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The perception of walking on an urban forest path in daylight and under electric lighting

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ABSTRACT

In daylight, urban forests promote human health and well-being by offering opportunities for recreation and psychological restoration. In urban forests, electric lighting is often installed to enable recreation during the dark season. This study explored how urban residents experience walking in an urban forest in daylight compared to walking in darkness with electric lighting. Local residents participated in a field study in an urban forest in Sweden. Participants, 48 in total ($n = 23$ in daylight, $n = 25$ in electric light) engaged in structured walks along a 270-m long gravel path equipped with pole-mounted electric lighting. During the walks, the participants completed observer-based environmental assessments for visual accessibility, prospect-escape, perceived safety, perceived comfort quality of the electric light, restorative potential, and reported their intentions to choose or avoid a similar path in the future. After the structured walks, participants verbally reflected upon their experience, providing contextualised qualitative information that nuanced the assessments. Analysis of variance, with age, gender, value orientation and connectedness with nature as co-variates, revealed that most of the assessed experiences deteriorated from daylight to electric light. Despite this, mean values indicated that the urban forest path was perceived to hold a restorative potential and that the participants had an intention to choose similar paths under electric light conditions. In a public health perspective, the provision of electric light along urban forest paths close to residential areas could be favourable but must be balanced against the detrimental effects of light pollution on other species and energy use.

1. Introduction

The majority of people worldwide live in urban environments, and that number is increasing (United Nations, 2019), but the access people have to natural settings varies, since the distribution of green spaces is not equal (Wolch et al., 2014). Today, a substantial amount of research indicates the benefits of natural settings in general (Hartig et al., 2014) and urban green spaces, such as urban forests, more specifically (Kondo et al., 2018) for people's health and well-being through recreation and psychological restoration. Urban forests, structurally equivalent to a natural forest stand with an unmanaged field layer (Lehvävirta and Rita, 2002) and of high perceived naturalness, are considered to have higher aesthetic value and offer greater support to psychological well-being (Ode Sang et al., 2016), as well as the formation of place identity (Knez, 2005), than more formal green areas, such as urban parks (Knez et al., 2018).

In Sweden, 80 % of the population hike at least once a year in a forest, and 30 % hike over 20 times a year (Statistics Sweden, 2024). Urban forests are the most frequently visited land cover type for city-dwellers, and 44 % of all recreational activities take place there (Lehto et al., 2022). To facilitate recreational use across the seasons of the year, electric lighting is often installed (Beeco et al., 2023). However, electric light also causes light pollution, with detrimental effects on ecosystems and wildlife species (Jägerbrand, 2021), and has negative effects on humans, impairing their circadian rhythm and sleep quality (Durmus et al., 2024; Zielinska-Dabkowska et al., 2023). Although urban forests are popular recreational areas, the understanding of people's experiences and use of these environments under electric light conditions is limited. Considering the UN sustainable development goals human health and well-being (SDG 3), sustainable cities (SDG 11), sustainable energy use (SDG7), and life on land (SDG 15), the recent European Nature Restoration Law (2024, amendment 49) emphasises that countries are obliged to reduce light pollution to increase biodiversity and improve human perception (Official Journal of the European

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Union, 2024). This knowledge gap seems counterintuitive and calls for empirical understanding of electric lighting in urban forests for recreational walking and psychological restoration.

Previous research has shown that light exposure can impact human health, both positively and negatively, in various ways (Boyce, 2022). However, light may also indirectly impact human health by undermining or supporting certain behaviours, such as walking. Studies on walking in urban streetscapes have, for example, established associations between the presence and quality of electric lighting and pedestrian flow, as well as effects on pedestrian speed, and position on the path depending on light (Fotios et al., 2019; Pedersen and Johansson, 2018; Yastremska-Kravchenko et al., 2024). It has also been shown that people's experience of urban environments may fundamentally change between daylight and under conditions of electric lighting during darkness, such as on pedestrian and cycle paths (Johansson et al., 2011; Rahm et al., 2024), in public squares (Hennig et al., 2025), and in green spaces (Masullo et al., 2023; Rahm et al., 2021). The presence and quality of greenery and electric lighting are closely intertwined in people's environmental experiences (Nikunen and Korpela, 2009, 2012), as well as choices to avoid passing through green spaces (Rahm et al., 2021). Therefore, straightforward associations between light and walking in urban forests should not be expected. Instead, such associations might be influenced by individual factors, such as gender, age, values, and attitudes (Küller, 1991).

The motivation for conducting empirical studies on the role of people's experience of electric light and walking in Swedish urban forests is manifold. In Sweden and countries at similar latitudes, daylight hours are limited in parts of the year, which restricts recreation and overall use of urban greenery. An average of 20 % of the urban areas in Swedish cities are covered by forests (Nielsen et al., 2017). Fifty-seven percent of all outdoor recreation in Sweden takes place in urban and peri-urban areas, mainly forests (Lehto et al., 2022). These forests not only provide a broad span of regulating ecosystem services, e.g. improvement of water quality and climate regulation (Escobedo et al., 2019), increasingly important in times of climate change, but also cultural ecosystem services, such as aesthetic experiences and psychologically restorative opportunities (Ode Sang et al., 2016). However, to the best of the authors' knowledge, field studies involving people's experience of electric lighting in urban forest settings during winter darkness hours are lacking. In this study our overarching question is: in what way does the perception of a recreational walk differ between daylight and under conditions of electric lighting after dark?

1.1. Theoretical background

The Human Environment Interaction (HEI) model (Küller, 1991) serves as a theoretical framework for this study. The HEI model considers the continuous interplay between the individual and the physical and social environment when engaged in an activity in a given setting, and their individual factors (e.g. gender, age, previous experiences, values and attitudes). The individual's perception of their physical and social surroundings thereby shapes the intra-individual psychological process (the basic emotional process) and in turn the associated (behavioural) responses, in our case, intentions to choose or avoid walking in a given setting after dark. For applications of the HEI model to assess associations between environmental experiences and walking behaviour, see (Johansson, 2006; Johansson et al., 2016).

The setting we focus on is the urban forest under different lighting conditions, i.e., daylight and electric light during dark hours. We acknowledge the importance of looking beyond mere exposure to certain environmental conditions to understand the individual's behavioural response – instead, the individual's experience of a (walking) environment (Johansson et al., 2024; Nasar, 2008; Rahm et al., 2024) must be addressed. Here, we are especially interested in analysing the individual's experience of the urban forest and intentions to walk along a forest path under the two light conditions.

We investigate environmental experiences and walking in more detail by making use of the hierarchy of walking needs proposed by Alfonzo (2005); see also (Rahm, 2019) for a previous empirical application of this model. While the HEI model is a general model, the hierarchy of walking needs helps to specify the environmental experiences of particular significance for walking intentions. The needs deemed necessary to be fulfilled by pedestrians' environmental experiences are feasibility, accessibility, safety, comfort, and pleasurability (Alfonzo, 2005).

Feasibility is whether the required distance can be walked, based on the individual's capabilities. In this study, an inclusion criterion was the ability to walk the required distance, so the feasibility aspect was not applicable. Accessibility is defined in terms of perceived visual accessibility of functional importance for orientation, obstacle detection and facial recognition in electric light conditions (Rahm and Johansson, 2021), all of which facilitate the walkability of the urban environment. Safety refers to perceived safety of being in the environment (Blöbaum and Hunecke, 2005). According to the prospect-refuge theory (Appleton, 1975)this is related to the level of overview (prospect) and escape possibilities from a potentially dangerous situation (Nasar, 2008). Our focus regarding perceived comfort is on the perceived outdoor lighting quality (perceived comfort quality, PCQ), i.e. the extent to which the electric light is considered to be sufficiently comfortable for the purpose (Johansson et al., 2014). The pleasurability of the environment is operationalised as the perceived restorative potential, the extent to which the environment is considered to hold certain qualities that support the process of psychological restoration during walking in a natural setting (Kaplan, 1995).

Considering the influence of individual factors in the psychological process stipulated by the HEI model, we take age and gender into account. A substantial amount of research show that visual capability generally deteriorates with age impacting on daily life activities for a review see Owsley (2016). As for gender, women tend to more often express concerns about safety when considering walking after dark (Rahm and Johansson, 2021), and seem to direct their gaze more towards the surroundings when exposed to walking paths of high entrapment after dark (Chaney et al., 2024), than what men do. We also include two other variables relevant for how people relate to natural settings – value orientation (Schwartz, 1992, 1994) and connectedness to nature (Mayer and Frantz, 2004). Values are, in general, beliefs that transcend specific situations and drive a person to act (Jacobs and Wollny, 2022). The value orientation system is formed by a distinction between the self-enhancement (egoistical values) vs self-transcendence (solidary values) and openness to change vs conservation values –e.g. tradition– (Lindeman and Verkasalo, 2005), which makes it a stable individual trait relevant for our study. Connectedness to nature is a construct that can be defined as the extent to which an individual includes nature as a part of themselves (Schultz, 2001).

All the above experiences (perceived visual accessibility, prospect, escape, safety, comfort and restorative potential) apply to the theoretical model proposed (Fig. 1) to strengthen walking intentions (Alfonzo, 2005), and might be altered by lighting conditions as previously shown for the built environment. Unsurprisingly, pedestrians report higher perceived visual accessibility for urban squares (Hennig et al., 2025) and pedestrian paths during daylight conditions as compared to electric lighting conditions (Rahm et al., 2024). However perceived visual accessibility may also differ between electric lighting conditions (Johansson et al., 2020; Rahm et al., 2024). Therefore, the discrepancy in perceived visual accessibility between daylight and electric light may be more or less noticeable. Both experimental laboratory studies varying environmental features of urban settings (Boomsma & Steg, 2014), and on-site studies (Blöbaum and Hunecke, 2005) show that environments with lower levels of electric light, and blocked escape (entrapment) are assessed as more unsafe. Other studies do not find significant differences in pedestrians' perceived safety between daylight and electric light (Rahm et al., 2024), or between lighting applications of different levels

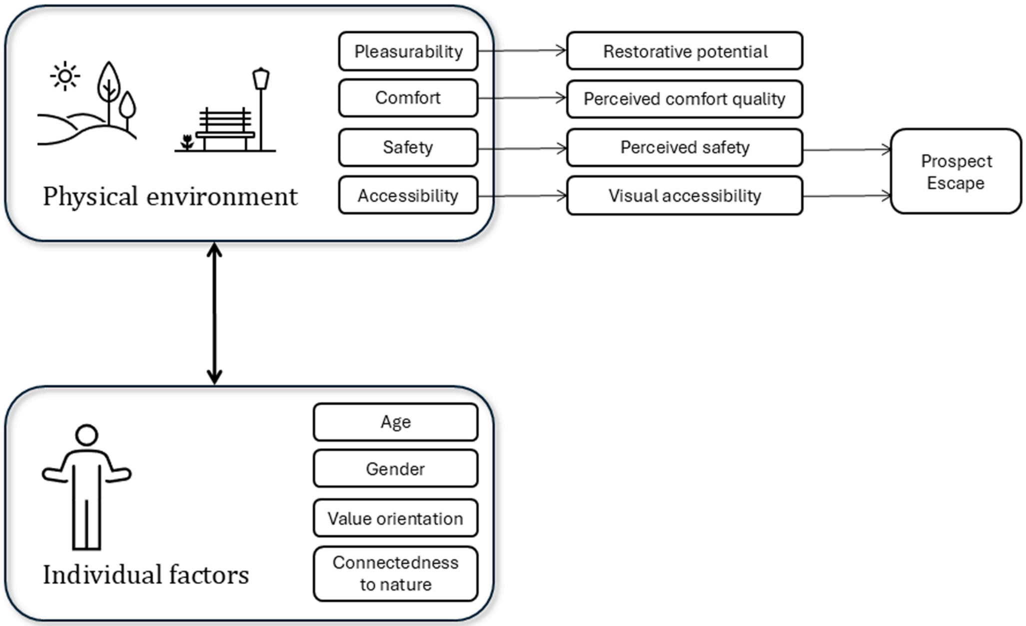

Fig. 1. Conceptual model based on theories relevant for the pedestrian experience of an urban forest path during daylight and electric lighting conditions.

of illuminance (Johansson et al., 2020). The perceived outdoor lighting comfort quality applies to electric lighting only and may vary between illuminance levels (Johansson et al., 2014). Most research on perceived restoration concerns daylight experiences of natural settings. An environmental simulation study concludes that the perceived restorative potential is higher in daylight conditions as compared to electric lighting conditions (Cheon et al., 2019), and an on-site study of urban pedestrian paths confirms this result (Rahm et al., 2024). While the knowledge on electric lighting for pedestrians has increased in recent years, little is known about how people experience waking paths in urban forests under different lighting conditions.

1.2. Study aims

The aims of this study are to explore how pedestrians experience an urban forest path during daylight conditions as compared to electric lighting in after-dark conditions, and to investigate the behavioural intentions of choosing or avoiding walking a similar path in the future. Employing our conceptual model we assess people's environmental experiences, addressing perceived visual accessibility, prospect, escape possibility, perceived safety, perceived comfort, and the psychological restorative potential. Two hypotheses were formulated:

Hypothesis 1 (H1): Daylight is better than electric lighting in supporting the needs of pedestrians regarding

a) visual accessibility,
b) prospect, escape possibility,
c) perceived safety, and
d) restorative potential.

Hypothesis 2 (H2): The stated intention to

a) choose a similar path in the future would be stronger during daylight than in electric light after dark
b) avoid a similar path in the future would be weaker during daylight than in electric light after dark.

We also investigate the perceived outdoor lighting comfort quality of the electric light, and test whether the individual factors age, gender, value orientation, and connectedness to nature moderate the environmental experience of the path in daylight and electric light.

2. Method

2.1. Participants

The study was conducted as 26 structured walks with observer-based environmental assessments on-site outdoors and were made by means of established questionnaire batteries and participants' verbal reflections (Johansson et al., 2016). In total the study involved 48 participants divided into one group assessing daylight conditions and one group assessing electric light conditions (Table 1) (men $n = 18$, women $n = 29$ and $n = 1$ did not specify) aged 28–82 years (mean age = 51 yrs, SD = 15 yrs). All participants were residents in the broader study area.

2.2. Setting

The study was conducted during November 2022-February 2023 in the neighbourhood of Sävja (10,000 inhabitants), located 6 km from the city centre of Uppsala (167,000 inhabitants), Sweden. The neighbourhood consists of a combination of detached and attached family housing, located adjacent to an urban forest.

The study was located on a path created for leisure for cyclists and pedestrians in a forest on the urban fringe (Fig. 2). The participants walked a distance of 270 m. The gravel path approx. 3-m wide, runs parallel with housing units at a distance of 50–100 m. For about 25 m on both sides of the path the forest is managed for safety reasons, with shrubs in the understory cleared. The forest is a mixed coniferous and deciduous forest with pine (*Pinus sylvestris*), spruce (*Picea abies*), and birch (*Betula spp*), with a ground layer of herbs and mainly European

Table 1
Descriptive statistics of the participants.

Condition	Daylight	Electric light	Total
Number of participants	23	25	48
Women	13	16	29
Men	10	8	18
		1 did not specify	1 did not specify
Age range, mean age (SD)	28–79 yrs, 56 (16) yrs	29–82 yrs, 46 (13) yrs	28–82 yrs, 51 (15) yrs

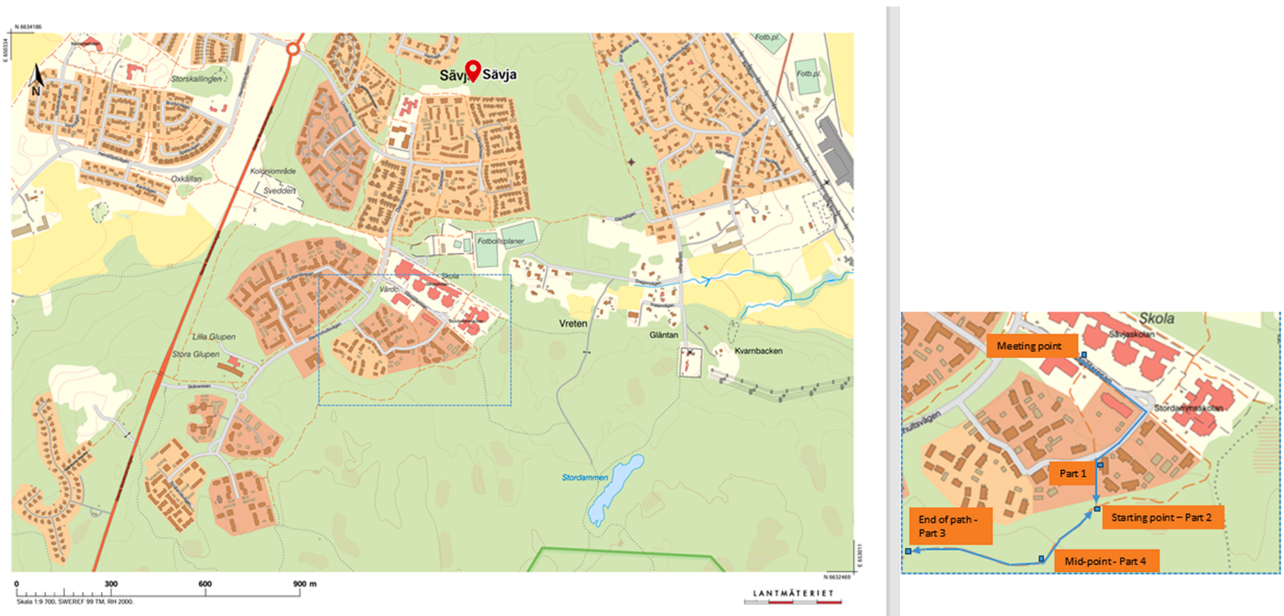

Fig. 2. The route of the structured walk (Source: Lantmäteriet). The dashed blue line indicates the area of which a close-up is presented to the right of the overview map.

blueberry (*Vaccinium myrtillus*) and lingonberry (*Vaccinium vitis-idaea*) and resembles a typical urban forest in these parts of Sweden (Hedblom and Söderström, 2008). The area is frequently used by people, and numerous minor paths lead from the houses to the gravel path and from the path into the forest. The forest can be freely visited through the Right of Public Access in Sweden (Swedish Environmental Protection Agency, 2018). The forest area is municipally owned and there are no production demands at present, which means that it has large old trees and is in a natural state. Part of the forest is a nature reserve and N2000 area (Swedish Environmental Protection Agency, 2018).

2.3. Lighting on the walking path

Lamp posts (4.5 m), installed by Uppsala municipality, are positioned at intervals of 28–32 along the entire path on one side (Fig. 2 and 3). Pole-top luminaires (Elton/Prisma light) along the path are equipped with LED light sources (power: 18 W, luminous flux: 2100 lm, correlated colour temperature: 3000 Kelvin). The average illuminance on the path during dark conditions was 12 lx (Range: 45 lx to near-zero) and the uniformity 0.07 (Dincel, 2023).

2.4. Procedure

Participants were recruited to the walks through a survey on people's outdoor habits in their neighbourhood, recruitment on site, through advertising on Facebook, and through personal networks. Most participants were not acquainted with each other or the researcher on site. Only two participants knew each other from before.

The participants who had signed up received written information about the study beforehand through e-mails and verbally on-site. They

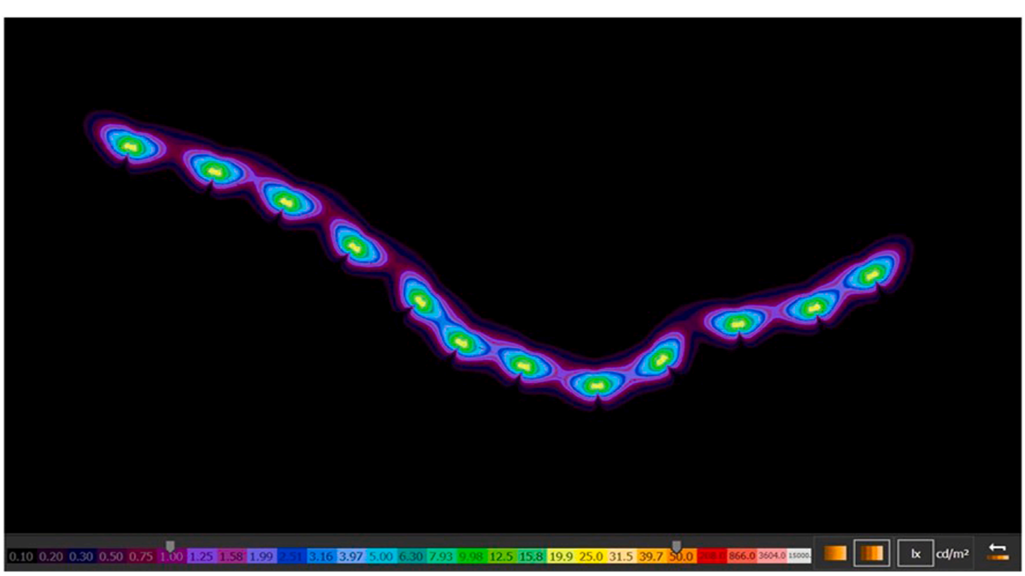

Fig. 3. Dialux simulation, light distribution of Elton/Prisma light (existing luminaires).

were informed of their right to withdraw at any time without giving an explanation. Written informed consent was then obtained from all participants before the start of the walk (see Ethics below).

At the time of the walks, the researcher met the participants, individually or in small groups (maximum 4 persons) at a local public building 300 m from the path, and they walked together towards the designated path. At a point approximately 100 m from the start of the route, the participants completed the first part of the questionnaire (see Fig. 2). When part 1 was completed, the researcher took the participants to the starting point of the route, where they completed part 2. Afterwards participants walked the path individually. This ensured that potential feelings of familiarity among participants would not affect the walking experience. At the end of the designated walk, a sign on light pole number 10 stated 'The route ends here.' The participants completed part 3 by the sign without the intervention of the researcher, who remained at a distance. This was done in order to let the participants experience the path and nature without being disturbed. The participants were then led by the researcher back to the middle of the path, where they completed part 4. Lastly, after returning to the starting point the participants were asked to reflect upon their assessments, as described below. Fig. 4 provides a flow-chart of the study procedure (Figs. 5 and 6).

The overall procedure lasted 40–50 min, depending on the number of participants. The walks were conducted early in the morning (11:00) early afternoon (14:00) and early evening (17:00 and 19.30) to provide conditions of daylight and electric light. The walks were conducted without snow cover on the ground and the temperature varied from approximately minus ten degrees to five degrees Celsius. Weather conditions in daylight varied from clear sky to overcast and light rain.

2.5. Measurements

2.5.1. Questionnaire

The participants completed a 16-page questionnaire, consisting of four parts: Part 1 referred to individual factors such as value orientation and trait connectedness to nature. Parts 2 and 3 covered the variables of valence/arousal, perceived restoration, and state connectedness to nature (not analysed in this paper). Part 4 covered assessments of the experienced environment, the lighting and the future walking intention. Measurements included in the analyses are described below.

2.5.2. Measures of environmental experiences

To assess whether the two different light conditions affected the participants' experience of the lit environment, several measures were used.

Visual accessibility was measured by seven statements: 'Being able to detect objects on the ground'; 'Read a street sign'; 'Recognise the people's faces'; 'Discover cracks and bumps on the path'; 'Discern trees and bushes along the path'; 'Could see what grew on the soil across the path'; and 'Overall I could see well.' A five-point response scale was used (1 = absolutely not, to 5 = yes, absolutely), and the responses were averaged into an index (Cronbach's alpha, α = 0.80) (Johansson et al., 2011).

Prospect-escape: Prospect was assessed by the statement ' I have good overview of the surroundings along the path', and escape by the statement 'In case of threatening danger, I could easily escape from this place'. Both items were rated using five-point scales (1 = absolutely not, to 5 = yes, absolutely) (Rahm et al., 2021).

Perceived safety (Blöbaum and Hunecke, 2005) was assessed by five statements: 'I would go a long way to avoid this place' (reversed); 'I feel uneasy at this place' (reversed); 'I would make haste to get away from this place' (reversed); 'I have an unpleasant feeling at this place' (reversed); 'I would walk along this path unaccompanied.' The participants rated each statement using a five-point scale (1 = Absolutely not, to 5 = Yes, absolutely). Responses were averaged into an index (α = 0.84).

Perceived comfort was assessed using one dimension, the perceived comfort quality. The perceived outdoor lighting quality scale (Johansson et al., 2014) was used, with five bipolar adjectives on seven-point scales (Mild – Sharp, Hard – Soft, Warm – Cool, Glaring – Shaded, Natural – Unnatural) (α = 0.67). Participants were also asked if they experienced any discomfort due to glare, with the response alternatives No/Yes (Hickcox et al., 2022).

Perceived restorative potential (Hartig et al., 1997): respondents indicated the perceived restorative potential of the setting by the statements: 'There is much to explore and discover here'; 'Spending time here gives me a good break from my day-to-day routine'; 'My attention is drawn to many interesting things'; 'The setting has fascinating qualities'. Responses were given on five-point scales (1 = Absolutely not, to 5 = Yes, absolutely) and averaged into an index (α = 0.66).

The behavioural intention was assessed by two statements, 'Specifically choose' and 'Specifically avoid walking along a similar path,' using a five-point scale (1 = Absolutely not, to 5 = Yes, absolutely) (Johansson et al., 2016).

2.5.3. Moderating variables

Value orientation: The Schwartz value orientation scale (Schwartz,

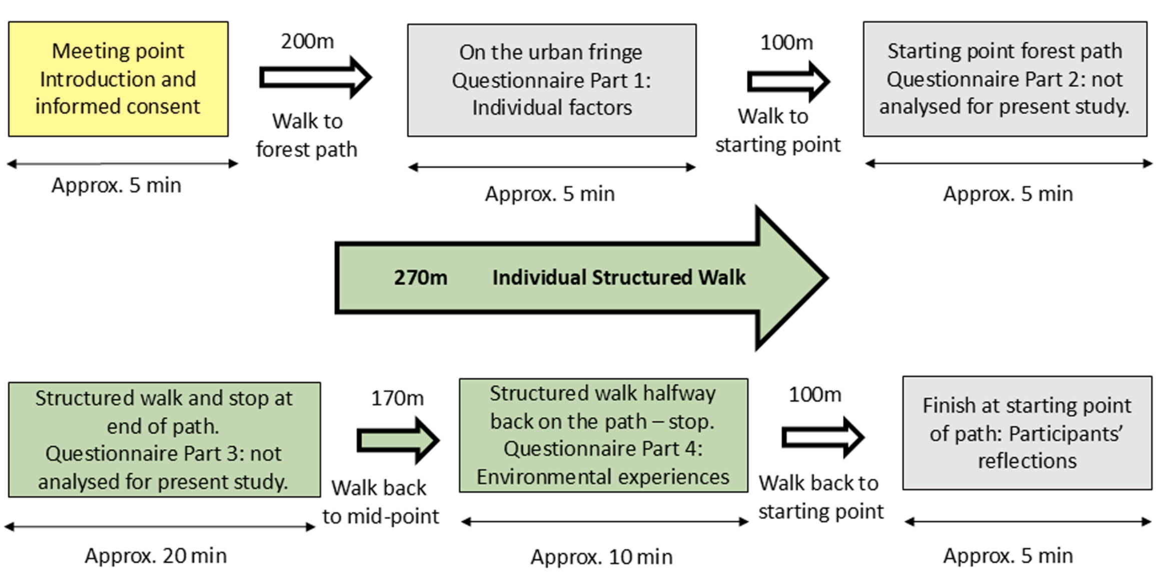

Fig. 4. Flowchart of the structured walk procedure.

Fig. 5. The pedestrian path at daylight condition.

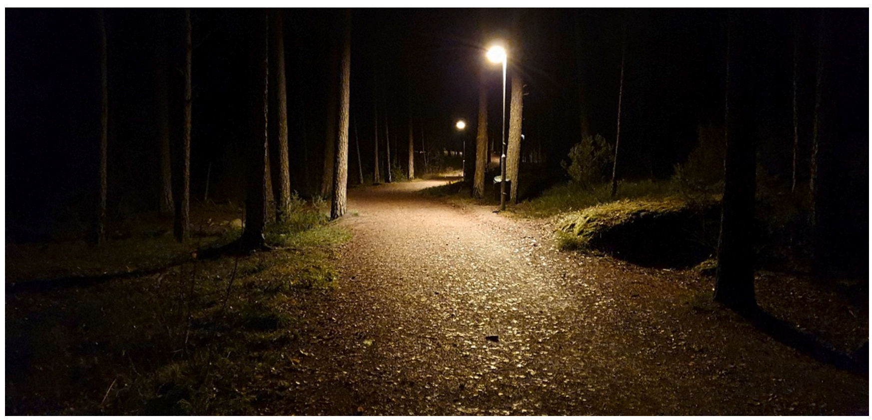

Fig. 6. The pedestrian path at electric light condition.

1994) assessed the four higher types of values for each individual: self-enhancement (power and achievement), openness to change (hedonism, stimulation and self-direction), self-transcendence (universalism and benevolence), and conservation (tradition, conformity and security). The seven-point scales ranged from 1 (‘Opposed to my values’) to 7 (‘Of supreme importance’).

The calculations of the values were further adjusted on the two-dimensional structure of values, that of conservation and self-transcendence distinction (Lindeman and Verkasalo, 2005), which uses the following equations:

$$\text{Conservation} = .92 + (.15 \times \text{Power}) + (.03 \times \text{Achievement}) - -(.17 \times \text{Hedonism}) - -(.25 \times \text{Stimulation}) - -(.31 \times \text{Self} - \text{Direction}) - -(.26 \times \text{Universalism}) + (.04 \times \text{Benevolence}) + (.30 \times \text{Tradition}) + (.30 \times \text{Conformity}) + (.20 \times \text{Security})$$

$$\text{Self} - \text{Transcendence} = - - .56 - -(.30 \times \text{Power}) - -(.33 \times \text{Achievement}) - -(.16 \times \text{Hedonism}) - -(.14 \times \text{Stimulation}) + (.04 \times \text{Self} - \text{Direction}) + (.22 \times \text{Universalism}) + (.24 \times \text{Benevolence}) + (.12 \times \text{Tradition}) + (.03 \times \text{Conformity}) + (.03 \times \text{Security})$$

Self-Transcendence = –.56 – (0.30 × Power) – (0.33 × Achievement) – (0.16 × Hedonism) – (0.14 × Stimulation) + (0.04 × Self-Direction) + (0.22 × Universalism) + (0.24 × Benevolence) + (0.12 × Tradition) + (0.03 × Conformity) + (0.03 × Security).Connectedness to nature (Mayer and Frantz, 2004) was assessed by fourteen statements (α = 0.66): ‘I often feel a sense of oneness with the natural world around me’; ‘I think of the natural world as a community to which I belong’; ‘I recognise and appreciate the intelligence of other living organisms’; ‘I often feel disconnected from nature’ (reversed); ‘When I think of my life, I imagine myself to be part of a larger cyclical process of living’; ‘I often feel a kinship with animals and plants’; ‘I feel as though I belong to the Earth as equally as it belongs to me’; ‘I have a deep understanding of how my actions affect the natural world’; ‘I often feel part of the web of life’; ‘I feel that all inhabitants of Earth, human, and nonhuman, share a common life force'; 'Like a tree can be part of a forest, I feel embedded within the broader natural world'; 'When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature' (reversed); 'I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees'; 'My personal welfare is independent of the welfare of the natural world' (reversed). Responses were given using a five-point scale (1 = Absolutely not, to 5 = Yes, absolutely) (Mayer and Frantz, 2004).

2.6. Participants' reflection

The participants were prompted to reflect upon their assessments considering a) their general experience of walking along the path in daylight/ after dark, b) the quantity and quality of the electric lighting and c) visibility of flora and fauna. The reflections were made after the walks were finished at the starting point of the route (pole nr 1), with a researcher moderating and recording each conversation with a voice recorder. The participants were standing together in a circle, answering the questions in turns. The reflections varied from two to six minutes in duration and consisted of 101 min of recorded data in total. Two of the researchers transcribed the recordings, and then together discussed and categorised the data according to their relevance to the study constructs (visual accessibility, perceived safety, restorative potential etc.). The reflections provided nuances and helped to contextualise the participants' assessments in relation to their lived experience of the urban forest path in daylight and electric light.

2.7. Ethics

All the participants had good command of both spoken and written Swedish. Written informed consent was obtained from all participants. Personal information was anonymised to retain the privacy of the participants, who received a cinema ticket, approximately 10 EUR in value, after participation. The study received the ethical approval reference number 2022–03857–01 from the Swedish Ethical Review Authority.

2.8. Statistics and analyses

The statistical analyses were performed with IBM SPSS 29.0.0.

1 Descriptive statistics (mean, standard deviation) were obtained.
2 In order to test the hypotheses H1 a-d, we examined the effect of the lighting condition on the participants' environmental experiences by ANOVA and ANCOVA analyses. In these analyses the lighting condition (daylight, electric light) was treated as the independent variable. Visual accessibility (H1a), prospect and escape possibility (H1b), perceived safety (H1c), and restorative potential (H1d) were treated as dependent variables.
3 In order to test the hypotheses H2a-b we examined the effect of the lighting condition on the participants' behavioural intentions by ANOVA and ANCOVA analyses. Also in these analyses the lighting condition (daylight, electric light) was treated as the independent variable and intention to choose (H2a) and intention to avoid (H2b) were treated as dependent variables
4 In all ANCOVAs age, gender, self-transcendence values, conservation values, and trait connectedness to nature were entered as covariates to test whether the individual factors moderated the differences experienced between the daylight and the electric light condition.
5 The significant p-value was set at $p > .05$ and the partial eta squared ($\eta_p 2$) was calculated to assess effect size.
6 Descriptive and differential statistics are presented in Table 2. The results from the ANOVA and ANCOVA analyses are similar with the exception for the intention to avoid, where the ANOVA indicated a significantly greater intention to avoid a similar path during nighttime, while the ANCOVA result was non-significant (Table 2, footnote). The results for the ANCOVAs are presented below.

3. Results

3.1. Environmental experiences

Visual accessibility: The light condition had a significant effect on the experienced visual accessibility ($p < .001$, $\eta_p^2 = 0.376$). In support of hypothesis 1a (H1a), the experienced visual accessibility was rated higher for the daylight condition than the electric light condition.

Prospect and escape (H1b): The lighting condition had a significant effect on both prospect ($p < 0.001$, $\eta_p^2 = 0.383$) and escape ($p = .027$, $\eta_p^2 = 0.114$). Prospect and escape were rated higher for the daylight condition than the electric light condition, confirming hypothesis 1b

Perceived safety (H1c): The light condition had a significant effect on the perceived safety ($p = .008$, $\eta_p^2 = 0.159$). Confirming H1c, the perceived safety was rated higher for the daylight condition than the electric light condition, taking the covariates into account.

Perceived comfort: The variable of perceived comfort quality (PCQ)

Table 2
Mean values for daylight and electric light conditions and results from ANCOVA. Non-significant results are labelled n.s.

	Daylight	Electric Light	ANCOVA	Covariates				
	Mean (SD)	Mean (SD)		Gender	Age	Self-trans	Conservation	Connect to nature
Visual accessibility	4.18 (0.27)	3.60 (0.44)	F(1, 41) = 24.737, ***p* < .001**, η_p^2 = 0.376	n.s	n.s	n.s	n.s	n.s
Prospect	4.70 (0.56)	3.40 (0.96)	F(1, 41) = 25.409, ***p* < .001**, η_p^2 = 0.383	n.s	n.s	n.s	n.s	n.s
Escape	4.13 (1.10)	3.35 (1.15)	F(1, 41) = 5.252, ***p* = .027**, η_p^2 = 0.114	n.s	n.s	n.s	n.s	n.s
Perceived safety	4.77 (0.56)	4.12 (0.91)	F(1, 41) = 7.727, ***p* = .008**, η_p^2 = 0.159	n.s	n.s	n.s	n.s	n.s
Perceived comfort quality	n/a	3.71 (1.05)	n/a	n/a	n/a	n/a	n/a	n/a
Restorative potential	4.48 (0.37)	4.23 (0.46)	F(1, 41) = 4.767, ***p* = .035**, η_p^2 = 0.104	n.s	n.s	n.s	n.s	n.s
Behavioural intention (choose)	4.83 (0.49)	4.28 (0.74)	F(1, 41) = 5.668, ***p* = .022**, η_p^2 = 0.121	n.s	n.s	n.s	n.s	n.s
Behavioural intention (avoid)*	1.38 (0.88)	2.00 (1.19)	n.s	Women: *M* = 1.99 Men: *M* = 1.28 F(1, 41) = 6.40 *p* = .015, η_p^2 =0.14	n.s	n.s	n.s	n.s

* The only result differing between ANCOVA and ANOVA. ANOVA behavioural intention to avoid F(1, 48) = 4.159, $p = .047$, $\eta_p^2 = 0.083$.

refers to a scale only applicable in electric light after-dark condition and gives an indication of how supportive electric lighting is perceived. PCQ had a mean value of 3.71 (1.05) in the electric light condition, on a scale from 1–7. Relevant to perceived comfort, the majority of participants (60 %) stated that they did not experience glare from the electric light. However, 80 % of those who reported discomfort from glare stated high glare levels (four and above on a scale of 1–6).

Restorative potential (H1d): The lighting condition had a significant effect on the restorative potential ($p = .035$, $\eta_p{}^2 = 0.104$). The restorative potential was rated higher for the daylight condition than the electric light condition, in support of H1d, taking the covariates into account. Notably, the mean value in the electric light condition was still above 4 on the scale from 1–5.

3.2. Behavioural intentions

Similar ANCOVA analyses were performed to test hypotheses H2 a-b, whether there were any differences in the behavioural intention to choose or avoid a similar path between daylight and electric light conditions. Age, gender, self-transcendence values, conservation values, and trait connectedness to nature were entered as covariates in this analysis. Statistics are presented in Table 2.

Lighting condition had a significant effect on the behavioural intention to choose a similar path ($p = .022$, $\eta_p{}^2 = 0.121$). The behavioural intention to choose a similar path was rated higher for the daylight condition than the electric light condition, confirming the H2a hypothesis, taking the covariates into account.

The behavioural intention to avoid a similar path was not rated significantly different during the daylight condition than the electric light condition, taking the covariates into account. However, there was a significant difference due to gender, where women rated their intention to avoid a similar path higher than did the men ($p = .015$, $\eta_p{}^2 = 0.135$).

3.3. Participants' reflections

The participants' prompted reflections contextualise the quantitative assessments. The reflections revealed that the participants usually walk along the path for recreational purposes, referring to their interest in nature. A few participants stated that they had chosen to live in the area because of the closeness to the nature reserve, and that the forest is considered to have a perceived restorative potential in daylight condition is expressed in several ways ('listening to the birds', 'the sound of the wind on the grass', 'looking at the plants and berries'). While participants enjoy walking in the forest in daylight, there is a variation during dark hours. Some participants stay indoors after dark, some walk close to the residential houses expressing that they appreciate the well-lit residential streets and the light spilling out from the windows, some state that they only walk in the forest if they are in company, while other participants do not at all hesitate to walk the forest path after dark and state that they often do so. Perceived safety was a reoccurring theme in almost all groups and was often brought-up in association with the choice to choose or avoid the path after dark. The social circumstances of the area (Sävja) were mentioned and participants were referring to youngsters hanging out and illegal substance use.

Most participants appreciated the presence of electric light along the path. The electric light seemed to be perceived as bright enough to meet the need of visual accessibility at the path also at different weather conditions.

> "I kind of see to the next lamp, I see most part in between, so I think it's pretty good"
>
> (man, electric light, walk #22).
>
> *"Yes, I think the lighting is good, it's not too sharp, it's not too strong, I like this lighting, I would also say that I can see well, so I am happy with the lighting".*
>
> (woman, electric light, walk #5).

The pruned greenery next to the path was appreciated by the participants and was considered to facilitate nature experiences during daylight. However, this was not the case during dark conditions since the luminaires were perceived as having a narrow light distribution, creating a light tunnel. This effect was limiting prospect and thus creating uncertainty regarding whether there were potential dangers lurking next to the path. *"It's a good lighting I suppose, but it is really just directed straight downwards, it kind of stops, you can't see much to the sides just straight towards the path"*

> (man, electric light, walk #8).
>
> *"It is only the path that is lit, which feels nice in a way, as I said before for the animals, light pollution etc. Since it is only the path that is lit, it spills into the forest, but to me it is dark, it is also a bit scary, that is black in there, you don't know what's there"*
>
> (woman, electric light, walk #8).

The overview of the forest next to the path was for some participants further hindered by their experience of the light as lacking in perceived comfort, i.e. to be too sharp and glaring, or too much directed upwards. In turn limiting the opportunity of nature experiences during dark conditions.

> *"I was a bit disappointed that I couldn't experience nature more, because I feel like I wanted to see the trees, but with this lighting from above, you can't see upwards. I would like to have the lighting a bit lower, at the knee level, so that I felt more as part of nature"*
>
> (woman, electric light, walk #13).

In parallel, the participants reflect upon the negative impacts of having electric light in nature settings in terms of energy usage, light pollution and the impact on animals. In this respect some participants even questioned if there is at all a need for electric light along the path. The participants' reflections revealed a holistic approach in their expectations from the lighting installation, and many of them expressed the importance of balancing people's needs for recreation with the needs of other species.

> "*I am very interested in nature and I'm always looking to the sides when I walk here at daytime, but now you don't get much of a view into the forest. I also don't think that the headlights should be directed in there"*
>
> (man, electric light, walk #28).

4. Discussion

This study aimed to assess potential differences in the pedestrian experience of walking along a path in an urban forest under two lighting conditions, daylight and electric light after dark. While pedestrian lighting conditions in urban areas have gained increasing attention (Fotios et al., 2024; Rahm et al., 2024), the importance of lighting conditions for the pedestrian experience of walking in less-managed urban green areas like urban forests has yet to be examined. Our results showed that the assessments for environmental experiences in general deteriorated from daylight to electric lighting. Nevertheless, participants assessed the urban forest to hold a relatively high restorative potential in both daylight conditions and electric light in darkness, even if the lighting was described as creating a light tunnel. One reason for the relatively high level of experienced restorative potential during dark conditions may be that the electric lighting was sufficient for fundamental aspects of walking and that walking on the path created a sensation of being in a forest, even if the participants were not able to discern specific details of it.

Notably, the forest in our study was rated to have a higher perceived restorative potential in the electric light condition (mean value = 4.23) than had previously been shown for pedestrian paths in other types of urban settings (asphalt paths next to residential houses, trees and shrubs) (Rahm et al., 2024) in daylight (mean value = 3.22) and electric light (mean value = 2.95). Thus, highlighting that forests with electric light during dark have higher restoration potential than urban settings during daylight. The participants' assessments in Rahm et al. (2024) were using the same instruments as in the present study including structured walks.

The differences in the participants' environmental experience of the walking path in the urban forest between daylight and electric light conditions after dark should be recognised. Perceived visual accessibility, prospect-escape, and potential for psychological restoration were rated significantly higher in daylight than in electric lighting.

The results showed a reduced visual accessibility in electric light, which is similar to other studies (Rahm et al., 2024). This discrepancy between daylight and electric light is crucial to local policy and planning, since it indicates a decline in residents' actual visual accessibility on forest paths during the dark season. Previous research on electric light for pedestrians shows that especially elderly and people with visual impairments may be negatively affected, as the current electric light may be insufficient for performing visual tasks (Mattsson et al., 2020; Rahm and Johansson, 2018).

The perceived prospect and escape were rated as high during daylight, and still towards the higher end of the scale under electric light conditions. One explanation might be that the forest setting was relatively permeable and without barriers compared to, e.g., an urban environment where adjacent residential buildings do not provide such possibilities. See Rahm et al. (2024), whose study showed that assessment of prospect and escape was much lower in electric light. However, the participants' reflections on electric light conditions were somewhat contradictory as they referred to the contrast between the lit path and the dark surroundings as creating a light tunnel.

In the assessments of perceived safety, the mean values in both light conditions were very high, indicating that despite the reduction in perceived safety in electric light, the participants experienced the path as safe in both daylight and electric light after dark (mean values above 4, scale 1–5). It has previously been proposed that the methodological approach, i.e. the structured walk, may create a perception of safety, as the participants are aware that there are familiar persons in the vicinity (they were accompanied by the researcher at the beginning and end of the walk or a small group of other participants), even if they walked along the path alone (Rahm and Johansson, 2021). The participants' reflections suggest that this may have been the case for some of them, although the majority of the participants were unknown to one another. It is, however, reasonable to believe that the high assessments of perceived safety in the current study for other participants can be partly attributed to their perception of prospect and escape in the electric light conditions. Such an interpretation is supported by previous research showing an association between low entrapment and perceived safety (Blöbaum and Hunecke, 2005). As places feel safer, they look more appealing and, in turn, attract more activity (Foster and Giles-Corti, 2008), which could reinforce the feeling of safety. Indeed, the studied path was in the reflections confirmed to be regularly used by local residents for walking dogs, running etc. during hours of darkness. According to the HEI model, the social environment is an important component of the human-environment interaction, and although our study did not specifically address the social environment. It should be acknowledged that the study procedure per se gathering a small group of people created some kind of social context. However, participants walked alone along the path and were instructed not interact with each other during the assessments of the urban forest path.

Perceived lighting comfort quality was rated relatively low with 40 % of the participants reporting glare from the electric light in the questionnaire, and the lighting was described as being sharp and glaring by some of the participants during the reflections. These results suggest that the lighting could be improved to better match people's expectations and minimize visual stress. Some of the participants suggested that they wanted changes to the light that would enable them to experience nature better during dark conditions (seeing the night sky and the forested areas next to the path). Others highlighted the need to consider wildlife and insects and argued for less lighting in natural settings.

High ratings for perceived safety, suggest that the participants felt safe while walking on the path, and a feeling of safety enables psychological restoration (Hartig et al., 1997; Kaplan, 1995; Ulrich et al., 1991). The electric light condition affected the environment's perceived restorative potential. While the restorative potential was rated higher by participants in the daylight condition than by the participants in the in the after dark electric light condition (both working as controls for one another), the mean value was still above 4 (scale 1–5) in the electric light condition. Restorative potential is generally rated highly in forests (Kaplan, 1995), and our results indicate that the urban forest holds a restorative potential regardless of light condition. Electric light could provide favourable conditions for psychological restoration during the dark season. However, in this respect participants in their reflections also stressed the importance of balancing the needs of humans and other species.

As for behavioural intentions, choosing a similar path in the future was rated significantly lower in electric light than in daylight. The relatively strong intention to choose a similar path in the future and weak intention to avoid the path might reflect that the participants lived relatively close to the urban forests, or that the path was easy to use, or that they already habitually use it (Johansson et al., 2016). The result might also be associated with participants' attachment to the place, as people attached to the place where they live tend to be more satisfied with it (Bonaiuto et al., 2003).

However a gender difference was noted in the intention to avoid the path, with women more likely to avoid the path than men, confirming that individual factors can partly differentiate the experience of walking in an urban forest. Due to the limited sample size the statistical result should be interpreted with caution.

However, the participants' reflections confirmed that some women altered their recreational walks after dark. The result is as well in line with previous research suggesting that women tend to avoid walking alone along secluded paths (Rahm et al., 2021).

From previous studies we know that women, more than men, use urban forests for recreation and well-being (Ode Sang et al., 2016). This implies that the consequences of insufficient or inadequate lighting in urban forest settings may be more adverse to women than men.

Our empirical study holds both strengths and weaknesses. Although virtual reality, films and photographs are acknowledged as possible methods for assessing nature experience (Hartig et al., 2014), assessing experiences in a real urban forest setting likely increased the ecological validity of the study. A drawback of the study being conducted in a real-world setting was the variation in weather conditions, which likely to some degree affected the light assessments. However, to minimize the impact data was not collected during days with snow cover, as snow on the ground may fundamentally alter the light conditions. It is sometimes argued that observer-based assessments by laypeople would be a limitation of the study because of their non-expert opinion on lighting, but as the participants were local residents and actual users of the urban forest, they provided contextual information contributing to a holistic understanding for the municipalities' planning (Uzzell et al., 2002).

From an ecological perspective there are strong arguments for the need of urban dark spaces and reduced light pollution to support other species (Jägerbrand, 2021). On the other hand, lighting standards suggest that paths correspond to a specific class of lighting specified on an average horizontal illuminance of 5.0 lx (Swedish Transport Administration, 2020). Improving the understanding of how actual users perceive the lit environment may aid in finding a middle ground, taking both human and non-human perspectives into consideration. The participants' assessments showed that the light did provide visual accessibility, which is coherent with both measurements at the site and light simulations that showed greater illuminance levels than required by the lighting standards (Dincel, 2023). However, by adding light to an urban forest to increase the perception of safety, light pollution level would increase and the experience of being in the environment may be impacted negatively, while also wasting energy (Candolin, 2024). Therefore, it is important to design environmentally friendly electric lighting solutions that can support people's needs without interfering with the forest ecosystem. This is highlighted by (Beeco et al., 2025) who stress the importance of discussing human preferences and conservation goals. The conflicting interest of human needs of electric light and the negative consequences of light pollution is not only a problem of Nordic countries but global (Mu et al., 2021). In the European South, protected areas in Greece are also facing light pollution problems and balanced lighting solutions are being proposed as well as a dark sky option- (Papalambrou and Doulos, 2019). Further research needs to consider how to reduce the negative impact of electric light in urban forests, (Ramírez et al., 2023) and there is a need to evaluate new designs of electric light in urban forests with regard to both humans and the needs of other species.

Practical implications for planners of urban woodlands based on our results are that electric lighting along paths would be favourable if human restoration is a priority. If so, the electric light should provide a good overview of the surrounding (visual accessibility and prospect) to facilitate safe interaction with other people (e.g. seeing their faces) and anticipation of the presence of other species. Yet, there seems to be potential to increase prospect and perceived safety and avoid the light becoming a "tunnel" by adapting the direction and intensity of the light. Linked to the suggested outdoor lighting principles summarized in Beeco et al. (2023), there is also a need to consider conservation actions in combination with human experiences.

4.1. Conclusion

The information provided from this study could guide urban planning and (light) design in urban forests. Our results confirm that the experiences of walking along an urban forest path differ between daylight and electric light condition, in key aspects such as perceived visual accessibility, prospect, escape, perceived safety, restorative potential, and behavioural intention to choose a similar path. Age was not a statistically significant covariate, but gender was significant in the intention to avoid a similar path, with women expressing a higher intention to avoid it. The results suggest that, from a human health perspective, it could be favourable to provide electric lighting along urban forest paths close to residential areas. Forests per se are particularly important for human well-being since our findings reveal that electric light in forests in dark seem to be perceived even more restorative than urban settings during daylight. While the perceived visual accessibility was retained in electric light, the light seemed to create a light tunnel limiting prospect. The perceived comfort of the electric light provided could be further improved by decreasing glare. It should however be recognized that the use of electric light in urban forests must be carefully balanced against the detrimental effects of light pollution for other species and ecosystems.

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CRediT authorship contribution statement

Georgios Tsiakiris: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Johan Rahm:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Marcus Hedblom:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Maria Johansson:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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