



LUND UNIVERSITY

Environmental experiences and the psychological impact of lighting during urban forest walks.

Differences in daylight, electric light, and head torch scenarios.

Tsiakiris, Georgios

2026

[Link to publication](#)

Citation for published version (APA):

Tsiakiris, G. (2026). *Environmental experiences and the psychological impact of lighting during urban forest walks. Differences in daylight, electric light, and head torch scenarios*. Department of Architecture and Built Environment, Lund University.

Total number of authors:

1

Creative Commons License:

CC BY

General rights

Unless other specific re-use rights are stated the following general rights apply:

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Read more about Creative commons licenses: <https://creativecommons.org/licenses/>

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Environmental experiences and the psychological impact of lighting during urban forest walks

Differences in daylight, electric light, and head torch scenarios

GEORGIOS TSIAKIRIS

DEPARTMENT OF ARCHITECTURE AND BUILT ENVIRONMENT | LUND UNIVERSITY



Environmental experiences and the psychological impact
of lighting during urban forest walks.

Environmental experiences and the psychological impact of lighting during urban forest walks

Differences in daylight, electric light,
and head torch scenarios

Georgios Tsiakiris



LUND
UNIVERSITY

DOCTORAL DISSERTATION

Doctoral dissertation for the degree of Doctor of Philosophy (PhD)
at the Faculty of Engineering, Lund University, Sweden. To be publicly
defended on 9th of June at 09.00 in the Department of Architecture and
Built Environment, Klas Anshelms väg 16

Faculty opponent
Cecilia Stenfors

Organization: LUND UNIVERSITY

Document name: Doctoral thesis

Date of issue 9th of June 2026

Author: Georgios Tsiakiris

Sponsoring organization: Nordforsk (via Formas), Dnr: 2021-00384. Swedish Energy Agency (under NorDark Research Consortium), Dnr: P2021-00024. Lund University Agenda 2030 Graduate School.

Title and subtitle: Environmental experiences and the psychological impact of lighting during urban forest walks. Differences in daylight, electric light, and head torch scenarios.

Abstract:

Contemporary urbanised societies can lead to limited access to urban forests for pedestrians and to increased psychological distress. Lighting is a factor that can indirectly impact human health by hindering or supporting certain behaviours, such as walking in the urban environment. Urban forests could support pedestrians' physical and mental health through recreational opportunities and psychological restoration, but during the Nordic winter season daylight hours are limited, hindering pedestrians' walking. A focus on pedestrians' environmental experiences under daylight and electric light conditions in urban forest paths could contribute to urban residents' walking intentions and well-being.

The human-environment interaction (HEI) model (Küller, 1991) and the hierarchy of walking needs (Alfonzo, 2005) served as the basis of the conceptual model in this thesis. The theoretical contribution of the model is that it introduces the context of lighting along urban forest paths while addressing the presence of wildlife and the perceived restorative potential of forests. The thesis addressed how an after-dark urban forest environment with electric light compares to daylight in terms of environmental experiences and behavioural intentions to walk along urban forest paths, and how different electric lighting scenarios compared with one another. Another focus was on whether individual factors can moderate nature experience in daylight and electric light scenarios during urban forest walks as well as the potential psychological impact on the pedestrians from the time spent in nature.

Across four interconnected studies conducted outdoors in urban forest paths in Sweden (Studies 1 and 2) and Norway (Studies 3 and 4) the method of structured walks was applied, with a total of 176 participants responding to a questionnaire and engaging in group discussions providing personal reflections. The studies investigated lighting scenarios designed to balance between enabling human access to urban forests after dark and minimising ecological impact from electric light; pole-mounted electric light in Sweden (pre-intervention municipal lighting and two types of customised post-intervention lighting) and head torches in Norway (off-the-shelf head torch and a customised version with modifications).

The results confirmed that the experiences of walking along an urban forest path differ between daylight and electric light scenarios in terms of accessibility, safety and pleasurability, and that the urban forest environment continued to hold its restorative potential to some extent in the electric light after-dark scenarios. The findings of the studies showed a pattern: visual accessibility, prospect, restorative potential, and the behavioural intentions of walking were all affected by variation in the lighting condition, indicating that lighting scenarios can alter human experience across an urban forest path, whereas wildlife related experiences did not show any significant results. The walks resulted in increased valence (positive affect) for the pedestrians, prevalent in all lighting scenarios with the exception of the customised head torch scenario. It is concluded that, from a human health perspective, it could be favourable to provide a certain level of electric light output along urban forest paths close to residential areas, since the walks seemed to enhance psychological benefits in both daylight and after-dark electric light scenarios.

Key words: urban forests, daylight, electric light, environmental experiences, psychological impact

Language: English

Number of pages: 65

ISSN and key title:

ISBN: 978-91-7740-143-8 (print) 978-91-7740-144-5 (pdf)

I, the undersigned, being the copyright owner of the abstract of the above-mentioned dissertation, hereby grant to all reference sources permission to publish and disseminate the abstract of the above-mentioned dissertation.

Signature

Date 2026-06-09

Environmental experiences and the psychological impact of lighting during urban forest walks

Differences in daylight, electric light,
and head torch scenarios

Georgios Tsiakiris



LUND
UNIVERSITY

Copyright

Pages 1-65 © 2026 Georgios Tsiakiris, ORCID 0009-0002-5561-9882, (licensed under [CC BY 4.0](#)).

Paper 1 © 2025 The authors (licensed under [CC BY 4.0](#)).

Paper 2 © 2026 by the authors (Manuscript submitted).

Paper 3 © 2025 by the authors (Manuscript submitted).

Paper 4 © 2026 by the authors (Manuscript unpublished).

Cover image by Jessica Bohlok Tsiakiris

Published by:

Environmental Psychology

Department of Architecture and Built Environment

Faculty of Engineering

Lund University

Lund 2026

ISBN 978-91-7740-143-8 (print)

ISBN 978-91-7740-144-5 (electronic)

Series title:

ISSN

Printed in Sweden by Media-Tryck, Lund University,
Lund, 2026



Media-Tryck is a Nordic Swan Ecolabel
certified provider of printed material.
Read more about our environmental
work at www.mediatryck.lu.se

MADE IN SWEDEN 

Table of contents

Abbreviations	10
Abstract	11
Populärvetenskaplig sammanfattning	13
List of original papers	14
Author's contribution	14
Acknowledgements	16
1. Introduction	17
1.1 Urban forest as an important arena for human well-being and as a habitat for other species.....	17
1.2 Lighting and walking	18
1.3 Lighting in urban forests	18
1.4 Recreation in urban forests in Sweden – Nordic context	19
1.5 Aim.....	20
2. Theoretical background	21
2.1 Conceptual model.....	21
2.2 Lighting scenarios	23
2.3 Individual factors	23
2.4 Environmental experiences	23
2.5 Psychological impact of forest walks.....	25
2.6 Behavioural intentions.....	26
2.7 Outline of empirical work	26
3. Research design	28
3.1 Methodological approach.....	28
3.2 Study participants.....	28
3.3 Settings of Uppsala and Ålesund	29
3.4 Lighting scenarios in Uppsala and Ålesund	31
3.5 Measurements	32
3.6 Participants' personal reflections	36

3.7 Structured walks.....	36
3.8 Data processing and analysis.....	39
3.9 Reliability and validity	39
3.10 Ethical considerations	39
4. Summary of the main results.....	41
4.1 Paper I	41
4.1.1 Aim.....	41
4.1.2 Method.....	41
4.1.3 Results	41
4.2 Paper II.....	42
4.2.1 Aim.....	42
4.2.2 Method.....	42
4.2.3 Results	42
4.3 Paper III.....	43
4.3.1 Aim.....	43
4.3.2 Method.....	43
4.3.3 Results	43
4.4 Paper IV	44
4.4.1 Aim.....	44
4.4.2 Method.....	44
4.4.3 Results	44
5. Discussion	46
5.1 General discussion	46
5.2 Theoretical implications.....	52
5.3 Limitations	53
5.4 Practical implications	53
5.5 Sustainability goals: developing adapted electric light solutions.....	54
5.6 Directions for future research.....	54
6. Conclusions	56
References	58

List of figures

Figure 1 Conceptual model of the thesis	22
Figure 2 Site locations of the NorDark project	26
Figure 3 Outline of the empirical studies	27
Figure 4 The path in Ålesund	30
Figure 5 The path in Uppsala	31
Figure 6 The route of the structured walk path in Uppsala	37
Figure 7 The route of the structured walk path in Ålesund	38
Figure 8 Flowchart of the structured walk procedure	38

List of tables

Table 1 Descriptive statistics	29
Table 2 Descriptive statistics	29
Table 3 Overview of the light scenarios and the light specifications	32
Table 4 Variables analysed in each study	33
Table 5 Instruments	34
Table 6 Significant results from the walks	45
Table 7 Significant results from the walks	45

Abbreviations

ALAN	Artificial Light at Night
CCT	Correlated Colour Temperature
CHT	Customised Head Torch
K	Kelvin
LS1	Pole-mounted Lighting Scenario 1 (Customised)
LS2	Pole-mounted Lighting Scenario 2 (Customised)
OHT	Off-the-shelf Head Torch
RL	Reference Lighting (Municipal)
UDL	Uppsala Daylight condition
ÅDL	Ålesund Daylight condition
W	Watts

Abstract

Contemporary urbanised societies can lead to limited access to urban forests for pedestrians and to increased psychological distress. Lighting is a factor that can indirectly impact human health by hindering or supporting certain behaviours, such as walking in the urban environment. Urban forests could support pedestrians' physical and mental health through recreational opportunities and psychological restoration, but during the Nordic winter season daylight hours are limited, hindering pedestrians' walking. A focus on pedestrians' environmental experiences under daylight and electric light conditions in urban forest paths could contribute to urban residents' walking intentions and well-being.

The human-environment interaction (HEI) model (Küller, 1991) and the hierarchy of walking needs (Alfonzo, 2005) served as the basis of the conceptual model in this thesis. The theoretical contribution of the model is that it introduces the context of lighting along urban forest paths while addressing the presence of wildlife and the perceived restorative potential of forests. The thesis addressed how an after-dark urban forest environment with electric light compares to daylight in terms of environmental experiences and behavioural intentions to walk along urban forest paths, and how different electric lighting scenarios compared with one another. Another focus was on whether individual factors can moderate nature experience in daylight and electric light scenarios during urban forest walks as well as the potential psychological impact on the pedestrians from the time spent in nature.

Across four interconnected studies conducted outdoors in urban forest paths in Sweden (Studies 1 and 2) and Norway (Studies 3 and 4) the method of structured walks was applied, with a total of 176 participants responding to a questionnaire and engaging in group discussions providing personal reflections. The studies investigated lighting scenarios designed to balance between enabling human access to urban forests after dark and minimising ecological impact from electric light; pole-mounted electric light in Sweden (pre-intervention municipal lighting and two types of customised post-intervention lighting) and head torches in Norway (off-the-shelf head torch and a customised version with modifications).

The results confirmed that the experiences of walking along an urban forest path differ between daylight and electric light scenarios in terms of accessibility, safety and pleasurability, and that the urban forest environment continued to hold its restorative potential to some extent in the electric light after-dark scenarios. The findings of the studies showed a pattern: visual accessibility, prospect, restorative potential, and the behavioural intentions of walking were all affected by variation in the lighting condition, indicating that lighting scenarios can alter human experience across an urban forest path, whereas wildlife related experiences did not show any significant results. The walks resulted in increased valence (positive affect) for the pedestrians, prevalent in all lighting scenarios with the exception of the customised head torch scenario. It is concluded that, from a human health

perspective, it could be favourable to provide a certain level of electric light output along urban forest paths close to residential areas, since the walks seemed to enhance psychological benefits in both daylight and after-dark electric light scenarios.

Populärvetenskaplig sammanfattning

Urbana skogar är viktiga platser för människor som bor i städer eftersom dessa skogsmiljöer ger möjlighet till psykologisk återhämtning, naturupplevelser och rekreation. Under det nordiska mörka vinterhalvåret kan bristen på dagsljus göra det svårt att promenera i urbana skogar, dels på grund av att det är svårt att se och dels på grund av upplevd otrygghet. Många kommuner väljer att installera elektrisk belysning längs med promenadstigarna i dessa skogar. Samtidigt kan elektrisk belysning störa djurlivet, orsaka ljusföroreningar och medföra negativa fysiologiska effekter för människor.

Avhandlingen syftar till att undersöka hur promenader längs gångstigar i urbana skogar under olika ljusförhållanden (dagsljus, elektrisk belysning från lyktstolpar och pannlampor) påverkar gåendes miljöupplevelser och beteendointentioner (intentionen att välja respektive undvika att promenera längs den här typen av stigar). Ett ytterligare syfte är att undersöka den psykologiska effekten av promenaderna under de olika belysningsförhållandena.

I fyra empiriska studier i Sverige (studie 1 och 2) respektive i Norge (studie 3 och 4) medverkade lokalt boende i så kallade strukturerade vandringar i urbana skogsmiljöer. Deltagarna, totalt 176 personer, besvarade frågeformulär och genomförde en kort gruppdiskussion. I studierna jämfördes deltagarnas miljöupplevelser i dagsljusförhållanden med olika typer av elektrisk belysning, först kommunens standardbelysning och en pannlampa som fanns tillgänglig på marknaden. Därefter testades olika belysningar som hade anpassats för att minska bländning och ljusförorening genom förändrad färgtemperatur och/eller ljusstyrka.

Studierna visade att även om de anpassade belysningarna (både armaturer som var monterade på stolpar och pannlampor) hade lägre ljusstyrka och en varmare färgtemperatur, så uppskattades de av deltagarna. Resultaten tyder därmed på att belysning kan utformas så att den både svarar mot människors behov och tar hänsyn till andra arter i urbana skogar. Både i deltagarnas självrapporterade enkätsvar och i deras personliga reflektioner framkom att både den anpassade stolpmonterade elektriska belysningen och pannlamporna hade en effekt på miljöupplevelser som anses centrala för att möta gåendes behov.

Resultaten bekräftade också att dessa upplevelser skiljer mellan dagsljus och elektrisk belysning. Den upplevda möjligheten till psykologisk återhämtning kvarstod dock i viss mån även vid elektrisk belysning. Resultaten pekar vidare på att promenader i urbana skogar både i dagsljus och elektrisk belysning kan bidra till positiv känsla, psykologisk återhämtning och stärka anknytningen till naturen. Avhandlingens resultat fördjupar förståelsen för belysningsdesign i urbana skogar som parallellt kan möta människors och naturens behov.

List of original papers

Paper I

Georgios Tsiakiris, Johan Rahm, Marcus Hedblom, Maria Johansson
“The perception of walking on an urban forest path in daylight and under electric lighting”. *Trees, Forests and People* 2025 Vol. 22.
doi.org/10.1016/j.tfp.2025.101012

Paper II

Georgios Tsiakiris, Johan Rahm, Ute Besenecker, Marcus Hedblom, Seren Dincel, Eva Persson, Maria Johansson
“Light interventions balancing the needs of human and non-human species in an urban forest”. *LEUKOS* (Under review)

Paper III

Georgios Tsiakiris, Johan Rahm, Ute Besenecker, Marcus Hedblom, Hamidreza Eizadi, Eva Persson, Maria Johansson
“Experiences of after-dark urban forest walks when using head torches: off-the-shelf vs customised”. *Journal of Urban Management* (Under review)

Paper IV

Georgios Tsiakiris, Johan Rahm, Marcus Hedblom, Maria Johansson
“Psychological impact of urban forest walks in electric light and daylight scenarios” (In manuscript).

Author’s contribution

Paper I

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

Paper II

Georgios Tsiakiris: Writing – original draft, Writing – review & editing, Visualisation, Project administration, Methodology, Investigation, Formal analysis,

Data curation, Conceptualisation. *Johan Rahm*: Writing – review & editing, Visualisation, Supervision, Methodology, Formal analysis, Data curation, Conceptualisation. *Ute Besenecker*: Writing – review & editing, Methodology, Funding acquisition, Conceptualisation. *Marcus Hedblom*: Writing – review & editing, Supervision. *Seren Dincel*: Writing – review & editing, Visualisation. *Eva Persson*: Writing – review & editing, Visualisation. *Maria Johansson*: Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualisation.

Paper III

Georgios Tsiakiris: Writing – original draft, Writing – review & editing, Visualisation, Methodology, Investigation, Formal analysis, Data curation, Conceptualisation. *Johan Rahm*: Writing – review & editing, Visualisation, Supervision, Methodology, Formal analysis, Data curation, Conceptualisation. *Ute Besenecker*: Writing – review & editing, Methodology, Funding acquisition, Visualisation, Conceptualisation, Project administration. *Marcus Hedblom*: Writing – review & editing, Supervision. *Hamidreza Eizadi*: Writing – review & editing, Visualisation, Conceptualisation. *Eva Persson*: Writing – review & editing, Visualisation. *Maria Johansson*: Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Visualisation, Conceptualisation.

Paper IV

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

Acknowledgements

When this undertaking started four years ago, I was wondering how I am going to develop as a person and as a researcher and being a PhD student makes you grow whether you realise it or not. I would like to thank my supervisors Maria Johansson, Johan Rahm and Marcus Hedblom for being present from the beginning and for being stable beside me throughout this academic journey. The group of Environmental Psychology and the Department of Architecture and Built Environment in Lund for creating a workplace without surprises, only with constant support and scientific dialogue. The Agenda 2030 Graduate school at Lund University for building a space where the doctoral students felt as home through interdisciplinary collaboration, information flow and collective scientific activities that helped us grow. To the NorDark team and to all my co-authors that gave me the opportunity to be a part of a consortium and evolve as a researcher through theory and practice. To my wife Jessica who supports me in life and in all professional decisions I make.

Funding

This work was supported by Nordforsk via the Research Council Formas, grant number Dnr: 2021-00384; the Swedish Energy Agency, grant number Dnr: P2021-00024 (under NorDark Research Consortium, <https://nordark.org>) and Lund University Agenda 2030 Graduate School.

1. Introduction

1.1 Urban forest as an important arena for human well-being and as a habitat for other species

Most people worldwide live in urban environments (United Nations, 2019) and the access people have to natural settings varies, since the distribution of green spaces is not equal (Wolch et al., 2014). In times of increasing sedentary behaviour and psychological distress (United Nations, 2019) urban green spaces not only provide important settings for human recreational activities but also promote higher biodiversity levels and mitigate the negative consequences of climate change, while also providing a range of health benefits (Kondo et al., 2018).

Urban green spaces are important components of healthy and liveable cities (Anguluri & Narayanan, 2017). One specific type of urban green space is the urban forest, defined as the tree-dominated ecosystem in and near human settlements. Urban forests promote people's health and well-being through recreational opportunities and psychological restoration (Kondo et al., 2018), offering greater support to psychological well-being than other types of urban green spaces (Ode Sang et al., 2016). From this perspective, public health would benefit if these forests could be used for walking all year round. Urban forests are also important wildlife habitats, as they are considered to have greater numbers of indigenous species than other urban green areas (Gunnarsson et al., 2017).

However, the suitability of a particular urban forest for recreational and restorative purposes depends on several interacting factors relating to landscape characteristics (Velarde et al., 2007), people's socio-demographic attributes (such as age and gender), and characteristics of recreational visits – season, duration and type of activity (Lehto et al., 2022).

Experience of nature gained through recreational activities such as walking can increase connectedness to nature (the sense of people considering themselves part of nature), attentional capacity, and positive emotions (Mayer et al., 2009), important benefits of walking in an urban forest. While it is well established that people report positive feelings when walking in nature (Hartig et al., 2014; Kramer et al., 2025; Wu et al., 2025) the after-dark pedestrian experience of urban forests has gained less attention. Studies on nature experience have commonly been conducted in summertime (Samus et al., 2022; Tyrväinen et al., 2014) and daylight hours (Gidlow et al., 2016; Haluza et al., 2025), showing that green spaces

significantly promote physical activity with a direct effect on mental restoration in summer, while no significant effect was shown in winter (Zhou et al., 2022). This raises the question of whether urban forests can provide benefits for humans when walking during after-dark hours in winter.

1.2 Lighting and walking

Lighting can indirectly impact human health by hindering or supporting certain behaviours, such as walking in the urban environment. Literature on urban streetscapes recognises walking as a sustainable mode of transport that is included in almost every urban destination (Xia et al., 2015) and that supports public health by reducing the occurrence of heart and chronic diseases (World Health Organization, 2009) promoting physical activity in sedentary lifestyles, as well as being a recreational activity in itself. Studies on walking in urban streetscapes have established associations between the presence and quality of electric light and the pedestrian flow (Fotios et al., 2019) and speed (Pedersen & Johansson, 2018), as well as pedestrians positioning themselves on a path depending on lighting (Johansson et al., 2020; Yastremska-Kravchenko et al., 2024).

1.3 Lighting in urban forests

The provision of electric light in urban forests to enable use during hours of darkness is a two-way story. On the one hand, research from the built environment shows that lighting provides important functions for pedestrians by facilitating wayfinding (Davoudian, 2017), supporting feelings of reassurance (Fotios et al., 2015), and enabling outdoor activities and social interaction (Casciani, 2020; Hennig et al., 2025; Litsmark et al., 2023) and the same might apply for urban forests. On the other hand, light pollution caused by electric light is a growing environmental issue, particularly pronounced in urban settings, resulting in detrimental effects not only for urban residents but also for wildlife (Candolin, 2024). Artificial light at night (ALAN) has resulted in extensive light pollution that has, in the wake of increasing urbanisation, become an important issue (Papalambrou & Doulos, 2019). Consequently, a balance must be found between dark and illuminated environments (Katabaro et al., 2022) with respect to non-human species (Jägerbrand & Spoelstra, 2023), but also on the levels of light exposure for humans, since artificial light strains the visual system, disrupts circadian physiology, and impairs sleep (Zielinska-Dabkowska et al., 2023).

There is also a need for balance between dark and illuminated environments when it comes to recreational activities. Dark environments may be appraised as unsafe

due to the lack of overview of the surroundings, creating potential hiding places from the pedestrian's point of view (Beeco et al., 2023). However, darkness should not be considered as only negative for human recreation and psychological restoration. The meaning of darkness has gained more attention in place-related studies, where people rely on it for their recreation in after-dark environments (Beeco et al., 2023) and for specific activities such as stargazing. This accentuates the delicate balance between safeguarding darkness and providing sufficient light to facilitate recreational activities.

This thesis investigates pole-mounted electric light installed along an urban forest path and the head torch, which is a type of personal lighting, presenting different options for electric lighting in urban forests. In contrast to permanently installed pole-mounted lighting, a head torch is a wearable device with temporary electric light, illuminating during the pedestrian walks and switching off when the user exits the urban forest. Wearing a head torch facilitates activities like cycling, since it enables visual accessibility by creating a distinctive tunnel of light across a dark environment (Cook & Edensor, 2017).

1.4 Recreation in urban forests in Sweden – Nordic context

Urban forests are perceived to be of high naturalness with an unmanaged field layer (Lehvävirta & Rita, 2002). They are the most frequently visited land type for urban residents, with 44% of all recreational activities in Sweden taking place in such environments (Lehto et al., 2022). Although the urban forest is such a popular recreational area, the understanding of pedestrian experience and use of these environments under electric light scenarios is limited, despite the limited daylight hours in the winter Nordic context being a main factor for recreation (Fredman et al., 2023).

The urban forest is a natural environment especially prevalent in the Nordic context, since urban forests occupy substantial parts in Norwegian (Gundersen et al., 2006) and Swedish cities (Nielsen et al., 2017). Forests dominate the landscape in most of the land surface of Sweden, while agricultural regions account for smaller areas. These differences in regional landscape type can be expected to influence urban forest cover (Nielsen et al., 2017).

In Sweden 87.5% of all adults reported they had been in the forest for nature experience at least once during the previous 12 months and one-third of them stated that they were out in the forest more than 20 times (Fredman et al., 2023). If the distance from someone's home to an urban green area increases from 300 m to 1 km, the probability of using this green area drops by 50% (Fredman et al., 2023). These statistics reinforce the relevance of this thesis in a cultural context.

1.5 Aim

The overarching aim of the thesis is to investigate how walking in different lighting scenarios – daylight, pole-mounted electric light and head torch – on urban forest paths affects pedestrians’ environmental experiences and behavioural intentions (the intention to choose or avoid a similar path in the future), and to investigate whether the nature experience has any psychological impact.

Research questions:

RQ1) How does an after-dark urban forest environment compare to daylight in terms of environmental experiences?

RQ2) How does an after-dark urban forest environment compare to daylight in terms of behavioural intentions?

RQ3) How do different electric lighting scenarios compare with each other in terms of environmental experiences?

RQ4) How do different electric lighting scenarios compare with each other in terms of behavioural intentions?

RQ5) Can individual factors moderate the experience of different lighting scenarios of an urban forest path?

RQ6) Can an urban forest walk in daylight and in electric light scenarios have a psychological impact?

2. Theoretical background

2.1 Conceptual model

The human-environment interaction (HEI) model (Küller, 1991) and the hierarchy of walking needs (Alfonzo, 2005) serve as the basis of the conceptual model of the thesis (Figure 1). These frameworks have previously been integrated in research on electric lighting for pedestrians in urban streetscapes (Rahm, 2019). The novelty in this thesis is that the conceptual model has been further developed for the context of lighting along urban forests paths, incorporating the presence of wildlife and the perceived restorative potential of forests, as well as the psychological impact of time spent in natural settings.

The HEI model displays the interaction between the individual (characteristics such as age, gender, and values) and the physical and social environment when performing an activity within a given environment. This framework is reflected in the conceptual model of this thesis by including individual factors of the pedestrian (age, gender, value orientation, trait connectedness to nature, and urban-nature type), the physical environment of the urban forest as experienced under different lighting conditions and walking as the activity in focus. The social environment was not analysed in the studies and was not included in the conceptual model. The interaction of the pedestrian with the physical environment initiates the basic emotional processes (Küller, 1991), operationalised here as the affective experiences of valence (positive affect) and arousal (physiological arousal) within the psychological impact section of the conceptual model, along with perceived restoration and state connectedness to nature (examined in more detail in Section 2.5).

The hierarchy of walking needs (Alfonzo, 2005) focuses on the activity (walking). The hierarchy sets *feasibility*, *accessibility*, *safety*, *comfort*, and *pleasurability* as different environmental experiences that moderate the pedestrian's decision to walk. The operationalisation of the hierarchy of walking needs is described in more detail below.

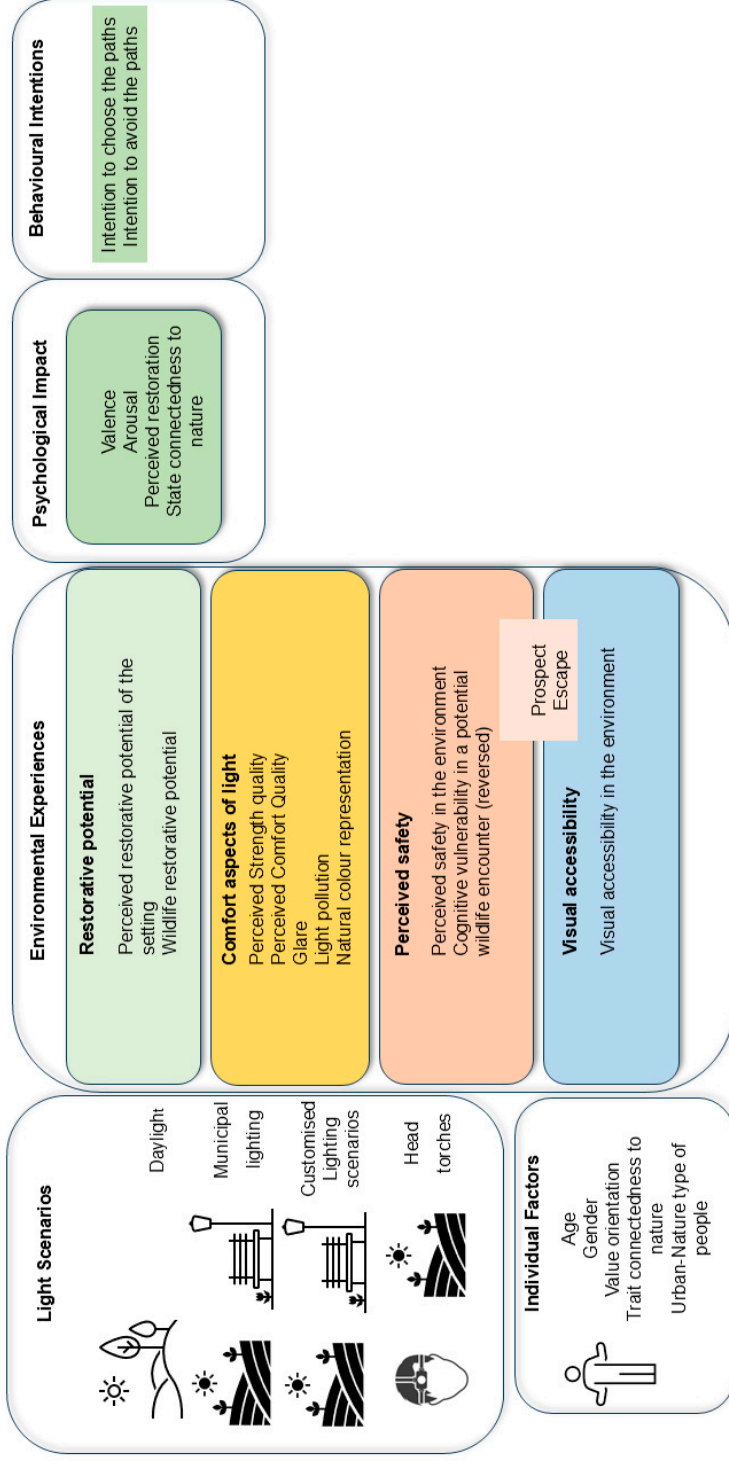


Figure 1 Conceptual model of the thesis

2.2 Lighting scenarios

The thesis investigates the environmental experiences, psychological impact, and behavioural intentions under different lighting conditions. These include daylight, three types of pole-mounted luminaires (the original municipal lighting and two customised lighting scenarios aimed to reduced light pollution) and two types of personal lighting, head torches (one off-the shelf head torch and one head torch customised to reduce light pollution). The lighting scenarios are described in more detail in Section 3.4.

2.3 Individual factors

Age and gender as central socio-demographic factors for the suitability of an urban forest for recreational and restorative purposes (Lehto et al., 2022) have been used in this thesis along with the following individual factors (traits) where all of them refer to the person's perceived relation to nature.

Value orientation assesses 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) (Schwartz, 1994).

Trait connectedness to nature assesses how close pedestrians feel to the concept of nature and if they feel part of nature (Mayer & Frantz, 2004). It is regarded as a stable individual factor (how our identity is shaped by the natural environment) that can potentially moderate the differences experienced between the daylight and the electric light condition.

Urban type and nature type people (Gunnarsson et al., 2017) assess how the pedestrians would evaluate themselves as urban and nature type people finding pleasure in city-related activities and in natural settings respectively. It is an attitude that can be regarded as a psychological construct on how people perceive an urban-related environment.

2.4 Environmental experiences

Based on previous research, this thesis considers several environmental experiences proposed to be relevant to pedestrian experience of walking on paths in daylight and after-dark hours. Pedestrian experience of urban environments differs between daylight and electric light scenarios on pedestrian paths in streetscapes (Rahm et al., 2024) and urban green spaces as assessed in virtual environments (Masullo et al., 2023) opposed to the real-life studies this thesis applied. Previous research has

explored environmental appraisals along walking paths with installed pole-mounted electric light and in daylight (Rahm et al., 2024).

Accessibility is operationalised as the perceived visual accessibility of the walking path (Johansson et al., 2011), which applies to the functional levels pedestrians need for orientation and obstacle detection (Mattsson et al., 2020). It is further operationalised as prospect, which explores how pedestrians assess the overview of the nearby surroundings (Rahm et al., 2021) and based on the prospect-refuge theory (Appleton, 1975) to ensure they can see the surroundings without being seen.

Escape possibilities refer to the pedestrian's perceived opportunities to walk away from the setting in potential danger and is derived from the Nasar et al. (1993) interpretation of the prospect-refuge theory in urban environments. When an individual perceives an environment as having a high level of entrapment, lighting scenarios become less important for the perception of safety, while prospect levels gain importance (Blöbaum & Hunecke 2005). People need to evaluate the environment as visually accessible to feel they can walk in it, to navigate themselves, and to receive information about the surroundings.

Safety is operationalised as the *perceived safety*, which addresses whether pedestrians feel safe when walking in an environment and it was reversed from the perceived danger scale (Blöbaum & Hunecke, 2005) and is further operationalised as the *perceived vulnerability* – the opposite to safety – in a potential wildlife encounter, along with the constructs that are incorporated in both accessibility and safety; prospect and escape (Rahm et al., 2021). Perceived vulnerability refers to the pedestrian's perceived lack of control when encountering wildlife, relevant in the setting of an urban forest where various species can interact, comprising perceived danger and the unpredictability of the animal's behaviour (Johansson et al., 2012). If safety requirements have been met for the needs of an individual in a specific part of their destination, that does not mean that perceived safety will be met throughout the walk (Alfonzo, 2005). If perceived safety is challenged, then the person will re-evaluate their decision on walking.

Comfort aspects of light are operationalised as the perceived outdoor lighting qualities of perceived strength quality (PSQ) and perceived comfort quality (PCQ) (Johansson et al., 2014), glare (Hickcox et al., 2022), light pollution (Kuhn et al., 2013), and natural colour representation (Kuhn et al., 2013). These experiences specifically relate to the electric light scenarios, since *comfort* applies to the electric light characteristics and its consequences for the perceived comfort of the pedestrians. In the studies where these constructs were included, the analyses were made only between after-dark electric light scenarios. *Light pollution* assesses how dark or bright the sky is in after-dark scenarios (Kuhn et al., 2013), and *natural colour representation* refers to how pedestrians experience the colour of natural objects of the environment, like bushes, trees, and grass (Kuhn et al., 2013). *Discomfort due to glare* (Hickcox et al., 2022) assesses whether the pedestrian experiences any glare looking towards the walking path in after-dark scenarios.

Pleasurability is operationalised as the restorative potential of the setting (Hartig et al., 1997). This is the extent to which an environment is considered to hold specific qualities (being away, fascination, extent, compatibility) that support the process of psychological restoration during walking in a natural setting, along with the wildlife restorative potential of the environment, which pertains to the restorative potential through the perception of wildlife presence as fascinating (Johansson, Hartig, et al., 2024b). This perspective is relevant to urban forests as an environment hosting a broad range of wildlife species.

2.5 Psychological impact of forest walks

The *effects of spending time* in the urban forest concern the part of the model on psychological impact and consequently the psychological impact of the short-time nature experience. *Valence* is the pleasure-displeasure dimension of affect (Russell et al., 1989) and *arousal* refers to physiological activity (Russell, 2003). Attention restoration theory (ART; Kaplan & Kaplan, 1989) argues that the benefits of nature are largely due to its ability to restore cognitive resources that could potentially be altered during a nature experience. This is crucial for the notion of urban forest walks and their significance in psychological impact as they assist pedestrians address their mental fatigue. Walking in natural environments normally imposes low demands on physical abilities and directed attention (Hartig & Staats, 2006), thereby supporting restoration.

Perceived restoration argues that the positive impact of nature as a state experience can fluctuate during nature exposure (Hartig et al., 1997), and *state connectedness to nature* denotes the present feelings (here and now) regarding nature (Hanley et al., 2022). These variables are included in the conceptual model.

Previous research indicates that even short exposure to nature can alter the pedestrians' emotional and physiological state; 30-minute walks in natural areas suggested positive effects on perceived stress relief (Tyrväinen et al., 2014) and psychological and physiological responses in pleasant natural environments showed stress reduction (Gidlow et al., 2016). Studies with 15-minute walks in urban green settings induced physiological relaxation (Song et al., 2015), connectedness to nature, attentional capacity, and increased positive emotions (Mayer et al., 2009). Forest immersion (30 minutes sitting and walking in a forest environment) showed significantly improved psychological well-being (Wu et al., 2025), and visits in a natural environment showed that nature experience reduced negative affect (Kramer et al., 2025).

2.6 Behavioural intentions

The behavioural intentions of walking the path were included in the conceptual model, since environmental qualities, such as lighting, and pedestrians' affective experiences connect to walking intentions (Johansson et al., 2016). The intention concerns choosing or avoiding respectively a similar path for future destinations.

2.7 Outline of empirical work

This thesis is part of the NorDark project, 'Mediating the needs of people and nature in Nordic after-dark environments' (nordark.org), so the empirical studies were conducted in two urban forest locations selected for the NorDark project in two different Nordic countries; Uppsala (city population 167,000 inhabitants) on Sweden's east coast (59th parallel) and Ålesund (city population 58,688) on the western coast of Norway (62nd parallel).



Figure 2 Site locations of the NorDark project

Ålesund municipality in Norway and Uppsala municipality in Sweden. Source: Nordark.org

The empirical work was divided into four studies. Study 1 in Uppsala was a pre-intervention study, investigating daylight and the electric light scenario already installed along the path by Uppsala municipality. The study was conducted November 2022-February 2023, and the data collected were used in Papers 1, 2 and 4. Study 2 was the post-intervention study in Uppsala (November 2023-March 2024), where customised luminaires were installed on the same light poles by the collaborating light designers within the NorDark project. The data were used in Papers 2 and 4.

Study 3 was the pre-intervention study in Ålesund (October 2023), where daylight and an off-the-shelf head torch were analysed, the latter being a product available to the public. The data were used in Papers 3 and 4. Study 4 was the post-intervention phase in Ålesund (October 2024), where the collaborating light designers customised the off-the-shelf head torch, and this modified version was used for the empirical study. The data were used in Papers 3 and 4.

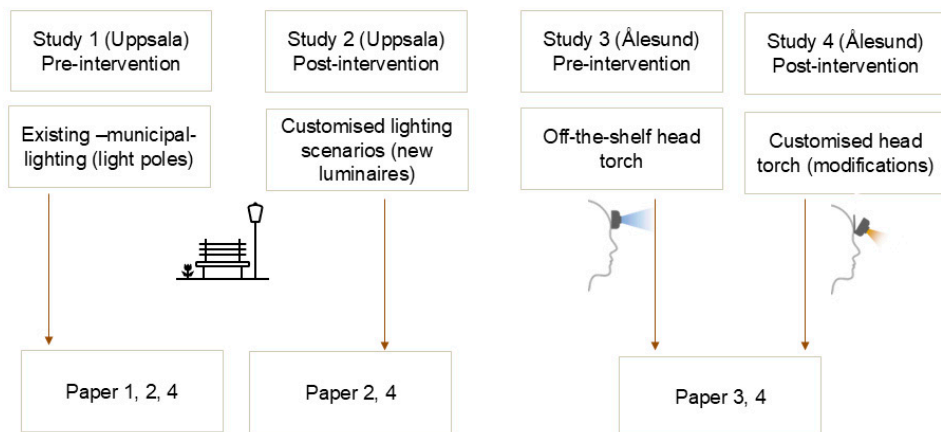


Figure 3 Outline of the empirical studies

Studies 1-4 and the papers in which their data were used.

3. Research design

3.1 Methodological approach

An experimental design was used that included a between-subject comparison of environmental experiences between the groups walking in the different lighting scenarios, and a within-subject design where each participant reported on the psychological impact scales before and after the walk. Using this research design, this thesis could deepen the understanding of the role of lighting, namely how the lighting scenarios affected the participants' environmental experiences and the psychological impact of walking the urban forest path.

The main method of data collection was the structured walk with observer-based environmental assessments on-site, followed by short group discussions where participants shared personal reflections (Johansson et al., 2016). The structured walk produces a real-life experience outdoors in the urban forest setting, mapping the human experience and reaction to daylight and electric light scenarios. This thesis thereby applied a mixed method approach, where both quantitative (questionnaires) and qualitative data (personal reflections) were collected, applying the quantitative data as main data and the qualitative data assisting in the interpretation if needed (Robson & McCartan, 2016). Moreover, the self-reported data collected for this thesis work, is related to the technical specifications of different lighting conditions collected by other parts of the NorDark project.

3.2 Study participants

The participants in all four studies were residents of the places in focus: Uppsala (Sweden) and Ålesund (Norway). It was highly relevant to have participants that reside in the respective city, since local residents are the frequent users of the urban forest (Fredman et al., 2023).

Participants in the empirical studies performed for this thesis had a wide age range (18-82), with 47-52 years being the mean age in the lighting groups, giving the studies a wide age representation. This is higher than the mean age of people residing in Uppsala which was 39.4 years (Statistics Sweden, 2025) and in Ålesund (38 years) (City-Facts, 2019).

A self-evaluation of the sample was made by the scale urban-nature type people, where nature type had mean values between 4.5 and 4.8 and urban type between 3 and 3.5 on a scale of 1-5. An explanation may be that people self-select to live close to nature reserves and the focus of the study may have especially attracted people who were more interested in forest settings.

Table 1 Descriptive statistics

Participants in Uppsala.

Uppsala	Daylight (Study 1)	Reference lighting (Study 1)	Lighting Scenario 1 (Study 2)	Lighting Scenario 2 (Study 2)	Total
Number of participants	23	25	25	28	101
Women	13	16	15	19	63
Men	10	7	9	6	32
Did not specify		2	1	3	6
Age range M	28-79 yrs	29-82 yrs	23-73 yrs	26-78 yrs	23-82 yrs
M(SD)	56 yrs (16)	47 yrs (14)	47 yrs (17)	51 yrs (15)	50 yrs (16)

Table 2 Descriptive statistics

Participants in Ålesund.

Ålesund	Daylight (Study 3)	Off-the-shelf head torch (Study 3)	Customised head torch (Study 4)	Total
Number of participants	26	26	23	75
Women	16	16	13	45
Men	10	10	10	30
Age range M	27-77 yrs	29-81 yrs	18-74 yrs	18-81 yrs
M(SD)	52 yrs (15)	52 yrs (16)	49 yrs (13)	51 yrs (15)

3.3 Settings of Uppsala and Ålesund

Uppsala: The study was conducted in Sävja (10,000 inhabitants) located 6 km from the city centre. The area consists of attached and detached housing. The empirical studies were located on a path 270-m long created for leisure for pedestrians and cyclists. For about 25 metres on both sides of the path, the forest is managed for safety reasons. The gravel path in the forest is approximately 3 metres wide, running parallel with housing 50-100 metres away.

The forest resembles a typical urban forest in these parts of Sweden (Hedblom & Söderström, 2008) with coniferous and deciduous forest. The forest area is municipally owned and there are no production demands, meaning that it has large old trees and it is in its natural state. Part of the forest is a nature reserve and an N2000 area (Swedish Environmental Protection Agency, 2018).

Ålesund: The study was conducted in Lerstad, located 9 km from the city centre. The area consists of detached family housing, located adjacent to a municipality owned urban forest, with no production demands. For this study, a 200-m long path was used, part of a longer path leading around a lake and used for both recreational and destination walking. The path has different characteristics in its 200-m length, widening after the first fifty metres, and with an upward inclination in the last part. The path is approximately two metres wide. At the start of the walk, the pedestrian has bushes, trees, and the lake on the right-hand side and houses on the left.

The locations were almost similar in relation to the distance from the city centre, type of activity (leisure walking), and having housing on one side and greenery on the other. They differed in terms of the water presence (lake in Ålesund), and the somewhat longer walking distance in the Uppsala field study. The daylight hours were approximately similar for both locations – Uppsala in November 2023 06.28-17.33, astronomical twilight 19.03-19.53, and night-time hours after 20.00; Ålesund in October 2023 daylight hours 07.10-18.21, astronomical twilight 19:53-20:49, and night-time hours after 21.00 (Time and Date, 2026).



Figure 4 The path in Ålesund

Daylight and after-dark hours. Photos: Georgios Tsiakiris.



Figure 5 The path in Uppsala

Daylight and after-dark hours. Photos: Georgios Tsiakiris.

3.4 Lighting scenarios in Uppsala and Ålesund

Daylight was a lighting scenario included in both Uppsala (Study 1) and Ålesund (Study 3). Along the Uppsala path, municipal pole-mounted luminaires (Elton/Prisma light) with LED light sources were installed (Dincel, 2023). The light poles were 4.5 high and placed at intervals of 28-32 m along the urban forest path.

In Study 2, Uppsala municipality changed the pole-mounted luminaires (same light poles) according to the light design provided by the work package of the NorDark project (Dincel, 2025). The objective of the pole-mounted lighting design was to develop the customised scenarios informed by lighting science and ecology, to balance pedestrian visual needs with the needs of non-human species (Dincel, 2025).

Lighting Scenario 1 (LS1) was designed to have the same light output as reference lighting, with new customised pole-mounted luminaires installed (Focus/Fox lighting). Each luminaire was equipped with two different kinds of lenses – clear lenses in the centre of the luminaire directing light towards the path and amber lenses at the edges, casting light with lower CCT towards the sides of the path.

Lighting Scenario 2 (LS2) used the same customised luminaire as LS1, but the light output – luminous flux – was dimmed to 11% of the original output (Dincel 2023).

In Study 3 in Ålesund the focus was on personal lighting, more specifically head torches. The study included two lighting scenarios: daylight and an off-the-shelf head torch (Clas Ohlson, Item number LED 36-5809).

In Study 4, a customised version of the off-the-shelf head torch was used, with three modifications: reduced light output, filtering out some of the short wavelength (blue) light, and adjusted light distribution to reduce peripheral light scatter, aiming the light beam 45 degrees towards the ground.

Table 3 Overview of the light scenarios and the light specifications

Power, light output, horizontal illuminance, vertical illuminance, average illuminance and uniformity, CCT

Lighting scenario	Power	Light output (lumen)	Horizontal illuminance (lux)	Vertical illuminance (lux)	Average illuminance (uniformity)	CCT
Reference lighting (Study 1)	18W	2100	10.9	5.5	12 lux (.07)	3000K
Lighting Scenario 1 (Study 2)	40W	2100	11.7	5.8	12 lux (.008)	1800-2400K
Lighting Scenario 2 (Study 2)	40W	231	5.8	5.2	6 lux (.05)	1800-2400K
Off-the-shelf head torch (Study 3)	n/a	39	14	47	n/a	7590K
Customised head torch (Study 4)	n/a	7	4	1	n/a	2803K

3.5 Measurements

The participants completed a questionnaire as part of the structured walks (see Section 3.7), consisting of four parts with each part including several measurements: Part 1 consisted of scales of value orientation, trait connectedness to nature, and urban-nature type people (see Section 2.3). Parts 2 and 3 covered the variables of valence, arousal, perceived restoration, and state connectedness to nature (see Section 2.5). Part 4 consisted of assessments of the environmental experiences (see Section 2.4) and walking intentions (see Section 2.6) and lastly socio-demographic factors such as age, gender and area of residence. Several measurements were used to assess whether the different lighting scenarios affected the pedestrians' experience of the environment. The variables analysed in each study is shown in Table 4 and the self-report scales used are given in Table 5.

Table 4 Variables analysed in each study

Individual factors, environmental experiences, psychological impact, and behavioural intentions

	Study 1	Study 2	Study 3	Study 4
Individual factors				
Age	x	x	x	x
Gender	x	x	x	x
Value orientation	x			
Trait connectedness to nature	x			
Urban-nature type	x	x	x	x
Environmental experiences				
Visual accessibility	x	x	x	
Prospect	x	x	x	
Escape	x	x	x	
Perceived safety	x	x	x	
Cognitive vulnerability			x	
Perceived strength quality		x	x	
Perceived comfort quality	x	x	x	
Glare		x		
Light pollution		x		
Natural colour representation		x		
Restorative potential	x	x	x	
Wildlife restorative potential			x	
Psychological impact				
Valence				x
Arousal				x
Perceived restoration				x
State connectedness to nature				x
Behavioural intentions				
Behavioural intention (choose)	x	x	x	
Behavioural intention (avoid)	x	x	x	

Table 5 Overview of self-report scales in the questionnaire
Items, response scale, internal reliability and reference for each scale

Variable/Scale	Example items	Response scale	Internal reliability	Reference
Individual factors				
Value orientation	Self-enhancement, openness to change, self-transcendence, conservation	Seven-point Likert scale (1=Opposed to my values, 7= Of supreme importance)	α UDL = .75, α RL = .57	Schwartz, 1994; Lindeman & Verkasalo, 2005 (10 items)
Trait connectedness to nature	'I often feel a sense of oneness with the natural world around me'; ...'My personal welfare is independent of the welfare of the natural world' (reversed)	Five-point Likert scale (1=Absolutely not; 5=Yes, absolutely)	α UDL = .90, α RL = .88	Mayer & Frantz, 2004; Hanley et al., 2022 (14 items)
Urban-nature type	'Finding pleasure in street life, shopping, and amusements of the city'; 'a nature-oriented person, finding pleasure in the sea, woods, and nature'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	Pearson's r = -.354	Gunnarsson et al., 2017 (2 items)
Environmental experiences				
Visual accessibility	'I could have detected an object on the ground'; ...'In general, I could see well'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	α RL = .70, α LS1 = .84, α LS2 = .88, α ADL = .79, α OHT = .94, α CHT = .95	Johansson et al., 2011; Rahm et al., 2024 (7 items)
Prospect	'I have good overview of the surroundings along the path'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	n/a	Nasar et al., 1993 (1 item)
Escape	'I could easily escape the path in the event of danger'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	n/a	Nasar et al., 1993 (1item)
Perceived safety	'I would go a long way around to avoid this place' (reversed); ...'I would walk along this path unaccompanied'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	α RL = .81, α LS1 = .92, α LS2 = .94, α ADL = n/a, α OHT = .88, α CHT = .99	Blöbaum & Hunecke, 2005; Johansson et al., 2011; Rahm et al., 2024 (5 items)
Cognitive vulnerability	'I think that the movement of (animal) is impossible to understand in advance'; ...'if an (animal) came near me, I would probably not feel in control'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	α RL = .73, α LS1 = .84, α LS2 = .79, α ADL = .99, α OHT = .89, α CHT = .87	Johansson et al. 2024a (6 items)
Perceived strength quality	'Clear – Drab' (reversed); ...'Dark – Light'	Seven-point differential scale	α RL = .75, α LS1 = .66, α LS2 = .77, α ADL = n/a, α OHT = .83, α CHT = .76	Johansson et al. 2014 (5 items)

Perceived comfort quality	'Mild – Sharp' (reversed),... 'Natural – Unnatural' (reversed)	Seven-point differential scale	$\alpha RL = .76$, $\alpha LS1 = .71$, $\alpha LS2 = .72$, $\alpha ADL = n/a$, $\alpha OHT = .66$, $\alpha CHT = .65$	Johansson et al. 2014 (5 items)
Glare	Single item on perceived glare	Six-point Likert scale (1=To a small extent; '6 = To a large extent)	n/a	Hickcox et al., 2022 (1 item)
Light pollution	Visually evaluating the dark sky; 'light and colour'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	Pearson's $r = .66$	Kuhn et al., 2013 (2 items)
Natural colour representation	Natural or unnatural perceived colour of grass, bushes, trees	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	$\alpha ADL = n/a$, $\alpha OHT = .95$, $\alpha CHT = .92$	Kuhn et al., 2013 (3 items)
Restorative potential	'There is much to explore and discover here ...' 'The setting has fascinating qualities'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	$\alpha RL = .70$, $\alpha LS1 = .84$, $\alpha LS2 = .90$, $\alpha ADL = .83$, $\alpha OHT = .90$, $\alpha CHT = .91$	Hartig et al. 1997 (5 items)
Wildlife restorative potential	'Dangerous and threatening for me' (reversed); 'I can be engaged and delighted by watching the animal's activity and movement'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	Pearson's $r = -.047$	Johansson et al. 2024b (2 items)
Psychological impact				
Valence	Negative-Positive affect	Affect grid, 5 x 5 cells	n/a	Russell et al., 1989; Johansson et al., 2016
Arousal	Passive-Active	Affect grid, 5 x 5 cells	n/a	Russell et al., 1989; Johansson et al., 2016
Perceived restoration	'Right now I am feeling calm', 'relaxed', 'can focus my thoughts', 'I can concentrate'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	$\alpha RL = .88$, $\alpha RL = .86$, $\alpha LS1 = .79$, $\alpha LS2 = .79$, $\alpha ADL = .81$, $\alpha OHT = .90$, $\alpha CHT = .87$	Hartig et al., 1997 (4 items)
State connectedness to nature	'Right now, I am feeling deeply aware of how my actions affect the natural world ...' 'Right now, I feel that all inhabitants of earth, human and nonhuman, share a common life force'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	$\alpha RL = .91$, $\alpha RL = .89$, $\alpha LS1 = .90$, $\alpha LS2 = .93$, $\alpha ADL = .88$, $\alpha OHT = .92$, $\alpha CHT = .95$	Mayer et al., 2009 (8 items)
Behavioural intentions				
Behavioural intention (choose)	'Specifically choose to walk along a similar path'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	n/a	Johansson, Sternudd, and Kärrholm 2016 (1 item)
Behavioural intention (avoid)	'Specifically avoid walking along a similar path'	Five-point Likert scale (1=Absolutely not, 5=Yes, absolutely)	n/a	Johansson, Sternudd, and Kärrholm 2016 (1 item)

3.6 Participants' personal reflections

Immediately after responding to the last part of the questionnaire, the participants were invited to together reflect upon their walking experience in the urban forest path in a short group discussion (approx. 10 minutes). During the reflection, the researcher prompted the participants to talk about their perception of the electric light in terms of quantity and quality and their assessments on flora and fauna along the path. Two researchers transcribed the recordings, performing a thematic analysis (Braun & Clarke, 2012) with repeated themes being coded into the themes above, and according to their relevance to the thesis concepts (visual accessibility, perceived safety, restorative potential, etc.). The reflections provided nuanced interpretations of the pedestrian experiences in empirical studies 1 and 2.

3.7 Structured walks

Uppsala: At the time of the walks, the researcher met the participants in small groups (maximum 6 persons) at the local community centre 300 m from the path and walked together to the designated path. At a point approximately 100 m from the start of the route, the participants completed the first part of the questionnaire. When part 1 was completed, the researcher walked with the participants to the starting point, where they completed part 2. Participants then walked the path individually at intervals of approximately 60 m. At the end of the designated route a sign attached on the light pole stated, 'The route ends here'. The participants completed part 3 by the sign, without the intervention of the researcher, who remained at a distance to allow the participants experience walking the path and nature without being disturbed. The participants were then led by the researcher back to the midpoint of the path, where they completed part 4. Lastly, after returning to the starting point, the participants were asked to reflect verbally upon their experience, and the group discussions were recorded. The overall procedure lasted 40-50 minutes for each group. The walks were conducted early in the morning (11:00) and early afternoon (14:00) for daylight conditions and early evening (17:00 and 19.30) for electric light conditions. The temperature varied from approximately minus ten degrees to eight degrees Celsius.



Figure 6 The route of the structured walk path in Uppsala

The path is marked with a red line, start-end of route from right to left. Source: Lantmäteriet, 1:9700.

Ålesund: At the time of the walks, the researcher met the participants, individually or in small groups (a maximum of 8 persons) outside the local school, located in the vicinity of the path (approximately 200 m) within the residential area. The groups then walked and completed part 1 of the questionnaire 50 m outside the path and part 2 at the start of the path. Participants then walked the path one by one, leaving some distance between one another, to create the feeling of walking alone in the urban forest. At the end of the designated walk, at a sign stating, 'The route ends here', the participants completed part 3. The participants were then led by the researcher back to the middle of the path, where they completed part 4. The overall procedure lasted approximately 50 minutes, depending on the number of participants. The walks were conducted in the morning (10:00) or afternoon for the daylight condition (16:00), and early evening after sunset (19.30) for the two head torch scenarios. The temperature varied from approximately minus three degrees to ten degrees Celsius.



Figure 7 The route of the structured walk path in Alesund

The path is marked with a red line, start-end of route from right to left. Source: Kartverket, 1:50000.

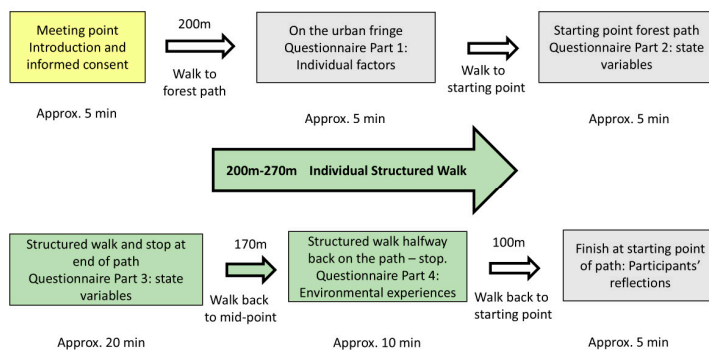


Figure 8 Flowchart of the structured walk procedure

The procedure according to questionnaire parts and designated places.

3.8 Data processing and analysis

The statistical analyses were performed with IBM SPSS 29.0.0. Descriptive statistics (median, mean, standard deviation) were obtained. Hypotheses were tested by ANOVAs and ANCOVAs and for variables not satisfying assumptions necessary for conducting parametric tests based on the data distribution (skewness and kurtosis per lighting scenario), non-parametric tests were used: Kruskal-Wallis as the non-parametric alternative of ANOVA for three or more independent groups, Mann-Whitney (for comparison between two groups), Fisher (two categorical variables of small sample as in the Glare scale) and Related-samples Wilcoxon Signed rank (for paired observations as in the before-after the walk comparisons of Paper 4). The significant p-value was set at $p > .05$ and the partial eta squared (η^2p) was calculated to assess effect size in parametric and $r = z/\sqrt{N}$ in non-parametric tests. Significant values have been adjusted for multiple comparisons by post-hoc Bonferroni correction and Dunn's test.

3.9 Reliability and validity

Reliability and validity are central components of research, ensuring the accuracy and trustworthiness of findings (Bolarinwa, 2015). The internal reliability of the scales used in this thesis has been analysed and Cronbach Alpha levels were of high internal reliability in most scales, namely above .70 based on a meta-analysis of published studies (Edelsbrunner et al., 2025), with some variables being of moderate levels (.50-.60). The scales that did not reach at least a moderate Cronbach Alpha level were excluded, as was the case for perceived safety in Study 3 ($\alpha = .27$) or the scales that were not applicable in a specific condition (*comfort* variables in daylight scenarios).

The instruments used in this thesis were established scales (Table 5) reinforcing the validity of the empirical studies. The ecological validity of this thesis, whether research findings can be generalised into the real world (Robson & McCartan, 2016) derives from the real-life empirical studies that were conducted at outdoor situations next to residential environments (including commonly used municipal lighting and off-the-shelf head torches) as opposed to simulation and laboratory studies.

3.10 Ethical considerations

The empirical studies followed the Helsinki Declaration ethical guidelines (World Medical Association, 2024) as the empirical studies were conducted with the participation of human subjects and their well-being (physically and mentally) was

the priority. The empirical studies gathered data on the psychological impact of different lighting scenarios, but did not involve collecting personal sensitive information, apart from the names of the participants, which were kept separate from the data and discarded after the completion of the structured walks. No personal information was written on the studies' questionnaires. The participants were informed about the studies' goals and written consent forms with all relevant information were signed before the structured walks. The participants were also informed that they could withdraw from the walks at any point. The study in Uppsala was approved by the Swedish Ethical Review Authority (reference number 2022–03857–01). The study in Ålesund was submitted for ethical clearance to the Regional Committees for Medical and Health Research Ethics and deemed that there was no need to be reviewed by the committee (reference number 626901).

4. Summary of the main results

4.1 Paper 1

4.1.1 Aim

Paper 1 comprised Study 1 and aimed to explore how pedestrians experience an urban forest path under two lighting scenarios: daylight and municipal reference electric lighting (RL) after dark, and to investigate the behavioural intentions of choosing or avoiding walking a similar path in the future. Pedestrians' environmental experiences were assessed (Table 4).

4.1.2 Method

The study was conducted as twenty-six structured walks with observer-based environmental assessments, obtained using established questionnaire batteries and participants' verbal reflections (see Section 3.6). The walks involved 48 participants aged 28-82 years (mean age = 51 years, SD = 15 years) assessing either daylight scenarios or RL (daylight $n = 23$, RL $n = 25$) (Table 1).

4.1.3 Results

The results showed statistically significant differences in the environmental experiences of the conceptual model (see Section 2.4). Daylight was rated higher than RL in visual accessibility ($p < .001$, $\eta^2p = 0.376$), prospect ($p < .001$, $\eta^2p = 0.383$), and escape ($p = .027$, $\eta^2p = 0.114$) (accessibility), perceived safety $p = .008$, $\eta^2p = 0.159$ (safety) and restorative potential ($p = .035$, $\eta^2p = 0.104$) (pleasurability). In the behavioural intentions, pedestrians were more likely to choose to walk the path in daylight than in reference lighting ($p = .022$, $\eta^2p = 0.121$). Perceived safety had relatively high mean values in both scenarios (daylight mean value = 4.77 and RL mean value = 4.12) and the same applied for restorative potential (daylight mean value = 4.48 and RL mean value = 4.23). Gender showed a significant difference in the behavioural intention to avoid the path, indicating that individual factors can differentiate walking intentions; women were more likely to avoid the path ($p = .015$, $\eta^2p = 0.14$) than men. (Appendix I, Table 2). Perceived safety was a recurring theme in the group discussions and perceived safety remarks varied, with some

pedestrians stating that they would walk the path only with other people, while others stated that they would not hesitate to walk alone.

4.2 Paper 2

4.2.1 Aim

Paper 2 comprised Study 1 (RL) and Study 2 (LS1 and LS2) and aimed to explore how pedestrians experience an urban forest path and the behavioural intentions of choosing or avoiding walking a similar path in the future under three different lighting scenarios: reference lighting (RL) installed by Uppsala municipality, LS1 with new customised pole-mounted luminaires, and LS2 that used the same customised luminaire as LS1 (Table 3), but with light output – luminous flux – dimmed to 11% of the original output. Pedestrians' environmental experiences were assessed (Table 4 and Table 5).

4.2.2 Method

Twenty-seven structured walks with observer-based environmental assessments were conducted (see Section 3.1). In total, the study involved 78 participants (RL $n = 25$, LS1 $n = 25$, LS2 $n = 28$) aged 23-82 years (mean age = 48 years, SD = 15 years) (Table 1).

4.2.3 Results

The results showed statistically significant differences in the environmental experiences of the conceptual model (see Section 2.1). Visual accessibility was rated higher for LS1 than LS2 ($z = 2.63$; $p = .025$, $r = .36$) and prospect was rated higher for RL than LS2 ($p = .028$, $r = .38$) (*accessibility*). Perceived safety was rated higher for LS1 than LS2 ($z = 2.98$, $p = .009$, $r = .41$) (*safety*). PSQ was rated higher for RL than LS2 ($p < .001$, $r = .55$) and higher for LS1 than LS2 ($p < .001$, $r = .55p$); PCQ was rated higher for LS1 than RL ($p = .009$, $r = .39$) and higher for LS2 than RL ($p < .001$, $r = .51$) (*comfort*). Restorative potential was rated higher for RL than LS2 ($z = 3.37$, $p = .002$, $r = .46$) (*pleasurability*). (Appendix II, Table 4).

In their personal reflections, participants stated that LS1 fitted well with the activity (walking) although the light was perceived as strong and created contrasts with the sides and between the light poles, thereby not helping with wildlife encounters. The lighting was appreciated as warmer, softer, and more natural than reference lighting, and prompted different opinions regarding glare.

LS2 was appreciated as pleasant and soft – creating no hard contrasts – but uneven to the sides and between the light poles. It evoked mixed emotions of relaxation and

fear among the pedestrians. Although it was rated as a bit dark, it was deemed appropriate for enjoying nature, suited to the rural area and was a good ‘compromise’ for both human and wildlife considerations.

4.3 Paper 3

4.3.1 Aim

Paper 3 comprised Study 3 and Study 4 and aimed to explore how pedestrians experience an urban forest path under different lighting conditions: daylight (DL); regular off-the-shelf head torches (OHT); and customised head torches (CHT) with three modifications – filtering short wavelength (blue) light, reducing the light output, and adjusting the light distribution (Table 3). This comparison explores whether pedestrian needs can be met by the head torch conditions. Another aim was to investigate the behavioural intentions of choosing or avoiding walking a similar path in the future under the three lighting scenarios. Pedestrians’ environmental experiences were assessed (Table 4 and Table 5).

4.3.2 Method

Twenty-three structured walks were conducted on-site. Participants completed questionnaires with observer-based environmental assessments (see Section 3.1). The study comprised 75 participants (DL $n = 26$, OHT $n = 26$, CHT $n = 23$) aged 18-81 years (mean age 51 years, $SD = 15$ years) (Table 2).

4.3.3 Results

The results showed statistically significant differences in the environmental experiences of the conceptual model (see Section 2.1). Visual accessibility was rated higher for daylight than OHT ($z = 5.43$, $p < .001$, $r = .75$) and higher for daylight than CHT ($z = 5.27$, $p < .001$, $r = .75$); prospect was rated higher for daylight than OHT ($z = 2.70$, $p = .02$, $r = .37$) and higher for daylight than CHT ($z = 2.50$, $p = .04$, $r = .36$) (*accessibility*). Restorative potential was rated higher for daylight than OHT ($z = 2.98$, $p = .009$, $r = .41$); and higher for daylight than CHT ($z = 2.50$, $p = .04$, $r = .36$) (*pleasurability*). The behavioural intention to choose the path showed that there were statistically significant differences between the light conditions ($H(2) = 6.893$, $p = .032$, $\eta^2_H = .07$) although the pairwise comparisons between the groups did not indicate any significant differences. In the behavioural intention to avoid the path, CHT was rated higher than daylight ($z = -2.72$, $p = .02$, $r = .39$). Safety was

excluded due to low internal reliability (Cronbach $\alpha = .27$) and *comfort* (non-applicable for daylight conditions). (Appendix III, Figures 7-12)

4.4 Paper 4

4.4.1 Aim

Paper 4 comprised data collected in Studies 1-4 and aimed to identify differences in the psychological impact of walking along an urban forest path (short-time nature experience) under the lighting scenarios of Ålesund daylight (ÅDL), Uppsala daylight (UDL), off-the-shelf head torch (OHT), customised head torch (CHT), reference lighting (RL), LS1, and LS2 (Table 3). Pedestrians' psychological impact was assessed (Table 4 and Table 5) immediately before and after the walk.

4.4.2 Method

The paper employed the structured walks method (see Section 3.7). Both locations were included in the analysis, with 75 participants in Ålesund (ÅDL: $n = 26$; OHT: $n = 26$; CHT: $n = 23$) aged 18-81 years (mean age 51 years, $SD = 15$ years) and 101 participants in Uppsala (UDL $n = 23$; RL = 25; LS1 = 25; LS2 = 28) aged 23-82 years (mean age 50 years, $SD = 15$ years) (Tables 1 and 2).

4.4.3 Results

The results showed statistically significant differences in the psychological impact section of the conceptual model (see Section 2.1). Valence was rated significantly higher after the walk in Ålesund daylight, off-the-shelf head torch, Uppsala daylight, reference lighting, LS1 and LS2. Arousal was rated higher after the walk in the customised head torch, Uppsala daylight, and LS1. Perceived restoration was rated higher after the walk in Ålesund daylight, off-the-shelf head torch and LS1. State connectedness to nature was rated significantly higher after the walk in Ålesund daylight, off-the-shelf head torch, Uppsala daylight and LS2 (Table 5-6 and for details; Appendix IV, Tables 5-6).

Table 6 Significant results from the walks

Ålesund

Ålesund	Comparisons before-after the walk			
Lighting condition	Valence	Arousal	Perceived restoration	State connectedness to nature
Daylight	p=.003, r = .59		p=.001, r = .64	p<.001, r = .79
OHT	p=.021, r = .45		p=.048, r = .39	p=.024, r = .44
CHT		p=.014, r= .51		

Table 7 Significant results from the walks

Uppsala

Uppsala	Comparisons before-after the walk			
Lighting condition	Valence	Arousal	Perceived restoration	State connectedness to nature
Daylight	p<.001, r = .69	p=.025, r =.47		p=.005, r =.58
RL	p=.003, r = .60			
LS1	p=.010, r =.51	p=.011, r = .51	p=.016, r =.48	
LS2	p=.046, r =.38			p<.001, r =.71

5. Discussion

5.1 General discussion

The aim of this thesis was to investigate how walking in different lighting scenarios – daylight, pole-mounted electric light, and head torch – on urban forest paths affects pedestrian environmental experiences and behavioural intentions (the intention to choose or avoid a similar path in the future) and to investigate any psychological impact from nature experience under these lighting conditions. This thesis addressed the nuanced experience of walking (Alfonzo, 2005) and the findings are place-related, referring to urban forests at the fringe of a city.

Research question 1 explored how daylight compared to electric light scenarios in terms of *environmental experiences*. The empirical studies showed that daylight was rated statistically higher than electric light scenarios in variables on *accessibility* (visual accessibility, prospect, and escape) for both pole-mounted electric light (Appendix I) and head torch electric light (Appendix III). The findings indicate that daylight provides more visual information than electric light after dark, better overview of the surrounding, and provides more perceived escape possibilities to the pedestrian (Hennig et al., 2025; Rahm et al., 2024). Prospect and escape are part of both *accessibility* and *safety* in the conceptual model, possibly linking to the findings that perceived safety was rated higher in daylight.

A variable on *safety* (perceived safety) was rated higher in daylight than electric light for pole-mounted electric light (Appendix I), but no significant results on perceived safety were shown for head torch electric light (Appendix III). The findings on *safety* confirmed that daylight is perceived differently to after-dark conditions in terms of perceived safety (Rahm et al., 2021). The theme of perceived safety was apparent in the pedestrians' personal reflections, which stated that the setting under LS2 could evoke feelings of fear. Interestingly, perceived safety was rated rather highly in the reference lighting and LS1 ($m_{RL} = 4.11$ $m_{LS1} = 4.30$ on a scale 1-5) suggesting that the after-dark urban forest setting was also experienced as relatively safe in the empirical studies.

The deviation between reference lighting-LS1 and LS2, where LS2 was rated less safe and evoked feelings of fear (personal reflections), is in line with previous research suggesting that light output levels are important to perceived safety (Fotios et al., 2015; Johansson et al., 2014). This connects to the prospect/refuge theory

(Appleton, 1975), as LS2 did not facilitate the pedestrians' sense that they can see the surroundings and not be seen by other people in potential hiding places.

A variable on *pleasurability* (restorative potential) was rated higher in daylight than electric light for both pole-mounted electric light and head torch electric light. This supports the notion of the restorative potential of urban forests in daylight (Kondo et al., 2018) and that the lighting condition affects the restorative potential, with daylight supporting higher perceived restorative potential than electric light scenarios (Cheon et al., 2019). However, reference lighting had a relatively high mean value in restorative potential ($m_{RL} = 4.23$) along with the OHT and CHT ($m_{OHT} = 3.88$ and $m_{CHT} = 3.90$) suggesting the innate restorative potential of urban forests, even after dark.

The concept of restoration as used in this thesis is derived from the Attention Restoration Theory (Kaplan, 1995), with being away, fascination, extent, and compatibility being the components of the restorative potential of the setting. In the physical environment of the urban forest, being away (the pedestrian not thinking of everyday life's problems), extent (rich and coherent environment such as a forest), and compatibility (a compatible environment with the pedestrian's purpose of walking) can be found in the daylight urban forest whereas fascination is probably not found since the activity at hand (walking) is not dynamic enough (Kaplan, 1995). There may lie the significance of the after-dark environment being more fascinating than daylight, as the darkness can create recreation through mystery (Edensor, 2015) resulting in the high mean values of restorative potential after dark.

No significant results were shown for wildlife restorative potential or cognitive vulnerability. This was shown by the personal reflections after the walks, where pedestrians stated that their reactions to possible wildlife encounters would be independent of the lighting and relate mostly to the type of animal they encountered. According to the cognitive vulnerability model (Armfield, 2007) there is an interplay between perceived danger and the unpredictability of animal behaviour, along with the lack of control in a potential wildlife encounter. Since the animal stated on the questionnaires was a fear-irrelevant one (roe deer) (Johansson et al., 2024) and since the structured walks made the pedestrians feel relatively safe, then this could be the explanation of why no significant results were found on wildlife scales.

Research question 2 explored how daylight compared to electric light scenarios concerning the *behavioural intentions* of the pedestrians. The behavioural intention to choose the path was rated higher in daylight than reference lighting in Study 1, and in Studies 3 and 4 behavioural intention to avoid the path was rated higher for the customised head torch than for daylight, connecting to previous research on the dichotomy lit/unlit urban landscapes (Fotios et al., 2019). The intention to choose the path was supported more in daylight, while an after-dark electric light condition made the pedestrians more inclined to avoid the path compared to daylight. These findings are in accordance with the results of this thesis, since the prerequisites of walking are *accessibility*, *safety*, *comfort*, and *pleasurability* (Alfonzo, 2005).

However, the intention to avoid the path during the customised head torch scenario walks was relatively low ($m_{\text{CHT}} = 2.19$ on a scale of 1-5) indicating that the customised head torch was not appraised as unsuitable for similar paths.

Research question 3 explored how different electric lighting scenarios compare with each other in terms of *environmental experiences*. Significant results were found only in Study 2 with the pole-mounted electric light comparisons (the head torch empirical Studies 3 and 4 showed no significant differences).

In *accessibility* variables, visual accessibility was rated higher for LS1 than LS2 and prospect was rated higher for reference lighting than LS2, supporting the idea that pedestrians need a certain amount of lighting to facilitate wayfinding (Davoudian, 2017). These results indicate that the dimmed LS2 did not provide adequate visual accessibility compared to the higher light output scenarios, in line with previous research suggesting that light brightness is important to visual accessibility (Bullough et al., 2020). Visual accessibility levels are crucial for recreational purposes when it comes to walking an urban forest path, but the dimmed LS2 could nonetheless assist in darkness-based recreational activities (Beeco et al., 2023) as a means for the pedestrian to walk the path and then go deeper into the forest and into complete darkness. LS2 enables pedestrians to get closer to nature, also mentioned in the personal reflections. Escape did not show any significant results, potentially indicating that lighting is not the prevalent factor here, whereas the urban forest setting itself and its characteristics of multiple paths leading outwards created more escape possibilities (Appendix I).

In *safety* variables, perceived safety was rated higher for LS1 than LS2, reflecting a pattern where the pedestrians rated LS1 as more suitable to provide for their walking needs than LS2. A possible explanation may be that pedestrians need a certain level of light in order to feel safe in an urban environment (Fotios et al., 2015; Rahm et al., 2024) and the same can apply in the urban forest setting, also suggesting that the drastically dimmed LS2 may not be compatible with the pedestrian *safety* walking needs. A dimmed lighting scenario substantially above the 11% of the reference lighting luminous flux output could potentially result in different findings.

In *comfort* variables, perceived strength quality (PSQ) was rated higher for reference lighting than LS2, and LS1 was rated higher than LS2. Perceived comfort quality (PCQ) was rated higher for LS1 than reference lighting, and LS2 was rated higher than reference lighting. These findings are in accordance with the results of a full-scale laboratory study on pedestrian lighting, where the lighting application with the highest mean illuminance was rated highest on perceived strength quality and lowest on perceived comfort quality (Rahm and Johansson 2018). LS1 and LS2 were rated higher than reference lighting in PCQ, making a strong argument that customised lighting scenarios were visually comfortable for the pedestrians. The finding that LS1 resulted in higher perceived comfort quality than reference lighting, along with being rated higher in perceived strength quality, could be used as an argument of being a balanced lighting scenario that pedestrians feel that it

covers their needs in *accessibility* and *comfort*. LS1 could be a good compromise for the balance with non-human species, since its amber light has been suggested to benefit certain non-human species (Jägerbrand & Spoelstra, 2023; Esposito & Radetsky, 2023).

LS2 corresponded to a P4 class of pedestrian lighting (Trafikverket, 2024) suitable for rural areas such as the study location in Uppsala, thereby supporting its suitability for the urban forest path. It was rated higher in PCQ than reference lighting, and assessments of perceived comfort quality have been shown to be associated with preference for light application (Patching et al. 2017). Both customised lighting scenarios therefore have merits in terms of exposure to certain lighting characteristics, which could potentially add to pedestrians' environmental experiences (Johansson et al., 2024).

The *comfort* variables of light pollution and natural colour representation did not show any statistically significant results. This may be because these variables were only included in Studies 3-4 with personal lighting (head torch) and not in the pole-mounted electric light scenarios, which they were initially designed for (Kuhn et al., 2013). Glare results provided from the NorDark project publications (Dincel & Tsiakiris 2026, under review) were in accordance with the PCQ results of this thesis, where 40% of the pedestrians experienced discomfort of glare from the reference lighting, whereas LS1 and LS2 resulted in 24% and 28.6% discomfort of glare among the pedestrians.

In *pleasurability* variables, restorative potential was rated higher for reference lighting than for LS2, indicating that people need certain visual accessibility levels to perceive the environment as restorative (Hennig et al., 2025; Nikunen & Korpela, 2012). This finding also follows the reasoning of the hierarchy of walking needs, where the pedestrians have to fulfil their more basic needs (Alfonzo, 2005) to reach *pleasurability*. In LS2 that was clearly not the case in comparison to reference lighting. When pedestrians have not reached their needs in safety, it becomes more difficult for them to engage in walking in an urban green area (Hartig et al., 2014) or to enjoy the environment as restorative. A choice therefore must be made between the unsafe after-dark environment and the fascination through mystery that darkness can provide (Edensor, 2015). If the physical environment of the urban forest is regarded as unsafe, visually not accessible, and not facilitating for the activity at hand, the aspects of being away, extent and compatibility (Kaplan, 1995) may decline.

The similarity between the assessments of the two head torches (mean values that were close in several scales) could be explained by their rather low light output, 39 lm and 7 lm respectively (see Table 3). This indicates possibilities for pedestrians to use a type of personal lighting with lower light output and distribution, such as the customised head torch (many off-the-shelf head torches have dimming modes) and still cover their walking needs in terms of, e.g., visual accessibility while reducing light pollution. However, the participants in the structured walks were nature type people, so probably felt close to nature and

willing to lower electric light levels when walking in urban forests (Crump et al., 2024).

Research question 4 explored how different electric light scenarios compare with each other in terms of *behavioural intentions*. No significant results were shown in these comparisons, which may indicate that electric light may not be the most critical factor in pedestrians' walking intention if they are familiar with a specific place (Wilkie & Trotter 2022) as was the case with the participants in the empirical studies. Instead, it could depend on presence/absence of electric light (Fotios et al., 2019).

Research question 5 explored whether *individual factors* moderate the experience of walking an urban forest path. Age and gender are the main covariates in this thesis, since literature focuses on the use of greenspace in relation to these demographic factors, where women experienced more well-being in natural areas than men (Ode Sang et al., 2016). The findings in Study 1 showed that women were more likely to avoid the path, shedding light on the significance of *individual factors* in the walking experience and supporting the notion of women perceiving more hindrances than men when walking after dark (Rahm et al., 2021), although gender did not show significant results in Studies 2-4. Other individual factors used as covariates in this thesis were value orientation and trait connectedness to nature, which did not show significant results in any of the studies perhaps due to low variation in the sample as the majority were nature type people. Age did not show any significant results in the statistical analyses, despite the wide age variation. An explanation could be that the participants did not have any visual impairment. Although the researcher did not check for this before the walks, it was an inclusion criterion when recruiting.

Research question 6 explored whether urban forest walks can affect *psychological impact* assessing valence, arousal, perceived restoration, and state connectedness to nature. Valence ratings were statistically higher after the walk in all lighting scenarios, apart from the customised head torch, possibly indicating that in low light output levels of personal lighting, pedestrians focus more on *accessibility* and *safety* needs, hindering them from feeling positive affect during the walks. The results on valence show that the walk and nature experience helped in increased positive affect (Kramer et al., 2025) in both daylight scenarios and in most of the electric light scenarios, notably including pole-mounted electric light and head torch personal lighting.

In arousal, the comparison before and after the walk showed a significant difference in customised head torch (CHT), Uppsala daylight (UDL) and Lighting Scenario 1 (LS1). These findings indicate that physiological activation occurred in daylight and in two electric light scenarios, including pole-mounted electric light and personal lighting. The difference in arousal levels for the customised head torch could suggest that, physiologically, this scenario required more alertness from the pedestrians (Küller, 1991) potentially due to the lower light output. The higher levels of arousal in UDL and LS1 is a finding that goes against the notion that

arousal would show a significant difference in lower light output scenarios because of the unexpected visual information. However, if it is regarded as equal to activation (Russell et al., 1989), walking a distance in an urban forest may have resulted in higher activation because of the physical activity.

In perceived restoration, significant differences were shown in Ålesund daylight (ÅDL), off-the-shelf head torch (OHT) and LS1. These findings suggest that pedestrians felt mentally restored when walking in daylight, under LS1 pole-mounted electric light and with the personal lighting of OHT. Perceived restoration may not have been significantly increased in the other lighting scenarios because of the already high mean values pedestrians had before the walks (above 4 on a scale of 1-5; no tasks were asked of them before the walks). Another factor may be that pedestrians were already in the urban forest area when completing the ‘before the walk’ ratings. The thesis contributes to restoration findings that walking in an after-dark urban forest under certain light scenarios may help pedestrians with mental restoration (Ode Sang et al., 2016). The results on perceived restoration are in accordance with previous research on nature experience, where people felt more mentally restored and had positive feelings under daylight conditions (Hartig et al., 2014; Wilkie & Clements, 2018). The novelty in this work is pinpointing two specific electric light scenarios (plus being in two different urban forest settings) that also led to increased perceived restoration. The findings are in line with the premise that short periods of walking in an urban forest decrease stress (Tyrväinen et al., 2014) and improve psychological well-being (Wu et al., 2025).

In state connectedness to nature, the comparisons showed that a significantly higher level in ÅDL, OHT, UDL and LS2 in the comparison before-after the walk. These findings show that pedestrians felt closer to nature after walking, not only in daylight but also under LS2 pole-mounted electric lighting and with OHT personal lighting. The CHT did not show significant results in state connectedness to nature, perhaps following the reasoning that the pedestrians needed their full attention to *accessibility* and *safety* needs during the walks. The finding that state connectedness to nature was rated higher in the dimmed pole-mounted electric light scenario (LS2) may indicate that light output has little effect on the sense of feeling connected to nature. These findings are notable, since daylight promotes the sense of being connected to nature after an urban forest walk (Mayer et al., 2009) but the same feeling occurred when walking in a dimmed electric light scenario and when wearing a head torch as the only electric light source. The result for LS2 is in accordance with the statements on the participants’ personal reflections that LS2 helped them come closer to nature and therefore rated it as suitable for the setting. The findings support the premise that a short-time nature experience can affect the present (here and now) state connectedness to nature (Hanley et al., 2022). Daylight was a light condition where positive changes occurred in valence, perceived restoration, and connectedness to nature (Kramer et al., 2025; Mayer et al., 2009) strongly indicating that walking an urban forest path in daylight promotes well-being (Kondo et al., 2018; Ode Sang et al., 2016; Wu et al., 2025). Notably,

the off-the-shelf head torch scenario also showed positive changes in valence, perceived restoration, and connectedness to nature. This raises the significance of after-dark urban forests for human well-being when bearing a type of personal lighting that provides relatively high visual accessibility, PCQ and restorative potential (see Table 3, Appendix III).

All the findings should be put into the frame of the activity asked of the pedestrians, which was walking and wayfinding (more accentuated in the head torch scenarios than the pole-mounted electric light) and not, e.g., stargazing, although walking is addressed in this thesis as a recreational activity of its own. If the activity in question was specifically dark-related recreation (Beeco et al., 2023) the significance of darkness and possibly the *behavioural intentions* would then be assessed differently.

5.2 Theoretical implications

The human-environment interaction (HEI) model (Küller, 1991) and hierarchy of walking needs (Alfonzo, 2005) formed the basis of the conceptual model. The theoretical contribution of this thesis was the inclusion of the physical environment of the urban forest (a type of urban green space) differentiating from the built environment, to which the hierarchy of walking needs mostly applied. The aspect of wildlife experience, which was added to the conceptual model, theorised that developing lighting scenarios for the urban forest environment can consider how pedestrians feel about wildlife presence and encounters, although this was not supported; no statistically significant results were found. The fact that there were no significant results on wildlife experience may indicate that wildlife presence was rather low on these specific urban forest paths and in the vicinity. Collaborating ecology researchers stated in their preliminary results that the lighting of paths in Sweden (and probably the presence of humans) created a barrier for wildlife presence. This was also stated in the personal reflections, where the pedestrians did not encounter any animals.

The contribution of the conceptual model to theoretical advances argues that pedestrians' walking experience in an urban forest path can be analysed in several aspects. More importantly, these aspects can be successfully operationalised through established scales. In the aspects of the conceptual model *accessibility*, *comfort* and *pleasurability*, lighting had a significant effect on at least one variable (*safety* had low internal reliability in daylight in Study 3, possibly influenced by the structured walk methods and the translation of the questionnaire to Norwegian that may have not correctly conveyed the construct of *safety*). Lighting supports the different walking needs of a pedestrian when visiting an urban forest and can support the decision to walk.

5.3 Limitations

A limitation of this thesis is that *safety* might have been appraised lower if the participants were walking alone along the paths and not seeing (or knowing) that there were other participants present. This was also mentioned in the verbal reflections, where pedestrians reported a difference between walking alone or with the presence of others, considering how feelings of *safety* might affect their walking intentions to use a similar path in the future.

Another limitation was the sample of participants, which comprised residents of the nearby area who have chosen to live in the urban fringe. This most likely led to a bias towards high nature type of people who at the same time were neutral urban type of people. The participants may therefore have potentially rated scales such as state connectedness to nature higher than urban type people and these results could potentially not be generalised to the general population of Uppsala and Ålesund.

Other sensory experiences than the focus on visual studies may affect the pedestrian experience, but the thesis design did not include scales on olfactory or soundscape. Related studies often take visual evaluation as the main factor for assessing the quality of urban green space (Xiang et al., 2022) and this thesis applied the same reasoning.

5.4 Practical implications

This thesis can provide urban planners with data on pedestrians' environmental experiences and assessments of outdoor electric lighting, thereby focusing on a bottom-up approach that can subsequently support the design of technical characteristics of electric light scenarios. There is also a need to customise or limit ALAN in outdoor lighting characteristics (Lewanzik et al., 2022) and a need for practices that take into consideration both humans and other species. A lighting scenario that reduced CCT from 3000K (reference lighting) to a CCT of 1800-2400K (LS1) with a trend of light appearing warmer with less short wavelength content (Dincel 2025) was included. Participants rated LS1 similar to reference lighting (and even higher in perceived comfort quality), opening a dialogue in terms of the ecologically friendly light scenarios that can be installed in urban forests and cover pedestrians' walking needs. The head torch as an alternative type of electric light can also be implemented in the urban forest as an ecologically friendly type of personal lighting. The thesis promotes citizens to be physically active in urban forests after dark by giving input to municipalities that could design inviting environments that in turn could improve urban residents' physical and mental health (Kondo et al., 2018). This is especially crucial for wintertime walking when daylight hours decrease.

5.5 Sustainability goals: developing adapted electric light solutions

Light exposure, referring to human-made alteration of outdoor light levels from those occurring naturally (DarkSky International, 2025) can impact human health both positively and negatively (Boyce, 2022), so balanced solutions should be considered. This thesis explores the reduction of light brightness and suggests alternative light sources like head torches that do not permanently affect urban forests. The head torches support the sustainability goals by proposing a practical solution that can be directly applied in urban forests. The findings of this thesis also suggest pole-mounted lighting scenarios (LS1) that promote benefits for human users with theoretically less impact for non-human species (based on previous research but not analysed here, e.g. animal movements and animal perspectives).

These perspectives are in accordance with the UN sustainable development goals that emphasise that countries are obliged to reduce light pollution to increase biodiversity and improve human perception (Official Journal of the European Union, 2024). The thesis specifically promotes human health and well-being (SDG 3) and promotes sustainable cities and communities (SDG 11) in urbanised societies where the distribution of urban spaces is not equal (Wolch et al., 2014). This could potentially be mitigated through the accessibility of pedestrians in urban forests supported by appropriate lighting in after-dark hours. Another SDG connected to this thesis is Life on Land (SDG 15), which entails a contradiction in that electric light in an urban forest is aimed exclusively at humans although the environment is shared between humans and animals. This thesis bridges this contradiction by suggesting lighting scenarios that would be less intrusive to animal species, warmer-appearing light with less short wavelength content (Dincel 2025). The interactions between the SDGs create similar contradictions and this thesis attempts to bridge these contradictions through alternative light design in urban forests that is suitable for pedestrians, allowing them to visit the urban forests all year round.

5.6 Directions for future research

Daylight is used as the baseline lighting scenario, and after-dark lighting scenarios create changes to the physical environment as well as how pedestrians experience the environment. Fully autonomous structured walks (one person at a time and with the researcher standing outside the path) could also benefit from a longitudinal study approach. This could lead to exploring well-being and quality of life aspects through the acceptance of after-dark urban green areas near a person's residence.

Future studies could include participants who assess themselves higher in urban type and lower in nature type or disconnected from nature, along with other cohorts

such as visual impaired people testing the lighting scenarios, or residents of other cities or lighting experts. Probable discrepancies can confirm or question the type of lighting that would function in urban forests, balancing the needs of people and other species. The configuration of the lighting interventions could be further explored, for example testing more groups with head torches with various designs or lighting scenarios with various levels of dimming.

6. Conclusions

The different lighting scenarios, involving daylight, pole-mounted electric light and head torch use, are the independent variables that form the physical environment of the urban forest path. Through the comparisons, the thesis established the significance of the lighting condition. Daylight hours are decreased in the Nordic winter, and this affects how pedestrians experience after-dark urban green areas and consequently urban forests. The findings could guide urban planning and (light) design in urban forests in promoting pedestrian walking needs and pinpointing the differences between daylight and after-dark electric light conditions, balancing the needs of human and non-human species in the Nordic context. The thesis also proposes a conceptual model suggesting that evaluations of pedestrians' walking experience of electric light scenarios in urban forest paths can be mapped in relation to the walking needs/constructs of accessibility, safety, comfort and pleasurability.

Applying the conceptual model to pedestrians' environmental experiences of walking along an urban forest path showed that daylight and electric light scenarios differed in key aspects, and this connects to the societal importance of the thesis. Daylight supports peoples' walking needs within the urban forest setting, but there is a nuanced distinction between daylight and after dark, with the latter also supporting pedestrian walking needs and providing positive psychological impact to some extent.

The findings of Papers 1-3 show a pattern: visual accessibility, prospect, restorative potential, and behavioural intentions were all affected by variation in the lighting condition, indicating that the specific lighting scenarios can alter pedestrian experience across an urban forest path. Both pole-mounted electric light and head torch electric light have supported pedestrians' environmental experiences and psychological benefits, emphasising the relevance of modifying electric light solutions towards more ecologically friendly luminaires and alternative types of electric light (personal wearable lighting as a head torch, but not exclusively).

From a human health perspective, it could be favourable to provide a certain level of electric light output along urban forest paths close to residential areas. Personal lighting can provide sufficient illumination to support the use of urban forests, but its lighting design requires further analysis. Light pollution can be reduced and light sources adapted to be more ecologically friendly. This thesis can inspire future research and advances, since the lighting scenarios of pole-mounted electric light and head torches aimed to reduce light brightness and CCT, which can support good health and physiology (Zielinska-Dabkowska et al., 2023) and a sense of

connectedness to nature, as well as benefitting other non-human species (Jägerbrand & Spoelstra, 2023). Pedestrians experienced higher positive affect after the walks, were more mentally restored and felt closer to nature in daylight condition. Psychological impact was positive even in after-dark hours for most lighting scenarios, indicating benefits for human health and well-being.

This thesis took a contemporary significant urban green area (urban forests) and applied a research design that included different daylight and electric light scenarios and how pedestrians experienced them, people's trait characteristics, and the subsequent psychological impact of a sustainable recreational activity (walking), along with the individual's walking intentions. The results confirmed the nuanced experience of walking in a place that supports physical and mental health and showed that the after-dark experience, although with less positive impact than daylight, can still support human well-being. After-dark hours can support recreation and physical exercise in an increasingly rapid pace of life that takes up a substantial amount of daylight hours (e.g. commuting to and from work plus the hours at the workplace) thereby relieving stress and promoting psychological relaxation (Su et al., 2026). An urban forest that can be used after dark accommodates environmental experiences and supports positive psychological impact, providing multiple benefits for urban residents.

References

- Alfonzo, M. A. (2005). To Walk or Not to Walk? The Hierarchy of Walking Needs. *Environment and Behavior*, 36(6), 808-836. <https://doi.org/DOI:10.1177/0013916504274016>
- Anguluri, R., & Narayanan, P. (2017). Role of green space in urban planning: Outlook towards smart cities. *Urban Forestry & Urban Greening* 25, 58-65. <https://doi.org/http://dx.doi.org/10.1016/j.ufug.2017.04.007>
- Appleton, J. (1975). *The Experience of Landscape*. Wiley.
- Armfield, J. M. (2007). Understanding animal fears: a comparison of the cognitive vulnerability and harm-looming models. *BMC Psychiatry*, 7(68). <https://doi.org/doi:10.1186/1471-244X-7-68>
- Beeco, J. A., Wilkins, E. J., Miller, A. B., Lamborn, C. C., Anderson, S. J., Miller, Z. D., & Smith, J. W. (2023). Support for management actions to protect night sky quality: Insights from visitors to state and national park units in the U.S. *Journal of Environmental Management*, 345. <https://doi.org/https://doi.org/10.1016/j.jenvman.2023.118878>
- Blöbaum, A., & Hunecke, M. (2005). Perceived Danger in Urban Public Space: The Impacts of Physical Features and Personal Factors. *Environment and Behavior*, 37(4), 465-486. <https://doi.org/DOI:10.1177/0013916504269643>
- Bolarinwa, O. A. (2015). Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Nigerian Postgraduate Medical Journal*, 22, 195 - 201. doi: 10.4103/1117-1936.173959
- Boyce, P. R. (2022). Light, lighting and human health. *Lighting Res. Technol.*, 54, 101-144. [10.1177/14771535211010267](https://doi.org/10.1177/14771535211010267)
- Braun, V.; Clarke, V. (2012). Thematic Analysis. APA Handbook of Research Methods in Psychology. In Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological; *American Psychological Association*, 2, 57–71.
- Bullough, J. D., Snyder, J. D., & Kiefer, K. (2020). Impacts of average illuminance, spectral distribution, and uniformity on brightness and safety perceptions under parking lot lighting. *Lighting Res. Technol.*, 5(52), 626–640. <https://doi.org/10.1177/1477153519875171>
- Candolin, U. (2024). Coping with light pollution in urban environments: Patterns and challenges. *iScience*, 27. <https://doi.org/https://doi.org/10.1016/j.isci.2024.109244>
- Casciani, D. (2020). *The Human and Social Dimension of Urban Lightscapes*. Springer Cham. <https://doi.org/https://doi.org/10.1007/978-3-030-57165-8>

- Cheon, S., Han, S., Kim, M., & Kwon, Y. (2019). Comparison between Daytime and Nighttime Scenery Focusing on Restorative and Recovery Effect. *Sustainability*, 11. <https://doi.org/doi:10.3390/su11123326>
- City-Facts. (2019). *Population Trends and Demographics* <https://www.city-facts.com/%C3%A5lesund/population>
- Cook, M., & Edensor, T. (2017). Cycling through Dark Space: Apprehending Landscape Otherwise. *Mobilities*, 12(1), 1-19. <https://doi.org/http://dx.doi.org/10.1080/17450101.2014.956417>
- Crump, M., Taff, B. D., Himschoot, E. A., Newton, J., Beeco, A., & Newman, P. (2024). Perceptions of Personal Lighting Devices and Associated Behaviors: Shifting Personal Norms and Behavior for Broader Conservation Actions. *Sustainability*, 16(1871). <https://doi.org/https://doi.org/10.3390/su16051871>
- DarkSky International. (2025). *What is light pollution?* <https://darksky.org/resources/what-is-light-pollution/#:~:text=Definition%20of%20light%20pollution,overlighting%20is%20an%20international%20concern>
- Davoudian, N. (2017). Background lighting clutters: how do they affect visual saliency of urban objects? *International Journal of Design Creativity and Innovation*, 5, 95-103. <https://doi.org/10.1080/21650349.2016.1182073>
- Dincel, S. (2023). NorDark Testbed, Uppsala/SE Light Level Measurements, Methods and Values. <https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-329469>. Stockholm: KTH Royal Institute of Technology.
- Dincel, S. (2025). NorDark Testbed, Uppsala/SE Post-intervention Design and Light Measurements. TRITA-ABE-RPT 2513. Stockholm: KTH Royal Institute of Technology.
- Dincel, S., & Tsiakiris, G. (2026). From research to practice: Stakeholder perspectives on wildlife-adapted illumination. *International Journal of Architectural Research* (under review).
- Edelsbrunner, P. A., Simonsmeier, B. A., & Schneider, M. (2025). The Cronbach's Alpha of Domain-Specific Knowledge Tests Before and After Learning: A Meta-Analysis of Published Studies. *Educational Psychology Review*, 37(4). <https://doi.org/https://doi.org/10.1007/s10648-024-09982-y>
- Edensor, T. (2015). Light design and atmosphere. *Visual Communication*, 3(14). <https://doi.org/10.1177/1470357215579975>
- Elbakidze, M., Dawson, L., Milberg, P., Mikusinski, G., Hedblom, M., Kruhlov, I., Yamelynets, T., Schaffer, C., & Johansson, K.-E. (2022). Multiple factors shape the interaction of people with urban greenspace: Sweden as a case study. *Urban Forestry & Urban Greening*, 74. <https://doi.org/10.1016/j.ufug.2022.127672>
- Fotios, S., Unwin, J., & Farrall, S. (2015). Road lighting and pedestrian reassurance after dark: A review. *Lighting Res. Technol.*, 47, 449–469. <https://doi.org/10.1177/1477153514524587>
- Fotios, S., Uttley, J., & Fox, S. (2019). A whole-year approach showing that ambient light level influences walking and cycling. *Lighting Res. Technol.*, 51, 55-64. <https://doi.org/10.1177/1477153517738306>

- Fredman, P., Sirén, A., Lehto, C., Lindhagen, A., & Hedblom, M. (2023). *Skogens rekreativsvärden: en förstudie med förslag till indikatorer*. Naturvårdsverket.
- Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., Smith, G., & Nieuwenhuijsen, M. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology*(45), 22-29. <https://doi.org/http://dx.doi.org/10.1016/j.jenvp.2015.11.003>
- Gundersen, V., Frivold, L. H., Myking, T., & Øyen, B. H. (2006). Management of urban recreational woodlands: The case of Norway. *Urban Forestry & Urban Greening*(5), 73-82. <https://doi.org/10.1016/j.ufug.2006.06.003>
- Gunnarsson, B., Knez, I., Hedblom, M., & Sang, Å. O. (2017). Effects of biodiversity and environment-related attitude on perception of urban green space. *Urban Ecosystems*, 20(1), 37-49. <https://doi.org/10.1007/s11252-016-0581-x>
- Haluza, D., Kersten, P., Lazic, T., Steinparzer, M., & Godbold, D. (2025). Unlocking the Power of Nature: Insights from a 20-Minute Forest Visit on Well-Being. *Forests*, 16. <https://doi.org/https://doi.org/10.3390/fl6050792>
- Hanley, A. W., Deringer, S. A., Sneed, J. C., Bettmann, J. E., & Gonzalez-Pons, K. M. (2022). The State of Interdependence with Nature Scale: Development and Initial Validation. *Ecopsychology*, 14(1), 47-57. <https://doi.org/10.1089/eco.2021.0014>
- Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research*, 14(4), 175-194. <https://doi.org/https://doi.org/10.1080/02815739708730435>
- Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and Health. *Annual Review of Public Health*, 35. <https://doi.org/10.1146/annurev-publhealth-032013-182443>
- Hartig, T., & Staats, H. (2006). The need for psychological restoration as a determinant of environmental preferences. *Journal of Environmental Psychology*, 26, 215-226. [doi:10.1016/j.jenvp.2006.07.007](https://doi.org/10.1016/j.jenvp.2006.07.007)
- Hedblom, M., & Söderström, B. (2008). Woodlands across Swedish urban gradients: Status, structure and management implications. *Landscape and Urban Planning*, 84, 62-73. <https://doi.org/10.1016/j.landurbplan.2007.06.007>
- Hennig, V. K. R., Gentile, N., & Johansson, M. (2025). Social interaction in public squares: the role of users' environmental appraisals in daylight and after dark. *Journal of Urban Design*. <https://doi.org/https://doi.org/10.1080/13574809.2025.2526214>
- Hickcox, K. S., Fotios, S., Abboushi, B., & Miller, N. J. (2022). Correspondence: A new two-step approach for evaluating discomfort from glare. *Lighting Res. Technol.*, 54, 91-92. <https://doi.org/10.1177/14771535211071133>
- Jägerbrand, A. K., & Spoelstra, K. (2023). Effects of anthropogenic light on species and ecosystems. *Science*, 380, 1125–1130. <https://doi.org/DOI: 10.1126/science.adg3173>
- Johansson, M., Hartig, T., Frank, J., & Flykt, A. (2024a). Vulnerability and fascination with wildlife encounters and psychological restoration in local natural settings. *Human Dimensions of Wildlife*, 1(30), 112-131. <https://doi.org/10.1080/10871209.2024.2326116>

- Johansson, M., Hartig, T., Frank, J., & Flykt, A. (2024b). Wildlife and public perceptions of opportunities for psychological restoration in local natural settings. *People and Nature* 6, 800–817. <https://doi.org/10.1002/pan3.10616>
- Johansson, M., Karlsson, J., Pedersen, E., & Flykt, A. (2012). Factors Governing Human Fear of Brown Bear and Wolf. *Human Dimensions of Wildlife*, 1(17), 58-74. <https://doi.org/10.1080/10871209.2012.619001>
- Johansson, M., Laureshyn, A., & Nilsson, M. (2020). Video Analysis of Pedestrian Movement (VAPM) under Different Lighting Conditions—Method Exploration. *Energies*, 13(4141). <https://doi.org/doi:10.3390/en13164141>
- Johansson, M., Pedersen, E., Maleetipwan-Mattsson, P., Kuhn, L., & Laike, T. (2014). Perceived outdoor lighting quality (POLQ): A lighting assessment tool. *Journal of Environmental Psychology*, 39, 14-21. <https://doi.org/10.1016/j.jenvp.2013.12.002>
- Johansson, M., Rosén, M., & Küller, R. (2011). Individual factors influencing the assessment of the outdoor lighting of an urban footpath. *Lighting Res. Technol.*, 43, 31–43. <https://doi.org/10.1177/1477153510370757>
- Johansson, M., Sternudd, C., & Kärrholm, M. (2016). Perceived urban design qualities and affective experiences of walking. *Journal of Urban Design*, 21(2), 256-275. <https://doi.org/10.1080/13574809.2015.1133225>
- Johansson, M., Tsiakiris, G., & Rahm, J. (2024). *People's conceptual environmental appraisals of urban space in daylight and electric light* Light Symposium 2023: Architecture Lighting Environments - Space With(Out) Light, Stockholm, Sweden. doi:10.1088/1755-1315/1320/1/012013
- Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *Journal of Environmental Psychology*, 15, 169-182. [https://doi.org/0272-4944/95/030169+14\\$12.00/0](https://doi.org/0272-4944/95/030169+14$12.00/0)
- Katabaro, J. M., Yan, Y., Hu, T., Yu, Q., & Cheng, X. (2022). A review of the effects of artificial light at night in urban areas on the ecosystem level and the remedial measures. *Frontiers in Public Health*, 10. <https://doi.org/10.3389/fpubh.2022.969945>
- Kondo, M., Fluehr, J. M., McKeon, T., & Branas, C. C. (2018). Urban Green Space and Its Impact on Human Health. *International Journal of Environmental Research and Public Health*, 15(445). <https://doi.org/10.3390/ijerph15030445>
- Kramer, M., Winhard, M., Juckel, G., & Mavrogiorgou, P. (2025). Nature exposure impacts affect and brain activation in health and major depression. *Journal of Environmental Psychology* 106. <https://doi.org/https://doi.org/10.1016/j.jenvp.2025.102730>
- Kuhn, L., Johansson, M., Laike, T., & Govén, T. (2013). Residents' perceptions following retrofitting of residential area outdoor lighting with LEDs. *Lighting Res. Technol.*, 45, 568–584. <https://doi.org/10.1177/1477153512464968>
- Küller, R. (1991). Environmental assessment from a neuropsychological perspective. In T. Gärling & G. W. Evans (Eds.), *Environment, cognition and action: An integrated approach* (pp. 111–147). Oxford University Press.

- Lehto, C., Hedblom, M., Öckinger, E., & Ranius, T. (2022). Landscape usage by recreationists is shaped by availability: Insights from a national PPGIS survey in Sweden. *Landscape and Urban Planning*, 227. <https://doi.org/https://doi.org/10.1016/j.landurbplan.2022.104519>
- Lehvävirta, S., & Rita, H. (2002). Natural Regeneration of Trees in Urban Woodlands. *Journal of Vegetation Science*, 13(1), 57-66.
- Lewanzik, D., Straka, T. M., Lorenz, J., Marggraf, L., Voigt-Heucke, S., Schumann, A., Brandt, M., & Voigt, C. C. (2022). Evaluating the potential of urban areas for bat conservation with citizen science data. *Environmental Pollution*, 297. <https://doi.org/https://doi.org/10.1016/j.envpol.2021.118785>
- Lindeman, M., & Verkasalo, M. (2005). Measuring Values With the Short Schwartz's Value Survey. *Journal of Personality Assessment*, 2(85), 170-178.
- Litsmark, A., Rahm, J., Mattsson, P., & Johansson, M. (2023). Children's independent mobility during dark hours: a scoping review. *Front. Public Health*, 11. <https://doi.org/10.3389/fpubh.2023.1110224>
- Masullo, M., Cioffi, F., Li, J., Maffei, L., Ciampi, G., Sibilio, S., & Scorpio, M. (2023). Urban Park Lighting Quality Perception: An Immersive Virtual Reality Experiment. *Sustainability*, 15. <https://doi.org/https://doi.org/10.3390/su15032069>
- Mattsson, P., Johansson, M., Almén, M., Laike, T., Marcheschi, E., & Ståhl, A. (2020). Improved Usability of Pedestrian Environments After Dark for People with Vision Impairment: an Intervention Study. *Sustainability*, 12(3), 1096. <https://doi.org/10.3390/su12031096>
- Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, 24, 503–515. <https://doi.org/10.1016/j.jenvp.2004.10.001>
- Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2009). Why Is Nature Beneficial? The Role of Connectedness to Nature. *Environment and Behavior*, 41(5), 607-643. <https://doi.org/10.1177/0013916508319745>
- Nasar, J. L., Fisher, B., & Grannis, M. (1993). Proximate physical cues to fear of crime. *Landscape and Urban Planning*, 26, 161-118.
- Nielsen, A. B., Hedblom, M., Olafsson, A. S., & Wiström, B. (2017). Spatial configurations of urban forest in different landscape and socio-political contexts: identifying patterns for green infrastructure planning. *Urban Ecosyst*, 20, 379–392. <https://doi.org/10.1007/s11252-016-0600-y>
- Nikunen, H. J., & Korpela, K. M. (2012). The effects of scene contents and focus of light on perceived restorativeness, fear and preference in nightscapes. *Journal of Environmental Planning and Management*, 55(4), 453-468. <https://doi.org/10.1080/09640568.2011.608548>
- Norrbrand, L., Grönkvist, M., Johannesson, B., Rappe, A., Sjölin, J., & Eiken, O. (2023). Increased Metabolic Demand During Outside Walking in Darkness With No Vision or With Visual Aid. *Military Medicine*, 188. <https://doi.org/188/9-10/e3118/7095187>
- Ode Sang, Å., Knez, I., Gunnarsson, B., & Hedblom, M. (2016). The effects of naturalness, gender, and age on how urban green space is perceived and used. *Urban Forestry & Urban Greening*, 18, 268-276. <https://doi.org/10.1016/j.ufug.2016.06.008>

- Papalambrou, A., & Doulos, L. T. (2019). Identifying, Examining, and Planning Areas Protected from Light Pollution. The Case Study of Planning the First National Dark Sky Park in Greece. *Sustainability*(11). <https://doi.org/doi:10.3390/su11215963>
- Pedersen, E., & Johansson, M. (2018). Dynamic pedestrian lighting: Effects on walking speed, legibility and environmental perception. *Lighting Res. Technol.*, 50, 522–536. <https://doi.org/10.1177/1477153516684544>
- Rahm, J. (2019). Urban outdoor lighting: Pedestrian perception, evaluation and behaviour in the lit environment. [Doctoral Thesis (compilation), Lund University, Faculty of Engineering, LTH, Department of Architecture and Built Environment]. Department of Architecture and Built Environment, Lund University.
- Rahm, J., Niska, A., & Johansson, M. (2024). The environmental experience during daylight and dark conditions: a conceptual model for pedestrians and cyclists / La experiencia ambiental en condiciones de luz diurna y oscuridad: Un modelo conceptual para peatones y ciclistas. *PsyEcology: Bilingual Journal of Environmental Psychology*, 15(1), 85-113. <https://doi.org/10.1177/21711976241232869>
- Rahm, J., Sternudd, C., & Johansson, M. (2021). “In the evening, I don’t walk in the park”: The interplay between street lighting and greenery in perceived safety. *Urban Design International*, 26, 42-52. <https://doi.org/https://doi.org/10.1057/s41289-020-00134-6>
- Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869, (2024). <http://data.europa.eu/eli/reg/2024/1991/oj>
- Robson, C., & McCartan, K. (2016). *Real World Research. 4th edition*. Wiley.
- Russell, J. A. (2003). Core Affect and the Psychological Construction of Emotion. *Psychol Rev*, 110(1), 145-172.
- Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect Grid: A Single-Item Scale of Pleasure and Arousal. *Journal of Personality and Social Psychology*, 57(3), 493-502.
- Samus, A., Freeman, C., van Heezik, Y., Krumme, K., & Dickinson, K. J. M. (2022). How do urban green spaces increase well-being? The role of perceived wildness and nature connectedness. *Journal of Environmental Psychology*, 82, 101850. <https://doi.org/10.1016/j.jenvp.2022.101850>
- Schwartz, S. H. (1994). Are There Universal Aspects in the Structure and Contents of Human Values? *Journal of Social Issues*, 50(4), 19-45. [https://doi.org/0022-4537/94/1200-0019\\$03.00/1](https://doi.org/0022-4537/94/1200-0019$03.00/1)
- Song, C., Ikei, H., Igarashi, M., Takagaki, M., & Miyazaki, Y. (2015). Physiological and Psychological Effects of a Walk in Urban Parks in Fall. *International Journal of Environmental Research and Public Health*, 12. <https://doi.org/doi:10.3390/ijerph121114216>
- Statistics Sweden. (2025). Befolkningens medelålder efter region och kön. År 1998 - 2025. PxWeb
- Su, Y., Li, H., Cao, Y., Li, Y., & Zhang, G. (2026). The impact of nighttime lighting satisfaction on the enjoyment of nocturnal physical activity and mental health. *Acta Psychologica*, 262. <https://doi.org/https://doi.org/10.1016/j.actpsy.2025.106086>

- Swedish Environmental Protection Agency. (2018). *The Right of Public Access*
<https://doi.org/https://www.naturvardsverket.se/en/topics/the-right-of-public-access/>
- Sunrise and Sunset. (2026). timeanddate.com (Accessed 15 March 2026).
- Tsiakiris, G., Rahm, J., Besenecker, U., Hedblom, M., Eizadi, H., Persson, E., & Johansson, M. (2026). Experiences of after-dark urban forest walks when using head torches: off-the-shelf vs customised (under review). *Journal of Urban Management*.
- Tsiakiris, G., Rahm, J., Hedblom, M., & Johansson, M. (2025). The perception of walking on an urban forest path in daylight and under electric lighting. *Trees, Forests and People*, 22. <https://doi.org/https://doi.org/10.1016/j.tfp.2025.101012>
- Trafikverket. (2024). *KRAV Grundvärden: Vägars och gators utformning*.
<https://urn.kb.se/resolve?urn=urn:nbn:se:trafikverket:diva-17979>
- Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology* 38, 1-9.
<http://dx.doi.org/10.1016/j.jenvp.2013.12.005>
- United Nations, Department of Economic and Social Affairs, Population Division (2019). *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)*. New York: United Nations.
- Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes – Landscape types in environmental psychology. *Urban Forestry & Urban Greening*, 6, 199-212. <https://doi.org/10.1016/j.ufug.2007.07.001>
- Wilkie, S., & Clements, H. (2018). Further exploration of environment preference and environment type congruence on restoration and perceived restoration potential. *Landscape and Urban Planning*, 170, 314-319.
<http://dx.doi.org/10.1016/j.landurbplan.2017.04.013>
- William, F. K. A. (2024). Mastering Validity and Reliability in Academic Research: Meaning and Significance. *International Journal of Research Publications*, 144(1).
doi: 10.47119/10.47119/IJRP1001441320246160
- Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities ‘just green enough’. *Landscape and Urban Planning* 125, 234-244.
<https://doi.org/http://dx.doi.org/10.1016/j.landurbplan.2014.01.017>
- World Health Organization. (2009). *World Health Statistics*.
<https://www.who.int/publications/i/item/9789241563819>
- World Medical Association. (2024). *Declaration of Helsinki: Ethical principles for medical research involving human participants*. <https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/>
- Wu, H., Chen, Z., Wang, G., & Tang, X. (2025). Does forest immersion benefit everyone? Investigating baseline stress and scene type as thresholds for neuropsychological restoration. *Trees, Forests and People*, 21
<https://doi.org/https://doi.org/10.1016/j.tfp.2025.100977>

- Xia, T., Nitschke, M., Zhang, Y., Shah, P., Crabb, S., & Hansen, A. (2015). Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia. *Environment International*, 74, 281–290. <http://dx.doi.org/10.1016/j.envint.2014.10.004>
- Xiang, Y., Hedblom, M., Wang, S., Qiu, L., & Gao, T. (2022). Indicator selection combining audio and visual perception of urban green spaces. *Ecological Indicators*, 137, 108772. <https://doi.org/10.1016/j.ecolind.2022.108772>
- Yastremska-Kravchenko, O., Laureshyn, A., Rahm, J., Johansson, M., Niska, A., Johnsson, C., & D’agostino, C. (2024). Video analysis of bicyclist and pedestrian movement on shared-use paths under daylight and electric lighting conditions—Method exploration. *Journal of Cycling and Micromobility Research* 2. <https://doi.org/https://doi.org/10.1016/j.jcmr.2024.100032>
- Zhou, Y., Yang, L., Yu, J., & Guo, S. (2022). Do seasons matter? Exploring the dynamic link between blue-green space and mental restoration. *Urban Forestry & Urban Greening*, 73. <https://doi.org/https://doi.org/10.1016/j.ufug.2022.127612>
- Zielinska-Dabkowska, K. M., Schernhammer, E. S., Hanifin, J. P., & Brainard, G. C. (2023). Reducing nighttime light exposure in the urban environment to benefit human health and society. *Science*, 380, 1130–1135. [10.1126/science.adg5277](https://doi.org/10.1126/science.adg5277)

