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**Article**

# Perspectives on urban lighting: Pedestrian visual comfort and safety preferences

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## ABSTRACT

This study investigates pedestrian preferences regarding outdoor public lighting, specifically examining their impact on the perception of visual comfort, safety in different urban settings. Despite extensive research on lighting parameters and pedestrian safety perception in recent years, gaps remain in understanding how users perceive different lighting scenes in real nighttime environments.
The laboratory study comprised 130 participants under 30 years old. Using real location data, we simulated four distinct urban lighting conditions using Dialux software and examined them in a dark laboratory setting. Participants viewed generated images of urban nighttime scenes of a well-known Ljubljana district and answered the questionnaire.
Our study employed various analytical approaches to examine the effects of height (low vs. high) of lamp-post and lighting uniformity (higher-uniform vs. less-uniform) on participants' perceptions of visual comfort, confidence, sense of distance and sense of direction in public spaces at night. The results demonstrate a preference for lighting with good uniformity, particularly in areas with higher lamp-post, suggesting its vital role in enhancing visual comfort. These findings emphasize the significance of continuous lighting design in promoting pedestrian visual comfort and safety in urban environments.

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## INTRODUCTION

Outdoor public lighting plays a critical role in influencing pedestrians' decision to walk after dark (CIE, 2019). Compared with an unlit road, a well-lit road enhances the reassurance that it is safe to walk (Fotios et al., 2015), and encourages walking activity (Fotios et al., 2019). Proper lighting environment improves pedestrians' obstacle detection ability (Fotios et al., 2020) (Uttley et al., 2017), and fosters a sense of security, which is particularly important in urban environments where uneven pavement, street furniture, and other pedestrians may increase the risk of accidents.

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The prospect-refuge theory further emphasizes the role of lighting in shaping perceptions of safety, particularly in natural environments such as parks (van Rijswijk & Haans, 2018). This theory suggests that people feel safer in environments where they can both see potential threats (prospect) and have the option to seek shelter if needed (refuge). Adequate lighting supports this by enhancing visibility and reducing the feeling of entrapment in dark, secluded areas, especially in natural outdoor public environments (Dosen & Ostwald, 2016).

Under consistent lamp and optical fixture conditions, increasing the height of lamp posts typically leads to more uniform illumination of the road surface. However, this increased height also raises the potential for light spillage (Bennie et al., 2016) (Kyba et al., 2017). To achieve better uniformity, also reducing the distance between lamp posts might help. Proper management of these factors, ensuring that uniformity is maintained within an optimal range, is crucial. Therefore, understanding user preferences for lamp post height and spacing is essential for designing effective and satisfactory lighting scenarios.

Traditional lighting design has often focused on factors such as illuminance levels and uniformity. However, this study adopts an approach by examining the effects of uniformity of illuminance and pole height. Higher poles generally offercreate a sense of spaciousness at night, enhancing visibility, while lower poles can create a more intimate atmosphere, albeit with potentially reduced visibility. A shorter distance between lamp posts usually results in more uniform lighting conditions, especially with higher poles, which improves spatial orientation and overall visual comfort—crucial for pedestrians navigating unfamiliar areas.

This study explores how lamp post distance and pole height affect pedestrians' perceptions of safety and visual comfort in urban outdoor public spaces during nighttime hours. Specifically, it investigates the effects of pole heights (lower vs. higher) and lamp post distances (closer with better illuminance uniformity vs. farther apart with worse uniformity) on participants' perceptions of safety, visual comfort, and ease of orientation in public squares during nighttime hours.

The study seeks to address two key questions:

1. Do pedestrians have a clear preference for pole height and uniform illuminance settings, and what is the preference?
2. How do the height and continuity of the lamp posts in the public square affect the perception of pedestrians?

## METHODOLOGY

### Participants

The experiment took place in the Lighting and Photometry Laboratory at the University of Ljubljana in the spring of 2022. A total of 130 participants, all from the Faculty of Electrical Engineering, were involved in the study. Of these, 16 (12%) were female and 114 (88%) were male, all under 30 years old with normal or corrected-to-normal vision. All participants confirmed familiarity with the location and surroundings before the experiment.

Due to COVID-19 safety protocols, the darkroom could only accommodate 25 participants at a time, with a required 1.5-meter distance between them. As a result, each trial involved 8 to 10 participants, and the same procedure was repeated for each group.

Participation was voluntary, with no financial compensation provided. The study was reviewed and approved by the University of Ljubljana's Ethics Committee, and informed consent was obtained from all participants before their participation.

### Photo Stimuli

The experiment utilised rendering images of night-time cityscapes and photometric datasets. Using Dialux software, we created a complex 3D model that simulated four different street lighting scenarios in front of the central train station in Ljubljana, as shown in Figure 1. Notably, all the participants confirmed that they were familiar with the locations of the stimuli in real. Building on the lighting paradigm described in previous research (Nasar & Bokharaei, 2017), our stimulus repertoire included subtle variations in light consistency. The images were displayed on a 300 cm × 230 cm screen, and the luminance was adjusted using computer and projector settings to maintain an average luminance of approximately 1.0 cd/m$^2$ across the visual area on the road surface.

An experimental paradigm with a 2×2 configuration was adopted, encompassing lamp-post height (low vs. high at 4.5 m vs. 12 m, respectively) and illuminance uniformity (uniform with 24 m lamp-post distance and less uniform with lamp-post distance of 48 m). These independent variables were operationalised through a quartet of rating reports. The survey aimed to assess the participants' subjective evaluations of their perceptions of safety, visual comfort, ease of discerning distances between pedestrians and street objects, and ease of orientation.

### Experimental Procedure

To maintain consistent illumination and mitigate the influence of external lighting, the use of mobile phones was prohibited throughout the presentation phase. This standardised protocol was meticulously adhered to across

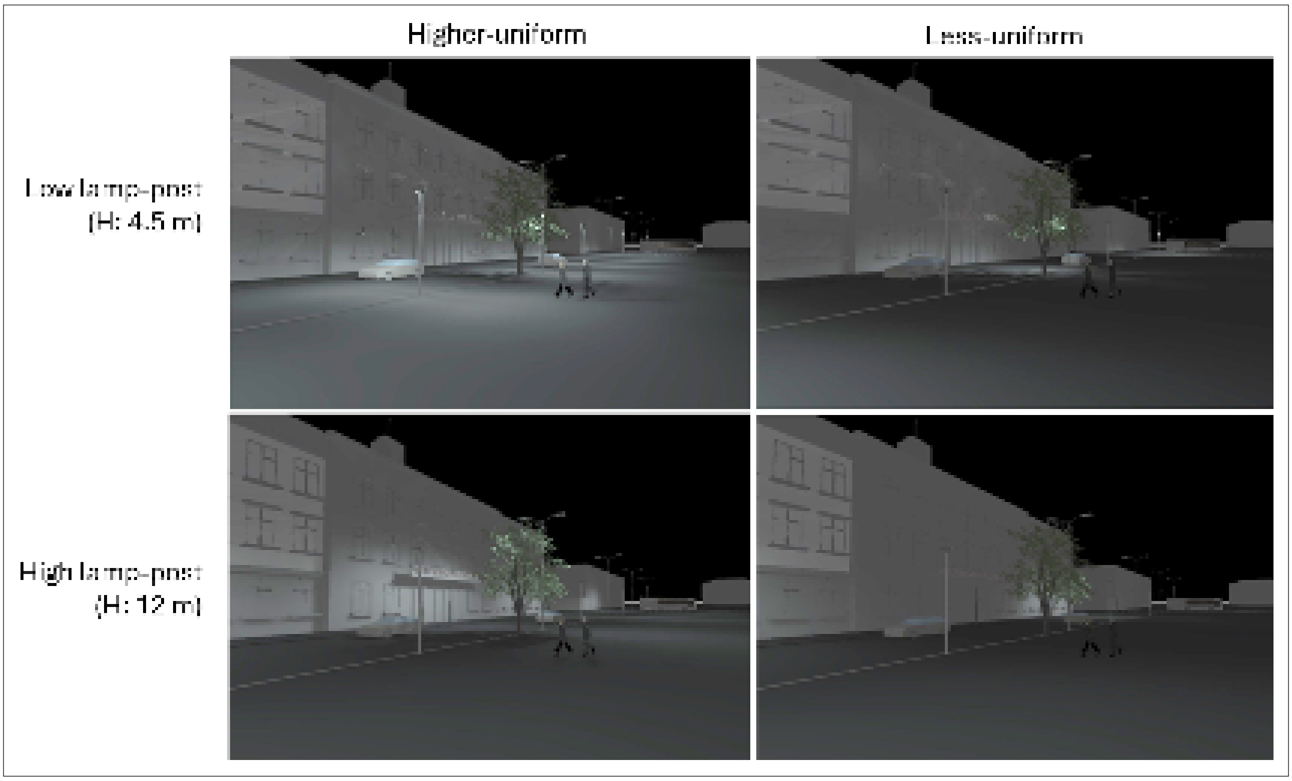


**Figure 1**. Example of the 3D Dialux rendering images used in the experiment.

all experimental groups, as illustrated in Figure 2.

The procedure began by displaying each image to participants for 3 seconds. To ensure robust perceptual engagement, the same set of comparative images was presented twice. During the questionnaire phase, pairs of images were shown simultaneously for an average duration of 105 seconds, allowing participants to compare and rate them. Participants were required to evaluate the images based on specific questions, and their responses were recorded using a five-point scale, ranging from 1 (not at all) to 5 (very much). The order of both images and questions was randomized. The questions were formulated as follows.

Question 1 (Q1), visual comfort: Do you notice a difference between these two images? How comfortable do you feel with Figure A? How comfortable do you feel with Figure B?

Question 2 (Q2), confident: How confident do you feel with Figure A? How confident do you feel with Figure B?

Question 3 (Q3), orientation: To what extent does lighting help you become oriented with Figure A? To what extent does lighting help you become oriented with Figure B?

Question 4 (Q4), distance estimation: How much does the lighting help you estimate the distance to other pedestrians and objects with Figure A? How much does the lighting help you estimate the distance to other pedestrians and objects with Figure B?

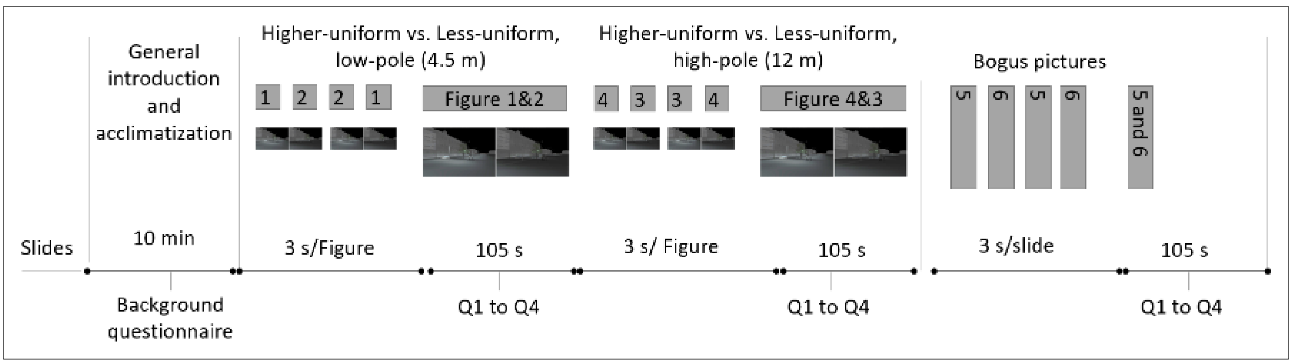


**Figure 2**. Timeline and order of the pictures in the experimental procedure.

## RESULTS AND CONCLUSION

For questions regarding whether there was a noticeable difference between the two images, participants consistently indicated that a difference was present. This suggests that participants were able to perceive variations in the images, despite only changes in the pole distance and height parameters.

First, we examined the mean rating results. As shown in Figure 3, the mean ratings span from 2.2 to 4.1, at a 95% confidence interval. Environments featuring uniform illuminance from high lamp posts had the highest mean scores, whereas those featuring less uniform illuminance from high lamp posts had the lowest scores. This observation suggests a preference among the participants for environments characterised by better uniformity of illuminance from high lamp posts. The standard deviation within this range varied from 0.9 to 1.1 across all means.

Subsequently, two-way ANOVA was employed to investigate the impact of lighting uniformity and lamp-post height on the four subjective rating indicators. Post-hoc analyses were conducted using the Bonferroni–Dunn method, with the significance threshold set at $p<0.05$. The full factorial ANOVA design consisted of higher and lower lamp post heights and higher uniform and less uniform lighting conditions. The results are summarised in Table 1. Significant effects were observed for both uniform and less-uniform lighting environments for all four questions. Moreover, the lamp-post height did not demonstrate any significant effect, regardless of uniformity. Analyses comparing the low and high lamp post settings across all questions revealed no statistically significant differences.

Overall, the collected data suggested a consistent participant preference for lighting with better uniformity of illuminance over one with worse uniformity that persisted across both higher- and lower-lamp-post environments.

This study explored the effects of lamp post distance and height on pedestrians' perceptions of safety, visual comfort, and ease of distance and orientation in public spaces at night. The findings indicate that continuously installed lamp posts which provide good illuminance uniformity and higher poles are preferred over lower ones providing worse illuminance uniformity. Specifically, the results demonstrate that higher lamp posts with higher illuminance uniformity significantly enhance visual comfort and instil a greater sense of safety among pedestrians, further improving visibility and spatial orientation. This may be attributed to the fact that higher and continuous light posts create a brighter and more spacious area for pedestrians to navigate more confidently.

Overall, these findings suggest that incorporating higher lamp posts and ensuring continuity and uniformity in lighting design can contribute to a safer and more visually comfortable nighttime environment for pedestrians in public spaces. On the other hand, practical project applications have shown that taller lamp posts, when not properly implemented, are more likely to emit unwanted spill light into surrounding areas compared to shorter ones, thereby contributing more significantly to light pollution. Effective lighting design must take into account a broad range of technical parameters to ensure the efficient use of light while minimizing light pollution. These parameters include, and are not limited to, the optical performance, luminous intensity distribution, and the design of the shading element, all of which are critical to controlling the direction and extent of the lighting. By carefully balancing these factors, it is possible to develop lighting solutions that are not only functional but also aesthetically pleasing, contributing to safer and more enjoyable public spaces.

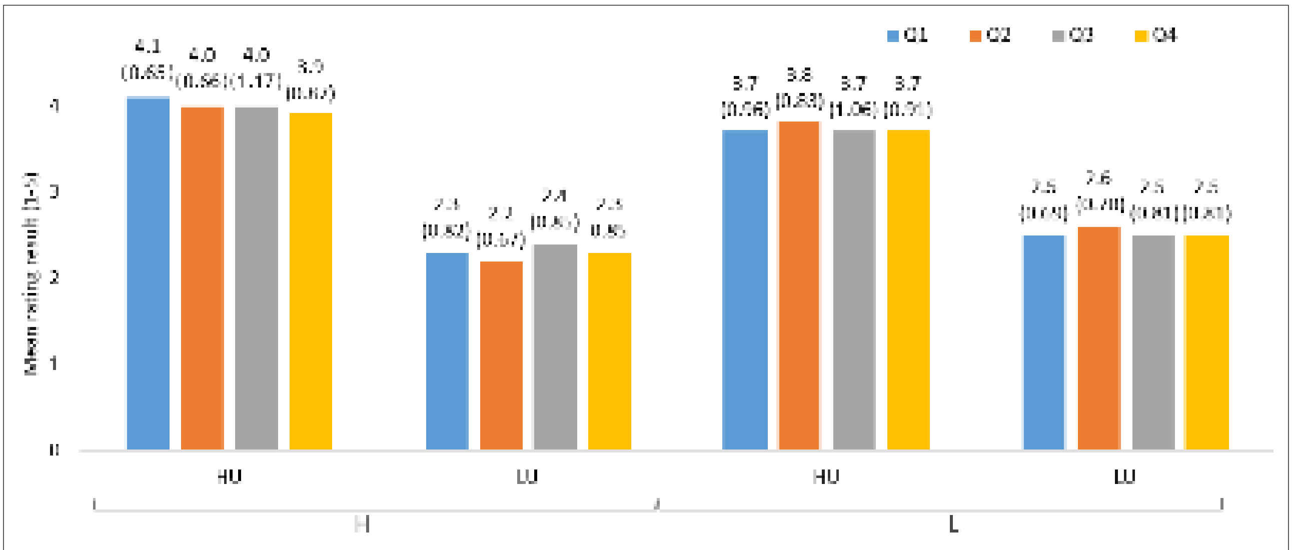


**Figure 3**. Mean rating results and variations (the number in parentheses) for all lighting scenes, categorized as higher uniform (HU), lower uniform (LU), high lamp-post (H), and low lamp-post (L). The ratings are based on four questions: visual comfort (Q1), confidence (Q2), ease of orientation (Q3), and ease of perceiving distances (Q4).

**Table 1.** Results of statistical analyses (ANOVA) for uniformity and lamp-post height

| Factors | df | Sum of Squares | F-ratio | Sig. |
|---|---|---|---|---|
| Visual Comfort | | | | |
| High street lamp-post (H), Low street lamp-post (L) | 1 | 0.95 | 1.23 | 0.2689 |
| Higher-uniform (HU), Less-uniform (LU) | 1 | 297.57 | 383.49 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 10.02 | 12.91 | 0.0004 |
| Confidence | | | | |
| (H), (L) | 1 | 1.11 | 1.55 | 0.2137 |
| (HU), (LU) | 1 | 286.53 | 400.91 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 6.47 | 9.05 | 0.0028 |
| Ease of Orientation | | | | |
| (H), (L) | 1 | 0.277 | 0.28 | 0.5940 |
| (HU), (LU) | 1 | 252.01 | 258.9 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 6.92 | 7.11 | 0.0079 |
| Perceived distances | | | | |
| (H), (L) | 1 | 0.03 | 0.04 | 0.8499 |
| (HU), (LU) | 1 | 243.72 | 283.9 | <0.0001 |
| (H), (L)* (HU), (LU) | 1 | 4.8 | 5.6 | 0.0183 |
| All | | | | |
| (H), (L) | 1 | 0.10 | 0.12 | 0.7313 |
| (HU), (LU) | 1 | 1077.95 | 1301.06 | <0.0001 |
| (H), (L)* (HU), (LU) | 1 | 27.73 | 33.48 | <0.0001 |

The significant differences are bolded.

**Appendices:** [https://tinyurl.com/yjz9kffe](https://tinyurl.com/yjz9kffe)

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