial lights were higher than those without artificial lights at full-moon night (Fig. 2). The one-way ANOVA analysis result revealed that there



2. Average scores ( $\pm$  standard error) of five visiting experience dimensions at 11 sample sites under artificial light and moonlight conditions at half- and full-moon nights, using letters a and b to represent the significant difference at the 0.05 level.

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**Table 2: One-way ANOVA for visitors' experiences with/without artificial lights**

|                      | Half-moon  |          | Full-moon |          |
|----------------------|------------|----------|-----------|----------|
|                      | F          | <i>p</i> | F         | <i>p</i> |
| Aesthetic preference | 2.106      | 0.162    | 0.952     | 0.341    |
| Safety               | 1,044.404* | < 0.001  | 225.984*  | < 0.001  |
| Relaxation           | 7.695*     | 0.012    | 0.091     | 0.766    |
| Willingness to visit | 149.647*   | < 0.001  | 10.209*   | 0.005    |
| Interestingness      | 12.414*    | 0.002    | 2.996     | 0.099    |

**NOTE**

\* indicates the difference is statistically significant at the 0.05 level.

was no significant difference in aesthetic preference, relaxation, and interestingness with and without artificial lights, while scores of willingness to visit and safety with artificial lights were significantly higher than those without artificial lights (Table 2).

## 4 Discussion

### 4.1 The Overall Role of Moonlight in Urban Green Spaces

Moonlight, as a natural element in the nightscape of urban green spaces, carries profound cultural connotations in traditional Chinese culture, where the moon is symbolically associated with beauty. The integration of moonlight into urban green spaces would play an important role in fostering a cultural atmosphere and enhancing its attractiveness. Findings of this study show that at full-moon night, there is no significant difference in aesthetic preference, relaxation, and interestingness with and without artificial lights; even at half-moon night, there is no significant difference in aesthetic preference between the two conditions. These results suggest that moonlight possesses the potential to serve as a partial substitute for artificial lights, especially at full-moon night.

### 4.2 Analysis of the Dimension of Safety

To the authors' knowledge, this study pioneers the role of moonlight in visitors' nighttime experiences within urban green spaces, providing a theoretical basis for reintroducing moonlight

into nightscapes. Notably, the results of this study show that, compared with other four experience dimensions, visitors' perceived safety with and without artificial lights fluctuates the most at both full- and half-moon nights. This discrepancy can be attributed to human's innate fear of darkness, especially their limited visual capacity during nighttime. Therefore, enhancing visitors' perceived safety without artificial illumination is a prerequisite for reintroducing moonlight into urban green spaces.

First, drawing from the information processing theory, the more (less) information people obtain from the environment, the more (less) safe they feel<sup>[25]</sup>. In the nightscapes with poor lighting conditions, visitors would optimize the use of auditory and olfactory senses to obtain environmental information, which to a certain extent can make up for the limitations of reduced visibility. Previous studies offer some useful clues. The research by Pingjia Luo et al. verified that introducing birdsong or playing classical Chinese music could significantly enhance visitors' perceived safety during nighttime use in constructed spaces<sup>[23]</sup>.

Second, more open spaces can be created to enhance landscape permeability<sup>[26]</sup>, allowing moonlight to infiltrate, enhancing the overall visibility of the place and thus the sense of safety.

Third, attracting more visitors into nightscapes of urban green spaces without artificial lights would help with the gathering of small social groups, which act as a form of social supervision that can effectively bolster people's perceived safety in the site<sup>[27]</sup>. Also, safety is closely related with other perceptions, for instance, an increased sense of safety can significantly influence the aesthetic preference<sup>[28]</sup> and foster a relaxed atmosphere within the environment<sup>[29]</sup>.

In summary, efforts to significantly improve safety in nightscapes without artificial illumination can pave the way for the feasible replacement of artificial lights with moonlight at specific moon phases, particularly around full-moon nights. Such a transition not only yields economic effects (e.g., saving energy, reducing cost of lighting facilities) and ecological benefits (e.g., decreasing light pollution), but also may enhance visitors' experiences within urban green spaces. In addition, it contributes to the protection of natural night sky, allowing urban residents to better enjoy the beauty of moonlight, starlight, and the sounds of night creatures. This will also benefit human health and contribute to the construction of livable cities and sustainable development.

However, the cyclical change of moon phases leads to the variations of moonlight brightness in a lunar month. The nights that have full-moon brightness only account for about 10% of

each lunar cycle. Therefore, the strategic addition of artificial lights becomes a vital consideration to complement moonlight, according to moon phases, weather conditions, and landscape features of the site, so as to strengthen visitors' overall experiences of nightscapes within urban green spaces.

#### 4.3 Analysis of the Dimension of Willingness to Visit

The findings of the present study reveal that the willingness to visit nightscapes in moonlight is significantly lower than that in artificial lights at both half-moon and full-moon nights. Although this study does not test the relationship between safety and willingness to visit, previous research has pointed out that the presence of risks would exert a significant negative effect on the willingness to visit<sup>[30]</sup>. This phenomenon can be attributed to the significant decrease of perceived safety when artificial lights are off. Consequently, design interventions can be used in improving the safety of nightscapes to enhance people's willingness to visit. Moreover, the willingness to visit urban green spaces is also affected by their function, scenic resource, and characteristic activity and effect image<sup>[31]</sup>. Therefore, improving the aesthetic value of nightscapes through appropriate lighting design and meeting users' diverse activity needs present a way to encourage their willingness to visit.

#### 4.4 Analysis of the Dimensions of Relaxation and Interestingness

At full-moon night, there is no significant difference in relaxation and interestingness with and without artificial lights. While, at half-moon nights, scores of the two experiencing dimensions with artificial lights is significantly higher than those without artificial lights. This suggests that when the lighting within green spaces is notably insufficient, the relaxation and interestingness of visitors would further decrease accordingly, necessitating artificial lights for ensuring visitors' experiences. This also implies that lighting design should wisely consider moon phases, so as to protect the natural night sky as much as possible while minimizing any significant reduction in relaxation and interestingness of visitors. Furthermore, the objects illuminated by artificial lights also depend on the functions of nightscapes. Previous literature has evidenced that illuminating natural elements is particularly effective for mental stress relief<sup>[32]</sup>. These findings provide specific guidance for the lighting design of nightscapes within urban green spaces.

#### 4.5 Limitations and Future Research

This study has the following limitations.

1) The use of photographs as the stimuli: photographs can

only convey visual information, whereas visitors' experiences of a landscape site involve a comprehensive perception process that includes auditory, olfactory, tactile, and other senses, especially in low-light conditions where people's visual capacity is restricted; even if only visual information is considered, there may be differences in experiences between photograph assessment and on-site evaluation.

2) Homogeneous participant demographics: the respondents recruited for this study were college students, who share similar age and educational level that may limit the generalizability of findings. Previous studies have demonstrated that the age and educational level of respondents can influence respondents' assessment results of aesthetic preference and safety<sup>[33][34]</sup>.

3) Exclusion of human figures in photographs: in order to eliminate the impact by other visitors as much as possible, the photographs used in this study excluded human figures. However, this is somewhat divorced from the reality of the public usage of urban green spaces, and the presence of other visitors implies social supervision, which may have a non-negligible impact on visitors' experiences. In addition, in most cases, visitors seldom visit a park alone at night, while this study did not consider the possible influence of companions on visiting experiences.

And 4) the effect of additional artificial lighting sources: this study treats the green spaces as a natural moonlight environment when artificial lights are off, without accounting for the effect of additional artificial lights (such as street lighting and the lights from surrounding buildings) cast, directly or indirectly, into the green spaces, which may also have influence on visitors' experiences.

The above limitations can light the directions of future research, such as recruiting respondents of higher representativeness, conducting on-site evaluations, and analyzing the impact of the quantity of visitors within a given nightscape, as well as the number and the identity of companions, on visitors' experiences. Such studies may benefit from addressing these aspects to deepen our understanding of the relationships between the non-artificial-illumination nightscapes of urban green spaces and visitors' experiences, providing more targeted guidance for the nightscape design of urban green spaces.

## 5 Conclusions

The rapid development of artificial lights since the invention of the electric lamp over a century ago has brought both advancement and negative consequences: artificial lights provide brightness to human lives while cause light pollution, especially leading to diminishing natural night sky. In response to these challenges, the

International Dark Sky Association, founded in 1988, launched the International Dark Sky Places program in 2001 that encourages communities, parks, and protected areas worldwide to protect natural night sky through responsible lighting policies and public education activities<sup>[35][36]</sup>. More importantly, though the brightness of moonlight sees variations by moon phases and weather conditions, this program aims at preserving natural night sky as a valuable natural resource, especially in urban areas where natural elements are scarce. In cities, green spaces have become everyday places for people to enjoy natural night sky. Thus, how to strengthen the role of green space in protecting natural night sky and enable urban residents to appreciate and experience the beauty of natural night sky has posed a new challenge for both landscape design and lighting design.

This comparative study analyzes visitors' experiences of nightscapes within urban green spaces under both artificial light and moonlight conditions, and the findings yield practical conclusions. At full-moon night, there was no significant difference in aesthetic preference, relaxation, and interestingness between artificial light and moonlight conditions; at half-moon night, the aesthetic preference between the two conditions also did not show any significant difference. These findings provide a theoretical basis for the integration of moonlight on specific dates and in appropriate weather conditions. This study also concludes that, though the brightness of moonlight varies by moon phases and weather conditions, reintroducing moonlight into the nightscapes of urban green spaces and partially or entirely replacing artificial lights has the potential to bring broad economic, ecological, and social benefits. The research also offers innovative concepts for the protection of natural night sky and the mitigation of light pollution.

## ACKNOWLEDGMENTS

The authors would like to thank the 78 college students who participated in the surveys.

## RESEARCH FUND

- Coexistence of Ecological Quality and Aesthetic Value of Urban Green Space and Optimization of Design, National Natural Science Foundation of China (No. 32071830)

**Competing interests** | The authors declare that they have no competing interests.

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# 城市绿地夜景游览体验： 人工照明和月光的对比

赵警卫<sup>\*</sup>，刘东瑜，邓淑惠

中国矿业大学建筑与设计学院，徐州 221116

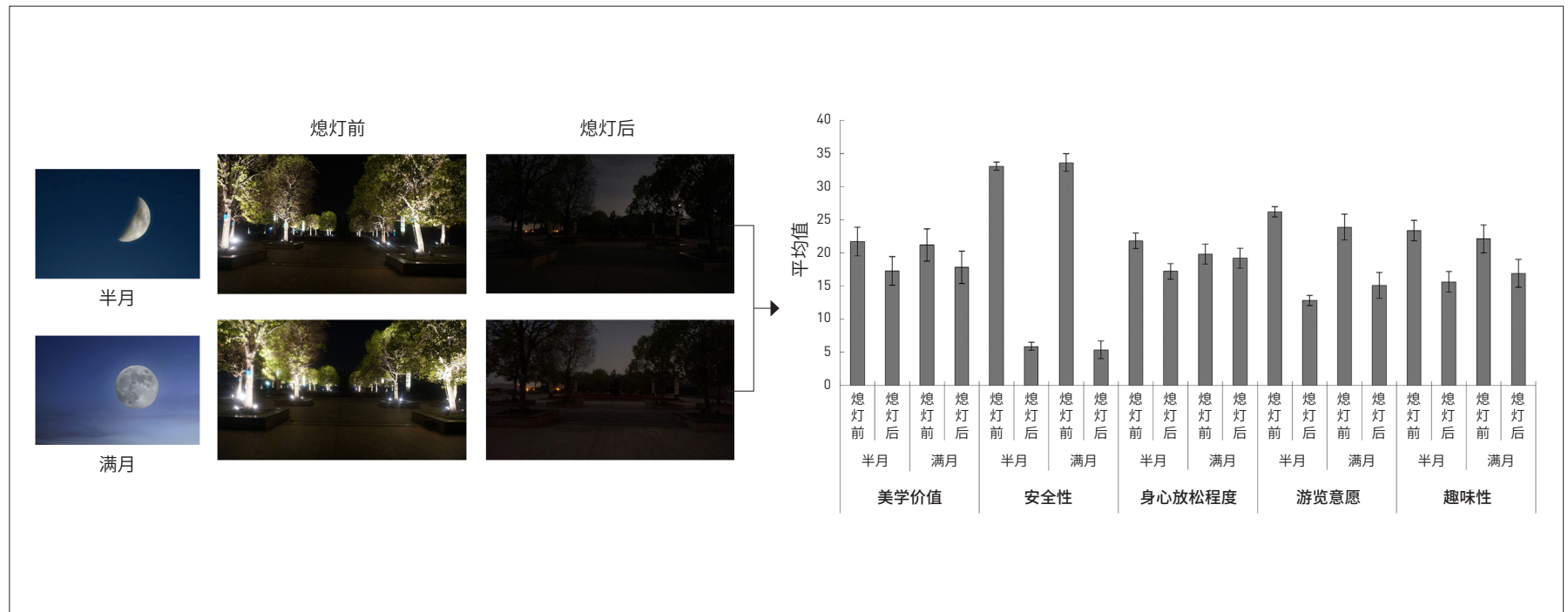
<sup>\*</sup>通讯作者

地址：江苏省徐州市大学路1号

邮编：221116

邮箱：4365@cumt.edu.cn

## 图文摘要



## 文章亮点

- 对比研究了人工照明和月光条件下游人在城市绿地夜景中的游览体验差异
- 半月时，熄灯前后的美学价值没有显著差异
- 满月时，熄灯前后的美学价值、身心放松和趣味性没有显著差异
- 把月光引入城市绿地夜景并部分代替人工照明是可行的

## 关键词

城市绿地；  
夜景；  
人工照明；  
月光；  
游览体验；  
光污染；  
比较研究

## 摘要

提高城市绿地夜景质量，从而提升人们的游览体验，对于发挥城市绿地的功能、促进居民健康具有重要作用。然而，当前设计师对于绿地夜景的关注主要集中在人工照明上，月光等自然光照几乎被忽略。本研究在11个城市绿地样地上分别拍摄了夜晚熄灯前后的对比照片，并在校大学生为评价人员，分别评价了城市绿地熄

灯前后夜景的五种游览体验。研究结果显示,无论在半月还是满月条件下,熄灯前的各种游览体验均优于熄灯后;在满月条件下,熄灯前安全性和游览意愿显著大于熄灯后,而美学价值、身心放松程度、趣味性在熄灯前后没有显著差异;在半月条件下,熄灯前后的美学价值没有显著差异,其他四种游览体验熄灯前皆显著高于熄灯后。本研究的上述结论可为在城市绿地设计中引入月光等自然光照提供理论依据。

编辑 田乐,王颖  
翻译 赵警卫,田乐

## 1 引言

城市绿地是城市居民体验自然、放松身心的重要场所,游览城市绿地可以显著提升游人的身心健康,如强健体魄<sup>[1]</sup>、减缓精神压力<sup>[2]-[4]</sup>等。随着生活节奏的加快和社会竞争的加剧,对于大多数中青年人类来讲,因白天忙于工作和学习,晚上则成为他们使用绿地的主要时间段<sup>[5]</sup>。因此,探究人们游览绿地夜景的体验对于充分发挥城市绿地的作用、提升城市居民生活满意度具有重要作用。

自1879年白炽灯发明以来,夜间人工照明得到迅速发展,城市绿地人工照明也已从单一的照明功能转变到如今的划分空间、氛围渲染、引导交通等多种功能<sup>[6]</sup>。与此同时,人工照明也对居民和生态系统带来了一系列负面影响,如光污染,即人们不需要的或者超量的人造光<sup>[7]</sup>。光污染是继废气、废水、废渣和噪声等污染之后一种新的环境污染源,可能抑制植物生长<sup>[8]</sup>、干扰动物行为<sup>[9]</sup>,从而威胁某一区域的生物多样性和生态平衡<sup>[10]</sup>;光污染也造成了大量的能源浪费,增加了碳排放,使全球环境进一步恶化;光污染让美丽的夜空消失,有超过三分之一的人类在日常生活中看不到美丽的银河<sup>[11]</sup>。另一方面,光污染对于城市居民身心健康也造成了一定的危害,引发了诸多疾病<sup>[10][12][13]</sup>。

已有的研究证明自然环境是有效的疗愈环境,与城市建成环境相比,自然环境对被试者精神压力的缓解更加有效<sup>[14][15]</sup>。月光作为夜间的自然要素,对人们身心健康的作用及对夜晚游览体验的影响长期被理论研究和规划设计者所忽略。让自然月光回归夜间生活可以促使居民实现视觉和心理上的延展,有效缓解光污染和昼夜紊乱导致的健康问题。月光照亮的天空具有自然的魅力,这种魅力也是疗愈景观的重要特性之一<sup>[16]</sup>。中国传统造景手法常常把月光作为夜景构成的重要元素<sup>[17]</sup>,然而,随着人工照明的发展,月光在城市绿地夜景中的作用逐渐被设计者所遗忘。目前,月光在城市绿地夜景中能否起作用、月相变化对人们的游览体验将产生什么样的影响、能否用月光部分替代人工照明等问题困扰着试图在城市绿地夜景中引入月光的设计实践,但现有研究尚无法为

之提供充足的证据。本研究对比了在人工照明和月光两种条件下城市绿地使用者的夜间游览体验,以期在城市绿地中引入月光提供理论依据。

## 2 研究方法

### 2.1 样地选择

截止到2021年底,江苏省徐州市城市绿地面积达到17 749hm<sup>2</sup>,城区绿化覆盖率43.3%,人均绿地面积达17.7m<sup>2</sup>。<sup>[18]</sup>徐州公园绿地类型多样,包括城市公园、植物园、森林公园、风景名胜、湿地,以及采煤塌陷地复垦公园等。本研究选择在当地知名度较高且具有代表性的云龙湖风景区内三个公园作为研究地点:云龙公园(建于1958年,面积30.7hm<sup>2</sup>)、滨湖公园(建于2001年,面积53.3hm<sup>2</sup>)和金山公园(建于1993年,面积2.1hm<sup>2</sup>)。在充分调研三个公园夜景的基础上,研究采用分层随机取样的方式共选取11个样地(云龙公园5个、滨湖公园4个、金山公园2个),涵盖滨水绿地(2个)、休闲广场(5个)、道路(4个)三种夜晚游人经常到访的景观类型,且保证每一个样地均有夜间照明设施。

### 2.2 照片拍摄

观者现场评价存在着众多不可控因素,包括声音的影响、其他游人的干扰等。既有研究认为,环境声音和游人数量会对人们的游览体验产生显著影响<sup>[19][20]</sup>。考虑到熄灯前后样地的声音环境和游人数量往往差异较大——熄灯前城市噪音较多,绿地中的游人数量也较多;熄灯后,噪音和游人数量均有所降低——且部分绿地零点以后才熄灯,评价人员深夜在绿地中可能存在安全隐患;此外,为了避免评价人员之间的相互影响,评价人员必须单独进入到绿地中,也可能造成伦理问题。因此,本研究使用照片评价法替代现场评价。尽管这种方法存在缺点,如不能完全反应真实场景、照片的质量受到拍摄者和拍摄设备质量的影响等<sup>[21][22]</sup>,但具有效率高、费用低、便于对比评价等优点<sup>[21]</sup>,且已被应用

于夜晚景观评价研究中<sup>[23]</sup>。

研究者于2021年4月7日（半月）和27日（满月）夜间在样地中进行拍摄，两天均为晴天，且均为工作日。拍摄时间为20:00至第二天01:00（云龙公园的熄灯时间是22:00，滨湖公园和金山公园熄灯时间是00:00）。拍摄使用同一款索尼数码相机（SONY NEX 3N，焦距35mm），设定为自动夜景模式，照片的长宽比为3:2，拍摄高度和大多数游客观景视角高度相当（1.70m），尽量保证拍摄者在半月和满月、熄灯前后站立的地点和相机的角度一致，且拍摄时尽量避开游人（图1）。研究共拍摄照片44张（11个样地，每个样地包含半月和满月条件下熄灯前后两张照片）。

### 2.3 评价过程

研究人员在中国矿业大学中招募到不同专业的在校本科生共计78名作为评价者。评价者分为两组，每组39人。两组评价者的性别比例基本相同（第一组中男性21人，女性18人；第二组中男性20人，女性19）。安德鲁·洛希安的研究认为，参加主观评价的人数超过30人就可以得到可靠的评价结果<sup>[24]</sup>，因此本研究中的评价者规模可满足研究需求。

研究人员把照片分为半月组和满月组，每组包含22张照片，投影在尺寸为1.6×1.2m的白色银幕上。每一组照片制作成11张幻灯片，每一张幻灯片上展示同一个样地熄灯前后的两张照片。两张照片尺寸相同，分别命名为A和B，但展示顺序随机。评价者被要求就美学价值、安全性、身心放松程度、游览意愿和趣味性五种游览体验分别对两组照片作出评价（表1）。评价者根据自己的主观感受，选取适当的选项。只有当所有

的评价者皆完成了对同一张幻灯片上照片的评价后，才会播放下一张幻灯片。

### 2.4 数据分析

如果一名评价者针对某一个具体问题选择了照片A，则照片A被赋值为1，照片B被赋值为0，因此每一张照片的每一种游览体验的得分范围为0~39。所有采集到的数据采用SPSS 17.0进行统计分析。正态分布（Shapiro-Wilk检验）和方差齐性检验（Levene检验）显示，除了满月熄灯后的身心放松程度不符合正态分布外（ $p=0.035$ ， $<0.05$ ），其他数据均符合正态分布（ $p=0.509\sim 0.894$ ， $>0.05$ ），且全部通过方差齐性检验（ $p=0.287\sim 0.776$ ， $>0.05$ ）。因此单因素方差分析被用来检验相同月相下熄灯前后的游览体验对比。

## 3 研究结果

### 3.1 半月条件下熄灯前后游览体验对比

在半月条件下，熄灯前5种游览体验的得分平均值均大于熄灯后（图2）。单因素方差分析显示，熄灯前后，除了美学价值无显著差异外，熄灯前其他四种游览体验的得分均显著高于熄灯后（表2）。

### 3.2 满月条件下熄灯前后游览体验对比研究

和半月时一致，满月条件下，熄灯前5种游览体验的得分平均值均大于熄灯后（图2）。单因素方差分析显示，熄灯前后，美学价值、身心放

表1：游览体验调查表

| 请认真观察对比 A、B 两张照片，并回答如下五个问题<br>(在相应的选项上打“√”) |                            |                            |
|---|----------------------------|----------------------------|
| 问题  | 选项                         |                            |
| 1. 你认为哪张照片更美?                               | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 2. 哪张照片让你感觉更安全?                             | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 3. 哪张照片让你感觉更放松?                             | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 4. 你更想游览哪张照片代表的景观?                          | A <input type="checkbox"/> | B <input type="checkbox"/> |
| 5. 哪张照片让你感到更有趣?                             | A <input type="checkbox"/> | B <input type="checkbox"/> |

表2：半月和满月条件下熄灯前后游览体验方差分析结果

|        | 半月条件下      |        | 满月条件下    |        |
|--------|------------|--------|----------|--------|
|        | F          | p      | F        | p      |
| 美学价值   | 2.106      | 0.162  | 0.952    | 0.162  |
| 安全性    | 1 044.404* | <0.001 | 225.984* | <0.001 |
| 身心放松程度 | 7.695*     | 0.012  | 0.091    | 0.012  |
| 游览意愿   | 149.647*   | <0.001 | 10.209*  | <0.001 |
| 趣味性    | 12.414*    | 0.002  | 2.996    | 0.002  |

注

\*表示在 0.05 水平上差异显著。

松程度和趣味性三种游览体验的得分没有显著差异，而熄灯前的游览意愿和安全性得分显著高于熄灯后（表2）。

## 4 讨论

### 4.1 月光在城市绿地中的整体作用

月光是城市绿地夜景中的自然要素之一。在中国传统文化中，月亮具有深厚的文化内涵，月光也往往与美好的事物联系在一起。因此，将月光引入城市绿地，对于营造绿地的文化氛围、增强绿地的吸引力具有重要作用。本研究的结果表明，在满月条件下，城市绿地的美学价值、身心放松程度、趣味性这三种游览体验在熄灯前后没有显著差异；即便在半月条件下，城市绿地的美学价值在熄灯前后也未见显著差异。这说明，在一定程度上月光可以部分代替人工照明，尤其在满月条件下。

### 4.2 城市绿地夜景安全性分析

就笔者所知，本研究首次验证了月光对于城市绿地夜景游览体验的作用，这在绿地中引入月光提供了理论依据。然而，本研究结果显示，无论在满月还是半月条件下，相对于其他四种游览体验，熄灯前后城市绿地的安全性体验差异最大，这是因为人类缺乏夜视能力，天然地恐惧黑暗环境。因此要做到用月光替代人工照明，前提条件是提升无人工照明城市绿地的安全性。

首先，根据信息处理理论，人们获取的环境信息越多（少），在该环境中越感到（不）安全<sup>[25]</sup>。在亮度条件较差的城市绿地夜景中，尽管人们的视觉感知受限，但可以利用听觉、嗅觉感知来收集环境信息，在一定程度上能够弥补视觉感知获取环境信息的不足。在这方面，前人的研究提供了一些有用的线索。罗萍嘉等人认为，在城市绿地夜景中的适当场所引进声景观也可以显著地提升游人的安全感，如把鸟鸣声引入规则式的植被中或把中国古典音乐引入人工化较强的环境中<sup>[23]</sup>。

其次，在进行城市绿地设计时可设计较多的开敞空间，以提升景观的通透性<sup>[26]</sup>；这样的环境有利于月光的渗入，可提升环境的可视性，从而提升安全感。

再次，可通过提升无人工照明的城市绿地夜景的吸引力，鼓励更多的游人到此游览——这样的场地意味着存在一个小规模社会群体，即形成了一种社会监督，能够有效提升人们在场地中的安全感<sup>[27]</sup>。另一方面，安全性体验也与其他游览体验相互关联，如安全感的提升可显著提升环境的美学价值<sup>[28]</sup>，也可以让人们在该环境中感觉更加放松<sup>[29]</sup>。

总之，如能大幅提升无人工照明城市绿地夜景的安全性，在特定时段（如满月前后）以月光代替人工照明在城市绿地中是可行的，不但具有显著的经济效益（节约能源、减少照明设施投资等）和生态效益（降低光污染等），而且可能提升游人的游览体验。此外，也可在一定程度上

上实现自然夜空保护，把月光、星光、夜晚生物及其声音留在城市的夜晚，这对于提升人类健康、建设宜居城市和可持续发展同样具有重要意义。

然而，随着月相的周期性变化，月光的亮度每月也在发生变化，能够接近满月时亮度的时间仅占每个月相周期的10%左右。因此，根据月周期的变化，以及天气情况和场所的景观特点，适当添加人工照明来补充自然月光，也是提升城市绿地游览体验的重要措施。

### 4.3 城市绿地夜景游览意愿分析

研究结果显示，无论在满月还是半月条件下，熄灯后游人的游览意愿均显著低于熄灯前。尽管本研究没有检验安全性和游览意愿这两项游览体验之间的关系，但前人的研究指出，风险的存在对游览意愿具有显著负面影响<sup>[30]</sup>。可以推断，熄灯后场所安全性的显著降低是导致游览意愿下降的一大原因。因此，通过设计途径提升夜景的安全性，是提升游人游览意愿的方法之一。同时，游览意愿还受到城市绿地的价值功能、风景资源、特色活动与功效等因素的影响<sup>[31]</sup>。因此，通过适当的照明设计提升城市绿地夜景的美学价值、满足使用者各种活动的开展需求能够提升游人的游览意愿。

### 4.4 城市绿地夜景身心放松程度与趣味性分析

在满月条件下，熄灯前后的身心放松程度和趣味性这两种游览体验未呈现显著差异。而在半月条件下，熄灯前的心身放松程度和趣味性显著高于熄灯后。这说明当绿地的照明严重不足时，对游人放松身心和游览趣味性的负面影响更大，这种情况下人工照明必不可少。这进一步说明人工照明设计应充分考虑月相变化，这样才能在不显著影响身心放松和游览趣味性的前提下，尽量多地保护自然夜空。同时，人工照明的照亮对象也与夜景的功能相关，前人的研究指出，照亮自然要素对于游人的身心疗愈作用更好<sup>[32]</sup>。这些都为城市绿地夜景照明设计提供了具体指导。

### 4.5 研究不足与启示

本研究存在如下不足。

1) 采用照片作为评价的媒介，然而照片只能传递视觉信息，而游客的游览体验是综合感知的过程，还包括通过听觉、嗅觉、触觉等感知到的信息，尤其是在视觉感知受限的较暗条件下。即便只考虑视觉信息，照片评价和现场评价也可能存在差异。

2) 本研究的评价者是在校大学生，他们的年龄和教育背景具有相似性，对城市绿地游览者的代表性较差。以前的研究证明，评价人员的年龄和教育背景对环境的美学价值和安全感评价具有一定的影响<sup>[33][34]</sup>。

3) 为了排除环境中游人数量对游览体验评价的影响，本研究在照片拍摄时，尽量避免游人出现在照片中。然而在实际情况下，城市绿地中

常常都有数量不等的游人存在；而游人的存在意味着社会监督，可能对游览体验产生不可忽视的影响。此外，在大多数情况下，人们很少在夜间独自使用城市绿地，本研究未考虑同行人员这一因素可能对游览体验产生的影响。

4) 本研究把绿地人工照明熄灯后作为自然月光环境来处理，而事实上，即便在熄灯后，依然有部分城市灯光（如街道照明、绿地外建筑的灯光等）直接或者间接地投射到绿地中，这些灯光会对游人的游览体验产生一定的影响。

上述研究不足也为未来的研究指明了方向。例如，在今后的研究中，可以邀请更具代表性的人员作为评价者在绿地现场进行评价；可以研究绿地夜景中游人数量的多少，以及陪同人员的数量和身份对于游览体验的影响等。这些研究将进一步加深我们对无人工照明绿地夜景与游览体验之间关系的理解，从而为城市绿地夜景设计实践提供更具针对性的理论指导。

## 5 结论

自从一百年多前电灯发明以来，人工照明迅速发展。然而，人工照明在给人类带来光明、驱除恐惧的同时，也造成了许多负面的影响。1988年，致力于保护自然夜空的国际黑暗天空协会成立，该协会于2001年启动了“国际黑暗天空地区计划”，旨在鼓励世界各地的社区、公园和保护区通过负责任的照明政策和公共教育来保护自然的黑暗场所<sup>[35][36]</sup>。这不仅是为了应对愈来愈严重的光污染造成的危害，更是把自然夜空当作一种重要的自然资源加以保护。尽管月光受到月相变化和天气条件的影响，其依然是一种珍贵的自然资源，在缺乏自然环境的城市区域更是如此。在城市里，绿地已经成为便于人们欣赏自然夜空的场所。如何加强城市绿地在保护自然夜空方面的作用、让城市居民更好地欣赏和体验自然夜空，这对城市绿地景观设计和照明设计都提出了新的挑战。

本文通过对比研究的方法，分析了人工照明和月光条件下游人在城市绿地夜景中的游览体验，并得出了可以应用到实践中的结论：在满月条件下，熄灯前后的美学价值、身心放松程度、趣味性三种游览体验没有显著差异；在半月条件下，熄灯前后的美学价值也未见显著差异。这在特定日期和天气条件下用自然月光代替人工照明的设计实践提供了理论依据。本研究认为，尽管月光受到月相和天气的影响，但在不同的月相和天气条件下，把月光引入城市绿地夜景，用月光全部或部分替代人工照明具有广泛的经济、生态和社会意义。这为自然夜空保护及光污染控制提供了新的思路。

## 致谢

感谢参与本研究照片评价的78名大学生。

## 基金项目

· 国家自然科学基金项目“城市绿地生态质量和美学价值共存度及其优化设计研究”（编号：32071830）

图 1. 11 个样地在半月和满月熄灯前后的照片

图 2. 在半月和满月条件下，熄灯前后，11 个样地 5 种游览体验的得分平均值（± 标准误）。当在 0.05 水平上存在显著差异时，用不同字母表示（a 和 b）。