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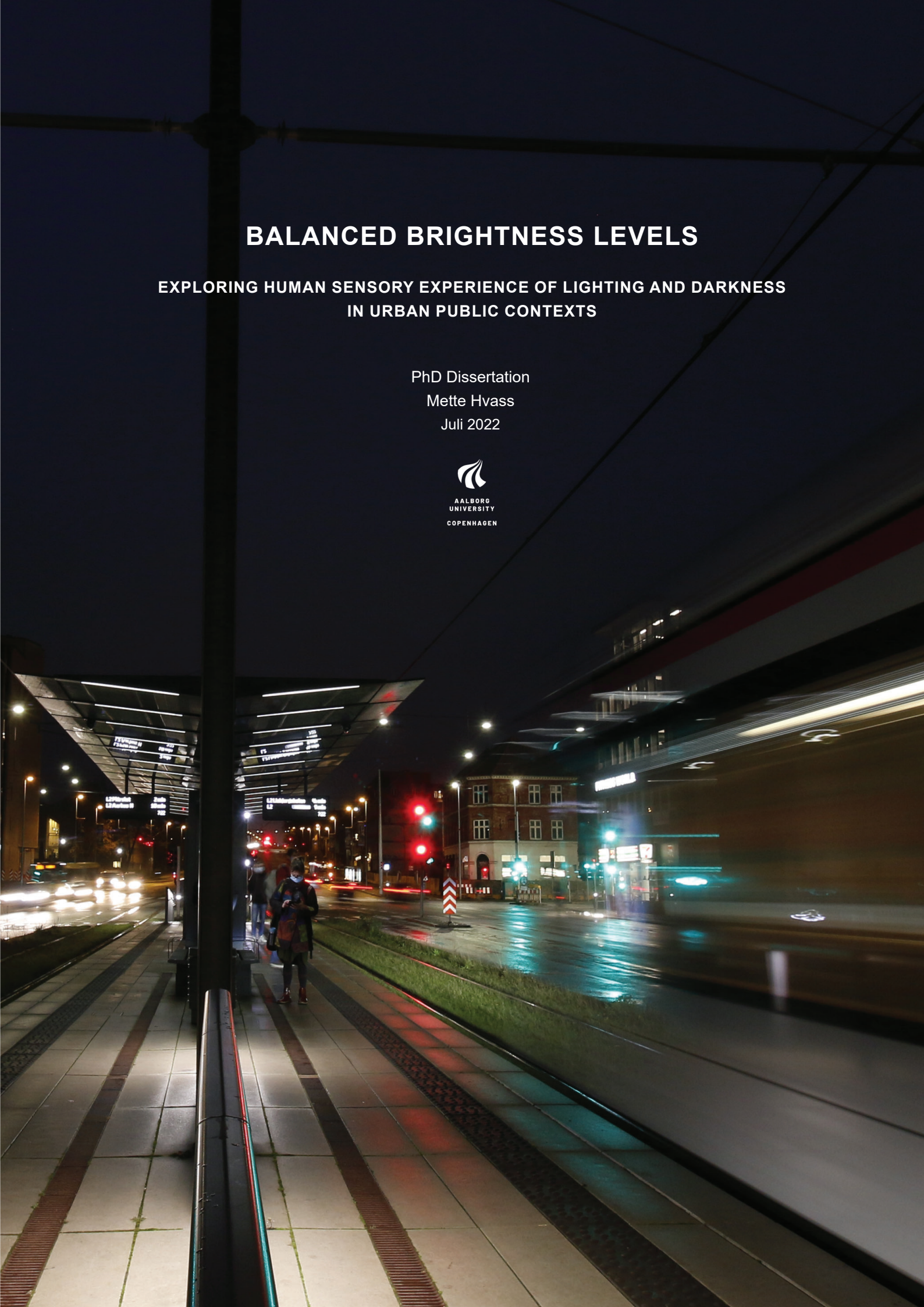
PhD Dissertation

Mette Hvass

Juli 2022

AALBORG UNIVERSITY
COPENHAGEN



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PhD Dissertation

Mette Hvass

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Schréder

Holscher Design

AALBORG UNIVERSITET

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ABSTRACT

The purpose of this PhD thesis is to investigate how lighting and darkness affects humans experience of architectural and social qualities in an urban public context during the dark hours. Furthermore, how these human experiences can be gathered in a transdisciplinary process where methods from different research disciplines are combined.

In urban contexts there is a preconceived notion that lighting is associated with safety and darkness is associated with danger. There is a need to challenge this notion, as overly lit spaces can create a tense atmosphere and an unsafe feeling of being exposed. To create livable, functional, and sustainable outdoor spaces, darkness, shadow, and variation of lighting are necessary. There is a need for research on outdoor lighting in relation to human sensing and experience to explore how brightness levels affects the feeling of atmosphere and co-presence with other people.

However, the experience of lighting in an urban setting can be difficult to describe because lighting is immaterial and is only experienced when reflected in a surface. It is necessary to conduct context-specific field experiments and combine methods from different research disciplines. To be able to understand the relationship between brightness and experience of either atmosphere or danger, co-presence with other people, and the characteristics of the specific urban environment which is being illuminated.

During this PhD thesis tram stations in Aarhus was used as context-specific case studies associated with an everyday activity. In this context studies were performed to investigate how brightness levels influence the human experience of the space, the people, and the activities which are performed associated with this urban function. The studies also investigate how humans experience the urban context when a balance is established between the brightness levels at the station, the local space, and the surrounding urban space

In this regard, the aim of this PhD thesis is to increase awareness of how brightness levels influence pedestrian experiences in architectural and social urban contexts, and to identify methods for studying these experiences. Two research questions are posed to address these needs: ‘How do brightness levels affect human experience of architectural and social urban context?’ and ‘How can research methods be combined to explore experience of brightness levels in the urban context?’

This PhD thesis employs methods from natural science, social science, and arts/humanities to study architectural lighting design. Four studies were conducted to answer the two overall research questions. A transdisciplinary process model referred to as 'The Architectural Experiment' was used to structure the four scientific studies of the PhD thesis.

The four interrelated studies were composed of three pre-analyses and a field experiment. First, a literature study which compares scenographic and urban lighting. Second, a field study which registers the role of lighting in specific urban contexts at two tram stations. Third, a lab study in which human perceptions of balanced brightness levels are examined. Fourth, a field experiment based on the knowledge derived from the three pre-analyses. Information about how brightness levels affect human experience of a specific context was collected at a tram station in the existing bright lighting setting and in a dimmed lighting setting.

During the field experiment, it was found that it was possible to dim and balance brightness levels between a local space and the surrounding space, without compromising visibility or safety. As a result of being able to see surroundings and people in a balanced lighting setting, a relaxed atmosphere was created, and an increased sense of security was felt. The specific field experiment conducted around the Nørreport tram station contradicts the preconception that high brightness levels promote a sense of safety in urban environments.

By conducting context-specific go-along interviews with visual probes, the PhD thesis provides insights into human sensory experiences of lighting and darkness in relation to the architectural and social qualities of an urban context. Likewise, luminance maps provide both measurable and unmeasurable information regarding the balance of luminance levels within a given urban context.

This PhD thesis demonstrates that lighting has a much greater impact on urban life than simply providing visibility and safety. Dim and balanced lighting can support architectural and social qualities of an urban context besides the advantages of energy savings, positive impact on biodiversity, and reduction of light pollution.

A hierarchy of lighting can be established by dimming and balancing brightness levels. In this PhD thesis focus has been directed to the general functional layer of lighting around everyday activities. When the general layer is dimmed, layers of low illumination can be added for task or accent lighting to emphasize e.g., the atmosphere where people gather, highlight functions, and support the identity of the specific context. But to be able to dim lighting in urban contexts the feeling of either atmosphere or danger has to be examined even further. This PhD thesis add some new insights to research and suggest new methods to investigate the complexity of lighting in the complex urban context. According to this PhD thesis, it is advantageous to conduct interrelated studies and combine research methods to bridge gaps between different research disciplines which are involved in outdoor lighting, to generate new knowledge about the potentials of lighting. This knowledge can be applied as part of transdisciplinary collaborations taking place in both research and practice environments and thus contribute to a nuanced understanding of lighting and darkness in urban public spaces.

RESUMÉ

Formålet med denne Ph.d.-afhandling er at undersøge, hvordan mennesker oplever lys og mørke i offentlige rum i døgnets mørke timer. Endvidere undersøger Ph.d.-afhandlingen, hvordan forskningsmetoder kan kombineres for at øge forståelsen for, hvordan lys niveauer påvirker oplevelsen af arkitektoniske og sociale kvaliteter i byens rum.

I udendørs byrum bestemmes lys niveauer ofte udelukkende i forhold til synlighed og sikkerhed. Når udendørsbelysning i byrum undersøges i forskning og planlægges i praksis bliver lysets rolle ofte ikke vurderet i forhold til følelsen af atmosfære og samvær med andre mennesker.

Et højt lys niveau bliver ofte forbundet med følelsen af sikkerhed, mens mørke bliver forbundet med fare. Men for at skabe beboelige, funktionelle og bæredygtige udendørsrum er mørke, skygge og variation af lys nødvendigt. Derfor bør udendørs belysning studeres i forhold til menneskelig sansning, adfærd og oplevelse. Da belysning er immateriel, og kun opleves, når det reflekteres i en overflade, kan oplevelsen af belysning i bymæssige omgivelser være svær at beskrive. Derfor er det nødvendigt at udføre kontekst specifikke felteksperimenter og kombinere metoder fra forskellige forskningsdiscipliner. For dermed at kunne undersøge belysning i forhold til atmosfæren, menneskelig adfærd og kvaliteterne i de arkitektoniske og sociale kvaliteter i et specifikt byrum.

I løbet af dette Ph.d.-projekt blev letbane stationer i Aarhus anvendt til kontekst specifikke casestudier. Felt og laboratorie studier blev udført for at undersøge, hvordan lys niveauer påvirker oplevelsen af rummet, menneskerne og de aktiviteter, der udføres i forbindelse med denne hverdags funktion.

Det er nødvendigt at udfordre den forudfattede opfattelse af, at et høj lys niveau er forbundet med sikkerhed og mørke er forbundet med fare. Da alt for oplyste rum kan skabe en anspændt atmosfære og en utryg følelse af at være eksponeret i det høje lys niveau. I den forbindelse er formålet med denne Ph.d.-afhandling at øge bevidstheden om, hvordan lys niveauer påvirker fodgængeres oplevelser i arkitektoniske og sociale kvaliteter, og at identificere metoder til at studere disse oplevelser. To forskningsspørgsmål stilles for at imødekomme dette behov for viden om menneskelige oplevelser af belysning og de metoder, der kan bruges til at udforske disse oplevelser. De stillede spørgsmål er: 'Hvordan påvirker lys niveauer menneskets oplevelse af den arkitektoniske og sociale urbane kontekst?' og 'Hvordan kan forskningsmetoder kombineres for at udforske oplevelsen af lys niveauer i den urbane kontekst?'

Denne Ph.d.-afhandling anvender metoder fra naturvidenskab, samfundsvidenskab og kunst/humaniora til at studere arkitektonisk lysdesign. Fire undersøgelser blev udført for at besvare de to overordnede forskningsspørgsmål. En transdisciplinær

procesmodel kaldet 'The Architectural Experiment' blev brugt til at strukturere Ph.d.-afhandlingens fire videnskabelige studier. Undersøgelsen var sammensat af tre for analyser og et felteksperiment. Først et litteraturstudie, som sammenlignede scenografisk og urban belysning. Derefter et feltstudie, som undersøgte belysningens rolle i specifikke bymæssige sammenhænge på to letbane stationer. Efterfulgt af et laboratorie studie, hvor oplevelser af balancerede lys niveauer blev undersøgt. Til sidst et felteksperiment baseret på viden fra de tre for analyser. Oplysninger om hvordan lys niveauet påvirker oplevelser af den arkitektoniske og sociale urbane kontekst blev indsamlet på en letbane station. Hvor test personer oplevede stationen i det eksisterende høje lys niveau og i et dæmpet lys niveau.

Felteksperimentet viste, at ved at dæmpe lys niveauet i et rum var det muligt at balancere lys niveauer mellem et lokalt rum (stationen) og det omgivende byrum, uden at gå på kompromis med synlighed eller sikkerhed. Som et resultat af at kunne se omgivelser og mennesker i et afbalanceret lysmiljø, vil der skabes en afslappet atmosfære, og en øget følelse af tryghed vil kunne mærkes. Det konkrete feltforsøg, der er udført omkring Nørreport letbane station, strider mod forforståelsen om, at høje lys niveauer fremmer en følelse af tryghed i bymiljøer.

Ved at gennemføre kontekst specifikke go-along interviews med visuelle probes giver Ph.d.-afhandlingen indsigt i menneskets sanselige oplevelser af lys og mørke i forhold til et byrums arkitektoniske og sociale kvaliteter. Ligeledes kan luminance maps give både målbare og ikke målbare information vedrørende balancen mellem luminans niveauer i et byrum.

Denne Ph.d.-afhandling viser, at belysning har en større indflydelse på livet i byen end blot at give synlighed og sikkerhed. Dæmpet og balanceret belysning kan resultere i energibesparelser, øge biodiversiteten og reducere lysforurening. Samt være gavnligt for at understøtte arkitektoniske og sociale kvaliteter i en bymæssig sammenhæng. Et hierarki af belysning kan etableres ved at dæmpe og balancere lys niveauer. Ved at have en generel funktionel belysning med et lavt lys niveau, kan der tilføjes andre belysnings lag med et lavt lys niveau for at understrege fx atmosfæren hvor mennesker samles, fremhæve funktioner og understøtte identiteten på det specifikke sted som lyssættes.

Ifølge denne Ph.d.-afhandling er det en fordel at kombinere forskningsmetoder for at bygge bro mellem forskningsdiscipliner, der er involveret i udendørsbelysning. Denne viden kan anvendes som en del af tværfaglige samarbejder, der finder sted i både forsknings- og praksismiljøer, og dermed bidrage til en nuanceret forståelse af lys og mørke i byernes offentlige rum.

LIST OF PAPERS

Paper 1:
Hvass, M., Hansen, E.K. (2019). Potentials of light in urban spaces defined through scenographic principles. Nordisk Arkitektur Forskning, NAF Symposium, June 2019, Gothenburg. Proceedings Series 2021-1

Paper 2:
Hvass, M., Hansen, E.K. (2020). Architectural and social potential of urban lighting, a field study of how brightness can affect the experience of waiting for public transportation. Passive and Low Energy Architecture, PLEA Conference, Proceedings September 2020.

Paper 3:
Hvass, M., Wymelenberg, K.V.D., Boring, S., Hansen, E.K. (2021). Intensity and ratios of light affecting perception of space, co-presence and surrounding context, a lab experiment. Building and Environment, Vol. 194, May 2021: 107680.

Paper 4:
Hvass, M., Waltorp, K., Hansen, E.K. (2022). Lights out? Lowering Urban Lighting Levels and Increasing Atmosphere at a Danish Tram Station. Lighting Design in Shared Public Spaces edited by Shanti Sumartojo. Routledge. Published May 2022

PREFACE

My interest in lighting was initiated at the School of Architecture through an architectural analysis of a building, designed by architect Le Corbusier. In my analysis I chose to work with the interplay between daylight and space, and I focused on an elliptical meeting room with a curved roof and light intake through two vertical skylights. I calculated and drew the movements of sunlight over a day on the organic forms of the room. In my architectural interpretation, the floor, walls, and roof were set in motion by the movements of sunlight. Time, day, and the season could be read into this movement of sunlight over the surfaces of the space. Thus, the dynamic, aesthetic and architectural power of daylight became clear to me.

Here my passion for light began, and it led me from working as a building architect, on to the job as a lighting designer in an engineering company, to later teaching lighting design at Aalborg University Copenhagen and then to writing a PhD project on outdoor architectural lighting design. In 2018 I initiated this co-financed PhD at the Department of Architecture, Design and Media Technology, at The Technical Faculty of IT and Design, Aalborg University with financial support from the Belgian company Schréder and the Danish company Holscher Design. The three parties constitute a transdisciplinary collaboration between architects and lighting designers (Aalborg University), a manufacturer of lighting fixtures and lighting control (Schréder) and a designer of light fixtures and urban furniture (Holscher Design).

In my professional career as a lighting designer, I have discovered how difficult it is to articulate a common language and understanding of the potentials of lighting. Lighting is at one extreme simply perceived as a quantity, a lux requirement that must be complied to lighting standards and regulations, and at the other extreme, light as pure aesthetics becoming an object in itself, not related to its context. In my work as a professional lighting designer, I have often been involved in challenging discussions, where I was the only one insisting on lighting as part of contextual whole and as a design parameter, which needs to be taken into account from the beginning of a design process. I wanted to take into consideration the relations between artificial lighting and daylight, form, materials, the intentions for human use of space and the activities taking place, and I had no research that included the architectural and social potentials of lighting to refer to. In practice the involved professional disciplines have different ap¬proaches and interests in the potentials of lighting. I therefore saw a need for an increased focus on the architectural and social potentials of lighting in research, which can hopefully lead to increased understanding in practice.

I see my PhD thesis and its results as an inspiration for researchers and practitioners to direct focus towards human sensory experience of lighting in urban contexts and to apply a transdisciplinary approach to be able to investigate the architectural and social

potentials of lighting. With the results of this project, we now know that there are advantages both of linking light with space, people and activities and of balancing brightness levels between urban lit zones. This can serve as inspiration to perceive lighting in a larger context and not only design lighting for a place but to use lighting as a tool to connect places and activities in the city in the dark hours. By using this understanding of the link between human experience of space and lighting in the dark hours, we can create ‘smart lighting’ which improves and increase use of urban public functions, such as public transportation, and thereby create livable and sustainable cities.

ACKNOWLEDGEMENTS

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None of this would have been possible without my two industrial partners; Schréder and Holscher Design. Thank you for believing in the project idea and for your willingness and support without knowing exactly which direction this would take. I have been very grateful for your patience the last three years. I owe a great thanks to Helmut Schröder, Jörg Richter from Schréder and thanks to Stig Myler, Jette Banke, Friederike Faller and Niels Holscher from Holscher Design.

Furthermore, I address thanks to Aarhus Tram for your collaboration. Thanks to former project manager Britta Lyager Degn, current project manager Martin Moth from Aarhus Tram and Benny Ernlund Jørgensen from Aarhus Municipality. A special thanks to Tonny Pagter from AFA JCDecaux who helped plan and implement dimming of the lighting in the final field experiment, thanks for making the experiment possible. Thanks to test participants who patiently lined up during the three empirical field and lab studies.

I greatly thank co-authors. Thanks to Kevin Van Den Wymelenberg for co-authoring paper 3 about the pre-analysis in the lab study and thanks to Sebastian Boring for conducting statistical data analysis. Anthropologist Karen Waltorp is to be thanked for an inspiring collaboration on the main field experiment. Thank you for exciting discussions, about the research design of the experiment and on how to mix anthropological and architectural methods. Thank you for your consistent support in writing up the last paper, and for enlightening me with knowledge about how an anthropologist work.

I wish to thank the Lighting Design Research Group at Aalborg University Copenhagen. Arthur van der Zaag is to be thanked for helping me install the lab setting and thanks to Emmanouil Xylakis and Micki Kofod for programming the lighting scenarios. Thanks to colleagues; Georgios Triantafyllidis, Nanet Mathiasen, Mimi Ravn, Thomas Bjørner and Kathrine Marie Schledermann for help and discussions along the way. My colleagues in our PhD office are also to be thanked, a special thanks to Stine Maria Louring Nielsen for introducing me to the wonders of anthropology. Likewise, a thanks go to PhD colleagues in the writing group ’Writing Together Matters’ and a thanks to students in the lighting design master's program, who chose to work with outdoor lighting and topics within my PhD thesis, it has been a great inspiration. For helping with writing in English I wish to thank Suzanne Slarsky Dael.

Finally, I would like to give a special thanks to family and friends who have supported me along the way. Thanks to my sister Helle Hvass for valuable proofreading, feedback, and support and most of all thanks to Karla, Freja and Anders for being very patient and helping me through this process.

TABLE OF CONTENTS

PART 1. INTRODUCTION

THE ROLE OF LIGHTING AND DARKNESS IN URBAN CONTEXTS

The introduction chapter describes the motivation and the background for this PhD thesis. The purpose is to explain the need to investigate how lighting levels affects pedestrians' experience of the architectural and social context of urban space. Both in research and in practice there is a preconceived notion of a high lighting level being connected to visibility and safety and darkness to danger. This PhD study seeks for knowledge on human sensory experience of both lighting and darkness in urban contexts. To get a nuanced understanding of how lighting levels can be adjusted to create atmospheres and enhance architectural and social urban qualities meanwhile providing a safe environment.

The introduction commences with a quote from a field experiment to frame the matters in concern. The quote is followed by a description of a gap in outdoor lighting research. Then, a chapter describes the background in relation to three important concepts of the PhD thesis: the context, human sensory experience and combining methods. Followed by a description of the scope, aim and research questions. Finally, the structure of the cover is presented.

1.1.THE MATTERS IN CONCERN

People generally believe that bright light is necessary to be able to see well, but less light can also increase visibility and a sense of connectedness between humans and their spatial and social surroundings. This connectedness is expressed in the following quote from a field experiment in a dimmed lighting setting:

'I actually start looking around in a different way because I have a feeling that I can see the surroundings. I'm in harmony with the surroundings now. It feels different from when I was in the very bright light…it is no longer the case that I am a target, exposed, and they can only look at me. Now, we can just look at each other' (Test Participant 10, female, 56 years old, dimmed lighting).

This quotation originates from a field experiment performed at Nørreport tram station in Aarhus, Denmark, after dark. This quotation is highlighted because it represents an example of a human sensory experience of balanced brightness levels in an urban context. The surroundings suddenly became visible and immediate thoughts were formulated in response to the dimmed lighting.

In this quote, both the architectural and the social aspects of lighting are influenced by the balanced brightness levels. The architectural aspects in this quote relate to being able to see the surroundings and being in harmony with the surroundings. While the social aspects relate to no longer being a target and exposed but equal to the people

in the surroundings.

The importance of the lighting in the surroundings, is often underestimated, when investigating outdoor lighting in a space. In this field experiment the surroundings became visible when the brightness level was dimmed, and the contrast was therefore less dominant. Thus, field experiments can provide an invaluable insight into human experience of the urban nocturnal context. When test participants get the chance to describe their experiences in their own words (Hvass et al., 2022).

1.1.2. HUMAN EXPERIENCE OF ARCHITECTURAL AND SOCIAL URBAN CONTEXT

Research on human experience of urban lighting has a long tradition of utilizing an engineering approach and through lab studies focus on visibility and safety (Nasar, 2017; Boyce, 2000). While in architectural writings there has been a long tradition of focusing on lighting and darkness in relation to atmosphere and aesthetics (Pallasmaa, 2014; Zumpthor, 2006; Rasmussen, 1966). In recent years, interest in how lighting affects human behavior and social interaction has increased in social science (Slater, 2015; Pink, 2018). Likewise, researchers in lighting design investigate of social lighting and the influence lighting has on our co-presence in a public space after dark (Casciani, 2020; Davoudian, 2019).

Research about the role of lighting in urban contexts defined in the field of architectural lighting design, seems to be lacking. There seems to be a lack of research, in the field of architectural lighting design research, about the role of lighting in urban context. The need refers to a holistic architectural approach to applied lighting research, which combines a knowledge of: 1) the ability of lighting to create an atmosphere and visual identity of a space, 2) the technical properties of lighting and 3) the ability of lighting to support social activities and co-presence in the urban public spaces.

Lighting designer Hervé Descottes describes this need for a holistic approach, to combine functional, technical, spatial, and experiential needs in a lighting design project. He states that lighting design should ‘not be understood as an interdisciplinary field but as a transdisciplinary field, that traverses the boundaries of conventional thoughts’ (Descottes, 2011: 9). Lighting designer Roger Narboni relates these holistic thoughts to lighting design in the urban context. He sees a need to change from Light Urbanism, where lighting is designed to produce visibility. To Nocturnal Urbanism, where the lighting adapts to the citizen’s needs, new infrastructures, and new ways of using the city in the dark hours (Narboni, 2016).

The researcher in light, Peter Boyce, formulates the need for context-specific studies, by stating: ’The point is, which lighting conditions are most suitable, depends on context. Until the importance of context is acknowledged, there is little likelihood of achieving a finer understanding of the effect of lighting in all its complexity’ (Boyce,

2014: 598). Likewise, Yvonne de Kort emphasizes that tests should be done in the field after the effect of light has been confirmed in the lab (de Kort, 2021). Furthermore, she describes that she seeks to gain knowledge about lighting in relation to, vision, comfort, health, performance, atmosphere, and energy savings, and this requires collaboration between various research fields and combining methods (de Kort, 2021).

In line with these statements from practitioners and researchers, this PhD study seeks to foster a deeper and nuanced understanding of how lighting, and in particular brightness levels can support human experience of the architectural and social urban context and how this can be explored by combining methods and doing field experiments in context-specific urban spaces.

This PhD thesis seeks to investigate the matters in concern through four studies: a literature study, a field study, a lab study, and a field experiment. These four studies are described in four peer reviewed papers. An extended summary (the 'cover') provides and overview of the background, theory and methods, a summary of the four studies and findings and contributions.

1.2. BACKGROUND

This background chapter introduces three important themes in this PhD thesis: 1) the context, 2) the human experience of lighting and 3) combining methods.

1.2.1.THE CONTEXT - TRAM STATIONS, PEDESTRIANS, AND URBAN INFRASTRUCTURE

Context is a central concept, in this PhD study, as the experience of lighting and darkness is conditioned by the context in which lighting is experienced. As Boyce describes above, we need to understand the importance of context to understand the complexity of lighting (Boyce, 2014).

Tram stations represents the context, in this PhD study. Through these studies in the specific context of tram stations, specific knowledge about human experience of lighting and darkness for this context is achieved. It is the intention that this specific knowledge and knowledge about how to combine methods to explore urban lighting, can inspire to a definition of general knowledge through future work.

Context-specific studies
Balancing brightness levels is about incorporating the surrounding context when considering lighting research or design in an urban space. The Latin word for context is 'contexere', which means to weave together. Brightness is an important factor in weaving together human experience of contexts at night. Since artificial light installations determine what is visible and what is not in the dark. Context has not been sufficiently stressed in past research according to Bruce Edmonds and Varol Akman. Instead,

a general model has been regarded as desirable and context-dependency has been discouraged. However, when individuals act in a certain way or say certain things, they do so in a context, and what they say is embedded in background assumptions that are only available in the context (Edmonds and Akman, 2002). Sociologist Erving Goffman has even used the phrase 'sins of noncontextuality' (Goffman, 1981: 32) to express the importance of taking context into account when conducting research.

The tram station as a case
In this PhD study tram stations were selected to be the context-specific case for field studies, for several reasons. First, the stations are part of the urban infrastructure that many pedestrians use every day. Second, the stations represent a new urban infrastructure in Denmark that had just been taken into operation when the PhD study started in 2018. Third, the stations are placed in different contexts throughouturban, suburban and rural areas. This gave the opportunity of working with lighting in relation to different contexts as the focus of the PhD study was developed. Fourth, Holscher Design, one of the two industrial partners in this PhD study, oversaw the station design. Because of my close collaboration with the company, it was possible to gather inside information about design intentions as well as the construction phase. It was also possible to establish contacts with the partners involved - Aarhus Tram, Aarhus Municipality, and the company that oversees operation and maintenance at the stations, called AFA JCDecaux.

The pedestrian, the waiting situation and everyday life activities
The tram stations, the pedestrians, and the everyday life activity of waiting for the tram serves as the context for the two studies in the field. The pedestrian is a central figure in sustainable urban design, since nearly all journeys in the urban environment incorporate walking in one way or the other (Rahm, 2021). Pedestrians' experiences of lighting, while walking, has been studied in several ways: in labs, living labs, field studies using e.g., evaluation of pictures, VR and eye-tracking (Rahm, 2021; Nasar, 2017; Davoudian, 2012).

In this PhD study the experience of lighting and darkness is investigated in relation to a context-specific spatial and social context and as part of an everyday life activity. The focus is directed towards the activity of waiting at a station. The pedestrian is standing or sitting and have the experience of being in a lit station space and at the same time being part of the lit urban surroundings. The waiting activity and taking the tram is part of the flow of moving through the lit urban space in the dark hours.

Pedestrians' experience of using public transportation plays an important role when it comes to increasing the number of people choosing public transportation instead of their car (Rahm, 2021). Therefore, as a part of supporting public transportation, there is a need to investigate, not only how lighting can create visibility and safety. However also, how lighting and darkness can enhance the pedestrians' experience of

architectural and social urban contexts, when using public transportation.

In Denmark, a political decision in 2013 led to an agreement about a national green transport policy, and tram infrastructures in the three largest cities became a part of this initiative. This was done to support the development of an energy-efficient infrastructure in sustainable cities and to reach the UN Sustainability Development Goals (SDG) in 2030 (UN, 2015). Two Sustainable Development Goals can be highlighted: the SDG 9 promotes that we build resilient infrastructure for public transportation and the SDG 11 target universal access to safe, inclusive, and accessible public spaces and human settlements. While the UN Habitat III policy paper The Right to the City and Cities for All supports public spaces that are participatory, enhance social interaction, and engender sense of belonging (UN, 2017).

1.2.2.HUMAN EXPERIENCE OF HOW LIGHTING AFFECTS THE ARCHITECTURAL AND SOCIAL URBAN CONTEXT

The following section will introduce themes about the experience of light and darkness in relation to the architectural and social potential of light, the local and the surrounding space, brightness levels, human night vision, darkness and the feeling of atmosphere or danger and finally, sustainable reasons for dimming lighting in public spaces

The architectural and social potential of light
The architectural urban context refers to the physical context, such as the buildings, objects, space, surroundings, materials and surfaces. The architectural potential of lighting can be described as a lighting design, which ensures, that the shapes of objects and buildings in the urban space are visible, that shadows are present, that colors and textures are visible in a local space, and that details in the physical surroundings are visible. In addition, the lighting design should create a certain atmosphere related to the architectural intentions of the space (Pallasmaa, 2012).

The social urban context refers to people in the built environment, the co-presence of people, and people performing activities in the shared public space. The PhD study seeks to investigate whether lighting consciously or unconsciously affects meetings with other people. Lyn H. Lofland describes the environment for meetings between people as the social psychological environment. She defines theses meetings between people, who are personally unknown to one another, as co-presence of people (Lofland, 2017). In the field of social lighting, inspiration has been found in research by the lighting designer and researcher Daria Casciani who explores the social values of lighting. She explains that outdoor lighting should provide accessibility (support the spatial organization), comfort (psychological comfort), and the sociability of a space. Sociability is linked to how people use the space, how many are present, and if the lighting supports the community who uses the urban public space. (Casciani, 2020).

Local space and surrounding space

This project examines the relationship between lighting in a local space and lighting in the surrounding space. How a balanced brightness level can support both architectural and social qualities of an urban context. Figure 1 origins from study 4 in the PhD thesis, the field experiment conducted at the Nørreport tram station. The sketch shows a local space, which in the field experiment was a tram station. As well as a surrounding space, which was the surroundings of Nørreport tram station and the buildings that frame the context. The sketch seeks to describe how lighting both affects experience of the local space and co-presence there, and the experience of the surrounding space and the people there. A light hierarchy is needed to create an optimal lighting setting which can support this complexity.

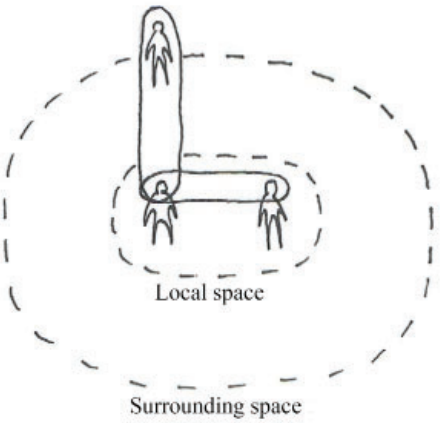


Figure 1. The local space and the surrounding space. Co-presence with people in the local space and visual contact to the people in the surroundings.

Brightness levels

Brightness levels became a key concept in the PhD study during the process of performing the empirical studies. But brightness level is just one out of several lighting parameters. The lighting designer Hervé Descottes divides lighting parameters into six principles of lighting: 1) illuminance, 2) luminance, 3) color and temperature, 4) height, 5) density and 6) direction and distribution (Descottes, 2011). Where Descottes uses the definitions 'illuminance' and 'luminance' to describe levels of lighting. In this PhD thesis the definition 'brightness' is used to describe the level of lighting. Brightness is the term describing the unmeasurable subjective experience of light. While illuminance can be measured in lux, and luminance can be measured in lumen. Böhme describes the unmeasurable brightness: 'Light as a phenomenon is primarily and actually brightness (i.e., bathed in light) the fundamental phenomenological fact relative to light'. He continues, 'We shall see that there is a wealth of other typical light phenomena besides, but the brightness is fundamental. When I open my eyes on a day I've overslept, the first thing I notice is that it is already light. Noticing brightness is primary and fundamental' (Böhme, 2017:206).

Illuminance can be described as the amount of light that falls on a surface, measured in lux (Tregenza and Loe, 2014: 21). While, luminance is the amount of light reflected

from a surface, measured in candela per square meter (cd/m2) (Tregenza and Loe, 2014: 22). Illuminance (lux) describes the amount of light falling on a surface from all directions, while luminance (cd/m2) describes the amount of light leaving a surface in a specific direction, implying that luminance better describes how the human eye perceives a surface's brightness (Dubois, 2019). For many years, existing lighting standards and regulations have relied mainly on the illuminance levels on horizontal surfaces. Current standards also include luminance, although illuminance is still the more commonly used measure in practice, likely because they are easy to measure with a luxmeter (Dubois, 2019).

Even though luminance better describes how the eye perceives brightness of a surface, as mentioned above. How bright a surface appears, or its apparent brightness, is not exclusively dependent on luminance. The state of the light–dark pattern in the eye and the actual pattern of brightness in the field of vision also affects how bright a surface appears. This perceived light-dark pattern of brightness is essential for how we design lighting. (Tregenza and Loe, 2014: 22).

Human night vision

When examining human experience of brightness levels in the urban environment it is necessary to consider, how human night vision functions. When doing research in outdoor lighting the fact that the human eye requires time to adjust from one level of brightness to another should be considered. Additionally, the human eye can perceive different levels of color and detail in low light conditions.The human eye requires approximately 20-30 minutes to adjust from sunlight to darkness. This process can be divided into three stages of sensitivity. Photopic vision occurs when there is a luminance greater than 5 cd/m2. This allows for fine detail perception as well as color perception. While scotopic vision occurs when luminance levels drop below 0,005 cd/m2. It is characterized by an inability to perceive colors and a reduced ability to resolve details. The stage of sensitivity between photopic and scotopic vision, is called mesopic vision. Mesopic vision occurs when luminance levels range between 0,005 and 5 cd/m2 . Mesopic vision enables detail and color perception when luminance levels are close the photopic vision and the ability is reduced, as the luminance levels drop to the range close to the scotopic vision (Boyce, 2014).

Darkness – atmosphere or danger

When we discuss light in the urban context, we often forget to talk about darkness as well. Standards and regulations for lighting are mostly related to a minimum level of lighting for a space, while a maximum level is seldom described. However, too much light can 'wipe away the sense of a place' as Pallasmaa describes it (Pallasmaa, 2012: 46). Therefore, brightness should always be explored in relation to darkness as Gernot Böhme observes: 'Brightness is what turns sight into a real capability in the first place and enables visible things to be seen in reality…Light is not the only precondition of visibility. Darkness is another. True, light and darkness are asymmetrical. Light is a precondition for seeing at all, whereas darkness (interacting with light) is a precondition

for our seeing something' (Böhme, 2017:206).

Nick Dunn and Tim Edensor explore the multiple meanings and uses of darkness across time and space (Dunn and Edensor, 2020). Specifically, they draw attention to the historical tradition of relating darkness to danger in urban spaces without considering the aesthetical values of darkness. Lighting and darkness can thus both be linked to the understanding and feeling of a pleasant/unpleasant atmosphere or a safe/unsafe space. A particular lighting design can never match all users of a public space, but a more detailed understanding of the experience of lighting and darkness is needed to challenge biased assumptions about the link between a high brightness level and safety (Dunn and Edensor, 2020).

Juhani Pallasmaa draw attention to the aesthetic values of darkness by stating: 'Deep shadows and darkness are essential, because when the sharpness of vision is dimmed the unconscious peripheral vision and tactile fantasy is invited' (Pallasmaa, 2012: 46). With a dim lighting level in urban contexts, only low levels of lighting are needed to create a lighting design which can create spatial variation, identity, atmospheres, highlight a function etc. The lighting designer Leni Schwendinger states that 'darkness is my canvas' when doing outdoor lighting design. She means that a dimmed and balanced lighting is needed to add experiential lighting in outdoor spaces (Schwendinger in Dunn and Edensor, 2020). At the theatre the starting point is darkness and then scenographic lighting is used to create atmosphere and spaces. Gernot Böhme uses scenography and the theatre stage as a metaphor to highlight a situation in which lighting and darkness are tools for producing atmospheres (Böhme, 2013). Inspired by Böhme, the scenographic metaphor has been used to create a link between the use of scenographic lighting and urban lighting in this PhD thesis. To direct focus towards how lighting and darkness can be designed to create atmospheres, when related to the qualities and the dramaturgy of a specific urban context.

However, much research in lighting shows that darkness in the urban public context is related to a feeling of unsafety. Light research conducted primarily in lab studies shows that test participants feel safer, if the lighting level is higher (Nasar, 2017). Likewise, tests with higher lighting levels in neighborhoods with high crime rates, show that robberies, physical assaults, etc. are reduced (Boyce, 2019). With higher lighting levels, traffic safety can also be improved in some occasions (Gibbons, 2014).

When it comes to the human sensory experience of brightness levels, the need exists to combine research methods to achieve a more nuanced understanding of people's experiences of a specific urban space. Because in one context the lighting level perhaps needs to be high because of specific circumstances, while in other contexts the lighting level can be dimmed. Therefore, human experience of lighting and darkness was studied in both non context-specific studies in the lab and context-specific studies in the field in this PhD study.

Sustainable reasons for dimming lighting
Urban lighting should be adjusted to promote less light pollution and support the human need for natural darkness and possibilities of seeing the stars at night (Bogard, 2014). Animals will also benefit from less light pollution as biodiversity in general will benefit from a decrease in brightness levels (Sanders, 2020). Finally, by dimming the lighting when it is not needed, we can conserve energy and reduce human energy consumption.

In many larger cities, smart lighting is implemented as part of smart city initiatives, which seeks to reduce energy consumption and use technology to improve urban quality of life. By utilizing technologies such as sensors in light fixtures, information about human movement, traffic, and weather conditions is collected, and lighting is adjusted according to this information. Both in research and industry, this modern technology is examined, and products are designed to create energy savings and at the same time, satisfy human needs primarily regarding safety and visibility. Currently smart lighting is mostly directed towards the large potential of energy savings for road lighting (Valpreda, 2019), as well as initiatives like dynamic street lighting, which adapt to the presence of pedestrians (Haans, 2012). Further knowledge on how lighting and darkness affects human experience of architectural and social urban context, could lead to smart lighting initiatives where both atmosphere and safety is prioritized in relation to a specific context.

1.2.3. COMBINING METHODS TO INVESTIGATE HUMAN EXPERIENCE OF LIGHTING AND DARKNESS

Exploring human sensory experience of light
Emphasis is placed on the fact that experiencing outdoor lighting is a human sensory experience, which should be experienced while being bodily present in the context (Pallasmaa, 2012). In a test situation, human night vision should be adapted to the experience of fine nuances between light and dark areas in an urban space (Boyce, 2014). Human senses such as hearing, smell, and touch should also be taken into consideration, because all senses have an influence on how a place is experienced (Pink, 2015). Pallasmaa touches upon the complexity of evaluating the quality of a space by stating: ‘The quality of a space is not merely a visual perceptual quality as it is usually assumed. The judgement of environmental character is a complex multi-sensory fusion of countless factors that are immediately and synthetically grasped as an overall atmosphere, ambience, feeling, or mood’ (Pallasmaa, 2014: 230).

However, experiences and feelings about light can be difficult to explore. Sumartojo and Pink describe reasons for this; ‘presence of light is often taken for granted in everyday experiences; a vocabulary is lacking’ (Sumartojo and Pink, 2017: 1). In a test situation, ‘a vocabulary’ can, for example, be formulated as a questionnaire with pre-defined words and the use of a semantic differential scale or through a semi-structured interview, where the participant formulates a vocabulary of their own. A big

difference exists between the two approaches, and there are advantages if you combine them.

Combining methods to study experiences of lighting and darkness
Methods for exploring outdoor lighting vary within the research disciplines natural science, social science, and arts/humanities. Lotte Rienecker and Peter Stray Jørgensen describe basic assumptions about the three methodologies. Methodologies from natural science are described as 'generalizable, measurable, controllable, and verifiable'. Methodologies from social science are described as 'critical and interpretive, and analytic through active participation and interaction (where subjectivity is an asset, and dialogue and communication are the goal)'. Finally, methodologies from arts/humanities are described as 'dialogue-based (interaction between source and theory), communicative, explicative, and interpretive, where subjectivity is an asset since pre-understanding exists in the researcher' (Rienecker and Jørgensen, 2000: 200).

In this PhD study, the combination of methods and knowledge across research disciplines are based on the transdisciplinary process model 'The Architectural Experiment' (Hansen, 2014). This model illustrates a process consisting of pre-analyses using methods from different research disciplines that feeds knowledge into a field experiment.

Theories and methods will be further unfolded and related to each of the four studies in Part 2: Theory and Methods.

1.3. RESEARCH SCOPE AND AIM

The scope of this PhD thesis is an investigation on how lighting and darkness influence pedestrians' experience of the architectural and social qualities in an urban context. Thus promoting an awareness of the potentials of dimmed and balanced brightness levels.

Current research on urban lighting for pedestrians is often solely planned according to visibility and safety. Likewise, in practice, high brightness levels are often linked to a feeling of safety in public urban spaces and the brightness levels in a local space are often not planned in relation to the surrounding brightness levels.

The preconceived assumption of darkness being related to danger and lighting being related to safety needs to be challenged. As overly lit spaces can create tense atmospheres and an unsafe feeling of being exposed. The aim of this PhD thesis is therefore to increase understanding of how brightness levels affect the pedestrians' experience of architectural and social urban contexts, and how these experiences can be studied.

To address the need described above, two overall research questions are posed:

1) **How do brightness levels affect human experience of architectural and social urban context?**
2) **How can research methods be combined to explore experience of brightness levels in the urban context?**

Four studies were performed to answer these overall research questions. These studies comprised three pre-analyses, consisting of a literature study with a comparison of scenographic and urban lighting (study 1), a field study at two tram stations about the role of lighting in the specific urban context (study 2) and a lab study where human experience of balanced brightness levels were tested (study 3). Finally, the findings from the three pre-analyses were incorporated in a field experiment. This field experiment was designed to investigate human experiences of the architectural and social context at Nørreport tram station in an existing bright lighting setting and a dimmed lighting setting (study 4).

The research questions are general, however the studies have been related to studies around context-specific spaces. Case study research is regarded as unreliable in some research disciplines. As a single example is not considered to be able to provide reliable information about a topic. According to Bent Flyvbjerg there are common misunderstandings about case studies. One misunderstanding is that one cannot generalize from a single case, and therefore, the single-case study cannot contribute to scientific development. Flyvbjerg argues that rather than viewing case studies as having no value, they should be viewed as means to gain knowledge of human experiences in real-life situations (2006). He states:

'One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas 'the force of example' is underestimated.'
(Flyvbjerg, 2006: 229)

As such, the case studies around tram stations and in particular the field experiment at Nørreport tram station enables the studies to concern architectural lighting design research in relation to the specific architectural and social qualities in this specific urban context. As experiences of atmosphere, the dramaturgy of a space and architectural and social qualities must be investigated in and related to a specific context.

1.4.STRUCTURE

The main content of this cover is structured in four parts: 1) introduction, 2) theory and methods, 3) empirical studies, and 4) findings and contributions, followed by four research papers and an appendix.

Part 1: Introduction. This part contains the matters in concern, the background, the scope, aim and overall research questions and a description of the structure of the cover.

Part 2: Theory and Methods. This part contains a general introduction to research methodologies, a brief introduction to research methods within lighting research, an introduction to the transdisciplinary process model 'The Architectural Experiment', a description of how methods are combined during the four studies of the PhD thesis, and a brief description of how inspiration has been found in the research philosophy pragmatism.

Part 3: Empirical Studies. This part contains a framing where the overall decisions are described and a summary of each study with a description of how the studies are planned, performed and connected.

Part 4: Findings and Contributions. This part contains an overview of the findings from the four studies, the limitations of the research, the contribution to the field of architectural lighting design, a discussion, future work and the conclusion of the PhD thesis.

Then, the four publications are presented:
Paper 1: Hvass, M., Hansen, E.K. (2019). Potentials of light in urban spaces defined through scenographic principles. Nordisk Arkitektur Forskning, NAF Symposium, June 2019, Gothenburg. Proceedings Series 2021-1

Paper 2: Hvass, M., Hansen, E.K. (2020). Architectural and social potential of urban light¬ing, a field study of how brightness can affect the experience of waiting for public transportation. Passive and Low Energy Architecture, PLEA Conference, Proceedings September 2020.

Paper 3: Hvass, M., Wymelenberg, K.V.D., Boring, S., Hansen, E.K. (2021). Intensity and ratios of light affecting perception of space, co-presence and surrounding context, a lab experiment. Building and Environment, Vol. 194, May 2021: 107680.

Paper 4: Hvass, M., Waltorp, K., Hansen, E.K. (2022). Lights out? Lowering Urban Lighting Levels and Increasing Atmosphere at a Danish Tram Station. Lighting Design in Shared Public Spaces edited by Shanti Sumartojo. Routledge. Published May 2022

Finally, the three appendices:
Appendix A: Pre-Analysis Field, Study 2
Appendix B: Pre-Analysis Lab Study 3
Appendix C: Final Field Experiment, Study 4

PART 2. THEORY AND METHODS

EXPLORING BALANCED LIGHTING

This part will describe which theories, methods, and processes have be used to acquire an understanding of how brightness levels affects human sensory experience of architectural and social urban context. During this PhD study, research methods were combined and collaboration with researchers from other fields than architecture were sought ,to enhance the significance of the findings. However, before discussing the transdisciplinary nature of this PhD study, an introduction to a general research methodology is presented. Alongside a brief review of how outdoor lighting research is conducted within some areas of natural science, social science, and art/humanities. Then the transdisciplinary process model 'The Architectural Experiment' (hereinafter the AE model) (Hansen, 2014) is presented. Followed by a description of how the AE model has been guiding for this PhD study and which methods have been used in each step of the PhD study. Finally, a reflection on the pragmatic concepts, of the philosopher John Dewey, are used to demonstrate the importance of combining methods and performing field studies. Likewise, Dewey's interpretation of the concepts of 'context', 'situation' and 'immediate senses' are used to support the argument that a phenomenon must be investigated in the real world, through field studies, to gain access to the 'immediate senses and thoughts' of test participants.

2.1. RESEARCH METHODOLOGIES

In this chapter a general introduction to research methodologies is presented. The purpose of this presentation is to illustrate an intradisciplinary approach to research, as a contrast to the transdisciplinary approach of this PhD study.

To illustrate a traditional research process, the Research Onion, developed by Mark Saunders et al. (Figure 2), can be used to give an overview (Saunders et al., 2007). The figure 2 illustrates the choices that must be made when developing a research methodology, which includes:

1. Research philosophy – the set of beliefs your research is based on (positivism, interpretivism, pragmatism)
2. Research approaches – the broader method you will use (inductive, deductive, qualitative and quantitative)
3. Research strategies – how you will conduct the research (e.g.,experimental, action, case study, etc.)
4. Choices – how many methods you will use (mono method, mixed-method or multi-method)
5. Time horizons – the number of points in time at which you will collect your data (cross-sectional or longitudinal)
6. Techniques and procedures (data collection methods, data analysis techniqu es, sampling strategies, etc.) (Saunders et al., 2007)

The Research Onion is an example of a tool that guides a process from research philosophy to desiding to conduct research in the lab or in the field. In some research disciplines, the path from the outer layer of the onion, the research philosophy, to the inner layer of the onion, the data collection, is always the same.

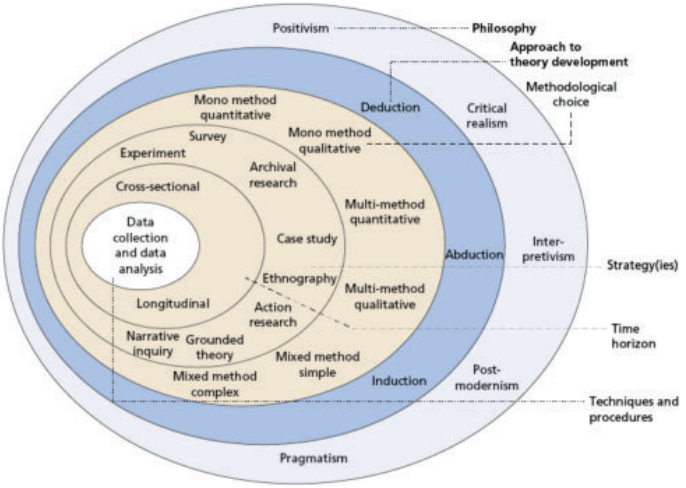


Figure 2. Research Onion (Saunders et al., 2007)

2.2. RESEARCH METHODS IN LIGHTING

There is a tendency for research in lighting to focus on either natural science, social science, or arts / humanities, rather than combining methods. In the next section, traditional focus areas within the three research disciplines will be presented.

Natural science and lighting

The natural sciences have a long tradition of supporting and developing the rules and recommendations of the International Commission on Illumination (CIE). Attention is given to measurable facts about light and reproducible numerical tests. In general, research is conducted in a lab environment to eliminate as much bias as possible. It can also involve scale models, simulations, virtual reality, and even field studies but these are usually in locations with limited impression from the dynamics of the city, as a means of controlling variables. Results must be quantifiable, e.g., via measurements or questionnaires that can be statistically analyzed. This is an approach used by other natural scientific fields, such as medicine.

Typically, field studies in urban settings are considered biased because of disturbances caused by people, weather, traffic, etc. When field studies are used, they may, for example, indicate statistically significant changes in behavior when lighting is changed. As mentioned earlier tests show that by increasing lighting levels, robberies, assaults, and other criminal acts can be reduced (Boyce, 2019). Additionally, tests show that through increased lighting levels fewer accidents happen in traffic (Gibbons, 2014). Results can be determined by comparing the situation (e.g., number of accidents) before and after changes in lighting levels.

Lighting research has traditionally focused on how lighting can support visibility and perceived safety in outdoor environments, often concluding that high-intensity, uniformly distributed lighting is the preferred solution among test participants (Boyce, 2000; Nasar, 2017; Johansson, 2014). A visibility test could consist of test participants evaluating if an object is visible in a certain light from a certain distance (Fotios, 2013, 2009). While a test about perceived safety could include testing if a face expression can be discerned in a certain light from a certain distance (Fotios, 2019; Dong, 2015; Baron, 1992).

Outdoor lighting tests performed within the tradition of natural science are especially good at producing results which are generalizable, measurable, controllable, and verifiable. Tests are often performed in labs, or in places without biases which could make the tests impossible to reproduce.

However, this tradition within natural science leads to a corresponding lack of experience of atmosphere and the complexity of the urban context in which the lighting is experienced.

Social science and lighting

Urban lighting has attracted the attention of sociologists and anthropologists in recent years (Sumartojo and Pink, 2017). The research is focused on the effects of lighting on social interaction, co-presence, human behavior, and what we experience when we move through urban lit spaces at night.

Interviews with the use of sensory and visual ethnographic methods have been described in a series of scientific articles discussing the human experience of the nighttime urban environment in relation to lighting and darkness (Ebbensgaard, 2020; Sumartojo, 2019; Edensor, 2019; Pink, 2018). Similarly, to understand the social impact of lighting in a residential neighborhood, existing lighting installations are evaluated and discussed with local residents. Through participatory design processes lighting can then be designed with locals while gaining a deeper understanding of how people experience and behave in light (Slater et al., 2015).

Outdoor lighting tests performed within the tradition of social science are especially good at establishing dialogue and communication between the researcher and the test participant. The goal is to create unique experiences through active participation and interaction.

However, when doing research in outdoor lighting within the tradition of social science the lighting parameters in an interview situation are seldom measured, calculated, or otherwise quantified since they are rarely of interest. The social scientific studies primarily focus on people's thoughts and ideas. Replication, as in natural science, will generally be difficult.

The Arts/Humanities and lighting

Architects have described lighting and darkness throughout history, focusing on the atmosphere created by light and how light can influence our perception of space, shapes and textures. Thus, the architectural approach combines both aesthetic and technical elements since the discipline of architecture is related to both the unmeasurable or imagined and the measurable or the built environments.

The unmeasurable character of lighting can be described by using the words of architect Juhani Pallasmaa. He describes the experience of environmental character as ‘a complex multisensory fusion of numerous factors, including experiences of lighting in an urban context’ (Pallasmaa, 2014). When researching lighting in the context of urban environments, an architectural approach to research in lighting will seek to describe the 'immediately and syntactically...overall atmosphere, feeling or mood’ (Pallasmaa, 2014).

The measurable character of lighting can be found by using different instruments to measure. Within the tradition of architecture, the method that reproduces the experience of lighting, from the viewpoint of a human will be the method preferred. In this PhD study luminance maps have been used, they reveal the luminance levels in a context from the viewpoint of a human. Therefore, the luminance maps are suitable for reproducing lighting levels in an urban context as experienced in the situation.

The eye can be trained to observe light and to evaluate a lighting level and other lighting parameters, according to Anders Liljefors. It is possible to combine these evaluations of light with the measurement of physical lighting factors (Liljefors, 1999). As a result, Liljefors establishes a link between technical measurements and sensory experiences as described by Pallasmaa. He argues that we can trust the human eye as we trust the measurements.

Outdoor lighting tests performed within the tradition of arts/humanities are especially good at describing and registering aesthetics, atmospheres, and sensory experiences of environments. Methods are communicative, explicative, and interpretive, where subjectivity is an asset since pre-understanding exists in the researcher.

In the following chapter a transdisciplinary process model is presented. The model describes a method where research traditions are combined to ensure that both unmeasurable and measurable knowledge is collected about the phenomenon being investigated.

2.3. THE TRANSDISCIPLINARY PROCESS MODEL - 'THE ARCHITECTURAL EXPERIMENT'

Sharing of knowledge between research fields

As described in the introduction, a transdisciplinary approach is required in order ‘to traverse the boundaries of conventional thoughts’ according to lighting designer Hervé

Descottes (Descottes, 2011: 9). Likewise, the researcher Yvonne de Kort states that there is a need to facilitate collaboration between different research disciplines to gain knowledge about lighting (de Kort, 2021). Theories within innovative processes also seek to bridge between research disciplines to strengthen innovation and knowledge production. These theories have led to the definition of concepts like ‘knowledge boundaries’ (Carlile, 2003, 2002) and 'knowledge brokering' (Hargadon, 2002).

Architects have historically collaborated with several research disciplines. Since architecture involves both: the unmeasurable and measurable, imagined and the built world, art and technical solutions (Hansen, 2014). Vitruvius (ca. 80/70-25 BC) was the first architect, engineer, and author to establish serious guidelines for the design of architecture. He emphasized the importance of combining knowledge from different disciplines. Vitruvius worked with three parameters: venustas (beauty), utilitas (utility) and firmitas (durability) (Morgan, 1960). These three parameters can also be applied to refer to the three research disciplines: the arts/humanities (beauty), social science (utility) and natural science (durability) (Hansen, 2014).

The AE model is based on knowledge about combining methods and innovative processes. Thus sharing knowledge, can be achieved at many levels and in many constellations. In the work of L. R. Meeth, collaborations between research fields can be grouped into five distinct categories (Meeth, 1978; Hansen, 2014):

1.Intradisciplinary	Studies within a single discipline.
2.Cross disciplinary	A research discipline is viewed from the view point of another.
3.Multidisciplinary	There is a juxtaposition of disciplines in which each disci pline contributes, but integration is not the intention.
4.Interdisciplinary	Combines different disciplines to solve a particular problem.
5.Transdisciplinary	Beyond the boundaries of a particular discipline, starting from a problem or issue, and then bringing different disci plines together to solve or address the problem or issue.

In the work of Paul R. Carlile, he summarizes the importance of creating knowledge across borders with the term 'Knowledge Boundaries' and describes how knowledge must be transported and translated through a common syntax and transformed to generate innovation (Carlile, 2003, 2002). While Andrew Hargadon uses the term ‘Knowledge Brokering’ to describe how innovation can be created by combining existing information in a new way, by linking, recognizing, and sharing knowledge (Hargadon, 2002).

‘The Architectural Experiment’ – a transdisciplinary process model

'The Architectural Experiment' model was introduced by Ellen Kathrine Hansen in her PhD thesis from 2014. The model can be used to describe the integration of methods and knowledge across research disciplines in a process where pre-analyses feed into a main field experiment (Figure 3).

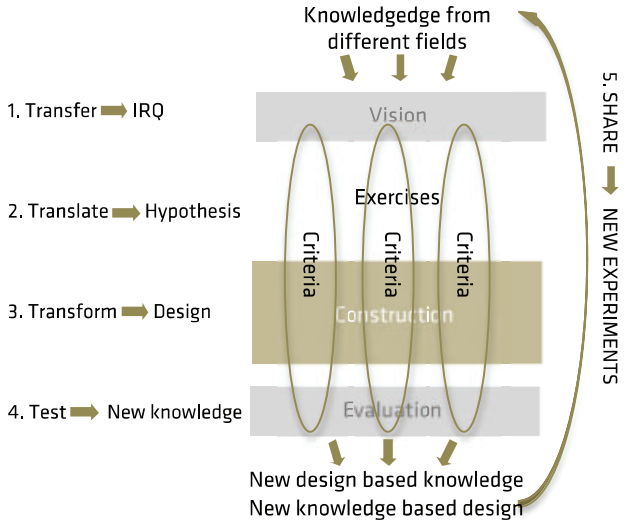


Figure 3. 'The Architectural Experiment' model (Hansen, 2014)

The AE model illustrates a transdisciplinary and knowledge-based design process in five steps. In all steps knowledge from the three research disciplines, natural science, social science, and arts/humanities are incorporated.

Step 1, Vision. In this step knowledge from different research disciplines can be included in the early design phase. Step 1 involves transferring knowledge into a vision.

Step 2, Exercises. In this step knowledge is translated and explorations and proposals are made through pre-analyses. The research question is posed during this process.

Step 3, Construction. In this step knowledge is transformed into a research design for a design experiment which include the knowledge from step 1 and 2 (pre-analyses).

Step 4, Evaluation. In this step the design experiment is performed and evaluated.

Step 5, Share. In this step the new knowledge is shared with other researchers and applied to new experiments (Hansen, 2014).

The three criteria (vertical ellipses on the model) represent knowledge and methods from the three research disciplines: natural science, social science, and arts/humanities. They are an integral part of the design process in each phase. The AE model is intended to bridge disciplinary boundaries and refers to theories about design research (Koskinen, 2011), and as already mentioned, theories on innovative processes and 'knowledge boundaries' (Carlile, 2003, 2002) and 'knowledge brokering' (Hargadon, 2002).

The AE model has guided the process in this PhD study, and the model has been used in the education of lighting designers at Aalborg University, Copenhagen since 2014.

2.4. COMBINING METHODS DURING THE PHD THESIS

2.4.1. A MODEL DESCRIBING THE TRANSDISCIPLINARY PROCESS OF THIS PHD THESIS

Figure 4 illustrates how the four studies of the PhD thesis are related to the five steps in the AE model. Horizontal bands represent the research process (step 1-5), and vertical bands represent the three research disciplines (natural science, social science, and arts/humanities).

The black dots indicate from which research discipline the main method of the study originates. While the dotted lines indicate the use of methods from other research disciplines. Arrows illustrate how knowledge has been transferred from one study to the next.

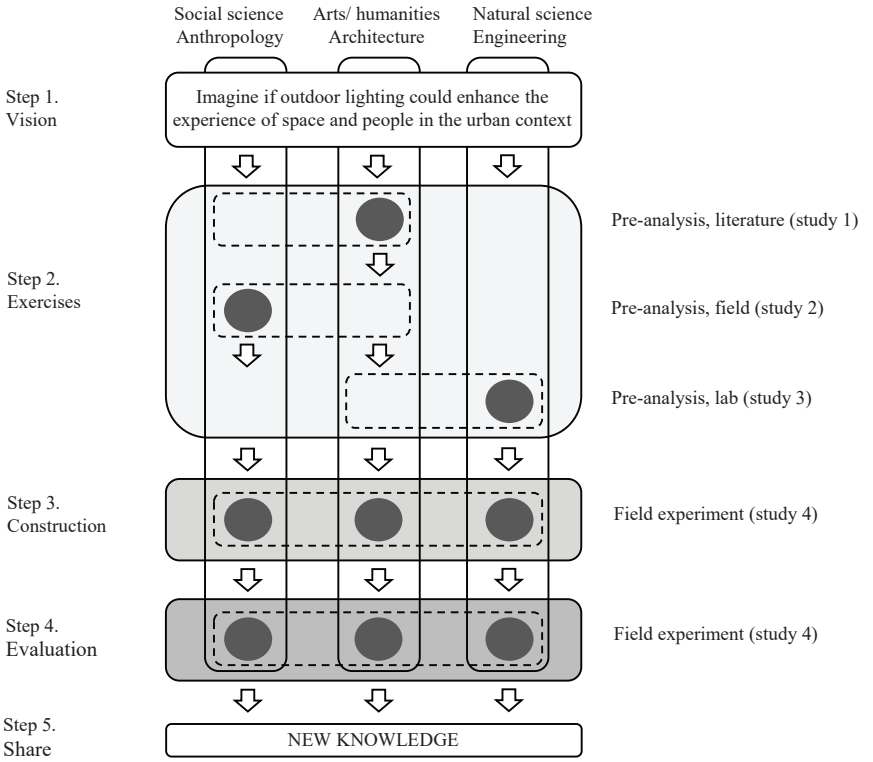


Figure 4. Process of this PhD thesis.

The four studies of this PhD are related to the AE model in the following way:

Step 1, Vision. In this step a broad vision started the project, ‘Imagine if outdoor lighting could enhance the experience of space and people in the urban context’. Thereby, the area of research was formulated.

Step 2, Exercises. The three pre-analyses were performed during this step. A literature study where the role of lighting in scenographic and urban contexts was compared, a field study at two tram stations and a lab study about balanced brightness levels.

Step 3, Construction. In this step, knowledge from the three pre-analyses was transformed into a research design for the main field experiment.

Step 4, Evaluation. In this step the experiment at Nørreport tram station was performed, and data was analysed to define findings.

Step 5, Share. Through the PhD thesis knowledge is shared.

Research methods from natural science, social science, and arts/humanities have been combined and integrated into the four studies. The figure 4 illustrates how the four studies, are designed to cross knowledge boundaries by combining methods in all phases of the research.

2.4.2. COMBINING METHODS DURING THIS PHD STUDY

As part of the development of the three pre-analyses (studies 1, 2 and 3) and the field experiment (study 4), the methods were carefully chosen to be able to answer the research question of each study. The following text describes the methods used in each of the four studies and explains the content of figure 4.

Pre-Analysis Literature, Study 1
The literature study relates to step 2 in the process model of this PhD thesis, figure 4, the study constitutes the first pre-analysis.

The literature for the study is mainly found within arts, concerning literature on scenography and architecture (black dot marked in figure 4). However, also within social science to add knowledge about co-presence and human behavior in the urban context (the dotted line marked in figure 4).

Inspiration was found in classical texts on atmosphere, scenographic and architectural lighting design, urban design, and social behavior in the urban context. Furthermore, a literature search was performed. The following search terms: 'scenography', 'urban space', and 'lighting design', were entered in the databases: ProQuest, Scopus, and Web of Science. The literature was categorized into three major categories: 1) scenography and scenographic lighting, 2) urban space and life, and 3) urban lighting design. Papers were selected because they addressed the three above mentioned themes. Furthermore, the papers addressed the complexity of urban space and the complexity of the theater stage where lighting is a part of the interrelationship between space, people and activity.
The study, and the scenographic lens developed in the study, is further described in Part 3: Empirical studies and in paper 1 (Hvass and Hansen, 2019).

Pre-Analysis Field, Study 2

The field study, at the two tram stations Skolebakken and Nørreport station, relates to step 2 in figure 4. The study constitutes the second pre-analysis.

The methods used in the field study is mainly from social science (black dot) supported by methods within art/humanities (dotted line). To combine an ethnographic approach to interview with an architectural approach to observations and registrations of the urban context.

The ethnographic registrations were performed using ethnographic descriptive observations and interviews (Spradley, 1980, 1979). Spradley's nine-dimension descriptive question matrix was used to structure observed impressions and interview data. The matrix provides a map for making action-based data collection and presents the dimensions: space, actor, activity, object, act, event, time, goal and feeling. The dimensions of space, actor and activity were primarily used for observations in this analysis. The descriptive question matrix and the scengraphic lens, developed in study 1 were closely related in their use of scenographic references and gave inspiration to explorative studies about the role of lighting.

Architectural assessments were conducted through serial vision photo registration of Skolebakken and Nørreport tram station in Aarhus (Cullen, 1961). The photographs were taken on the way to the station, to investigate the appearance of the lighting at the station and in the surroundings while approaching the station. Photo registrations were also done at the station to observe lighting in the local space and the people arriving, waiting, and departing. The photo registrations provided knowledge about rhythms the space, such as traffic, rhythm of people, and rhythm of light (Lefebvre, 2013).

Field notes from observations and interviews were transcribed and analyzed using traditional coding techniques (Bjørner, 2015). Photo registrations supported the analysis of observations.
The study is further described in Part 3: Empirical studies and in paper 2 (Hvass and Hansen, 2020)

Pre-Analysis Lab, Study 3
The lab study relates to step 2 in figure 4. The study constitutes the third pre-analysis, and it was performed in the light lab at Aalborg University, Copenhagen.

The methods used in the lab study is mainly from natural science (black dot) supported by methods within art/humanities (dotted line). An engineering approach, with methods anchored in natural science, was combined with an architectural approach to investigate how balanced brightness levels affect the experience of space, co-presence, and surrounding context.

Questionnaires with semantic differential scale were structured in accordance with the elements in scenographic lens (study 1). The findings from the pre-analysis in the field

(study 2) were used to define the focus for the lab study.
Six lighting scenarios with variations in lighting ratios between two defined light zones were evaluated. Participants responded to questionnaires with semantic differential scales while observing lighting scenarios involving different brightness levels and different ratios between two light zones.

Non-parametric data from the questionnaires was analyzed statistically using Friedman ANOVAs.

This analysis was supported by measurements of luminance levels, lux levels, and luminance maps derived from HDR images processed in the program Photosphere (Inanici, 2006; Ward, 2005).

The study is further described in Part 3: Empirical studies and in paper 3 (Hvass et al., 2021)

Field Experiment, Study 4
The field experiment relates to step 3 and step 4 in figure 4. Knowledge from the three previous pre-analyses was incorporated in the field experiment.

The methods used in the field experiment are from all three disciplines. Methods from social science were used to plan interviews. While methods from arts/ humanities were used to inspire to the content of the interviews and seek to direct focus towards the dramaturgy of the space and the importance of incorporating the context in the study. Finally, methods from natural science were used to measure and document levels of illuminance and luminance levels. Additionally, luminance maps illustrations of luminance distribution in the urban context were produced.

Sensory and visual ethnographic methods were used to plan comparative go-along interviews with the use of participant-produced photos (Pink, 2021, 2015), as well as shorter vox pop interviews that included evaluations of the atmosphere (Vogel, 2008). The go-along interviews consisted of two scheduled meetings at the station. An initial meeting took place in existing lighting, while the second took place in dimmed lighting. The interviewer and participant met at Nørreport tram station, traveled to a nearby tram station (Universitetsparken) and returned to Nørreport during both go-along interviews. During the vox pop interviews, random commuters were approached at Nørreport tram station while waiting for the tram.

To perform architectural observations, concept sketches were used to illustrate ideas about the role of lighting in the urban environment. Sketches were produced as part of a reflection-in-action process (Schön, 1991) and as part of a process for generating feedback through self-generated sketches (Goldschmidt, 2003). Time lapse photography was used to capture the relationship between the space, surroundings, people, and activities. Timelapse videos demonstrated the rhythms of daylight, urban light, traffic,

and people (Lefebvre, 2013; Edensor, 2012), as well as the movement of people and the 'vibe' of the space (Madden, 2017).

An engineering approach was used to measure the illuminance levels (lux) of horizontal surfaces at ground level, at the station, and on the pavement along the building facades in the vicinity. At selected points, luminance levels were measured on the station's vertical surfaces and surrounding facades. Additionally, luminance maps based on HDR (High Dynamic Range) images provided an overall understanding of the differences in brightness levels on urban surfaces.

Recorded interviews were transcribed, coded in Nvivo and the data was analyzed using traditional coding techniques (Bjørner, 2015).
The study is further described in Part 3: Empirical studies and in paper 4 (Hvass et al., 2022).

2.4.3. COLLABORATION BETWEEN RESEARCH FIELDS

As explained above were methods combined and collaborations with researchers from outside the architectural field was established. To support innovative processes and build bridges between research areas (Carlile, 2003, 2002; Hargadon, 2002; Hansen, 2014). Researchers in light assess that these collaborations are necessary to uncover the complexity of light (de Kort, 2021). To find the link between modern lighting technology, and 'citizen’s needs, new infrastructures and new ways of using the city' (Narboni, 2016), we need collaboration between research disciplines.

The pre-analysis in the lab (study 3) was planned in a collaboration with Professor Kevin Van den Wymelenberg from Oregon University. He approaches lighting research from an engineering perspective. He inspired to a less complex research design in the lab, than first planned, and the use of only one lighting parameter in the lab study. Likewise, he encouraged to the use of luminance maps to gather information about the distribution of luminance levels in a space. In addition, he co-authored paper 3.

The main field experiment (study 4) was planned and analyzed in collaboration with Anthropologist Karen Waltorp from Copenhagen University. She inspired the use of go-along interviews with participant-produced photos and vox pop interviews. In addition, she co-authored paper 4.

2.5. INSPIRATION FROM PRAGMATISM

The description of how methods have been combined during the PhD study will be followed by an introduction to the thoughts of philosopher John Dewey and the philosophy of pragmatism. This information is added to describe the link between arguments formulated by John Dewey and arguments posed during this PhD study regarding combining methods and conducting context-specific field experiments to get access to human sensory experiences.

As a starting point, some notions of John Dewey which are relevant for this PhD study will be presented. Followed by two examples of how John Dewey is refered to by the architect Juhani Pallasmaa and the sociologist and urban planner Jean-Paul Thibaud.

John Dewey (1859-1952) was an American philosopher and educator.He was a co-founder of the philosophical movement known as pragmatism, a pioneer in functional psychology, an innovative theorist of democracy, and a leader of the progressive movement in education in the United States. His work has been crucial to the PhD study because he delivers arguments for combining methods, doing context-specific field studies and trusting human sensory experiences when doing research.

Combining methods
The pragmatic worldview is linked with the use of combining methods. ‘Pragmatists do not see the world as an absolute unity. Thus, researchers using mixed methods look to many approaches for collecting and analysing data rather than subscribing to only one way’ (Creswell, 2014: 11). Within pragmatism the problem being investigated is the generator of the choice of the method, not the research tradition of the researchers performing the research.

Context-specific field studies
Dewey argues for context-specific field studies. In his essay "Theory and Practice", John Dewey emphasizes that theories must be evaluated with reference to practice, meaning that one cannot have knowledge of the world without participating in it (Dewey, 1922: 69). In his view, research must be carried out in the field because the researcher needs to be an actor in the world to be able to investigate it. He emphasizes the notion of the ‘situation’ which he defines as the assemblage of a subject and their environment, including other people, things, spaces, and social constructs (Hansen and Dalsgaard, 2012).

Trusting human experiences when doing research
As described earlier it can be difficult for test participant to describe experiences of lighting. Because lighting is a phenomenon that many people take for granted when being in the urban space. In relation to this Dewey’s thoughts on emotions and immediate senses can guide an argumentation and choice of methods, when seeking to get information from test participants during field studies.

Emotions are not irrational according to Dewey, instead, he considers them intentional sources of knowing (Brinkmann, 2013: 107). Richard Shusterman highlights Dewey's argument that the best evidence of the presence of emotions comes from the immediate senses, without which people would have no unifying sense of coherence, pertinence, or direction. We have a constant sense of belonging or not belonging, an immediate sense which is not the product of reflection (Dewey, 1934: 198). Schusterman brings forward this quote; 'For unless the sense were immediate, we should have no guide to our reflection. The sense of an extensive and underlying whole is the context of every experience, and it is the essence of sanity…Without an indeterminate and undetermined setting, the material of any experience is incoherent' (Dewey in Shusterman, 2010: 36).

Dewey describes emotions as feelings or affects: 'Emotion in its entirety is a mode of behavior which is purposive, or has an intellectual content, and which also reflects itself into feeling or affects, as the subjective valuation of that which is objectively expressed in the idea or purpose' (Dewey, 1895: 15). His work on emotions expresses an overall respect for the world of human experience. In which a phenomenological perspective on feelings reveals that emotions are always associated with those objects and qualities about which they constitute emotions (Brinkmann, 2013, Kestenbaum, 1977).

Researchers referring to Dewey in urban and lighting research
As part of my PhD study, I have come across references to John Dewey in several scientific papers. Even though, John Dewey was a philosopher with a certain focus on education, democracy and functional psychology, his worldview has also been used to support research in architecture and urban planning like the two following quotes.

The sociologist and urban planner Jean-Paul Thibaud employs Dewey's work in formulating propositions regarding urban ambiance and framing urban complexity: 'What is designated by the word 'situation' is not an object or an event or a series of events. For we never experience nor form judgments about objects and events in isolation, but only in connection with a contextual whole. This latter is what is called a 'situation' (Dewey, 1938: 66). As Thibaud summarizes, ' … by drawing on the notion of pervasive quality, we define ambiance as the quality of the situation. In this respect, perceiving does not just mean interpreting the world, it also involves integrating a situation – that is, it requires us both to pull the various components of a context into a consistent whole and to get involved in activities from a practical standpoint' (Thibaud, 2011: 208). Therefore, it emphasizes the importance of the context and the fact that, to define ambiance, we cannot simply refer to, for example, a space, but we also need to consider the quality of the situation. A situation that can only be examined through physical presence in the field as opposed to in a laboratory.

The architect, Juhani Pallasmaa, discusses Dewey's work, and explains how Dewey grasped the immediate, embodied, emotional, and subconscious essence of experience eight decades ago. Dewey articulates the nature of this existential encounter as follows: 'The total overwhelming impression comes first, perhaps in a seizure by a sudden glory

of the landscape, or by the effect upon us of entrance into a cathedral when dim light, incense, stained glass, and majestic proportions fuse in one indistinguishable whole. We say with truth that a painting strikes us. There is an impact that precedes all definite recognition of what it is about' (Dewey, 1934 in Pallasmaa, 2014: 230).

Thus, pragmatism and Dewey's worldview are used as guidance, in this PhD thesis, to investigate the architectural and social potentials of lighting in the urban context. The pragmatic approach favours investigating problems via combining methods and in practice. By refering to Dewey's concept of 'context' and 'situation', lighting is investigated as a component in the contextuality of the city, throughout the studies. By refering to Dewey's concept of emotions, the sensory experience of lighting and atmosphere is investigated through a field experiment at tram station. As a means of gaining insight in people's immediate sensory experiences about lighting in urban contexts. Thereby supporting Dewey's idea that senses are not irrational, but sources of knowledge about a given problem.

The purpose of this part 2 of the PhD thesis, has been to argue for the use of combined methods in a transdisciplinary process when exploring lighting and darkness in urban contexts. In addition, why it is crucial to work with field studies in the urban context to access the immediate senses of test participants. The following chapter describes the four studies, the decisions that shaped them, and how they were conducted and linked.

PART 3. EMPIRICAL STUDIES
EXPERIENCING BALANCED BRIGHTNESS LEVELS

The purpose of this chapter is to unfold the four studies of the PhD thesis. The transdisciplinary process is explained and how one study informs the next and methods from different research disciplines have been combined. Furthermore, the chapter explains how the studies have shaped the development, from the broad theme of the role of lighting and darkness in urban space, to how balanced brightness levels can affect pedestrians' experience of the architectural and social urban context.

The four studies consist of, first, a pre-analysis with a comparison between scenographic and urban lighting which was performed through a literature study. Second, a pre-analysis in the field about the role of lighting at two tram stations. Third, a pre-analysis about human experience of balanced brightness levels which was conducted in the lab. Fourth, the main field experiment where lighting was dimmed at Nørreport tram station and thereby balanced in relation to the lighting in the surroundings.

3.1. FRAMING THE FOUR STUDIES

The purpose of this section is to present an overview of the overall decisions that influenced the development of the four studies. This general information about the studies and the choices made, will allow readers to gain an understanding of how the studies were formed and how they are connected.

3.1.1. STUDY 1 - PRE-ANALYSIS LITERATURE STUDY, WHY SCENOGRAPHY?

The reference to the scene in the theater was chosen as a starting point for the PhD study, to explore if parallels could be made between how lighting is used at the theater and how lighting is used in the urban contexts at night. The purpose of the comparison was to learn from the role of lighting at the theater and thereby inspire to urban lighting which goes beyond securing visibility and safety. To seek inspiration in the theater where lighting is a part of the dramaturgy of the play. The word dramaturgy is from the Greek dramatourgía, 'a dramatic composition' or 'action of a play' and can broadly be defined as 'adapting a story to actable form'.

Other researchers have used the scenographic metaphor to describe how they analyze the real world. The sociologist Erving Goffman used a dramaturgical analysis to examine social interactions in urban settings. His theatrical metaphor was used to describe a social situation as a setting and people as actors (Goffman, 1959). Gernot Böhme also uses the scenographic metaphor in his work on atmosphere. Böhme asserts that theatrical lighting can contribute to the formulation of an aesthetics of atmospheres (Böhme, 2013). Intangible concepts such as atmosphere and mood are difficult to define

and create. However, on stage an atmosphere can be created with scenography and lighting. An atmosphere which enhance a specific scene and the drama in this scene. By using this ability lighting has to enhance atmospheres on stage, as a metaphor in the urban space, it is possible to study whether lighting supports the drama in the urban space or not.

Lighting designer Hervé Descottes refers to the 'instruments of lighting' when describing lighting characteristics and divides them into six principals of lighting, as described in the introduction (Descottes, 2011). In a theater, these principals or parameters of lighting can be used to match the dramaturgical development of the play and create an atmosphere. To a certain extent these lighting parameters can also enhance the urban context. However, the circumstances for lighting in public spaces are different then at the theater, and therefore some differences will be presented in the following section. Four theatrical elements will be used to explain the differences: space, actor, drama, and lighting (Palmer, 2013; Hvass and Hansen, 2019).

Space
In the theater, the stage is often a defined space. It is a limited space where set constructions and decorations are modified to reflect the drama being performed.
In the urban context, the space consists of a series of visual connected spaces.
In this PhD study, tram stations and the surroundings are the spaces being studied.

Actor
In the theater, the actors are on the stage performing a play, while the audience is looking at the actors.
In the urban context, everybody is both actor and audience, moving between each other and everybody look at each other.
In this PhD study, the test participants are the actors. As their experiences during interviews in the lab or in the field, are the focus of these studies.

Drama
In the theater, the drama at the theater is most often defined, rehearsed, and structured to tell a story in the appropriate order.
In the urban context, there is not only one drama taking place, but there are many activities or dramas taking place simultaneously.
In this PhD study, the drama is represented by the everyday life activities taking place at a tram station, the waiting activity, and the series of activities that are associated with the waiting situation at the tram station.

Lighting
In the theater, the scenographic lighting is carefully planned to match the desired atmosphere, the stage constructions, the location of actors, and the flow of the drama. Generally, lighting is directed one way, towards the stage and the actors. All lighting parameters can be used at the theater since lighting fixtures can be placed almost

anywhere.
In the urban context, there are requirements from legislation and standards regarding visibility, safety and the lighting fixture must be resistant to different weather conditions and vandalism. Therefore placement, type of fixture etc. is much more limited in the urban space then in scenography.
In this PhD study, the lighting at the tram station and the lighting in the surrounding context has been investigated.

It is important to emphasize that the scenographic lens is about analyzing lighting as part of the dramaturgy of a drama. The urban space is not a theater, however, with inspiration from the world of theater, it is the intention to explore lighting as part of the dramaturgy of the urban context. To investigate whether lighting supports both the architectural qualities of the space, the social qualities such as interaction between people, and the activity taking place in a particular context.

3.1.2. STUDY 2 - PRE-ANALYSIS IN THE FIELD, WHY TRAM STATIONS?

The Aarhus tram stations were selected for context-specific case studies, because the stations and the surroundings represent an architectural and social context that serves the everyday life activity of using public transportation.

A new public infrastructure
The newly installed tram in Aarhus is an example of an urban transformation, a new public infrastructure that has been integrated into an existing public infrastructure. The tram is an example of a sustainable development in the city, which will reduce car traffic and make it easier for commuters to travel between urban, suburban, and rural areas. Trams are being built in Denmark's three largest cities, Copenhagen, Aarhus, and Odense. In 2017, the tram in Aarhus was completed and in 2022 the tram in Odense was completed. In 2025 the tram infrastructure will be completed in Copenhagen.

The tram stations in Aarhus were designed by Holscher Design, one of the two industrial partners on this PhD thesis. Because of the close collaboration with the company access to information about the tram project could be established. The collaboration provided access to information about design intentions and the planning-, and execution process for the lighting at the stations. The collaboration also provided contact with project partners such as Aarhus Municipality, Aarhus Tram, who operates the trams on an everyday basis, and the company AFA JCDecaux, who oversees operation and maintenance of the stations.

The design intentions for Holscher Design were to create a minimalistic and functional station design, which was intended to blend with the existing urban architecture and the existing transportation system. Throughout the station, uniform materials and surfaces are utilized and construction dimensions are minimized. Glass surfaces separate the

sides of the platforms to achieve transparency and to allow pedestrians to observe the urban environment on the other side of the station through glass walls.

Initially, the lighting at the stations was designed to be dimmable. However, lighting control, and therefore the ability to dim the lighting, was removed from the project due to construction costs. Therefore, it is not possible to adjust the brightness level at the tram station according to the brightness level in the urban context in dark hours. As a result, design intentions were not met during the dark hours. A high brightness level in the sheltered area causes reflections in glass walls and other glossy surfaces. Therefore, the shelter at the station is not transparent as intended by the designers.

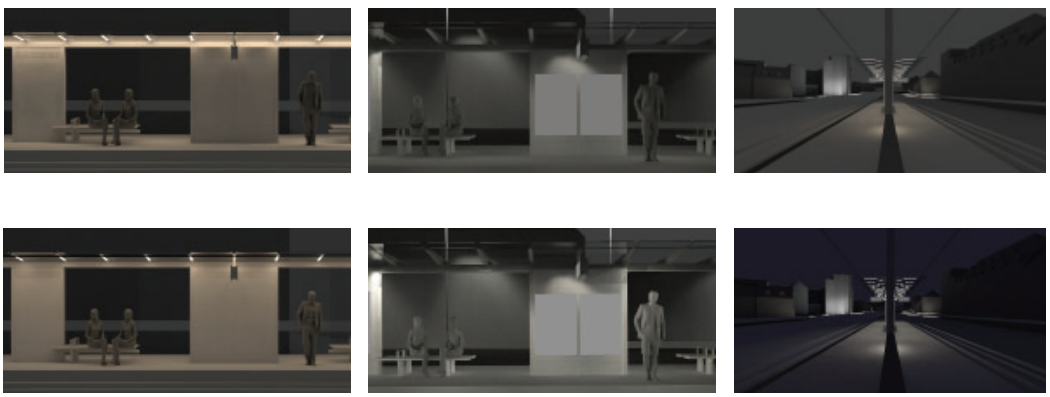
The choice of Skolebakken and Nørreport tram station.
At a study tour in Aarhus, tram stations in urban, suburban, and rural contexts were visited to determine which tram stations should be included in the pre-analysis in the field (study 2). The original plan was to analyze several tram stations in different contexts, to be able to compare the role of lighting in these different contexts. The study tour, as well as a meeting with Aarhus Tram, Aarhus Municipality, Holscher Design, in autumn 2018, resulted in the selection of the two tram stations Skolebakken and Nørreport. A comparison between two urban stations was evaluated to be more valuable then comparing stations in different contexts. The fact that people were present at the urban stations and in the surroundings also supported this choice. The stations were chosen based on their location in urban areas, close to the city center and in areas with shops, businesses, educational institutions, and residential areas. Aarhus Tram and the municipality of Aarhus were especially interested in the tram stations located close to the city center, because the lighting here had been a challenge, and more fixtures were added to Skolebakken station late in the construction phase.

Description of Skolebakken and Nørreport tram stations
Skolebakken and Nørreport tram stations are examples of two different station platforms that entail two different ways of orienting oneself towards the city while waiting. Furthermore, the two stations are situated within two different urban contexts. Accordingly, this combination of different conditions was a good starting point for analyzing the lighting setting at the stations and balance in relation to lighting setting in the surroundings. Nørreport is an island platform, where the tram passes on each side. As people wait at the station, they tend to look toward the rails and at the surrounding urban context. The platform is situated in the middle of a road with buildings on both sides. While Skolebakken Station has two side platforms. The tram runs between two platforms and, when waiting at the station, people often stand or sit with their backs towards the surroundings, while looking at the tracks between the platforms or the opposite platform. On one side, the station is surrounded by a road and buildings, and on the other side, the station is adjacent to a recreation area and the harbor. Lighting is installed in railings and standing furniture and lights up the platform. While lighting placed in the ceiling in the sheltered area lights up people and the platform.

3.1.3. STUDY 3 – PRE-ANALYSIS IN THE LAB, WHY BALANCED BRIGHTNESS LEVELS?

The word balanced, in relation to brightness levels, indicates that the connection between two or more brightness levels are evaluated to be in balance. The pre-analysis in the field (study 2) revealed that the brightness level at the station was high and in the surroundings the brightness level was low. This lack of balance between a high brightness level at the station, the local space, and a low brightness level in the surrounding space, created a tense atmosphere in the waiting area and the surroundings became invisible because of the contrast. However, before the decision of focusing on balanced brightness levels was made, other lighting parameters were investigated while planning the lab study.

A series of visualizations were done to prepare the lighting settings for the lab study. The lab study was originally planned with tracks for spots in a sheltered area. Lighting settings with an opportunity to change between diffuse and directed, and to change between warm and cold color temperatures were planned. These visualizations, show an elaboration on the findings from the field study 2 and was an inspiration for the lab study at an early stage (Figure 5)



Front or back light Direction of light Color temperature

Figure 5. Visualizations of alternative lighting settings in the sheltered area at the tram stations, as inspiration for the research design for the lab study (Illustrations: Stavroula Angelaki and Afroditi Panagiotopoulou)

Further planning of the lab study, however, revealed that there were too many lighting parameters in the research design. There were too many combinations of lighting parameters, and the parameters were in conflict, when the lighting in the local space should relate to the lighting in the surrounding area. Of all the parameters, brightness level was chosen for the lab study to be able to investigate this balance. Brightness is a fundamental lighting parameter which is always present in lit urban contexts, especially for functional lighting around everyday activities. Therefore, the findings from the PhD thesis could prove valuable to urban lighting and lead to sustainable solutions due to the suggested dimming of the lighting.

3.1.4. STUDY 4 – FIELD EXPERIMENT, WHY NØRREPORT TRAM STATION?

When planning the research design for the main field experiment, the initial idea was to do interviews both a tram station in an urban context and a tram station in a rural context. At the rural tram stations, there is an even greater contrast between the brightness level at the station and the brightness level in the surroundings, as the surroundings are often in total darkness.

To determine which stations should be used for the main field experiment, study trips with the tram were made in daylight and darkness. Several options for research design were proposed, and Nørreport was chosen for several reasons. As the research design was developed, it became clear that:

1. When using the scenographic lens to analyse the role of lighting in an urban context, a certain level of activity in the space and surroundings was important for the studies.
2. The surroundings should be lit, to be sure that test participants would be able to see something in the surroundings and to define the change, when the lighting was dimmed.
3. People should be present at the station and in the surrounding area, to be able to evaluate co-presence.
4. The interview should have a certain length and it should consist of a trip with the tram. If a trip to a station in a rural area should have been part of the interview. The journey with the tram would have taken too much time of the interview.
5. The station should have an island platform, where people are looking towards the urban surroundings while waiting.

Accordingly, Nørreport tram station was chosen for the experiment. Including a visit to a neighboring station, Universitetsparken.

The direction of people's view while waiting was important for the choice of Nørreport Tram station. The station is designed as an island platform and here people look at the surroundings while they wait. Compared to two sided platforms where people are waiting with their back towards the surroundings. Nørreport tram station is symmetrically located in the roadway, with a bike path, sidewalks, and buildings on both sides. Many people use the tram station since it is located on the edge of the city center and people are present in the surrounding area throughout the afternoon and evening.

3.2. PRESENTATION OF THE THREE PRE-ANALYSES

The framing of the studies provides insight into some of the decisions made during the PhD study and how these decisions formed the following study. After the presentation of general considerations, the three pre-analyses and the field experiment will be presented through summaries of the studies and information gathered from the papers. To give an overview of the research design, the findings, and the connection between the studies.

3.2.1. STUDY 1 - PRE-ANALYSIS LITERATURE STUDY, THE SCENOGRAPHIC LENS

Objective
The objective of the literature study (study 1) was to explore the role of lighting in the urban context. Inspiration was taken from the art of scenography and scenographic lighting, where light is an aesthetic and affective tool that creates moods and atmospheres to enhance a drama. The intention was to translate knowledge about the role of lighting in scenography into knowledge about how lighting around everyday activities in the urban space can be investigated and designed.

A summary of the literature study is presented below. The study is described in detail in the conference paper (Paper 1): Potentials of light in urban spaces defined through scenographic principles (Hvass and Hansen, 2019).

Research question
The following research question was defined to explore how a comparison between the use of scenographic and urban lighting can inform urban lighting research and design: How can principles of scenography inspire the definition of the correlation between urban space, people and lighting and thereby describe architectural and social potentials of light in urban spaces?

Method and theories
The first pre-analysis is a literature study (study 1). The literature mainly derives from arts on the topic of scenography, architecture, and lighting design with inspiration from literature from the field of sociology (figure 4).

The atmosphere that lighting can create was studied, in relation to how humans experience light and atmosphere in the theater and in the city (Thibaud, 2015; Pallasmaa, 2014; Böhme, 2013). Inspiration was found in literature on scenography and scenographic lighting at the theater (Palmer, 2013; Keller, 2010; Fischer-Lichte, 1992) and urban scenographic lighting (McKinney, 2017; Gröndal, 2014; Lavrinec, 2013). The role of lighting at the theater was analysed in relation to the role of lighting in architectural lighting design (Narboni, 2016; Mende, 2013; Brandi, 2006). Finally, to collect knowledge public spaces literature on urban design (Gehl, 2010; Jacobs, 1961; Lynch, 1960), urban mobility (Jensen, 2016) and social interaction in urban environments

(Goffman, 1959, 1967) was consulted.

When analyzing and discussing the above-mentioned literature in the literature study, it was intended to gain a deeper understanding of the role of light in urban environments. How lighting can be used as a tool to create atmosphere and should be investigated and designed as part of the dramaturgy of an urban context.

Findings and connection to the following study
The literature study led to the formulation of a scenographic lens, which is based on the quote from the architect and scenographer Adolphe Appia concerning the role of light in the theater. The quote explains how lighting can combine scenographic elements on stage and this quote was an inspiration to investigate how lighting combines the same elements in the urban context. His words read as follows:
'The actor presenting the drama, space in three dimensions, in the service of the actor's plastic form, light giving life to each' (Adolphe Appia in Palmer, 2013: 149).

Figure 6. The scenographic lens

The four scenographic elements can be translated into urban elements which match the case chosen for the PhD study. The space is then the tram station and the surrounding context. While the actor is the pedestrian, and the drama is the activity of waiting. Lighting is 'giving life' to the three elements in the dark hours, meaning that the station and the pedestrian become visible in the dark and the lighting can enhance or give life to the activity of waiting and create an atmosphere suitable for this situation.

The scenographic lens is a helpful tool to investigate and communicate how lighting can become a part of the dramaturgy of a specific context. To investigate how people and their everyday activities (the drama) are an integrated part of a performance orchestrated by lighting. Human experiences of lighting in this dynamic situation are collected during the following studies. The findings can inspire the use of modern lighting control technologies, to direct focus towards the architectural and social potentials of lighting.

By examining literature within both scenography, architecture and sociology, the experience of light has been examined in relation to an artistic approach to light, light in the built environment and light in relation to the people who use this specific context. Hence, to direct focus towards the staging and atmosphere that lighting can provide.

In studies 2, 3 and 4, the scenographic lens served as an inspiration for planning observations and interviews. In the study that follows, the pre-analysis in the field (study 2), the scenographic lens guided the structure for the observations and photo registration and informed the questions for semi-structured interviews.

3.2.2. STUDY 2 - PRE-ANALYSIS IN THE FIELD, CASE STUDIES AT TRAM STATIONS

Objective
The objective of the pre-analysis in the field was to explore how lighting affects human experience of architectural and social urban context, through a context-specific field study. Through architectural observations and ethnographic semi-structured interviews at Skolebakken and Nørreport tram station in Aarhus. It was the intention to get a closer understanding of the experience of lighting in relation to a specific everyday activity (drama), in a specific urban context (space) in the co-presence of other people (actor) during dark hours.

A summary of the pre-analysis in the field is presented below. The study is described in detail in the conference paper (paper 2): Architectural and social potential of urban lighting, a field study of how brightness can affect the experience of waiting for public transportation (Hvass and Hansen, 2020).
Research question
To explore how lighting affects human experience of architectural and social urban context in dark hours in a context-specific field study, the following research question was defined:
How does the lighting at tram stations in Aarhus support the experience of the space (stage), people (actor) and activities (drama)?

Method and theories
The primary methods used in the field study were based on a social scientific approach with inspiration from the field of architecture (Figure 4).

For ethnographic observation and semi-structured interviews, James P. Spradley's descriptive question matrix was used for action-based data collection (Spradley, 1979, 1980). The scenographic lens, developed during the literature study (study 1), was used to structure the interviews (Hvass and Hansen, 2019). And Gordon Cullen's, serial vision, was used for photo recordings and observations (Cullen, 1961).

The field study was inspired by literature and research on architectural lighting design, urban design, urban mobility, and social interaction (Lofland, 2017; Narboni, 2016; Jensen, 2016; Descottes, 2011; Brandi, 2006; Gehl, 2010; Goffman, 1959). Inspiration was also found in research which evolve around the effects of urban lighting on behaviour, environmental psychology and social interaction and how lighting can enhance our experience within the built environment (Davoudian, 2019). Another inspiration

was Daria Casciani who investigate the social dimensions of urban lightscapes. She defines three criterias for fulfilling humans needs for lighting. These criterias are accessibility, comfort and sociability (Casciani, 2020). Finally, aspects of sustainability concerns such as energy efficiency, and a socially sustainable approach to designing our cities for human use (UN, 2015; Dempsey, 2009), gave inspiration to the field study.

Conditions of the study
The pre-analysis in the field was performed during three days in January 2019. In all 20 persons participated in the interviews. Skolebakken and Nørreport tram station were visited mornings and evenings to perform observations and interviews in the dark hours, where people commute to and from work.

Observations and interviews
The serial vision observations were done by taking photographs at six positions (Cullen, 1961). Three positions while approaching the station and three positions at the station. At each position, the space, the light, the people, and their activities were observed. Besides the photos taken at each position, field notes describing the observer's impressions in words were collected. The photos were taken in the transition hour and dark hours.

Interviews
Twenty test participants were approached at the two stations, and they volunteered to participate in interviews while waiting for the tram to arrive (3-8 minutes). An interview guide for semi-structured interviews included guiding questions about experiences of the space and surroundings, and co-presence with other people. The interviews took place in the dark hours morning and evening (See appendix A).

Data analysis
The data was analyzed through a traditional coding method, where observation and interview data were analyzed in four steps: organizing, recognizing, coding and interpretation (Bjørner, 2015). Organizing field notes and photos was step 1, recognizing themes and categories was step 2, coding the text for focus areas was step 3, and during step 4 the findings of the analysis was interpretated.

Findings and connection to the following study
The observations and interviews at two stations revealed that the brightness level in the sheltered area of the station was too high. As the lighting was diffuse, materials, objects and people's faces were without shadow to accentuate shapes and the space became tense and lacked atmosphere. Both at Nørreport and Skolebakken, the contrast between the local space and the surrounding space was high. The high contrast made it difficult to see the surroundings.The brightness hierarchy for the whole area was unbalanced. These brightness parameters adversely affected the architectural and social qualities of the stations since their high fluctuations in brightness could not be compensated for with the sensitive night vision of the test participants (Figure 7).

Brightness hierarchy Brightness ratio Brightness level

Figure 7. Brightness parameters, Nørreport station. The white frames represent the hierarchy of lighting in the context, the local space in relation to the surroundings and finally the local space and the brightness level here

As described earlier these observations were examined through 3D visualizations (Figure 5). Lighting parameters such as directed light and color temperature was investigated to decide which lighting parameter should become the focus of the study. The choice was made because the observations and results from interviews revealed that the balance of the brightness levels was of great importance in relation to the experience of the architectural and social context. Therefore, the focus for the lab study became investigating experiences of the balance of brightness levels.

3.2.3. STUDY 3 – PRE-ANALYSIS IN THE LAB, BALANCING BRIGHTNESS LEVELS

Objective

The objective of the pre-analysis in the lab was to investigate, how balanced brightness levels influenced test participants' experience of space, co-presence, and the surrounding context. In a lab set-up, test participants experienced six lighting settings. The lighting settings differed in brightness level between the local area, where test participants were placed, and a surrounding area.

A summary of the pre-analysis in the lab is presented below. The study is described in detail in the journal paper (paper 3): Intensity and ratios of light affecting perception of space, co-presence and surrounding context, a lab experiment (Hvass, Wymelenberg, , Boring and Hansen, E.K., 2021)

Research question and hypothesis

To explore how brightness levels affects human experience of architectural and social context in a lab study, the following research question was defined:
How does the balance between brightness levels in a local space and in its surroundings affect human experience of space, people, and surroundings?

The following three hypotheses were defined to guide the lab study:
H1) Space – lowered lighting intensity in the waiting area will have a positive impact on the perception of the atmosphere of the space.
H2) Co-presence – lowered lighting intensity will improve test participants' impression

of other people in the space.
H3) Surroundings - lower ratios between luminance in the waiting area and in the surrounding context will have a positive impact on perception of the surroundings, including for the visibility of objects.

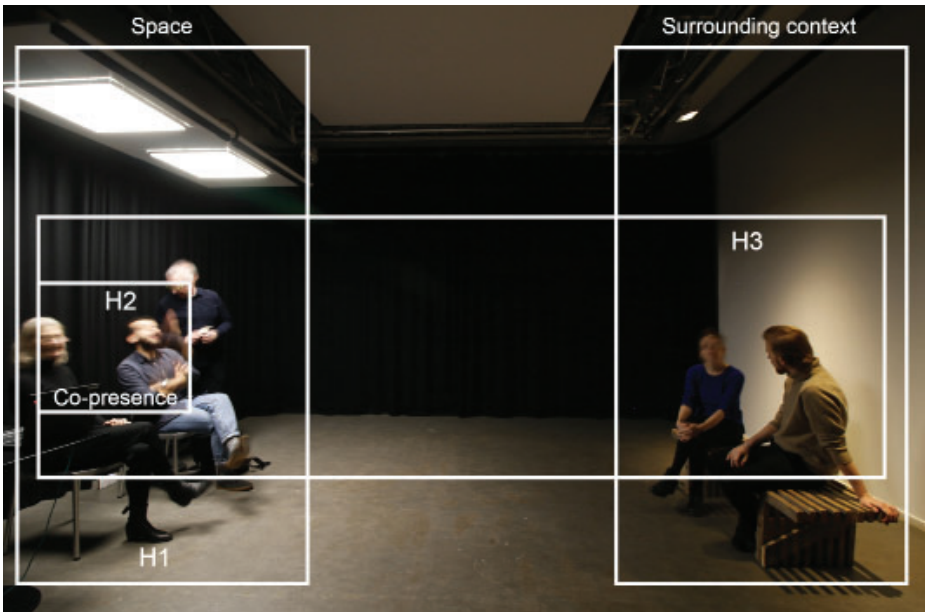


Figure 8. Lab set-up. Hypotheses : H1-space, H2 - co-presence, and H3 - surroundings

Methods and theories
The primary methods used in the lab study were based on a natural scientific approach with inspiration from literature from the field of architecture (Figure 4).

The study was informed by research in lab studies about outdoor lighting (Boyce, 2000; Nasar, 2017; Flynn, 1988, 1979, 1977). Inspiration was found in these studies in relation to the research design and formulation of questionnaires with a semantic differential rating scale. Likewise, inspiration was found in research on lighting conditions for pedestrians (Rahm, 2021) and on how lighting affects obstacle detection and facial recognition (Fotios, 2019; Dong, 2015) to understand the impact of lighting on experiences occurring in urban environments.

In the search for literature related to the concept of balanced brightness levels, only a few scientific papers were found. Inspiration was found in research about the perception of a lit object in relation to a lit background (Davoudian, 2017) and the effect of spatial luminance distribution on dark adaptation (Stokkermans, 2016). Through studies of architectural references, the importance of darkness, atmosphere and the aesthetics of lighting inspired the research design as a counterweight to the primary focus on safety in outdoor lighting research (Lam, 2015; Pallaasma, 2014; Zumpthor, 2006).

To quantify differences in luminance levels between the six settings in the lab study, luminance measurements and luminance maps were produced (Inanici, 2006; Ward, 2005). The luminance maps served as a record of the lighting conditions under which the participants were tested.

Conditions of the study

The lab was divided into two light zones to simulate a local space, the waiting area, and the surrounding context. Two chairs were placed in the waiting area, one for the test participant and one for the interviewer. To simulate a shelter and provide lighting for the waiting area, a white plate with lighting fixtures was mounted above the chairs. Opposite the two chairs, a wood bench of neutral shape and color was placed to represent an object in the surrounding context. Test participants used the bench to evaluate details in each of the six lighting settings.

Two types of fixtures were used for the test:
Fagerhult: type, 23,511-402 Multilume Slim Opal; measure, 60 × 60 cm; optics, front, opal; color rendering, Ra (CRI) 80; color temperature, CCT, K 4000; and light source, LED (The local space, waiting area).
ERCO: type, Logotec Floodlight, 72560.000; measure, 16.8 cm (h) x 18.1 cm (w); optics, front, Spherolit lens flood; color rendering, Ra (CRI) 90; color temperature, CCT, K 3000; and light source, LED (surroundings).

Fixtures were connected to a DALI track, and the lighting settings were programmed in Helvar Design software. The lighting settings were controlled via a computer, with eight programmed settings in total: six lighting settings for the lab study, one baseline condition and one scene with all lights turned off. To define intensity for the six lighting settings, lux measurements was taken directly under the fixtures to program the settings. For the waiting area, high, medium, and low intensity illuminance levels as 200, 100 and 30 lux were defined. For the surroundings, a high intensity of 20 lux and a low intensity of 5 lux were defined. Luminance intensities in each setting was documented through luminance maps based on HDR images.

The lighting levels in the waiting area in the lab study were based on light conditions at the tram stations tested during the pre-analysis in the field (study 2) and on legal requirements. The high intensity value was set to 200 lux based on lux measurements taken at Skolebakken tram station during study 2. The low intensity value was set to 30 lux based on two norms that describe the legal requirements for tram stations. According to tram standard Bane Norm BN2-81-1 (Banedanmark, 2015), the light level at a small station must be at least 30 Es, mid lux (the mean lux value of the lighting intensity). The light intensities in the surrounding context were based on contextual lighting levels, e.g., 20 lux for a brightly lit street and 5 lux for a street with lower intensity lighting (Figure 9).

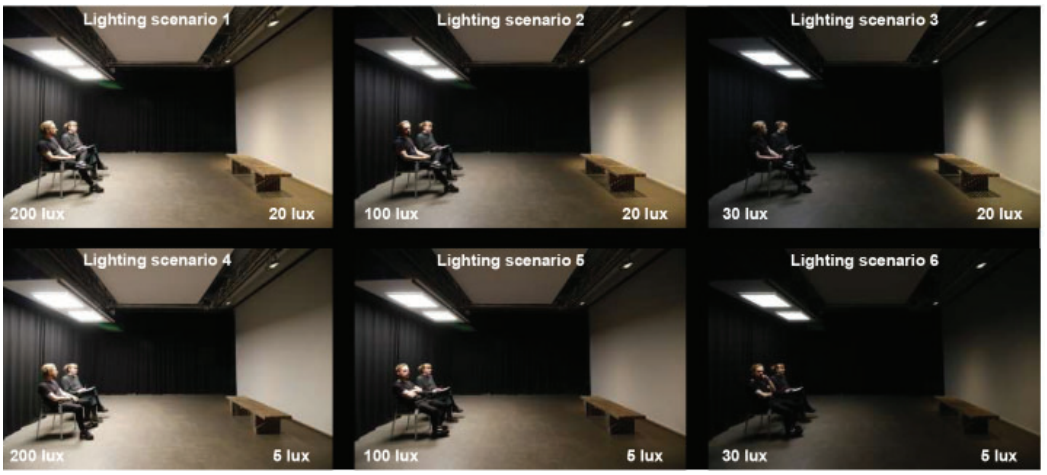


Figure 9. lab set-up, the six lighting settings

Quantitative questionnaires
The questionnaire consisted of 12 questions and it was divided into three topics, associated with the three hypotheses. A semantic differential scale was connected to each question, to evaluate the importance of luminance intensity in visually related light zones to the perception of the waiting area, the co-presence of other people and the surroundings. Test participants were asked to evaluate the following:
(H1) Space
relaxed / tense, safe / unsafe, comfortable / uncomfortable, and exciting / boring

(H2) Co-presence
How are faces lit? comfortable / uncomfortable
How does the lighting affect socialization? motivating / not motivating

(H3) Surroundings
harmonious / non-harmonious, comfortable / uncomfortable, non-glaring / glaring, light / dark, and object (bench) is visual / object is not visual
(see appendix B)

Participants
The pre-analysis in the lab was performed in a period of three weeks in January 2020, in all 30 persons participated. The experiment included thirty participants, fifteen male and fifteen female, in the following age group: 20–29 years – 16 participants, 30–39 years – 5 participants, 40–49 years - 1 participant and 50–59 years – 8 participants. Test participants included Aalborg University administrative staff, teachers, research staff, students, and people outside of the university.

Procedure
The procedure of the test was divided into five steps.

Step 1, test participants began the experiment with filling out a consent statement and provide general information in a room without daylight, lit only by a low level of indirect light from a table lamp.
Step 2, test participant and interviewer entered the light lab and took their places on the two chairs set up in the waiting area, representing a 'local area', the area where the observer is placed. When entering the lab, the surroundings were illuminated with 20 lux, this lux level represented the baseline scene.
Step 3, the interviewer gave a brief explanation of the interior of the room, the lighting and the test.
Step 4, the six settings were presented with a baseline scene in between the settings. A questionnaire had to be filled out for each setting.
Step 5, the experiment was concluded.

Data analysis
For statistical analysis, the 12 questions in the questionnaire were analyzed separately using Friedman ANOVAs. The Dunn-Bonferroni post-hoc test was used if any differences were observed between the six lighting settings.

Findings and connection to the following study
The results suggested that a lower brightness level in the waiting area and balanced brightness level between the waiting area and the surrounding area increases a relaxed feeling. Furthermore, the results partially suggest that the lower brightness levels in the waiting area increase the perception of privacy, and that low contrast in the brightness levels between the two areas lead to more harmonious perception of the context.

The questionnaire was inspired by the scenographic lens, regarding questions about space, surroundings, and people. However, it was not possible to address questions in relation to activities or the drama of the space. As the study was performed in the lab set-up and it was difficult to mimic the dynamic urban context and get reliable answers about the experience of lighting in relation to the waiting situation. Studies with different lighting settings could then have been done in virtual reality to be able to recreate the dynamics of the city but in a VR set-up. However, a lab study was prefered, when planning the test, experiences of co-presence would also be difficult to distinguish in a VR test.

The natural scientific methods used in the lab made it possible to further develop the findings from study 2. In the lab study the focus of the PhD study was narrowed down to the concept of balanced brightness levels. Hence, in the lab setting a variation of the lighting settings could be easier installed than in the field.

3.3. PRESENTATION OF THE FIELD EXPERIMENT

The objective of the field experiment was to explore how dimmed and balanced brightness levels affect human experience of the architectural and social urban context at Nørreport tram station. The experiment was based on the three pre-analyses and was conducted with the use of methods from natural science, social science, and arts/humanities. An existing bright lighting setting and a dimmed lighting setting were investigated through measurements, observations, and semi-structured interviews.

The field experiment is described in detail in a book chapter (paper 4): Lights out? Lowering Urban Lighting Levels and Increasing Atmosphere at a Danish Tram Station (Hvass, Waltorp and Hansen, 2022).

Due to the social scientific nature of the anthology to which paper 4 was incorporated, paper 4 mainly describes how the anthropological and architectural methods are combined, and the text is focused on the go-along interview. Therefore, this section about the field experiment provides an analysis of Nørreport tram station and the context, it presents light measurements and luminance maps, and it describes both go-along and vox-pop interviews to reveal the transdisciplinary nature of the main field experiment.

Research question
Two research questions were defined and directed towards investigations at Nørreport tram station. The research questions for the field experiment are similar to the overall research questions, except from the fact that the questions are addressed a specific context, Nørreport tram station.

A specific knowledge of exactly Nørreport tram station is defined during the experiment. The intention is that Nørreport tram station is an example, an example that reveals results in relation to human experiences of the lighting in a specific place and an example of which methods can be combined to explore human experiences of brightness levels. This specific knowledge can inspire others to investigate and design lighting in relation to the space, surroundings, co-presence and the activities performed.

The following questions were asked:
How do brightness levels affect human sensory experience of Nørreport tram station after dark? How can these sensory experiences of brightness levels be explored by combining methods?

Methods and theories
The field experiment is based on the findings from study 1, 2 and 3. During the field experiment methods from both natural science, social science and art/humanities were combined. The methods are described in Part 2: Methods and Theories and figure 4 shows how the methods have been combined. To provide further insight in the ethnographic methods used, an overview of the methods is provided in the following section.

Sensory ethnography is an approach to ethnographic studies, where focus is related to a multisensory embodied experience in the studies. The approach to ethnographic studies implies that senses such as hearing, smell, taste, touch, and vision can be interconnected and interrelated while investigating a topic. Studies of the senses' significance for the experience of a place are best achieved in field studies where the senses are affected by the variability of the surroundings (Pink, 2015). In the planning and description of the field experiment, reference to sensory ethnography is included to argue for the importance of experiencing lighting setting in real world field studies. Where influences from the dynamic urban context influence the human experience.

Visual ethnography is used to gather knowledge from test participants by using probes such as film, photos or drawings (Pink, 2021). Probes are self-documented data from participants which are designed to prompt and elicit information from participants about a topic (Bjørner, 2015). In this field experiment photos were use as probes in field experiment. The method is described by Gaver et al. who regard photos as a cultural probe that provides access to user-centered inspiration (Gaver et al., 1999).

Go-along interviewing is a method for obtaining contextualized perspectives from users by conducting interviews on the move, in which the participant acts like a navigational guide. The go-along interview is a form of in-depth interview but is conducted by researchers accompanying individual participants (Kusenbach, 2003; Bjørner, 2015). In this field experiment the go-along interviews were used to collect experiences of the lighting settings while the test participants were doing the activities of arriving at the station from the city, waiting for the tram, taking the tram to the nearby station and back again. The methods of the go-along interviews and the participant produced photos were combined to seek access to test participants immediate thoughts about the existing bright lighting setting and the dimmed lighting setting.

Vox pop interviews are conducted to gain insight into people's attitudes, experiences, and ideas in relation to a limited topic. Test participants are approached in the context where the target group of the research is placed. In this field experiment, vox pop interviews were used to supplement the longer go-along interviews where people were aware of the dimming of the brightness level. With knowledge from test participants who knew nothing about the dimming of the brightness level at the station.

3.3.1. ANALYSIS OF NØRREPORT TRAM STATION AND SURROUNDINGS

Nørreport tram station and the surrounding context has been analyzed using the scenographic lens. Nørreport tram station is described in words and pictures to gain an understanding of the specific context where go-along and vox pop interviews as well as light measurements have been performed. The dynamic situation at the station and in the surroundings is described though descriptions of the movements or rhythms of e.g., the tram arriving and departing, lights from cars, lights controlling the traffic and lights in people's homes.

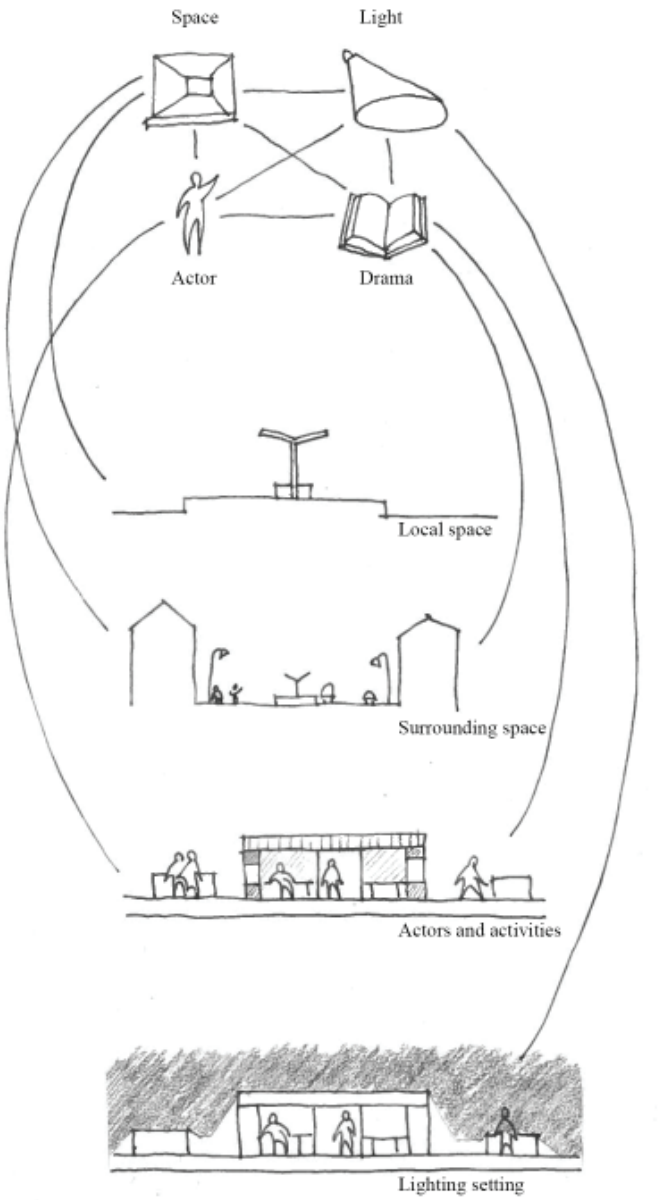
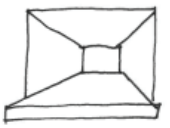


Figure 10. The scenographic lens and the waiting area at Nørreport tram station



Space and surroundings (stage)

When approaching the station from the city, a pedestrian crossing connects to a ramp which leads up to the platform in the middle of the road. A check-in stand is in the front zone of the platform where standing furniture and a ticket vending machine is also situated. Next, a sheltered area with benches, glass walls, information boards and advertising stands are placed. Standing furniture is located at the rear of the platform, and a railing marks the end of the platform (Figure 11). There is a direct visual connection between the platform and the surrounding urban area. However, when a tram stops at the station, the visual connection to the surroundings is lost.

The pavement consists of concrete tiles, and the railings and furniture are made of metal. This sheltered area consists of a steel frame with horizontal steel panels for display of information and lighted advertisements, as well as glass sections in the wall.

The station is located in the middle of Nørrebrogade at the intersection of Nørregade. On one side of the station there is a view towards apartment buildings, and to the other side of the station there is a view towards a building with a shop at ground level and a fitness center above, as well as an office building and an apartment building (Figure 12).

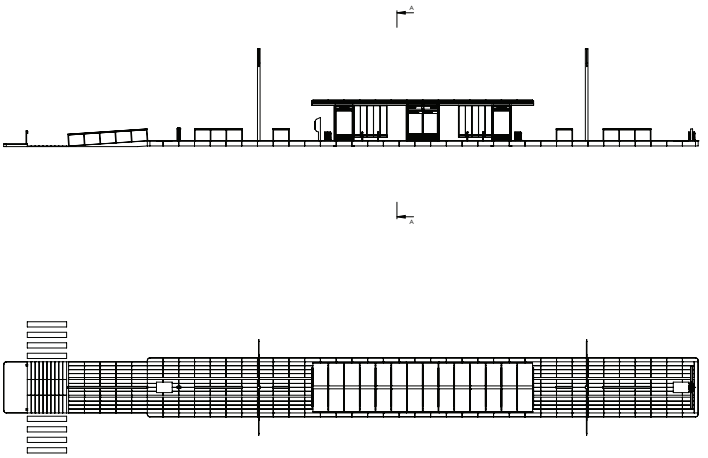


Figure 11. Plan and section, Nørreport tram station (Aarhus Letbane)

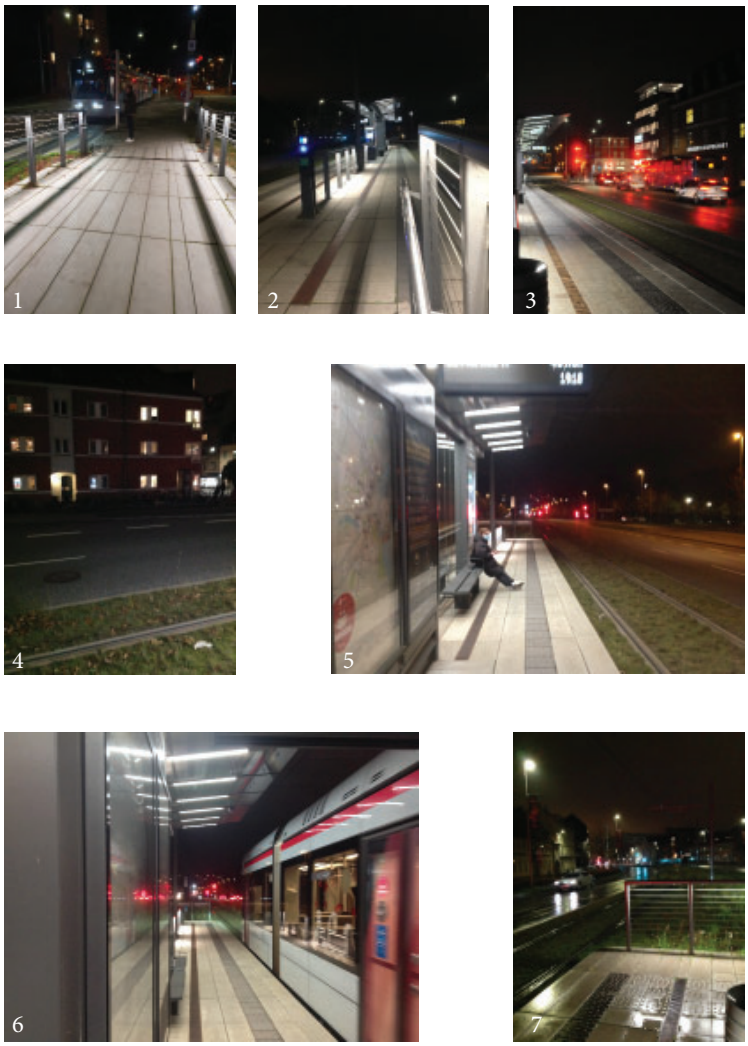
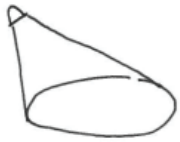


Figure 12. Photos from Nørreport tram station illustrating the space.
From top left: 1) Arrival and departure ramp with connection to the crossing; 2) Arrival area with check-in stand; 3) Cars waiting at a red traffic light; 4) The view of the windows of people's homes; 5) Sheltered area; 6) Sheltered area with tram blocking the view 7) The rear of the station. Photos by test participants and the author.



Lighting at the station (lighting)
There are three types of electrical lighting at the station: 1) fixtures in railings and standing furniture that illuminate the ground, 2) fixtures installed in the shelter ceiling, and 3) lighted commercial posters. Additionally, the timetable shows lighted letters and numbers that indicate when trams are arriving (Figure 13). On both sides of the station, lights from moving trams, cars, motorbikes, and bikes dominate the surroundings. Traffic lights direct traffic at the intersection of the crossing roads, while the road lighting identifies the extent of the road. Light in windows in the apartment buildings, offices, shops, and the fitness center reveal whether anyone is present in the building or not. The lighting fixtures installed at the stations are type: Vaya Linear LP, LED, Philips.

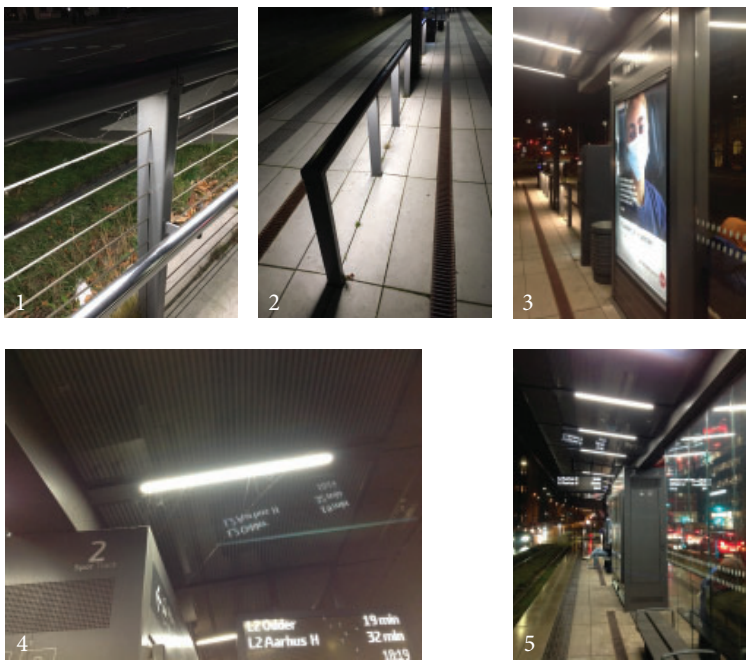


Figure 13. Photos from Nørreport tram station illustrating the light.
From top left: 1) Light in railings; 2) Light in standing furniture; 3) Light in advertising posters; 4) Light in shelter ceiling and timetable sign; 5) Sheltered area, traffic lights and reflections in glass walls. Photos by test participants and the author.

People at the station (actor)

In the first zone of the platform, people stand or lean against standing furniture, or they go to the sheltered area, where they sit or stand. On the rear part of the platform, people stand or lean (Figure 14). People choose their position when they are waiting according to their preference in terms of standing or sitting, and according to the station at which they will exit (e.g., being closest to the exit). It is common for people to take bicycles on the tram, and their positioning at the station is then determined by this. Some people come in groups, but most people come alone. They observe the station, other people present, the surroundings or they look at their cell phones or other devices. Faces are illuminated in diverse ways depending on the position of the lighting. In areas with lighting placed at hip height, faces are in the dark, whereas in the sheltered area where lighting is placed in the ceiling, faces are brightly illuminated.

Figure 14. Photos from Nørreport tram station illustrating people at the station.
From top left: 1) People at the station seen from the surroundings; 2) Person standing waiting for the tram; 3) Face in existing lighting; 4) Beneath, face in dimmed lighting; 5) Man waiting with his bike in the sheltered area; 6) People leaving the tram and the station. Photos by test participants and the author

Activities (drama)
At the station, the rhythms of light overlap. The rhythms of people, traffic, and the surrounding city as well as the activities of daily life define the drama of the place.

Rhythm of light and darkness in twilight
The Nørreport tram station changes character as the lighting changes from dynamic daylight to twilight to the dark of night. In the daytime, lighting changes between sunlight or an overcast sky and the different angles of the sun make shadows and textures appears different during the day. In the dark hours, the station is lit by static artificial lighting and a brightness hierarchy should be established at night to ensure that the urban context also can be read and understood in the dark (Cuttle, 2015).

Figure 15. Nørreport tram station in daylight, twilight and the dark hours

Rhythm of the people
People are present at the station, in the trams, and in the surrounding areas. The timetable of the tram dictates the rhythm of people arriving, waiting, and departing from the train station. After a tram has left the platform, the station slowly begins to fill again, and co-presence increases in accordance with the timetable. According to Lyn H. Lofland (2017), this is the public realm; that is, the co-presence of people who are not known to one another and who form the social-psychological environment. In the surrounding area, people move along the facades on the sidewalk, or they walk towards the station in the crossing. Some people cross the tram tracks to enter the station.

Figure 16. Nørreport tram station: tram leaving (no people) and tram arriving (people waiting)

Rhythm of the tram

The tram arrives and departs on both sides of the platform. The digital station clock mounted in the shelter ceiling gives the tram passengers information about arrival and departure times. At times one tram stops at the platform, and sometimes two trams at the same time. However, most of the time the platform is vacant. As a result of the rhythm of the tram the station changes its character from an open space into a closed space. The lighting level increases when the tram stops due to the reflection of the light on the white tram surface.

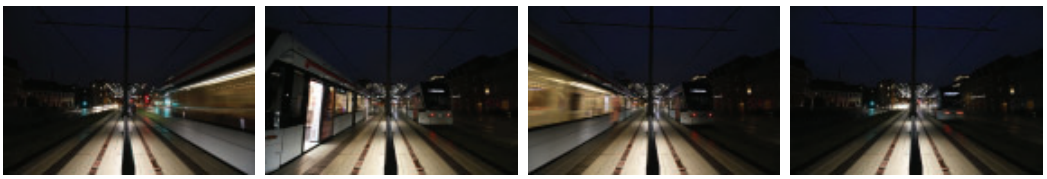


Figure 17. Nørreport tram station with one, two or no trams at the station

Rhythm of the traffic

At night, traffic patterns vary according to the activities of people passing by. Traffic is backed up on one side of the station when there is a red light and cars drive when the light turns green. In the photographs, figure 18, red taillights of the cars can be seen one side of the station, and on the opposite side, cars with white headlights are waiting. The traffic lights change from red to yellow to green and dictate the flow of traffic.

Figure 18. Nørreport tram station, traffic lights.

Rhythm of the light in façade windows

The rhythm of light in the façade windows tells us whether it is a shop, a fitness center, an office building, or a home and whether people are present. Using the example of an apartment, Mikkel Bille describes lighting as follows: 'Light, and the atmospheres it co-creates, extend beyond the walls of the apartment and permeate the neighborhood with a glow of 'hygge'; Light offers a sense of security and belonging' (Bille, 2015: 63). The sense of community and being able to observe people's life patterns through use of lighting, became apparent during two weeks of observations and interviews at Nørreport tram station.

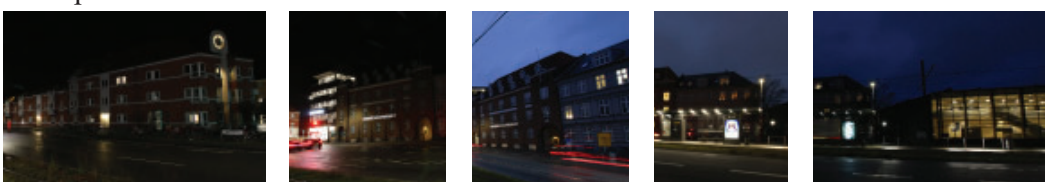


Figure 19. Nørreport tram station, lights in façade windows revealing activity in the building.

3.3.2. LIGHT MEASUREMENTS AND LUMINANCE MAPS

The lighting fixtures in the shelter ceiling at Nørreport tram station were dimmed using LEE ND filter type 211. This filter reduced the brightness level without changing the colors. The illuminance level (lux) was measured to approximately 20 lux with a lux meter on the ground. Which means that the illuminance level was reduced approximately 80% in relation to the existing illuminance level in the sheltered area.

To quantify the lighting levels at Nørreport tram station and in the surroundings, three distinct types of measurements were performed: Measurements of horizontal illuminance levels (lux), Measurements of vertical luminance levels (cd/m2) and Luminance maps based on HDR images (cd/m2). A lux meter Hagner Model EC1 and luminance meter Konica Minolta LS-150 was used for light measurements. A Canon EOS 70D camera was used for time lapses as well as HDR images for the luminance maps. Photosphere software was used to produce the luminance maps (Inanici, 2006; Ward, 2005). The measurements were performed to support the analysis of the interviews, to compare with the lighting standards and regulations and to quantify the differences in the lighting levels between the station and the surroundings.

Illuminance -Lux

The map below represents Nørreport tram station and the surrounding context (Figure 20). Horizontal illuminance measurements were performed at the numbered spots, and the results can be seen in the table below (Table 1). Lux levels were measured with a lux meter placed on the pavement along the building facades and on the platform floor at the station.

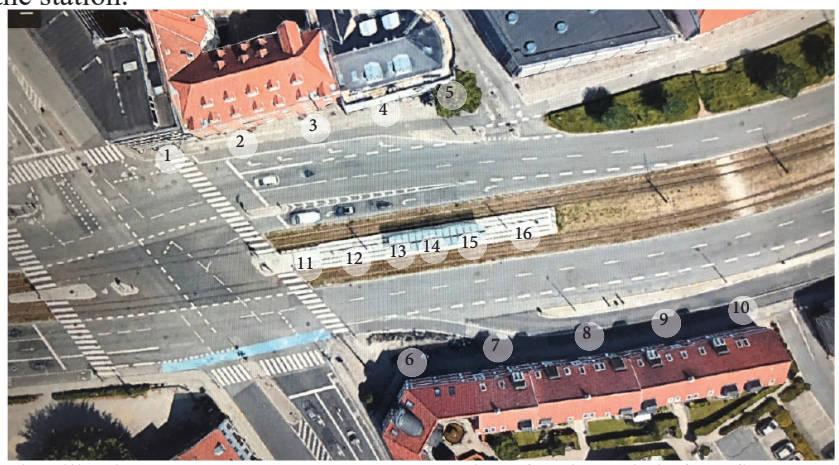


Figure 20. Plan, illuminance measurements on pavement along facades and platform floor (Google Maps)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Surroundings east	83	6	3	1	2											
Surroundings west						1	1	4	4	2						
Platform – Existing lighting setting											181	130	168	158	165	75
Platform – Dimmed lighting setting											181	130	22	15	23	75

Table 1. Illuminance measurements, lux, on pavement along facades and platform floor, referring to figure 20

The lux measurements revealed the difference between the lux level at the station platform and the lux level on the pavement along the facades. The difference between the lux level in the existing and dimmed lighting settings in the sheltered area is marked in yellow (Table 1). During the go-along interview a tram ride was included, the lux level in the tram was measured to approximately 220 lux on the floor in the tram aisle.

Luminance - cd/m2

The photos below illustrate the view from the station towards the east and west facades and the view from the city towards the tram station in daylight and in the dark hours (Figure 21). The labelled spots, on the photos in daylight, represent the luminance measurement points, and the values are marked in the table below (Table 2).

View towards east facades

View towards west facades

View towards the station

Figure 21. Photos illustrating Nørreport tram station and the surrounding facades during day and nighttime. Spots with letters mark positions of luminance measurements points.

Surroundings, east façade	A. 27,6 cd/ m²	B. 0,4 cd/ m²	C. 0,1 cd/ m²	D. 0,2 cd/ m²	E. 0,2 cd/ m²
Surroundings, west façade	F. 0,2 cd/ m²	G. 0,1 cd/ m²	H. 1,1 cd/ m²	I. 0,4 cd/ m²	J. 0,4 cd/ m²
Station	K. 3,2 cd/ m²	L. 9,8 cd/ m²	M. 1,4 cd/ m²	N. 43,9 cd/ m²	O. 1,1 cd/ m²

Table 2. Luminance measurements referring to the photos in figure 21

The luminance measurements demonstrate the difference between the luminance levels on station surfaces and the luminance levels on the facades surrounding the station in selected measurement points.

Luminance maps
While the luminance measurements only reveal the level in selected points, the luminance maps illustrate how luminance is balanced between the station and the surroundings in the existing and dimmed lighting settings. A luminance map is the technical term for a representation of luminance levels which are often used to evaluate point-in-time lighting scenes from a selected viewpoint. In this PhD thesis the luminance maps are used to observe the station, and evaluate the brightness levels at the station in relation to the brightness levels in the surroundings. Thereby it is possible to evaluate the lighting conditions, and register if the design intentions for the station design have been meet.

The luminance maps were also used in the lab study to register luminance levels. However, in the field study the luminance maps were found even more useful. Because they revealed details about the distinct types of lighting that an urban context consists of, and they revealed the transition between the luminance levels.

The luminance maps are presented under photos of the views. The legend indicates luminance levels from 0, with the color purple, up to 1 lumen and above, marked in yellow.The station and the surroundings are seen from the 1) east side of the station, 2) the west side of the station and 3) the rear end of the station.

1. Luminance map, view from east

Figure 22. Photos and luminance maps, view from east towards the station.
Left, existing lighting setting. Right, dimmed lighting setting.
Legend, colors illustrating from 0-1 lux

When the station is seen from the east, the luminance maps reveal how the reflections from glass walls block the view, when the brightness level is high. Here reflections of light form a visual border

instead of making the station transparent and adapt to the context.
This reveals how the lack of balance in the brightness levels works against the design intentions for the station. During daytime the station design adjusts to the surrounding area as intended, but after dark, the high brightness level reflects off the glass walls, floor and other materials, and the sheltered waiting area at the station is no longer transparent (Figure 22).

2. Luminance map, view from west

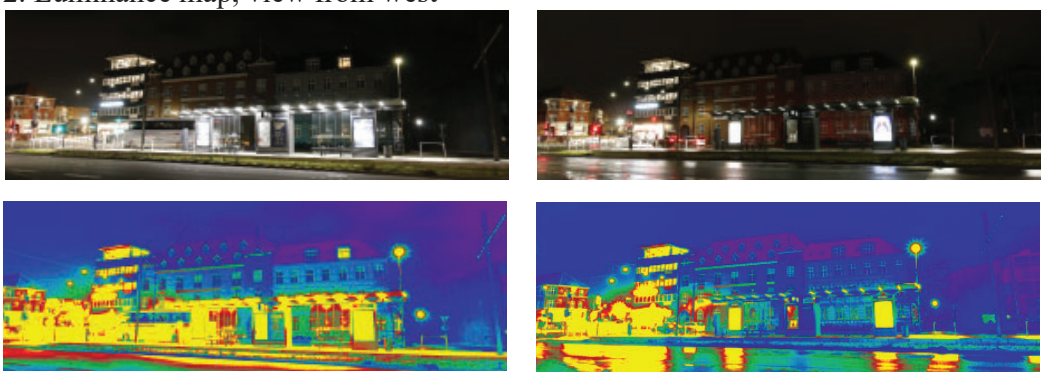


Figure 23. Photos and luminance maps, view from west towards the station.
Left, existing lighting setting. Right, dimmed lighting setting.

When the station is seen from the west, the brightness level at the station matches the high brightness level at the crossing and the lit corner building. However, again, the buildings behind the station disappear because of the high contrast to the surroundings and the reflections of light on the surfaces of the station (Figure 23).

3. Luminance map, view from rear end of Nørreport station

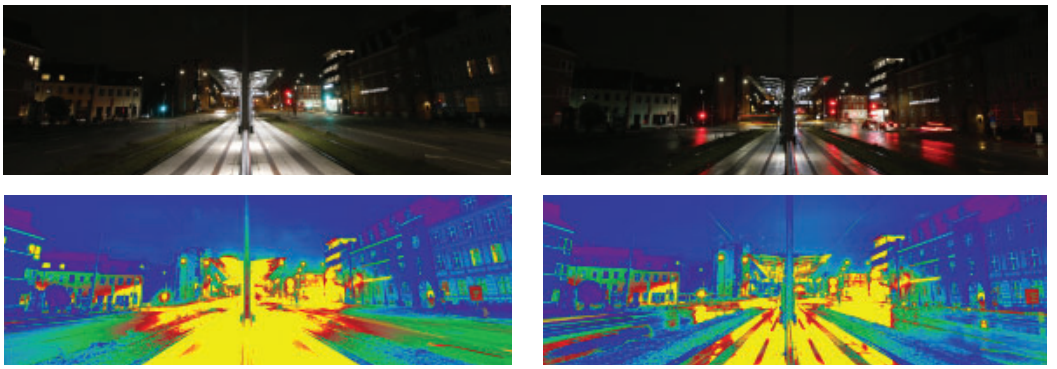


Figure 24. Photos and luminance maps, view from rear end of Nørreport station.
Left, existing lighting setting. Right, dimmed lighting setting.

When the station is seen from the rear end, the light from the shelter roof spreads over the ground level and onto the tram tracks. The shelter ceiling appears very bright in contrast to the dark sky. The ceiling surface is less contrasting, in the dimmed version, and the ground level is reflecting less light (Figure 24).

Legislations for lighting at tram stations
In Denmark, outdoor lighting is planned in accordance with the standard: DS/EN 12464-2: 2014; Light and lighting - Lighting at workplaces Part 2: Outdoor workplaces (DS/EN, 2014), and the Håndbog, Vejbelysning (Vejregler, 2020). According to the project manager of Aarhus Tram, the level of illumination at the tram stations is based on two standards: Banenorm BN2-81-1 (Banedanmark, 2015) and Vejregler, Standsningssteder for Letbaner (Vejregler, 2016). Both norms are indicative, and Aarhus Tram defines the regulations as guidelines rather than demands. As the tram has become a part of Aarhus's road network, the Vejregler, Standsningssteder for Letbaner (Vejregler, 2016), has been guiding when planning lighting for the tram stations in the urban areas. To obtain more information about tram rules, engineers, who had been involved in the lighting project for the Aarhus tram project and the Copenhagen tram project, were contacted. Some engineers referred to Banenorm BN2-81-1 (Banedanmark, 2015), in which a mean lux level is 30 lux at a small station, 40 lux at a medium size station, and 50 lux at a large station.

According to Banenorm BN2-81-1 Nørreport tram station is a small station. The lux level documented in the sheltered area at the station, was approximately 165 lux in the existing lighting settings. The measured lux level is much higher than the recommendation in Banenorm BN2-81-1 (Banedanmark, 2015), where 30 lux is recommended for small stations.

In the field experiment at Nørreport tram station the lux level in the dimmed lighting setting was measured to approximately 20 lux in the sheltered area. This lighting level was decided at a mock-up test at Nørreport tram station, one month before the experiment took place. Two types of ND filters were mounted on 4 luminaires each, for the mock-up. At a meeting with Aarhus tram and AFA JCDecaux, Aarhus tram approved of the darkest of the two filters. The illuminance level was dimmed to approximately 20 lux, so the dimming turned out to be 10 lux lower than the recommendations in in Banenorm BN2-81-1 (Banedanmark, 2015). This was an advantage, because then it was more likely that the test participants would notice that the lighting was dimmed.

3.3.3. GO-ALONG WITH PARTICIPANT-PRODUCED PHOTOS

To obtain a better understanding of how people experience a dimming of the lighting while waiting for a tram, comparative go-along interviews were planned. Furthermore, participants produced photos were used as visual probes. To prompt and elicit information from participants about experiences at the tram stations in the existing bright lighting setting and the dimmed lighting setting

Participants

The experiment included 10 test participants who showed up twice (six females and four males). Six test participants were in their mid-20s, and four test participants were in their mid-50s to late 60s. Three were regular tram commuters and six seldom used the tram, but experienced the tras as part of the urban nightscape when moving through the city (Table 3)

Test participant	Gender	Age	Use of tram
TP1	Female	22	Rarely
TP2	Male	56	Every day
TP3	Female	22	Rarely
TP4	Female	27	Every day
TP5	Male	29	Rarely
TP6	Male	25	Every day
TP7	Female	26	Every day
TP8	Female	69	Rarely
TP9	Male	59	Rarely
TP10	Female	56	Rarely

Table 3. Go-along interviews, general information about test participants.

Procedure

The registrations of lighting and interviews took place in two weeks in November 2020, in the dark hours. The first week of registrations and interviews took place in the existing lighting setting, and the second week interviews took place in the dimmed lighting. The interviewer met each test participant at Nørreport station, took the tram to Universitetsparken station, and then went back to Nørreport station (Figure 25)

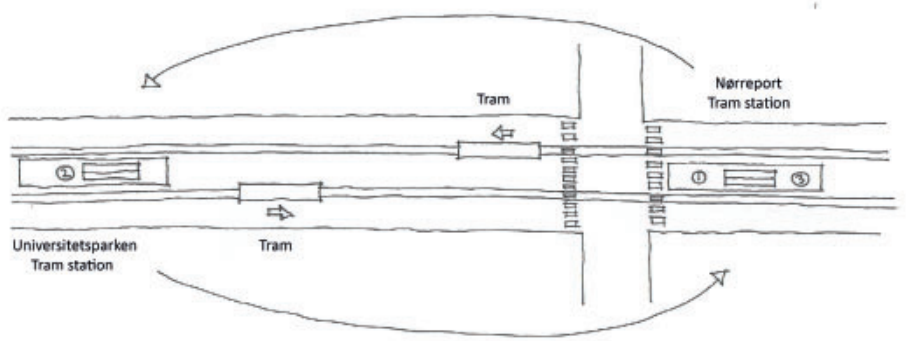


Figure 25. Route for the go-along interview

The interviews were recorded, and each interview lasted approximately 30 minutes, depending on the arrival and departure time of the tram. The interview was divided in three parts (interview guides are placed in the appendix C). On arrival, the test participant was interviewed about the experience of lighting in relation to the space, surroundings, co-presence with other people and the activities they perform while waiting. At the tram station Universitetsparken, the test participants described how the station

was experienced in relation to Nørreport tram station. They were encouraged to describe narratives and memories related to previous transit situations. When returning to Nørreport, the interview was related to the 'return' to the station and how the lighting affected the experience of the space (Figure 25).

Participant produced photos

An overview of the procedure of the participant produced photos are presented in figure 26. A first set of photos was produced before the first interview. Test participants were asked to take photos of the tram station in dark hours and to capture what their eye caught in the situation. At the first interview the test participants took a second set of photos in the existing lighting setting at Nørreport, at Universitetsparken and again at Nørreport tram station. The photos were taken with an Apple Ipad. At the second interview a third set of photos was taken in the dimmed lighting setting at Nørreport, the existing lighting setting at Universitetsparken and again at Nørreport tram station. At each tram stop, several questions were posed, and the test participant was asked to take photos in relation to the issues described by the test participant during the interview. Then the participants explained why they took the picture and what they saw. (See appendix C)

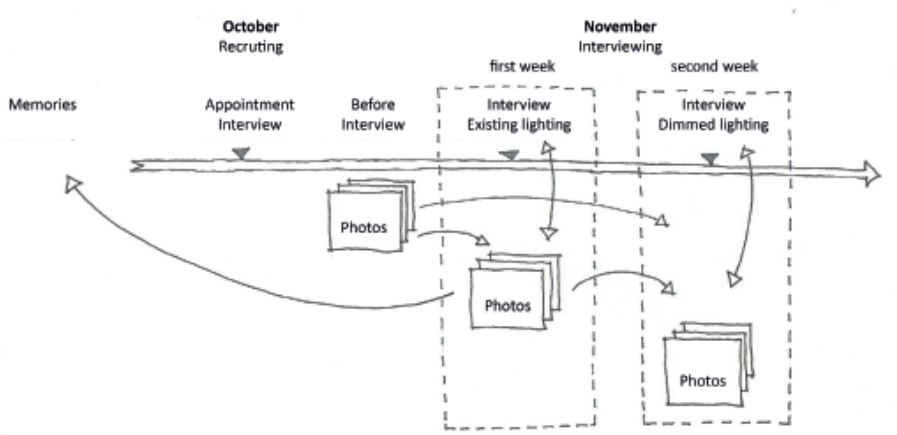


Figure 26. The use of participant-produced photos. Photos taken before the first interview, at the first interview in existing lighting and at the second interview in dimmed lighting.

Data analysis

The recorded interviews were organized and transcribed in Word and then the transcribed text was coded in NVivo12. At a first sorting of the material, themes were relating to the concepts: atmosphere in the space, surroundings, people, and activities. These themes were detected and recognized. At a second coding of the data, new angles and perspectives to the project were introduced (Madden, 2017; Kvale, 2015). An overview of coding themes is placed in the appendix C.

The data was analyzed through a content analysis revealing both negative or positive opinions about the existing bright lighting setting and the dimmed lighting settings.

Photos from the go-along interviews were structured in folders to match the interviews according to the three times test participants were asked to take pictures; before the first interview, at the first interview and at the second interview (Figure 26). Photos were guiding during the content analysis process. However, most of all the photos served as a tool to make test participants talk about what they experienced and to help them develop their own vocabulary of lighting experiences (Table 5). Three examples of how the photos match the go-along interviews can be seen later in this section.

Results of field experiment

Information about the test participants' gender, age and use of the tram are presented, together with their either positive or negative opinion about the dimming of the light (Table 4). Then, expressions are gathered to show the vocabulary and association the test participants used in both the existing and dimmed lighting setting (Table 5).

All test participants noticed the difference in the brightness level between the two visits. During the go-along interviews, the test participants had both positive and negative opinions about the dimmed lighting at the station. For some test participants their attitude towards the lighting setting was dependent on whether they were in the waiting situation or arriving from the nearby station and stepping out of the highly lit tram to the dimmed station.

The test participants made the following choices: eight test participants had positive views of the dimmed lighting setting. Five of the eight positive test participants changed their mind during the field experiment. They found the dimmed brightness level suitable while waiting. However, the brightness level was experienced as too low when stepping out of the highly lit tram onto the platform at Nørreport tram station with the dimmed lighting setting. Finally, two test participants had negative views of the dimmed lighting setting (Table x).

Because of the limited sample of test participants, it was not possible to conclude that the answers were related to gender, age, or frequency in using the tram.

Test participant	Gender	Age	Use of tram	Noticed the dimming	Positive towards dimming	Positive while waiting and negative when arriving	Negative towards dimming
TP1	Female	22	Rarely	Yes	x		
TP2	Male	56	Every day	Yes			x
TP3	Female	22	Rarely	Yes			x
TP4	Female	27	Every day	Yes		x	
TP5	Male	29	Rarely	Yes	x		
TP6	Male	25	Every day	Yes		x	
TP7	Female	26	Every day	Yes		x	
TP8	Female	69	Rarely	Yes	x		
TP9	Male	59	Rarely	Yes		x	
TP10	Female	56	Rarely	Yes		x	

Table 4. Go-along interviews, opinions about the dimming of the lighting at Nørreport tram station,

During the go-along interviews test participants used expressions and associations to describe their immediate thoughts about the existing and the dimmed lighting settings (Table 5). The participant-produced photos helped them find words and formulate associations, which the lighting situation reminded them of.

Taken together, these results reveal that in the waiting situation, most of the test participants found the dimmed setting suitable. While when arriving with the tram at Nørreport station, the brightness level was found too low. These results indicate that the activity that takes place while judging the lighting plays a role in the evaluation. The go-along interviews are effective in revealing how lighting is experienced in transitions between activities.

	First interview - existing lighting setting		Second interview - dimmed lighting setting		
	Positive expressions	Negative expressions	Positive expressions	Positive and negative	Negative expressions
TP1		sharp, clinical, institutional, not cozy, light bubble	less clinical, natural, evening mood, calming, relaxed		
TP2	safe				too dark, scary, unsafe
TP3	spacy, enlightened, calm	not cozy, chaotic			fatigue, drowsy, irritable, unsafe
TP4	practical, security		comfortable for the eyes, more calm, natural	dark when returning with the tram	
TP5		sterile, sharp	comfortable, less sterile, the station fits the context, does not take attention, cozier		
TP6	modern, minimalistic design	bathed in too much light, feels like standing on an over lit island	comfortable, safe, sophisticated, serious, exclusive	dark when returning with the tram	
TP7	enough light for reading	grey, prisoner on an island	intimate, calm	dark when returning with the tram	
TP8		boring, lack of texture and atmosphere, cold lighting	comfortable, intimate		
TP9		not cozy, exposed, like a gas station, threatening traffic, too bright light for the waiting activity, glare, stressful	not luminescent anymore, indoor atmosphere, less extreme	dark when returning with the tram	
TP10		uncomfortable, unpleasant, exposed, prison yard, operating room at a hospital, prison yard, big contrast, the center of a target	calm, less exposed, more protected, private	dark when returning with the tram	

Table 5. Go-along interviews, positive and negative expressions, and associations in the two lighting settings.

Experiences from the interviews will be exemplified through three quotes from interviews in the dimmed lighting setting. The quotes represent experiences about connectedness to the surroundings (quote 1), an example of how the participant-produced photos helped the test participant formulate an experience (quote 2) and two quotes about brightness level and the feeling of safety (quote 3).

Quote 1. Connectedness to surroundings
Two test participants expressed their view towards the surroundings in the dimmed lighting setting as such:

'I actually think the surroundings are clearer; it's like it's becoming more of a whole [the station and the surroundings]. Before you stood in quite a lot of light, and then the surroundings became secondary. Now it seems more homogeneous'.
(TP8, female, age 69, dimmed lighting)

'Somehow it seems that the station is better connected to the rest of the city because it is not a luminous bubble anymore'.
(TP1, female, 22 years old, dimmed lighting)

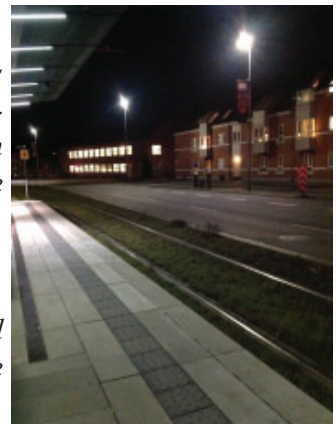


Figure 27.
Participant-produced photo 1

The test participants expressed that they could see the surroundings more clearly. Harmony was established between the local space and the surrounding space, in the dimmed lighting. The urban context had turned into a cohesive space instead of two spaces.

Quote 2. Participant-produced photos as a tool to explore the impact of brightness level
One participant was quite surprised when the contrast to the surroundings became clear to him in the existing lighting setting:

'Well, this was not really what I thought I would take a picture of. It is actually quite funny with the contrast. On the one side, you see the bright tram, and on the other side, the very dark street. It is quite a big contrast; it is actually funny that the contrast is that big. When, I turn around it is actually quite dark on the street'.
(TP2, male, 56 years old, existing lighting)

Figure 28
Participant-produced photo 2

Nine out of 10 test participants preferred the view to the surroundings in the dimmed lighting setting. It came as a surprise to many, but it was difficult for them to express what they saw and why this happened. The majority of the test participants did not consider the importance of the surroundings in the existing lighting setting. However, when the lighting had been dimmed, all test participants experienced a regained connection to the surroundings and sensed that the station had become a part of the urban context.

According to Sara Pink (2021), participant-produced photos can give to access to knowledge from test participants of which they are not always aware. During the go-along interviews these moments of realization often occurred, when the test participants explained what they saw in the pictures during the interviews. The analysis of this interview thus indicates that visual ethnography, and especially participant-produced photos, was a suitable method for exploring the relationship between brightness level and the human sensory experience of urban context.

Quote 3. Brightness level and feelings of safety
The following two quotes represent opposite views on the dimming of lighting in relation to safety.

One positive quote in relation to the dimming of the lighting reads as follows:
'This is calmer and safer, and I feel more protected than when I'm not exposed'.
(TP10, female, 56 years old, dimmed lighting)

A negative quote in relation to dimming reads as follows:
'It's a little scary…. I think it is an advantage to be exposed in the light because if some strange people come to the station, you can see them'.
(TP2, male, 56 years old, dimmed lighting)

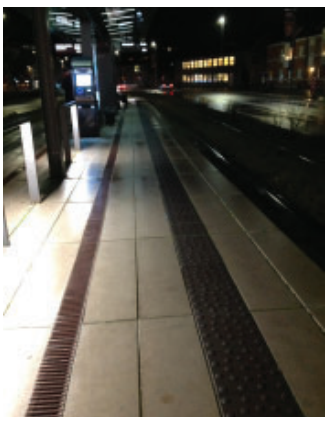


Figure 29.
Participant-produced photo 3

The two test participants have opposite feelings about the brightness level and safety. One feels safe and calm in the dim light and the other feels unsafe. When dimming the brightness level, the majority of the test participants saw an advantage in the regained visual contact with the surroundings, and linked this regained connection to the surroundings with a feeling of safety.

3.3.4. VOX POP INTERVIEWS

To obtain a better understanding of how people experience a dimmed lighting setting while waiting for a tram, shorter interviews were made with people who were unaware of the dimming of the lighting. This was done to investigate how results from these

shorter interviews could relate to the results from the longer go-along interviews. To get further understandings of experiences of lighting and to compare the methods.

Participants

People were approached at the station while waiting for the tram, and they were asked if they would like to participate in a short interview, while waiting for the tram. The interviews included 15 test participants in the existing lighting setting and 15 in the dimmed lighting setting.

Existing lighting setting				Dimmed lighting setting			
Vox Pop test participant	Gender	Age	Use of tram	Vox Pop test participant	Gender	Age	Use of tram
Vox Pop 1Exist.	Female	27	Every week	Vox Pop 101Dim.	Female	26	Every week
VP2 E	Male	24	Every day	VP102D	Male	49	Every week
VP3 E	Female	23	Rarely	VP103D	Female	22	Rarely
VP4 E	Female	17	Every week	VP104D	Female	22	Rarely
VP5 E	Male	22	Every week	VP105D	Female	21	Every week
VP6 E	Male	20	Every week	VP106D	Male	35	Every day
VP7 E	Female	30	Every week	VP107D	Male	65	Rarely
VP8 E	Female	25	Rarely	VP108D	Female	23	Every week
VP9 E	Female	28	Every day	VP109D	Male	30	Every day
VP10 E	Male	27	Rarely	VP110D	Female	21	Every day
VP11 E	Male	23	Rarely	VP111D	Male	23	Every day
VP12 E	Female	29	Rarely	VP112D	Female	23	Rarely
VP13 E	Female	32	Every day	VP113D	Female	32	Every day
VP14 E	Female	29	Rarely	VP114D	Female	23	Every week
VP15 E	Female	28	Every week	VP115D	Female	24	Every day

Table 6. Vox Pop interviews, general information about test participants

Procedure

The following description of the vox pop interviews will focus on the results from the interviews in the dimmed lighting setting.

The group of test participants in the dimmed lighting setting consisted of 5 men and 10 women, of whom 13 were in their 20s to mid-30s and two were in their 50s to mid-60s. Six test participants were regular commuters, five used the tram 1-3 times every week and four rarely took the tram (Table 6).

Test participants were approached at the station and asked if they wanted to participate in a short interview. The vox pop interview lasted until their tram arrived, approximately 3-8 minutes.

First, test participants were asked some introduction questions about their age and how often they used the station (Table 6). Afterwards they were asked where they placed themselves at the station and why, if they noticed other people and navigated according to them, and if they noticed the surrounding city (The interview guide is placed in the appendix C). Second, they were encouraged to describe the atmosphere at the station. After having tried to find own words, they were asked to pick words from a printed list with words describing atmospheres (Vogels, 2008). The list included the

following words: relaxed–tense, safe–unsafe, public–private, motivating–demotivating, overview–lack of visibility, cosy–creepy, pleasant–uncomfortable, presence–distance, formal–informal, committed–uninvolved, personal–impersonal, and natural–clinical. At the end of the interviews the test participants were asked if they had noticed a change at the station.

Data analysis
The recorded vox pop interviews were organized and transcribed in Word and later thematic coded in Nvivo12.

Results
The most important finding from the vox pop interviews was that none of the 15 test participants had noticed that the brightness level had been dimmed. Seven test participants could see the difference when they were told, and eight could not see the difference. Eight test participants were positive about the dimmed lighting setting, two test participants were negative about the change and five did not have an opinion about the dimmed lighting setting (Table 7).

When asked about atmosphere, most people had difficulties expressing an opinion and finding words. When they saw the list with words describing atmospheres, they chose a few words. There were no major differences in the choice of words when comparing the existing and dimmed lighting settings – that is, the answers pointed in many directions. The most common words chosen form the list with words were ‘public’, followed by ‘informal’ and ‘formal’. These words were chosen in both the existing and dimmed lighting setting. Words like safe, natural, and relaxed were also chosen in both lighting settings, but the word cosy was chosen by some, only in the dimmed lighting setting.

The interviews revealed that when test participants were confronted in the short vox pop interview. It was difficult for test participants to find or choose words from a list to describe the atmosphere in a space. Changes in lighting, such as dimming of the brightness level, can be difficult to detect. Because experiences of lighting is often difficult to describe and is often taken for granted while performing everyday activities, such as waiting for the tram.

Opinions about the dimming of the lighting at Nørreport tram station						
Vox Pop Test participant	Experience difference	Experience a difference when told	Cannot see a difference when told	Positive in relation to the dimming	Negative in relation to the dimming	Have no opinion about the dimming of the brightness level
VP101D	No		x	x		
VP102D	No		x			x
VP103D	No		x			x
VP104D	No		x			x
VP105D	No	x		x		
VP106D	No		x			x
VP107D	No		x		x	
VP108D	No	x		x		
VP109D	No		x			x
VP110D	No	x		x		
VP111D	No	x		x		
VP112D	No	x		x		
VP113D	No		x			x
VP114D	No	x		x		
VP115D	No	x		x		

Table 7. Vox Pop interview, opinions about the dimming of the lighting at Nørreport tram station.

Quotes from interviews

Test participants were encouraged to describe their reactions when they were told that the brightness level had been dimmed approximately 80%. To demonstrate these reactions about the dimmed brightness level, two positive reactions and two negative reactions are presented. The quotes presented only contain the answers about whether the test participant was able to see the dimming or not.

Quote 1. Vox pop test participant VP111D (Male, 23 years old, dimmed lighting)
Interviewer: *Have you noticed that there has been a change at the station in recent days?*
Test participant: *Not really. It is not something I've thought about; it's obviously getting darker. I do not know if I have overlooked something.*
Interviewer: *I have dimmed the lighting as part of my experiment. Can you see it now?*
Test participant: *Oh yes, that does not bother me. It gives the opportunity to just wake up. I get up very early, earlier than I am used to, so it's nice not to be greeted with harsh light and get too many impressions.*
Interviewer: *Thanks for your answers; have a good day. (We take up the conversation again)*
Test participant: *Now that I have been made aware that the lighting is dimmed, I think it's nice; it's comfortable.*
Interviewer: *Do you think that something has happened to the space after the lighting is dimmed?*
Test participant: *I think that it is more welcoming now.*

Quote 2. Vox pop test participant VP112D (Female, 23 years old, dimmed lighting)
Interviewer: *Have you noticed that there has been a change here the last few days?*
Test participant: *No, I have not noticed anything.*

Interviewer: *I have dimmed the light as part of my study.*
Test participant: *Ah, okay. I can really see the change when you say that. The light is not so harsh when you sit here.*
Interviewer: *What do you think it does to the experience of being here?*
Test participant: *It is a little nicer, especially here in the morning or if you go home late at night – you will not be sitting in the spotlight.*

When the test participants realized that the lighting was dimmed, they were both positive. They both thought that the dimmed lighting was beneficial in relation to the waiting activity in the morning and evening and that the lighting was less harsh. Also, they preferred not to be in the spotlight. They used the following words: nice, comfortable, and welcoming.

Two negative reactions to the dimming of the brightness level:

Quote 3. Vox pop test participant VP107D (Male, 65 years old, dimmed lighting)
Interviewer: *Have you noticed that something is different at the station?*
Test participant: *No, I haven't.*
Interviewer: *I have dimmed the lighting at the station.*
Test participant: *Well, I also thought that it was not so bright. How can you dim the light?*
Interviewer: *I have mounted filters on the light fixtures. I work together with Aarhus Tram.*
Test participant: *Ah, okay.*
Interviewer: *What do you think about the light level?*
Test participant: *I think the lighting is too low, the level must be higher.*

Quote 4. Vox pop test participant VP 109D (Male, 30 years old, dimmed lighting)
Interviewer: *Have you noticed that there has been a change at the station these days?*
Test participant: *No.*
Interviewer: *I have dimmed the light.*
Test participant: *I have not thought about that at all.*
Interviewer: *What do you think about it when I tell you that it is dimmed?*
Test participant: *Oh, when you tell me, I think I can see the difference. But I just think that when there are so many cars and so much traffic light, you do not think that the light should be dimmed here.*
Interviewer: *Do you find this problematic?*
Test participant: *If I came to the station late at night, I might think it was creepy, but right now it does not matter to me.*

One test participant evaluated the brightness level as too low for the waiting situation. Whereas the other test participant focused on safety issues and said that it might be uncomfortable when waiting for the tram late at night in the dimmed lighting setting.

The results from the Vox Pop interviews differed from the results from the go-along interviews were test participants were aware of the dimming of the lighting.
In the vox pop test situation, people were waiting for their tram and did not know the scope of the interview.

However, the most interesting finding was that none of the test participants in the vox pop interviews had noticed the approximately 80 % dimming of the brightness level, and few could see it when they were told. This result differs from the result in the longer go-along interviews where all test participants could see the dimming clearly. Furthermore, the company Keolis, which is responsible for driving trams, was contacted via email to ask how the tram drivers experienced the dimming of the brightness level. The reply from Keolis indicated that tram drivers assessed the dimmed brightness level at the Nørreport station to be low but acceptable, when arriving with the tram at the station.

3.3.FINDINGS AND CONNECTIONS BETWEEN THE FOUR STUDIES

It would not have been possible to design and perform the field experiment, without having done the three pre-analyses. The studies 1, 2 and 3 provided knowledge to the field experiment about the overall role of light in an urban space and how lighting can be part of the urban dramaturgy. The role of lighting at tram stations and how the lighting at a station is experienced in relation to the lighting in the surrounding urban space (study 2). How test participants experience different brightness levels in a local space and how they experience differences in brightness levels between the local space, in which they are placed, and the surrounding space (study 3). Knowledge from all three pre-analyses inspired the research design of the field experiment.
During the field experiment, methods were combined. In more precise terms, combining methods meant incorporating tools from natural science into the process of measuring and calculating light. However, methods from social science played an important role when interviewing. Additionally, methods from arts/humanities contributed to the exploration of atmospheres, observations of the space, lighting, people, and activities as well as the overall design of the experiment.

The light measurements showed large differences in the horizontal measured lux levels at the station platform, compared to the pavement by the surrounding facades. Likewise, large difference in the vertical measured luminance levels on the walls in the sheltered waiting area and the surrounding facades. The luminance maps visualized these differences by showing luminance levels both at the station and in the urban context.

The go-along interviews with participant-produced photos provided access to people's immediate senses and gave valuable insight in experiences of changes in brightness levels. These experiences gave a closer understanding of how lighting and darkness is

related to the feeling of atmosphere and safety. When the brightness levels were balanced, a connectedness between the waiting area and the urban context was established, because the surroundings and the people there became visible.
The vox pop interviews exemplified that people tend to not notice how an urban space is lit and how difficult it is to express experiences about lighting and darkness.

Combing methods is important when investigating lighting in an urban context. Because lighting is both measurable and unmeasurable. There is a need to quantify lighting to be able to compare with legislation, lighting defines the spaces where we are co-present with other people and lighting creates atmospheres and help us to read the built environment in dark hours.

The purpose of this review of the four studies was to describe how the concept of balanced brightness levels was developed with inspiration from the use of lighting in scenography and through field and lab studies with a focus on brightness levels and ratio of brightness level between a local space and the surrounding space. General considerations about the research design of the studies were presented in the framing section and later a summary of each project. It was the intention to reveal how the studies were connected, and how research methods from different research disciplines were combined during this process.

PART 4. FINDINGS AND CONTRIBUTIONS

BALANCED BRIGHTNESS LEVELS IN URBAN CONTEXTS

The purpose of this final part is to summarize and discuss the knowledge gathered in the PhD thesis. The gathered knowledge concerns both human experiences of balanced brightness levels in the urban context and combining methods to explore these experiences.

An overview of the findings from the four studies is presented. Afterwards, the limitations of the research are described. Then, the contributions to the research field of architectural lighting design are outlined. After this, the contribution is discussed and evaluated. Finally, possible research directions for future work are described and a conclusion is presented.

4.1 FINDINGS

4.4.1. RESEARCH QUESTION 1. LIGHTING AND HUMAN EXPERIENCE

Study 1 - Pre-Analysis Literature study, The Scenographic Lens
A literature study, about use of lighting at the theatre and in the urban space, was conducted to gain a better understanding of how lighting influences human experiences of the urban context.

The results of the literature study revealed that, in the theatre, lighting is an integral component that influences and creates atmospheres as well as it weaves the experience of the stage, actors, and drama into one. Lighting designers have always been inspired by lighting at the theater. This PhD thesis uses the inspiration from the theater to show how lighting can be a part of the dramaturgy of a context-specific urban space.

The findings from the literature study are combined in the scenographic lens, which is inspired by the writings of Adolpe Appia (Palmer, 2013). The scenographic lens can be used to analyze an urban space, to investigate how lighting enhance and combine the experience of the space, co-presence between people and the activities in the space. The scenographic lens has been used in the following three studies of this PhD thesis to guide research design for observations and interviews.

Study 2 - Pre-Analysis in the Field, case studies at tram stations
Field studies were performed at Skolebakken and Nørreport tram station to gain a better understanding of how lighting affects the human perception of the architectural and social context in a context-specific urban space.

The results showed that the diffuse lighting with a high brightness level in the sheltered area at the stations contrasted the dim brightness levels in the surrounding spaces. At the stations, objects and the faces of other people present appeared flat and without texture, because the diffuse light and the high level of the light made objects and people appear without shadows. Due to the high brightness level the atmosphere in the waiting area was tense and because of the high contrast, the surroundings became invisible.

The findings indicated that the lack of hierarchy of brightness levels in the area, created an unbalanced lighting setting. The lighting did not support the human experience of the architectural and social qualities of the waiting area and the experience of the surroundings. As it was not possible to compensate for the high contrast with the human eye.

The field study showed that there were several challenges in relation to the lighting design at the stations. These challenges were further addressed in the following lab study where the concept of balanced brightness levels was developed based on these findings.

Study 3 – Pre-Analysis in the Lab, Balancing Brightness Levels
A lab study was planned to gain a better understanding of human experiences of brightness levels and human experience of different ratios of brightness between a local space and a surrounding space.

The results revealed that the low level of brightness in the local space, where the test participant and interviewer were placed, contributed to the experience of a relaxed (as opposed to tense) and private atmosphere. By reducing contrast between a local space and a surrounding space, the area was experienced as harmonious.

The findings from the lab study led to the definition of the concept of balanced brightness levels. This concept creates awareness about the importance of coordinating and balancing brightness levels in an urban space, in relation to the brightness level in the surroundings. In addition, the concept suggests that the brightness level should be kept as low as possible to prevent contrast.

Study 4 – Field Experiment, dimming and balancing brightness levels
The findings from the lab study were tested in a field experiment at Nørreport tram station. To gain a better understanding of how dimmed and balanced brightness levels affected human experience of the architectural and social context-specific urban space.

The results indicate that, a dimmed lighting setting created a relaxed atmosphere in the local space compared to the existing bright lighting setting. Furthermore, as it was possible to see people in the surroundings, from the waiting area at the station, the feeling of safety increased. Other results indicated that the brightness level, in the dimmed lighting setting, was too low in relation to the activity of arriving at the station. This was due to a high contrast between the brightness level in the tram, and the dimmed

brightness level at the station during the field experiment.

The findings from the field experiment showed that a dimmed and balanced brightness level tend to have advantages in terms of a relaxed atmosphere, a better view to the surroundings and an increased feeling of safety. Findings also reveal that, when investigating or designing human experience of lighting, brightness levels should be investigated as part of the activity being performed in the space. To include experiences of transitions between light zones while moving in the research.

4.1.2. RESEARCH QUESTION 2. COMBINING METHODS IN LIGHTING RESEARCH

Methods were combined in a transdisciplinary process during the four studies to gain a better understanding of human experience of lighting and darkness in the urban complex context.

The results indicate that new knowledge can be accumulated through a series of pre-analyses to support research design for field experiments. This can be done by combining research methods and continuously developing and focusing the phenomenon being investigated, during the process of performing the pre-analyses.

The findings show that with the knowledge accumulated in the pre-analyses it was possible to conduct the field experiment in the complex urban context. The participant-produced photos developed during the go-along interviews, helped the test participants develop a vocabulary about their experiences. In addition, the fact that they were walking and taking the tram to the next station and back. Made it possible to register their experience of the lighting in many different positions related to the use of the tram. Documenting brightness levels in luminance maps served both as a tool for documenting the measured levels and for illustrating how brightness was balanced in an urban context from a pedestrian's perspective.

4.2. LIMITATIONS

The findings of the empirical studies should be viewed in the context of some limitations. The limitations will be described in relation to the studies 2, 3 and 4.
Study 2 - Pre-Analysis in the Field
The first field study was conducted over only three days and at only two sites, Skolebakken and Nørreport tram station. A better foundation of knowledge could have been provided, if the field study had been carried out over more days and if more stations in different contexts had been investigated.

Knowledge on human experiences of lighting could also be gathered using online questionnaires. Contact with tram users from other parts of Aarhus and areas along the tram line could have been established by using Facebook or other social media

platforms to contact tram users. The answers could have contributed to new insights from user groups living in suburban and rural areas. This could have added insights to the PhD study about human experience of the lighting in relation to tram stations in other contexts.

Study 3 – Pre-Analysis in the Lab
The results from the lab study provided limited information on safety and co-presence of other people. Test participants found it difficult to link experiences of lighting settings to a real-world environment, because of the big difference between the human experience of a lab environment and an urban environment.

Qualitative semi-structured interviews could have supplemented the quantitative questionnaires and provided access to knowledge about safety and co-presence.

Study 4 – Field Experiment
The field experiment revealed several limitations related to the COVID-19 pandemic. A week before the field experiment at Nørreport tram station began, restrictions regarding the COVID-19 pandemic were announced. Due to warnings concerning a lockdown in Denmark, several already recruited test participants withdrew, and it was difficult to recruit new test participants. Therefore, the results of the experiment should be interpreted considering the relatively small number of test participants.

One of the purposes of the field experiment was to study how the dimmed lighting affected the experience of the social context such as co-presence with other people at the station. However, it was difficult to investigate the social effects of brightness levels when people were required to keep a safe distance to each other, and cover their faces with masks due to COVID-19 restrictions.

Also, technical challenges regarding the dimming of the brightness level limited the field experiment. Unfortunately, it was not possible to install an electrical lighting dimming system at the station. The initial plan was to test more lighting settings, and the comparison of different lighting settings could have been made continuously. Instead of having to arrange two meetings with one-week intervals.

4.3. CONTRIBUTION

4.3.1. BALANCING BRIGHTNESS LEVELS

Overall, this PhD thesis contributes with knowledge of how brightness levels affect human's experience of the atmosphere in an urban space, in relation to the architectural and social qualities of the space. Much research focus on lighting in relation to visibility and safety. While this project contributes with knowledge about how lighting influences experiences of the space, surroundings, co-presence and the activity being performed in the lighting setting.

This PhD thesis contributes with the concept of 'balanced brightness levels' which is the result of investigations of human's experience of brightness levels in a local space, in relation to brightness levels in the surrounding space. Since the urban contexts consists of a series of spaces that are visually connected, the lighting in a space should be investigated and planned with the overall context in mind. This became obvious in the field experiment, where a dimmed and balanced lighting setting led to a relaxed atmosphere as opposed to a tense atmosphere in a bright lighting setting. Furthermore, the dimmed lighting setting led to an increased feeling of safety because surroundings became visible.

These contributions are valuable when investigating and planning urban lighting because currently, the number of people living in cities are growing. Therefore, in public spaces and around urban infrastructure, lighting is important to support the use of the cities in the dark hours. The lighting of a city must be designed to highlight the qualities of an urban environment and make pedestrians appear in a pleasant light to support co-presence. As a result, cities can become more livable, functional, and sustainable and pedestrians will use the urban public spaces and infrastructure more during the evening hours.

4.3.2. CONTEXT-SPECIFIC FIELD STUDIES

This PhD also contributes with results from context-specific field experiments which indicates that brightness levels can be dimmed without compromising the feeling of safety. New insights in human experience of lighting were obtained by doing embodied field studies in a specific urban context. At this specific context, Nørreport tram station, the built environment was closely studied, and the co-presence of people and the activity of the place was considered while doing the studies. By walking, talking, and taking pictures during interviews, a vocabulary was developed, about experiences of the urban context in relation to the lighting setting.

These contributions are valuable for the understanding of human experience of atmospheres and safety in an urban context in the dark hours. The understanding is specific for Nørreport tram station and the surrounding context. It serves as an example which contradicts the preconceived assumption that higher brightness levels lead to increased visibility and safety. Bent Flyvbjerg calls this 'The force of the example' as opposed to formal generalization in scientific development (Flyvbjerg, 2006: 229). An increased understanding of human experience of dimmed brightness levels can inform general legislative requirements for outdoor lighting and make room for darkness and atmosphere in urban public spaces.

4.3.3. COMBINING METHODS

This PhD thesis also contributes with an example of how to combine methods in architectural lighting design research. In the four studies, both quantitative and qualitative methods were used, such as lab and field studies, with questionnaires or semi-structured interviews and with statistical or content analysis of the data. Combining methods is necessary in lighting research, because to study lighting includes both the technical, the spatial and the human aspects. Traditionally, research in lighting takes place in either natural science, social science, or arts/humanities. The studies in this PhD thesis have shown that the methods can be combined, and findings provide new perspectives on experiences of lighting in urban contexts.

There is a need for this knowledge because many researchers, particularly in the natural sciences, consider field studies conducted in urban complex contexts as biased. Some researchers in social sciences consider a lab study biased because the context is missing. It is the intention that the knowledge from this PhD thesis about combining methods, can provide inspiration to researchers from different research disciplines. And inspire to include other perspectives and methods from other disciplines in their future research.

This need for combining methods is addressed in two reviews from the book, 'Lighting design in shared public spaces' (Sumartojo ed., 2022). Paper 4 of this PhD thesis constitute one of the 10 chapters in this book. The reviews are included here to explain the reviewers' thoughts about needs for research about outdoor lighting and how the book contributes to these needs.

First review is from Nick Dunn, Executive Director, ImaginationLancaster, Lancaster University: 'This book responds to the important and urgent need to improve our understanding of lighting design and its application in built environments. By examining the experiential, complex relationships we have with light, it illustrates new interdisciplinary ways for conceptualizing and designing lighting towards a more sensitive and context-specific practice' (Routledge, 2022).

The second review is from Jean-Paul Thibaud, CNRS Research Director, ENSA Grenoble: 'This is a major book that provides an original alternative to the ideology of full light and to the dominance of technology in lighting design. By developing an atmospheric conceptual framework, this collective work subtly explores the diversity and complexity of the everyday lit world. This book will undoubtedly become a reference work' (Routledge, 2022).

This PhD thesis contributes to some of the needs described in these reviews. These are needs like; interdisciplinarity, sensitive and context-specific practice, and an atmospheric conceptual framework to explore the complexity of the everyday lit world.

4.4. DISCUSSION

The discussion is organized around the two research questions of the PhD thesis. The first section of the discussion relates to findings about human experiences. While the second section of the discussion relates to findings about combining methods.

4.4.1. HUMAN SENSORY EXPERIENCE OF ARCHITECTURAL AND SOCIAL URBAN CONTEXT

The field experiment showed the differences in human experience of either atmosphere or danger when brightness is dimmed. The theme of atmosphere vs safety is complex and related to several research disciplines. The field experiment, and the small number of test participants who participated in the experiment, can only give an initial idea of the problem, which should be further investigated.

Atmosphere
The difference between the test participants view on the dimmed brightness level at the stations were expressed in the go-along interviews. Eight out of ten respondents described the dimmed lighting setting in the waiting area in a positive manner. They used words like 'calming', 'relaxing', 'comfortable for the eyes', 'natural', 'cosy', and 'intimate' to describe the atmosphere in the sheltered area. But two test participants, a 22-year-old woman (TP3) and a 56-year-old man (TP2), had opposite opinions. They used negative words to describe the dimmed lighting setting, they felt unsafe in the dark.

The different opinions about lighting and darkness can also be found in research. Some researchers focus on the aesthetics of darkness and the atmosphere dimmed lighting can create. Pallasmaa argues that too much light can wipe away the sense of a place (Pallasmaa, 2012). Because shadows and darkness are essential, when the lighting is dimmed the peripheral vision is also used and the context is perceived in its entirety (Pallasmaa, 2012). Likewise, Dunn and Edensor explain how the aesthetics of darkness are often overlooked due to its association with danger (Dunn and Edensor, 2020).

While other researchers, within other research disciplines, darkness is connected to an unsafe feeling. Studies show that bright and uniform street lighting tends to be perceived as safer than dim and targeted lighting. Many of these studies are carried out in laboratories (Nasar, 2019), in living laboratories (Casciani, 2020) or on paths in parks (Rahm, 2021). Therefore, the context of the studies is not related to all the impressions an urban dynamic context consists of, because this is considered biased.

This PhD thesis seeks to investigate human experience of lighting in the urban dynamic complexity. Sensory and visual ethnography was used in the field experiment to get access to knowledge about this delicate balance between when dimmed brightness levels create a feeling of atmosphere and when a feeling of danger (Pink, 2021, 2015).

Safety
The same eight participants, as mentioned in the section about atmosphere, used negative words when they described the existing bright lighting setting using expressions and associations related to an unsafe feeling. Among the terms used were 'chaotic', 'exposed', and 'stressful', as well as associations such as 'prison yard', 'operating room', and 'feels like standing on an overlit island'. While the remaining two test participants expressed a feeling of safety when being in the existing bright lighting setting.

Within natural scientific studies research on safety in relation to e.g., brightness levels are often focused on facial recognition and object detection (Dong, 2015; Fotios, 2019; Markvica, 2019). The methods can consist of registrations of how brightness affects the perception of a face (a picture or a person) or of an object (such as an object on the ground). Often these studies show that a high brightness level makes faces and objects visible, and this is associated with a feeling of safety.

This PhD thesis seeks to examine safety in a broader perspective, where the feeling of safety is based on experiences in a context-specific urban space.

It was surprising how the regained visual contact with the surrounding environment increased the feeling of safety in the field experiment. This result showed a tendency which is opposite of the preconceived assumption that a high brightness level is connected to safety. This confirms that the subject is complicated and that context-specific field studies are necessary to get a broader perspective on the matter.

4.4.2. COMBINING METHODS TO EXPLORE EXPERIENCES OF BALANCED BRIGHTNESS LEVELS

Combining research methodologies
Researchers often prefer either to use lab or field studies in the work, as mentioned earlier. However, both practitioners and researchers point out that to study the complexity of lighting, methods need to be combined (de Kort, 2021; Narboni, 2016; Descottes, 2011). Hansen proposes the AE model for combining methods in a transdisciplinary process (Hansen, 2014). This model is based on research about innovative processes and knowledge sharing (Carlile, 2002, 2003; Meeth, 1978; Hargadon, 2002). An important component of the AE model is that it emphasizes the appropriate use of methods for investigating lighting. The methods are combined in a procedure where knowledge is collected in pre-analyses and followed by an experiment. Collaborations with researchers from other research disciplines are crucial to bridge the knowledge gaps in this process, as it is not possible to master all research disciplines simultaneously.

Sensitive and context-specific field studies
By performing studies in the urban context, it can be difficult to distinguish experiences of light from experiences of other impressions from the urban dynamic context. But in the lab, it can be difficult to access the human sensory experience and immediate

thoughts because of the lack of the real-life context.

Both research approaches are necessary in lighting research because with quantifiable results from lab studies, it is possible to compare with other studies and create general knowledge. However, when it comes to the experiences of atmosphere, the built environment and co-presence with other people field studies are appropriate. This PhD thesis find it essential to perform sensory ethnographic studies and to get access to test participants immediate thoughts about their experiences in embodied field experiments.

Luminance maps proved to be a useful tool to describe both quantitative and qualitative information about urban lighting and darkness. Information about luminance levels as well as the balance of the luminance levels in an urban context can be obtained in the luminance maps. In contrast to the horizontal light measurements used in legislative requirements for lighting, the luminance level is visualized from the point of view of a human. Horizontal lux measurements from legislative requirements are often used in practice to evaluate a lighting setting. This is because lux levels are easy to measure using a lux meter, but it does not offer any insight into the human experience of light (Dubois, 2019).

4.5. FUTURE WORK

This PhD thesis argues for the qualities of dimmed and balanced brightness levels in public spaces around everyday activities. This should be investigated further in future works within research e.g., in relation to exploring other urban contexts, other light parameters, and the use of lighting control in the studies.

In addition, the PhD thesis argues for sensory context-specific field studies and transdisciplinary research processes where methods are mixed. These methods might be further developed to inform practice and support the general standards and regulations with context-specific recommendations for urban lighting.

Research
Based on the findings in this PhD thesis, further investigations can be conducted, to understand how lighting affects human experience of the architectural and social urban context. For example, the concept of balanced brightness levels can be applied to other urban public spaces, than tram stations, to study other urban contexts and urban activities. This could be public spaces for everyday public activities such as bus stations and bus stops, areas around bridges and tunnels and places where areas for heavy car traffic need increased brightness levels but the brightness levels in surrounding spaces for people are not designed to meet human needs.

Further investigations could also be conducted to study the implementation of other lighting parameters around everyday public activities. These lighting parameters could be a combination of direction and distribution of light, color of light and color

rendering. If additional lighting could be added, to improve atmosphere and functionality, the level of this additional lighting could also be low because of the low general lighting. Additional lighting could be a spotlight to highlight a function or colored lighting to mark a meeting area. Unfortunately, additional lighting is seldom used in public spaces around everyday activities. Often only a general lighting is installed, with a certain brightness level matching demands in legislative requirements.

The results from the field experiment only briefly describes the importance of investigating and designing the control of lighting in relation to human movement and the specific activities in the space. Therefore, further investigations could be conducted to support the ongoing research on smart lighting. Presently, smart lighting initiatives are used to reduce power consumption, for example, lighting is dimmed in accordance with human presence. The findings of this project can inform future initiatives related to smart lighting, with a particular focus on the architectural and social potential of lighting in urban contexts.

A closer understanding of the human sensory experience of whether darkness is connected to the feeling of atmosphere or safety, can be investigated by exploring other urban contexts, other lighting parameters and the use of lighting control.

The methods used during the PhD study could also be further developed. These improvements could consist of collaboration with researchers in other research disciplines and by combining other methods in the transdisciplinary process. For example, the ethnographic methods and the go-along interviews could be further developed in terms of interview strategies, e.g., interviewing groups, and the use of other visual ethnographic probes, e.g., video. Methods including virtual reality or eye tracking might be used in field studies. While, brain activity and other biological responses might be measured in lab studies.

Practice
Further investigation should be made to match the knowledge from the PhD thesis to the needs of practice. Knowledge generated in this PhD thesis might serve as inspiration for architects, designers, lighting designers, and manufacturers of lighting fixtures and lighting control systems. This inspiration might be used to design lighting for the nocturnal use of public spaces, and for design of lighting fixtures and lighting control systems to match human needs. When planning lighting in relation to human needs, the scenographic lens might be used to interpret the use of lighting in a complex urban context. Municipalities, leaders of public construction projects, as well as citizens at large might benefit from the findings, as the concept of balanced brightness levels seeks to create more livable, functional, and sustainable public spaces.

Legislation
Standards and legislations concerning lighting for urban public spaces are by nature general demands. The rules are general to be able to cover general conditions in many

areas of an urban context. This PhD thesis argues for supporting these general demands with specific needs for lighting in the context-specific space being lit. The balance between the general demands and the specific human needs in specific contexts should be further investigated.

4.6.CONCLUSION

This PhD thesis represents the first study of the effects of brightness levels on tram waiting areas during the dark hours. A particular emphasis is placed on how dimming and balancing brightness levels might enhance the experience of the architectural and social characteristics of the city. Especially, this study investigates how differences in brightness levels can affect human sensory experiences of urban environments, and how these experiences may be explored through a transdisciplinary approach based on four studies.

A high level of brightness is often associated with visibility and safety when lighting is studied or planned for everyday activities in urban public spaces. Whereas a dimmed brightness level is often associated with danger. Furthermore, lighting is often evaluated and planned at a local space without considering the surrounding space when evaluating human experience. This PhD thesis questions these perceptions and practices and calls for the human sensory experience of dimmed brightness levels in the context-specific space to be considered in research and in practice.

An initial inspiration for this PhD thesis came from the use of lighting in the theater, where lighting creates atmosphere and combines context and narrative together. A comparison between lighting in the theater and in urban contexts led to a scenographic lens (study1). The scenograhic lens was used to analyse lighting around tram stations to examine the role of light in relation to context-specific urban space. A pre-analysis in the field showed that a high brightness level at the tram stations led to a tense atmosphere and to an experience of the surroundings being invisible (study 2). A pre-analysis in the lab revealed the importance of the brightness level in a space and the importance of the balance between brightness level in a local area and the brightness level in the surrounding space (study 3). Finally, the main field experiment gave further insights into the positive effects that a dimmed brightness level has on the feeling of atmosphere and visual connection to the surroundings (study 4).

The transdisciplinary process model ‘The Architectural Experiment’ (Hansen, 2014) was used to structure the process of the four studies and the implementations of methods from different research disciplines. This transdisciplinary process was necessary to obtain new knowledge about the complexity of lighting in the complex urban context. This knowledge concerns both technical, spatial, and social insights in the human experience of dimmed and balanced brightness levels in dark hours.

The results of context-specific experiments can provide insight into how dimmed and balanced brightness levels can enhance the architectural and social qualities of an urban environment. In addition, a dimming of the lighting will have sustainable benefits in cities regarding light pollution, biodiversity, and energy savings.

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LIST OF FIGURES

APPENDIX

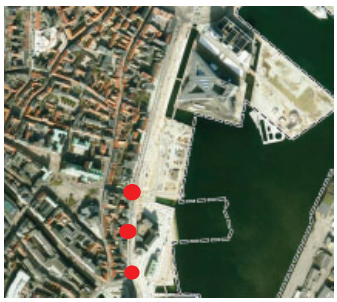
APPENDIX A - PRE-ANALYSIS FIELD, STUDY 2

The first empirical study was carried out at Skolebakken and Nørreport tram station in Aarhus from the 30th of January to the 1 th of February, 2019. Registrations were done in the morning from 6 - 8 a.m. and in the afternoon/evening from 4 - 6 p.m. The intention was to experience the two sites in twilight and darkness, during rushhour. Selected documents from planning and performing the study are presented on the following pages.

Skolebakken og Nørreport station

Scene 1,2 og 3 – ”moving towards the station”

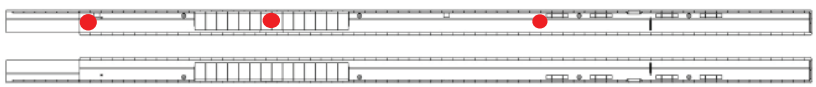
Skolebakken station



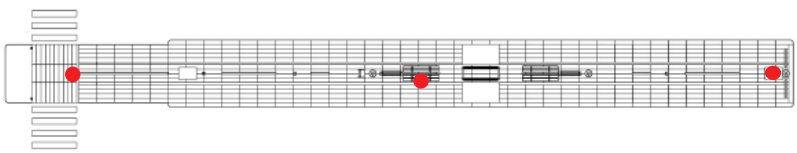
Nørreport station

og scene A, B og C ”waiting at the station”

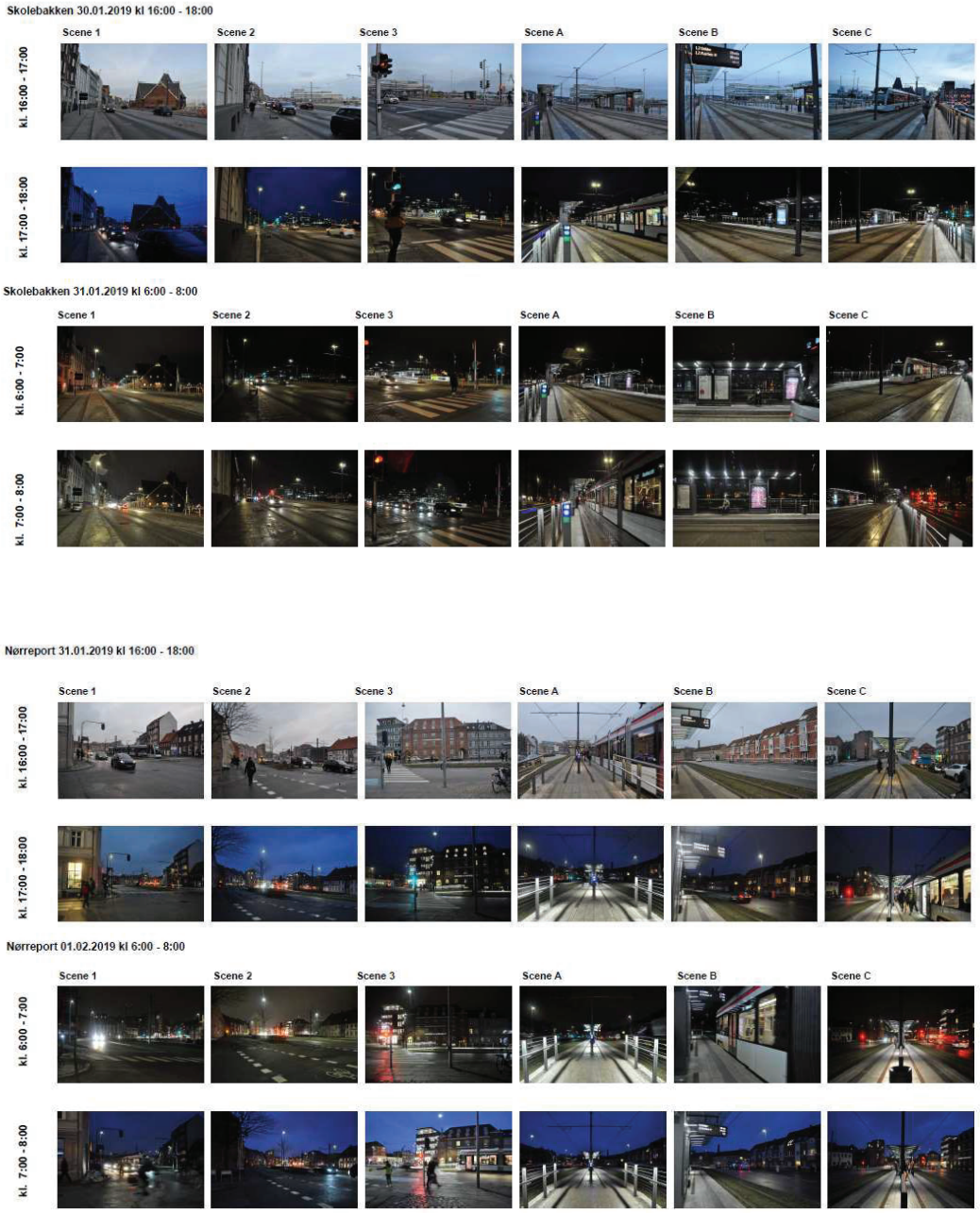
Skolebakken station



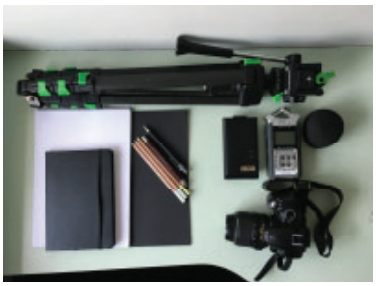
Nørreport station

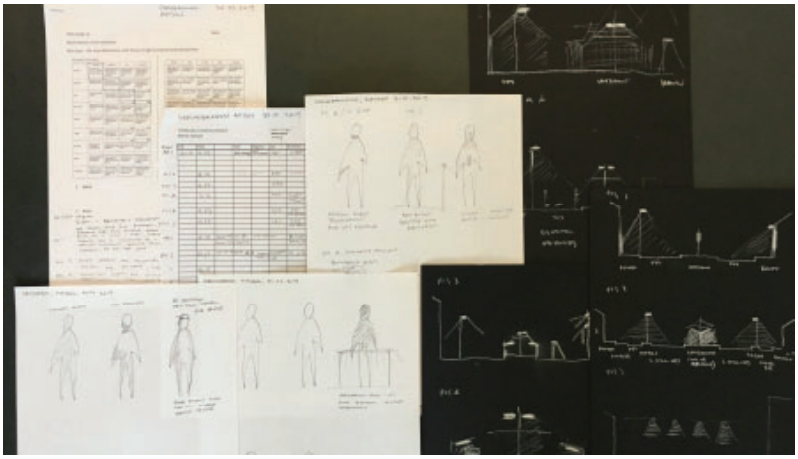


Route for serial vision photos



Serial vision photos





Equipement for observations, interviews and sketches

Interviewguide, Letbanen Aarhus, Skolebakken og Nørreport station
Sted:
Dato:
Tid:

Tema - Generelt
Køn:
Alder:
Hvor mange gange tager du letbanen om ugen:

Tema 1 – Rum
Station - Kan du beskrive rummet – er der nogle detaljer du vil fremhæve?
På afstand - Kan du beskrive byrummet – er der nogle detaljer du vil fremhæve?

Tema 2 - Lys
Station – Hvor opholder du dig når du er på stationen og hvorfor? Kan du beskrive lyset hvor du stiller dig?
På afstand – Når du går mod stationen er der nogle specielle ting ved lyset du hæfter dig ved?

Kan du beskrive hvor der er lyst med få ord?
Kan du beskrive hvor der er mørket med få ord?

Tema 3 – Fodgængeren / social interaktion
Hvordan vil du beskrive de mennesker du ser på stationen?
Hvad kan du se?
Kan du se deres ansigtstræk?
Betyder det noget for dig at du kan se menneskene omkring dig i det offentlige rum?

Hvordan vil du beskrive de mennesker du ser i bybilledet?
Hvad kan du se?
Kan du se deres ansigtstræk?
Betyder det noget for dig at du kan se menneskene omkring dig i det offentlige rum?

Tema 4 – Bevægelsen, handlingen
Kan du beskrive din bevægelse på stationen.
Hvor kommer du fra? Hvor stiller du dig? Og hvorfor?

Kan du beskrive din vandring mod stationen?
Er der noget du navigerer efter?
Hvad er bevægeligt i bybilledet?
Hvad står stille?

Afslutning - Har du nogle afsluttende kommentarer?

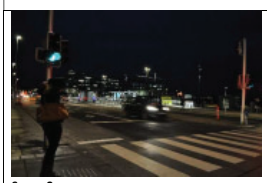
Afrunding af interview – Afrunding og opsummering

Interview guide

Observationer – "*moving towards the station*"
Skolebakken, 30.01.2019, kl. 17:00 – 18:00

Scene 1
Gadelys tændt, ny lyssituation i gadeplan
Himmel stadig blå
Kontraster, omgivelserne ændrer karakter, nye billeder "nye" omgivelser.
Mennesker bliver "sorte", detaljer kan kun ses tæt på
Sammen trafiksituation som før

Scene 2
Ingen mennesker, (midt på gaden, intet kryds)
"flydende trafik"
Lys fra biler giver blænding da kontrasten til vejbelysningen er stor



Scene 3
Flere biler, da de stopper op ved vejkryds
Lyset fra stationen blandes med vejbelysning og lyskryds "be
Mennesker stopper op og går over vejen når der er grønt
Mennesker, silhuetter, ses passere på rekreativt område.

Step 1 - Transskription	Step 2 - Recognizing	Step 3 - Coding
Skolebakken aften 20.02.2019 **1.** Station/position: Skolebakken Tid: 20.10 Retning: mod Dokken Person: Mand 50+ (med cykel) Letbane brug: 1 gang om ugen Setting: Lyst om dagen, har åbent mod havnen, godt at stationen er åben. Sikkert om aftenen Usikkert længere henne ved Navitas (det tilstødende område, kontorbygning) Kender ikke andre letbanestationer end denne Light: Adgangen til stationen er mørk (uden for letbaneområdet) Sætter sig altid under udhæng, lys fra udhænget og gadelyset Under udhæng er der læ og det er et privat rum Actor: Sikkert og behageligt rum Usikker hvis der er grupper af unge mennesker (fokus på lys og sikkerhed) Tydelige ansigter, Ok med lys på mennesker som kommer gående mod udhæng (havde ikke lagt mærke til "lys på benene problematikken") Hvis andet lys på ansigter, up-lights det går ikke Kommentar: altid spændende at tale om lys Play: Sætter sig samme sted hver gang, en vane. Venter samme sted under udhæng hver gang med sin cykel	Åbent sted Sikkert Mørke omgivelser, utryghed Sætter sig hvor lyset er (udhæng og gadelys) Læ og privat rum Mennesker er rigeligt oplyst Sætter sig samme sted / vane	Mørke tilstødende arealer, utryghed Åbent sted Læ og privat rum Sikkert Mennesker er rigeligt oplyst Sætter sig samme sted / vane
2. Station/position: Skolebakken Tid: 20.35 Retning: mod Nørreport Person: Kvinde 60+, ifølge med mand (havde ikke lyst til at snakke) Letbane brug: 1-2 gange om ugen Setting: Kontakt til byen, ligger godt i forhold til bymidten Tager lang tid at komme over lyskryds, meget trafikeret vej Stiller sig ved overdækket område i læ for regn og vind, sol ….det er som sådan et rum skal være, ingen yderligere kommentarer…. Light: Overdækning giver skygge Skarpt lys oppefra	Irritation i forbindelse med adgang til station (lyskryds) Stiller sig i læ for regn, vind, sol Lys giver sikkerhed Mennesker lette at genkende på stationen Mørke omgivelser Stiller sig samme sted, vane	Mørke omgivelser Lys giver sikkerhed Mennesker lette at genkende på stationen Stiller sig i læ for regn, vind, sol Stiller sig samme sted, vane Irritation i forbindelse med adgang til station (lyskryds)

Example transcription observations and interviews

APPENDIX B - PRE-ANALYSIS LAB, STUDY 3

The second empirical study was carried out in the light lab at aalborg University, Copenhagen. Registrations were done from the from the 13th to the 30th of January ,2020. Selected documents from planning and performing the study are presented on the following pages.

Eksperiment protokol:

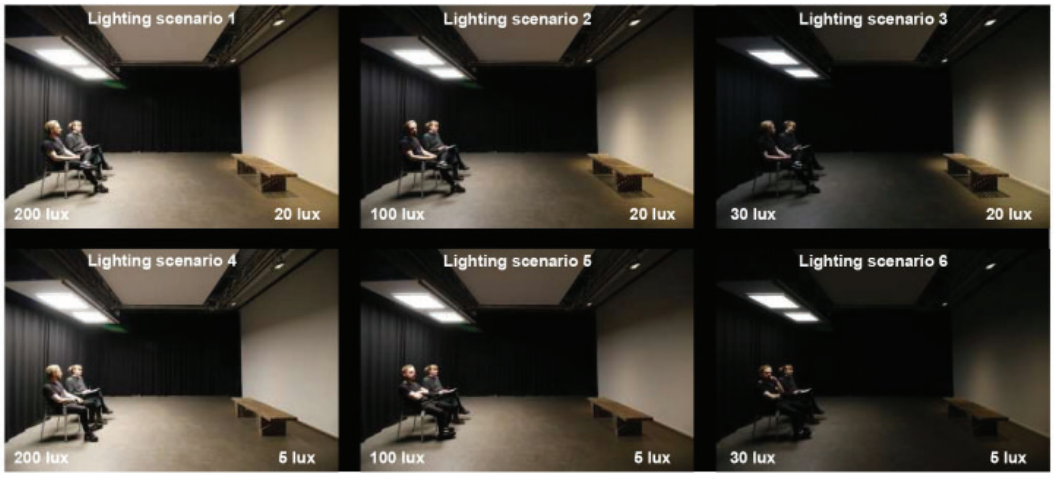
30 personer

Spørgsmål til oplevelsen af lys i det nære rum og i det omgivende, Semantic differental rating scale

6 lys scenarier. 3 lysscenarier (200, 100 og 50 lux) med 20 lux i omgivelserne og 3 lysscenarier (200, 100 og 50 lux) med 5 lux i omgivelserne. Lysscenarierne mixes.

Tid	**Aktivitet**	**Forløb**	**Lys indstilling**
3 min	Intro	1.Samtykke erklæring, projektinfo	Forrum
		2.Generelle oplysninger	
2 min	Intro	3.Beskriv test forløb: lysinstallation, scener og spørge skema	Testrum Gadelys
5 min	Test 1.1 (20 lux)	Spørgeskema	1.
0,5 min			7.Gadelys
3 min	Test 1.2 (20 lux)	Spørgeskema	2.
0,5 min			7.Gadelys
3 min	Test 1.3 (20 lux)	Spørgeskema	3.
0,5 min			7.Gadelys
3 min	Test 2.1 (5 lux)	Spørgeskema	4.
0,5min			7.Gadelys
3 min	Test 2.2 (5 lux)	Spørgeskema	5.
0,5 min			7.Gadelys
3 min	Test 2.3 (5 lux)	Spørgeskema	6.
0,5 min		Afrunding	7.Gadelys
Total 28-30 min.			

Research design



Serie A – 5 stk.	1.1 **(1)** – 1.2 **(2)** – 1.3 **(3)**		2.1 **(4)** – 2.2 **(5)** – 2.3 **(6)**
Serie B – 5 stk.	1.1 **(1)** – 1.3 **(3)** – 1.2 **(2)**		2.1 **(4)** – 2.3 **(6)** – 2.2 **(5)**
Serie C – 5 stk.	1.2 **(2)** – 1.1 **(1)** – 1.3 **(3)**		2.2 **(5)** – 2.1 **(4)** – 2.3 **(6)**
Serie D – 5 stk.	1.2 **(2)** – 1.3 **(3)** – 1.1 **(1)**		2.2 **(5)** – 2.3 **(6)** – 2.1 **(4)**
Serie E – 5 stk.	1.3 **(3)** - 1.2 **(2)** – 1.1 **(1)**		2.3 **(6)** - 2.2 **(5)** – 2.1 **(4)**
Serie F – 5 stk.	1.3 **(3)** – 1.1 **(1)** - 1.2 **(2)**		2.3 **(6)** – 2.1 **(4)** - 2.2 **(5)**

Lighting scenarios

Calibration readings, 03.07.2020

	Natural grey card	Light spot (Light fixture)	Dark spot (Black curtain)
LS1	0,682	1054	0,011
LS2	0,398	541,7	0,007
LS3	0,188	161,3	0,002
LS4	0,610	1057	0,010
LS5	0,295	538,3	0,007
LS6	0,116	173,3	0,001

Luminance measuremens

Outdoor lighting research, methods and questions

Forfatter	Test type	Light setting / modes of light	Subjective issues, percieved	Subjects for the rating scale	Scale
Jack L. Nasar, 2016/2017 Impressions of Lighting in Public Squares After Dark	24 virtual environments, it covered each combination of the three modes of lighting in each of three squares.	The illumination level (a physical measure of brightness), The distribution (uniformity), and The	Three salient aspects of human emotional appraisals of environments:		Likert scale
			preference	unappealing-appealing	
			excitement	dull-exciting	
			restfulness	unsafe-safe from crime	
John E. Flynn, 1979. A guide to methodology procedures for measuring subjective impressions in lighting	Guidelines	1) overhead/periferal. 2) uniform/ non-uniform, 3) bright/dim 4)visually warm/cool	Subjective impressions:		Semantic differental rating scale
			Visual clarity	**Clear-hazy**	
				Distinct - vauge (uklar)	
				Bright - dim	
				Faces clear - faces obscure (utydelig)	
			Spaciousness	Large - small	
				Spacious - cramped	
				Wide-narrow	
				Long - short	
				Horizontal - vertical	
			Evaluative scales	**Like - dislike**	
				Pleasant - unpleasant	
				Harmony - discord	
				Satisfying - frustrating	
				Beautiful - ugly	
				Interesting - monotonous	
				Cheerful - somber (dyster)	
			Relaxation	**Relaxed - tense**	
			Social prominence	**Public - private**	
				Faces clear - faces obscure	
			Complexity	**Simple - complex**	
				Uncluttered - cluttered (uoverskueligt, uorden)	
			identify the presence of Modifying influences	Warm - cool	
				Glare-non-glare	
				Colourful - colourless	
			Spatial modifiers	Focused-unfocused	
				Overhead-peripheral	
				Uniform - non-uniform	
				Non-spectacular - spectacular	
				Real - fantasy	
				Stable - unstable	
Maria Johansson, 2014. Perceived outdoor lighting quality (POLQ): A lighting assessment tool	Outdoor lighting on-site tests, LED lamp poles.	10 different conventional and led outdoor light sources in urban residential areas (table 1) (335 observations) illuminance, colour temperature, and colour rendering			
			percieved lighting qualities	Clear - (kedelig) Drab	
				Strong - Weak	
				Unfocused - Focused	
				Subdued (dæmpet) - Brilliant	
				Dark - Light	
				Mild - Sharp	
				Hard - Soft	
				Warm - Cool	
				Glaring - Shaded	
				Natural - Unnatural	
				Uncoloured - coloured	
				Scattered - concentrated	
				Flicker - no flicker (excluded)	
				Varied- monotonous	
				Uneven distributed - even distributed (excluded)	
				Pleasant - un pleasant	
			experienced visual acessibility	low visual accessibility - high visual accessibility	5 point Likert scale
			percieved danger	Low danger - high danger	5 point

Review, research methods and questionaire topics

Davoudian, N. 2011. Visual saliency of urban objects at night:Impact of the density of background light patterns. And 2017	Forced choice task compairing saliency of objects in pairs of images.	Two urban scenes in black and white photos. Four levels of background density and four levels of target background luminance contrast - 16 pictures. Luminance contrast of	Saliency value of the target object in different levels of background density and luminance contrast. (Friedman's test)	No, Low, Medium, High (Saliency)	
			Saliency value of target object in different levels of background density of light	No, Low, Medium, High (Saliency)	
Casciani, Daria. 2016: What does light do? Reflecting on the active Social Effects of Lighting Design and	Three lighting probes.				
	1.Social appraisal of street lighting. Living Lab Eindhoven, lighting influence on territorialisation and personalization.	Lightlevel changes connected to sensors, warm light. A path with people walking	Lighting influence on territorialisation and personalization. 'environmental experience' (Canter, 1986) that describes the space as a unit of physical attributes, emotional cognitions and human activities.	50 users were observed (focusing on body language, gestures, head movements and detournament) and 50 semi–structured interviews were conducted with audio recordings, followed by the transcript and clustering of quotations for	
	2.Social appraisal of square lighting scenarios; colour temp (3000-6000K) and lighting distribution (uniform - non uniform).	colour temp (3000-6000K) and lighting distribution (uniform - non uniform). A path with benches	Privacy / publicness, cosyness / detachment, safety)	atmospheric survey (Vogels, 2008) 40 questionnaires were administered followed by semi–structured interviews.	
	3.Social behaviours in a public/private shelter. Environmental testing room Politecnico Milan. Lighting shelter with integrated sensors for monitoring presence and body posture.	cold/varm - direct/indirect. A shelter with people sitting opposite each other.	sociopetal/sociofugal behaviours and social proximity	They were videotaped for research purpose and interviewed about the experience (20 interviews). Kobayashi (2013) and Magielse and Ross (2011),	
MS Rea, 2011, Toward a model of outdoor lighting scene brightness.	Three experiments with compairson of two scale model scenes to test outdoor brightness perception.	Typical lightlevels for outdoor lighting. Lightsourses with different spactral irradiance distribution and the impact on brightness perception.	Brightness perception	1. on which side does the overall scene appear brighter?	Comparison
				2. on which side is a specific object (e.g. the building facade, or each of the cars) brighter?	
SA Fotios, 2011, Brightness matching with visual fields of different types	Spatial brightness. Brightness matching experiments in which lamps of different SPD (spectral power distribution) were compaired in Side -by-side brightness matching tests, in four different visual fields	Four different design of "boxes". Achromatic, coloured objects, coloured surfaces, uniform field. And four different lamp types.	Brightness perception	(1) Does an illuminated achromatic interior environment produce the same outcome as an illuminated flat, uniform surface? (2) Does the insertion of coloured objects into an achromatic environment affect the outcome? (3) Does the presence of coloured surfaces in the achromatic environment affect the outcome?	Comparison

Review, research methods and questionaire topics

Oplevelsen af belysningen i venteområdet og i det omgivende rum

Hvordan opleves stemningen i venteområdet:

Afslappet *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **anspændt**

Tryg *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **utryg**

Behagelig *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **ubehagelig**

Spændende *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **kedelig**

Offentlig *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **privat**

Hvordan opleves medpassagerer i venteområdet:

Hvordan er ansigter oplyst

Behageligt *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **ubehageligt**

Hvordan påvirker stemningen socialisering

Motiverende *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **umotiverende**

Questionnaire

Hvordan opleves belysningen i venteområdet i forhold til belysningen i det omgivende rum

Harmonisk *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **uharmonisk**

Behageligt *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **ubehageligt**

Ikke blændende *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **blændende**

Hvordan opleves belysningen i det omgivende rum

Lyst *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **mørkt**

Objekt er tydeligt *: ___ : ___ : ___ : ___ : ___ : ___ : ___ :* **Objekt er utydeligt**

Questionnaire

Light scenario 6

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30
S1. Relaxed / tense	1	3	2	4	6	4	6	4	4	2	6	2	5	3	3	1	2	6	2	4	6	6	3	4	2	4	7	6	6	6
S2. Safe / unsafe	2	3	2	3	4	4	6	5	5	2	5	2	3	3	3	3	2	6	3	4	5	6	3	5	1	6	7	5	4	5
S3. Comfortable / uncomfortable	1	3	1	4	6	5	5	3	5	2	6	2	3	2	2	3	2	6	4	5	4	7	3	4	2	5	7	6	6	7
S4. Exciting / boring	4	5	4	4	4	4	7	3	4	4	4	4	5	4	3	5	1	6	5	3	3	6	3	4	5	4	2	4	6	6
S5. Public / Private	6	4	5	4	6	4	1	5	4	4	6	5	2	6	6	2	2	1	5	3	3	3	4	4	2	3	2	3	1	3
S6. Comfortable / uncomfortable (faces)	2	2	3	4	6	2	5	4	3	3	6	5	5	2	3	5	1	5	3	5	4	5	4	4	1	4	6	3	6	6
S7. Motivating / not motivating (for socializing)	6	2	3	3	7	3	6	3	3	4	4	3	5	3	2	5	3	6	4	5	5	6	4	4	1	5	2	5	6	5
S8. Harmonic / not harmonic	2	2	2	6	6	5	5	4	5	2	6	3	3	2	3	6	2	4	3	6	5	5	4	3	2	6	7	2	3	5
S9. Comfortable / uncomfortable	2	3	2	6	3	5	6	4	5	2	6	3	2	2	6	4	2	5	4	6	4	6	3	4	2	5	7	3	5	6
S10. Not glary / glary	1	2	5	2	2	5	3	2	5	2	2	2	2	2	6	5	4	1	5	1	4	5	4	5	3	5	6	3	6	5
S11. Light / dark	5	5	4	5	5	5	5	5	6	4	6	5	6	4	6	3	2	7	6	6	6	6	5	6	5	7	7	6	6	6
S12. Object (bench) is clear / Object is unclear	3	5	3	5	6	2	5	4	5	4	5	3	5	3	6	6	1	7	6	2	5	5	2	6	5	6	7	6	6	4

Light scenario 6

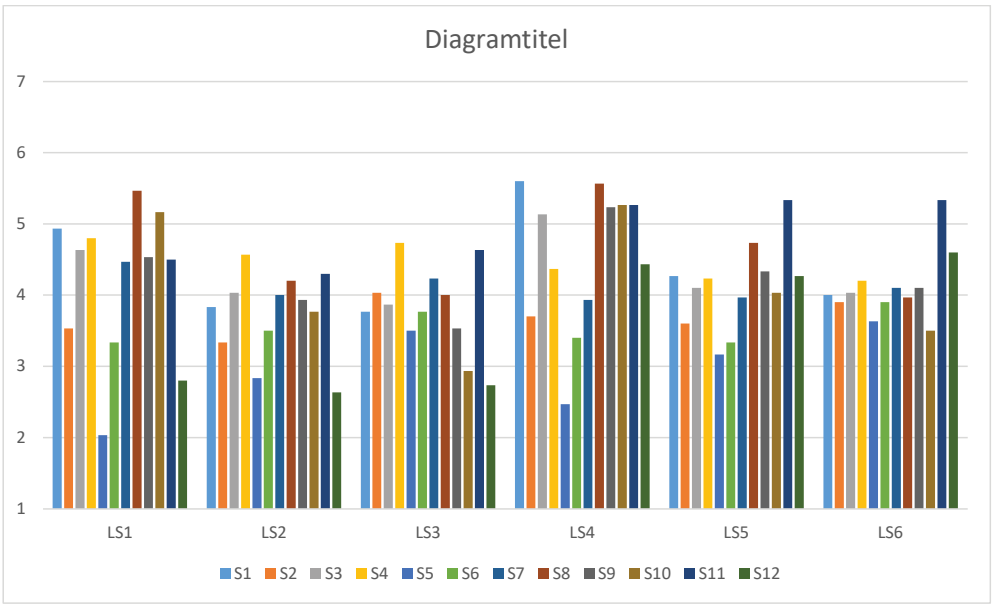
	T1	T2	T3	T4	T5	T6	T7	T8
S1. Relaxed / tense	1	3	2	4	6	4	6	4
S2. Safe / unsafe	2	3	2	3	4	4	6	5
S3. Comfortable / uncomfortable	1	3	1	4	6	5	5	3
S4. Exciting / boring	4	5	4	4	4	4	7	3
S5. Public / Private	6	4	5	4	6	4	1	5
S6. Comfortable / uncomfortable (faces)	2	2	3	4	6	2	5	4
S7. Motivating / not motivating (for socializing)	6	2	3	3	7	3	6	3
S8. Harmonic / not harmonic	2	2	2	6	6	5	5	4
S9. Comfortable / uncomfortable	2	3	2	6	3	5	6	4
S10. Not glary / glary	1	2	5	2	2	5	3	2
S11. Light / dark	5	5	4	5	5	5	5	5
S12. Object (bench) is clear / Object is unclear	3	5	3	5	6	2	5	4

Laboratorie forsøg – "Architectural and social potential of urban lighting" **04.05.2020**

	Lighting scenarios														
	LS2-LS1	LS3-LS1	LS4-LS1	LS5-LS1	LS6-LS1	LS3-LS2	LS4-LS2	LS5-LS2	LS6-LS2	LS4-LS3	LS5-LS3	LS6-LS3	LS5-LS4	LS6-LS4	LS6-LS5
S01-Question 1	**.007**	**.009**	**.005**	**.026**	**.037**	.917	**.001**	.192	.735	**.000**	.250	.543	**.001**	**.001**	.511
S01-Question 2	.418	.222	.512	.912	.127	.041	.197	.301	.166	.406	.295	.675	.585	.614	.373
S01-Question 3	.111	.104	.048	.138	.213	.683	**.006**	.911	.977	.020	.592	.565	**.005**	.059	.932
S01-Question 4	.366	.955	.156	.067	.146	.464	.525	.179	.345	.222	.028	.059	.356	.623	.732
S01-Question 5	**.008**	**.000**	.127	**.005**	**.000**	.110	.338	.214	**.036**	**.029**	.462	.740	.077	**.009**	.353
S01-Question 6	.789	.164	.908	.765	.143	.272	.883	.565	.203	.291	.182	.630	.764	.237	.110
S01-Question 7	.213	.588	.063	.170	.318	.477	.857	.837	.779	.577	.390	.918	.986	.799	.706
S01-Question 8	**.010**	**.004**	.707	**.043**	**.004**	.635	**.006**	.237	.559	**.001**	.131	.958	**.005**	**.001**	.137
S01-Question 9	.113	**.039**	**.017**	.262	.109	.296	**.001**	.215	.657	**.001**	.127	.126	**.023**	**.005**	.605
S01-Question 10	**.005**	**.000**	.826	**.015**	**.001**	.057	**.003**	.610	.576	**.000**	**.021**	.127	**.001**	**.001**	.187
S01-Question 11	.413	.611	**.028**	**.013**	**.032**	.206	**.003**	**.001**	**.003**	**.038**	**.022**	**.004**	.772	.966	.609
S01-Question 12	.585	.842	**.000**	**.001**	**.000**	.599	**.001**	**.000**	**.000**	**.000**	**.000**	**.000**	.412	.951	.419

First steps data analysis

Average



Lys scenarier:
LS1 – 200 lux venteområde/20 lux omgivelser
LS2 – 100 lux/20 lux
LS3 – 30 lux/20 lux
LS4 – 200 lux/5 lux
LS5 – 100 lux/5 lux
LS6 – 30 lux/5 lux

Spørgsmål som analyseres yderligere, har brugbare svar:
S1 (blå) Afslappet - anspændt
S3 (grå) Behagelig - ubehagelig
S5 (blå) Offentlig – privat
S8 (rødbrun) Harmonisk - uharmonisk
S9 (grå) Behageligt - ubehageligt
S10 (brun) Ikke blændende - blændende
S11 (mørk blå) Lyst - mørkt
S12 (grøn) Objekt (bænk) er tydeligt - Objekt er utydeligt

First steps data analysis

APPENDIX C - FINAL FIELD EXPERIMENT, STUDY 4

The third emperical study was carried out at Nørreport tram station. Registrations were done from the 9th -23th of November, 2021. Selected documents from planning and performing the study are presented on the following pages.

Screeningsnotat vedrørende letbanesikkerhed

(Skabelon 116-b-DK)

Projekttitel:	**Forsøg med sænkning af lysniveau på Nørreport Standsningssted**
Journalnr.	SLS-07-20-073-IR
Versionsnr.	1.0
Versionsdato	01.10.1010
Udarbejdet af	Mette Hvass / Martin Korgaard
Gransket af	Erik Hansen
Godkendt af (AAL)	Peter Morell

Indhold

Udarbejdet af: VIJ Gransket af: PEM Godkendt af: PEM	Skabelon 116-b-DK Rev. 4.0 Rev. dato: 08.09.2020	

CSM tilladelse

(Skabelon 116-g)

Informationer om CSM tilladelsen:			
Ansøger:	Aalborg Universitet v. Mette Hvass	**Intern udarbejder/ gransker/godkender:**	MAKD/MMO/PEM
Sagsnr.:	3P20011	**Udstedelsesdato:**	05-10-2020

CSM tilladelsen henfører til screeningsnotat:	
Screeningsnotatstitel:	Forsøg med sænkning af lysniveau på Nørreport Standsningssted
Journalnr.:	SLS-07-20-073-IR
Evt. bilag:	...

CSM tilladelsen omfatter følgende arbejder:

Der er givet tilladelse til midlertidig sænkning af lydniveauet på Nørreport Standsningssted i et nærmere aftalt tidsrum. Sænkningen sker som led i et forskningsprojekt, der skal undersøge lydniveauets indflydelse på hverdagsaktiviteter i byrummet.

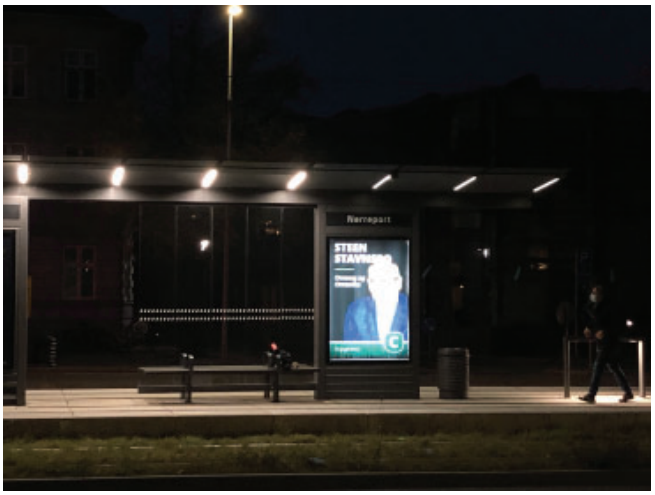
Der er givet tilladelse til de arbejder, der er beskrevet i screeningsrapporten, der er dateret 08.09.2020.

Vilkår for CSM tilladelsen:

- Det forudsættes at eventuelle øvrige tilladelser er blevet indhentet
- Aarhus Letbane skal orienteres om start og sluttidspunkt for forsøgsperioden, så snart den er fastlagt. Der forbeholdes ret til at afvise den ønskede forsøgsperiode, hvis der er omstændigheder ved driften af letbanen, der skal tages hensyn til.
- Der skal udføres en "mock-up", hvor lysniveauet i forsøgsperioden aftales. Martin Moth vil deltage fra Aarhus Letbane. Tidspunktet aftales nærmere. Martin kan kontaktes på mmo@aarhusletbane.dk

Udarbejdet af: VIJ Gransket af: MAKD Godkendt af: PEM	Skabelon 116-g Rev. 3.0 Rev. dato: 29.09.2020	Side **1** af **1**

Application and permission to test



Mock up, placing filters and test equipement

Vox pop interview
Go-along interview
Foto af stationen til luminance maps
Time lapses in twilight
Lux målinger

Standard belysning

Uge 46	Mandag 9/11	Tirsdag 10/11	Onsdag 11/11	Torsdag 12/11	Fredag 13/11	Lørdag 14/11	Søndag 15/11
6-7			Vox pop	Vox pop		Lux målinger	Lux målinger
17-18			GA-TP8	Timelapse	GA-TP9	Timelapse	
18-19	GA-TP3	Vox pop	Vox pop	GA-TP6	GA-TP10	Lum. maps	Lum. maps
19-20	GA-TP4	GA-TP5	GA-TP1	GA-TP7		Luminans målinger	Luminans målinger
20-21		GA-TP2					

Dæmpet belysning

Uge 47	Mandag 16/11	Tirsdag 17/11	Onsdag 18/11	Torsdag 19/11	Fredag 20/11	Lørdag 21/11	Søndag 22/11
6-7		Vox pop	Vox pop	Lux målinger			
14-17	Filtre, lys armaturer						
17 - 18	GA-TP10	Timelapse	GA-TP8	GA-TP6	Timelapse		
18-19	GA-TP2D	Vox pop	Vox pop	GA-TP7		Lum. maps	
19-20	GA-TP4D	GA-TP5D	GA-TP1D	Lux målinger	Luminans målinger	Lum. maps	
20-21	GA-TP3D	GA-TP9			Luminans målinger		

Feltstudie Aarhus Letbane november 2020

Demografisk information testpersoner

Go-along interview

Nummer	Køn	Alder	Brug af letbanen
GA1	K	22	Sjældent
GA2	M	56	Pendler
GA3	K	22	Sjældent
GA4	K	27	Pendler
GA5	M	29	Sjældent
GA6	M	25	Pendler
GA7	K	26	Pendler
GA8	K	69	Sjældent
GA9	M	59	Turist
GA10	K	56	Turist

Vox Pop standard

Nummer	Køn	Alder	Brug af letbanen
VP1S	K	27	Hver uge
VP2S	M	24	Pendler
VP3S	K	23	Sjældent
VP4S	K	17	Hver uge
VP5S	M	22	Hver uge
VP6S	M	20	Hver uge
VP7S	K	30	Hver uge
VP8S	K	25	Sjældent
VP9S	K	28	Pendler
VP10S	M	27	Sjældent
VP11S	M	23	Sjældent
VP12S	K	29	Sjældent
VP13S	K	32	Pendler
VP14S	K	29	Sjældent
VP15S	K	28	Hver uge

Vox Pop dæmpet

Nummer	Køn	Alder	Brug af letbanen
VP101D	K	26	Hver uge
VP102D	M	49	Hver uge
VP103D	K	22	Sjældent
VP104D	K	22	Sjældent
VP105D	K	21	Hver uge
VP106D	M	35	Pendler
VP107D	M	65	Sjældent
VP108D	K	23	Hver uge
VP109D	M	30	Pendler
VP110D	K	21	Pendler
VP111D	M	23	Pendler
VP112D	K	23	Sjældent
VP113D	K	32	Pendler
VP114D	K	23	Hver uge
VP115D	K	24	Pendler

Timetable and overview test participants

Test protokol for Go-along interview

Interview 1 – uge 46, standard belysning

Indledende snak med præsentation af test procedure – 3 trin + 3 billeder

1. Nørreport (foto)
   Togtur
2. Universitetsparken (foto)
   Togtur
3. Nørreport (foto)

Personlige oplysninger:
Testperson ID / Alder / Hvor tit bruger du letbanen

1. Nørreport
A. Hvor stiller du dig når du venter på toget, har du tænkt på hvorfor? (Place)

B. Hvis du kigger
på perronen? (Pe

C. Hvis jeg beder
(Surroundings)

D. Hvis du skulle
Både positivt og
Testperson tager

2. Universitetspa
E. Hvad ligger du

F. er der noget sa

G. Synes du at de
Testperson tager

Gennemgang fot
H. Vil du fortælle

I. har du historier
eller fra rejser /fr

3. Afrunding. Nø
J. Er der noget sæ

K. Er der noget sa
stationen og omg
Testperson tager

L. Du må meget g
interview med at
Tak for i dag

Test protokol for Go-along interview

Interview 2 – uge 47, dæmpet belysning

Indledende snak med præsentation af test procedure – 3 trin + 3 billeder

1. Nørreport (foto)
   Togtur
2. Universitetsparken (foto)
   Togtur
3. Nørreport (foto)

Er der noget generelt du har tænkt over siden vi mødtes i sidst uge?

1. Nørreport
A. Er der noget der falder dig ind i forhold til venteområdet, noget som er anderledes end sidst vi mødtes? (Place)

B. Ser menneskene på perronen anderledes ud? Kan du se dem? (People)

C. Hvis jeg beder dig om at lægge mærke til omgivelserne, hvad kan du så sige om dem?
(Surroundings)

D. Hvis du skulle sige noget om belysningen og stemningen her på perronen hvad kunne der så være? Både positivt og negativt (Ambiance)

Testperson tager billede 1

2. Universitetsparken
E. Hvordan opleves forskellen på Universitetsparken standsningssted og Nørreport standsningssted nu hvor belysningen er dæmpet på Nørreport?

Testperson tager billede 2

Gennemgang fotos (billeder fra første interview)

F. Hvis vi kigger på billederne fra interviewet i sidste uge har du så nogle bemærkninger i forhold til det du har oplevet her til aften?

G. Kan du fortælle om historier fra andre venteområder/situationer, giver den anderledes belysning dig nogle andre associationer?

3. Afrunding. Nørreport

H. Er der noget særligt du bemærker når vi kommer tilbage på Nørreport standsningssted, noget der er anderledes end ved sidste interview? Hvordan oplever du det at komme ud af toget?

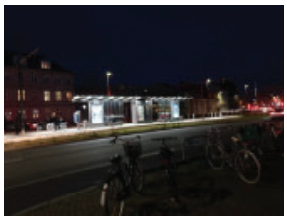
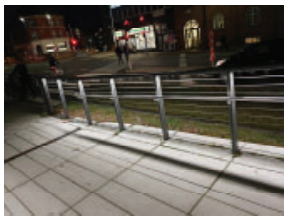
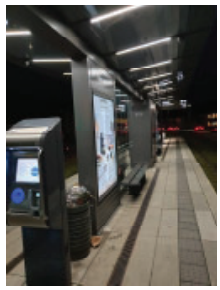
I. Er der noget særligt du vil fremhæve efter vores snak i dag i forhold til venteområdet, menneskene på stationen og den visuelle kontakt til omgivelserne?
Testperson tager billede 3

Tusind tak for din deltagelse - gave

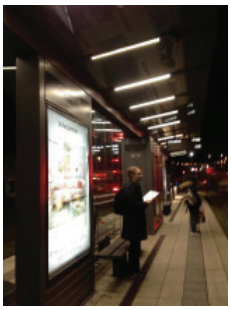
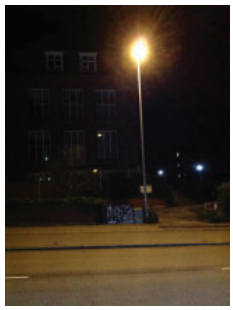
Interview guide go-along interviews

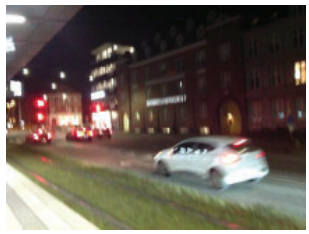
Interviews Nørreport Letbane standsningssted - Testperson 9

Billeder før første interview

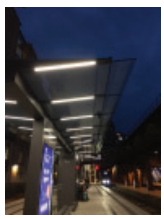
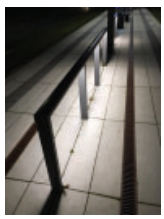
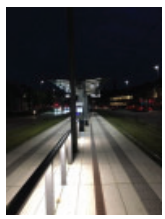
Billeder, første interview

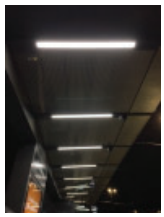
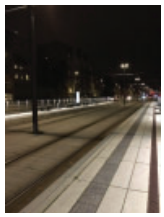



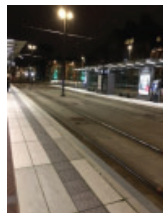


Interviews Nørreport Letbane standsningssted - Testperson 1

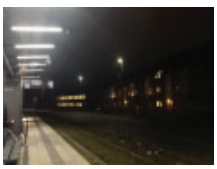
Billeder for første interview

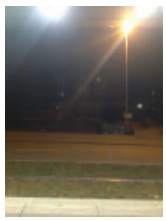







Billeder, første interview





Example, participant produced photos for the second go-along interview

Test Protokol for Vox Pop interviews

Uge 46 – standard belysning, uge 47 – dæmpet belysning

Interview 1 og 2

Kontakt deltager:
Vil du deltage i et kort interview på ca. 5 min?

Denne test er en del af et forskningsprojekt på Aalborg Universitet København om oplevelsen af det offentlige rum, med letbane som et eksempel.

Jeg vil stille dig nogle spørgsmål om hvordan du oplever stationen, mennesker og omgivelserne og bede dig om at vælge nogle ord fra en liste som beskriver dette.

Jeg vil optage vores samtale, du vil være anonym.

Spørgsmålsrunde:

A. Hvor stiller du dig når du venter på toget, har du tænkt på hvorfor? (Place)

B. Hvis du kigger på venteområdet, hvad ligger du så mærke til? (People)

C. Hvis jeg beder dig om at lægge mærke til omgivelserne lige her nu, hvad kan du så sige om dem? (Surroundings)

D. Hvis du skulle sige noget om stemningen her på perronen hvad kunne der så være? Både positivt og negativt (Ambiance)

Ordliste, stemninger:

Denne undersøgelse handler om belysningen på perronen, vi undersøger belysningens rolle for de ting jeg tidligere har spurgt ind til.

Hvis du skal sætte tre ord på hvordan synes du så at stemningen er her, ud fra denne liste?

Vis liste.

Afrunding:

Tak for din deltagelse

Interview guide vox pop interviews

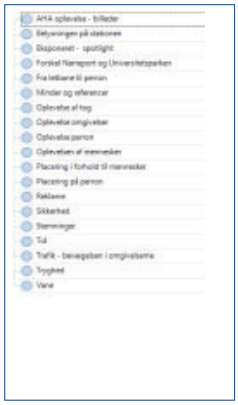
Afslappet	**Anspændt**
Tryg	**Utryg**
Offentlig	**Privat**
Motiverende	**Demotiverende**
Overblik	**Manglende udsyn**
Hyggelig	**Uhyggelig**
Behageligt	**Ubehageligt**
Nærvær	**Distance**
Formel	**Uformel**
Engageret	**Uengageret**
Personlig	**Upersonligt**
Naturligt	**Klinisk**

Vox Pop - Existing lighting setting			Vox Pop - Dimmed lighting setting	
VP-TP1E	Offentlig, formel, naturligt		VP-TP1D	trygt og afslappet
VP-TP2E	Uformelt, trygt		VP-TP2D	ingen holdning
VP-TP3E	funktionelt, formelt		VP-TP3D	uengageret
VP-TP4E	ingen holdning		VP-TP4D	Trygt, offentligt, uformelt
VP-TP5E	Offentlig, Klinisk, upersonligt, uformel, uhyggelig (kontrast til omgivelserne)		VP-TP5D	Offentlig, Upersonlig og klinisk Det plejer faktisk at være meget klinisk her, nu er det behageligt
VP-TP6E	Trygt, hygge eller behageligt		VP-TP6D	uformel, upersonligt, behageligt, offentligt
VP-TP7E	Offentlig, behagelig		VP-TP7D	ingen holdning
VP-TP8E	Offentligt, afslappet		VP-TP8D	Offentlig, upersonligt, unsafe
VP-TP9E	Offentlig, uformel		VP-TP9D	jeg ville nok vælge ord til den negative side,
VP-TP10E	offentligt		VP-TP10D	meget naturlig, upersonlig, hygge
VP-TP11E	Offentlig, Trygt		VP-TP11D	Distance, upersonlig Behageligt, velkomment
VP-TP12E	tryg og uformelt		VP-TP12D	Offentlig, formel, hyggeligere
VP-TP13E	Formel, tryg, afslappet, lyst		VP-TP13D	engageret
VP-TP14E	tryg og offentlig, og overblik		VP-TP14D	ingen holdning
VP-TP15E	Tryg, genkendelighed		VP-TP15D	distance, naturlig, rart

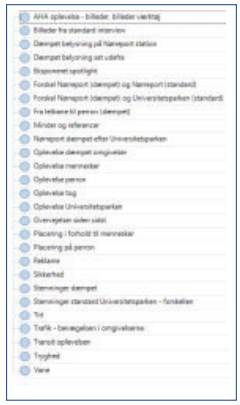
Atmosphere evaluations

Feltstudie
Dæmpning af belysning på Nørreport standsningssted
5. Analyse – første codning Nvivo

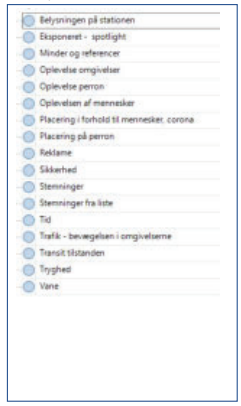
Go-along standard



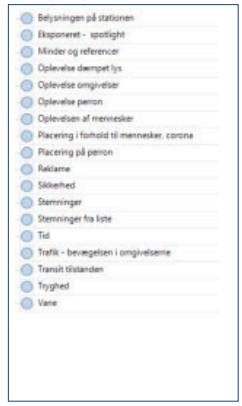
Go-along dæmpet



Vox Pop standard

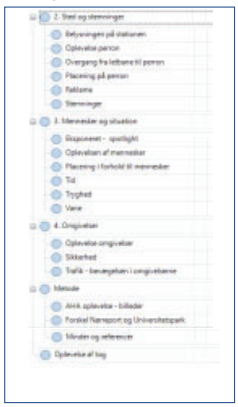


Vox Pop dæmpet

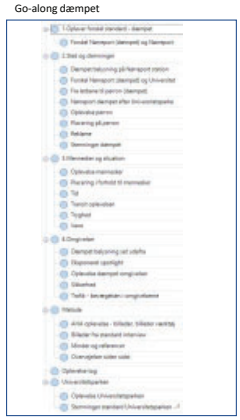


Feltstudie
Dæmpning af belysning på Nørreport standsningssted
5. Analyse – Anden kodning - kategorier

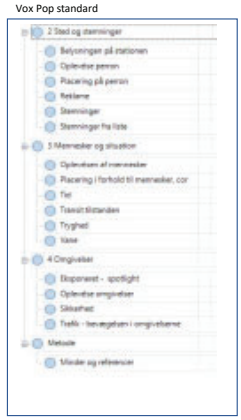
Go-along standard



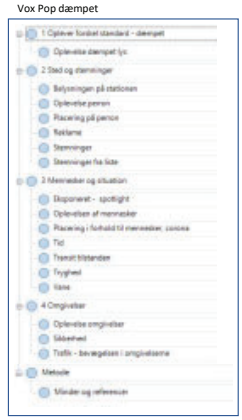
Go-along dæmpet



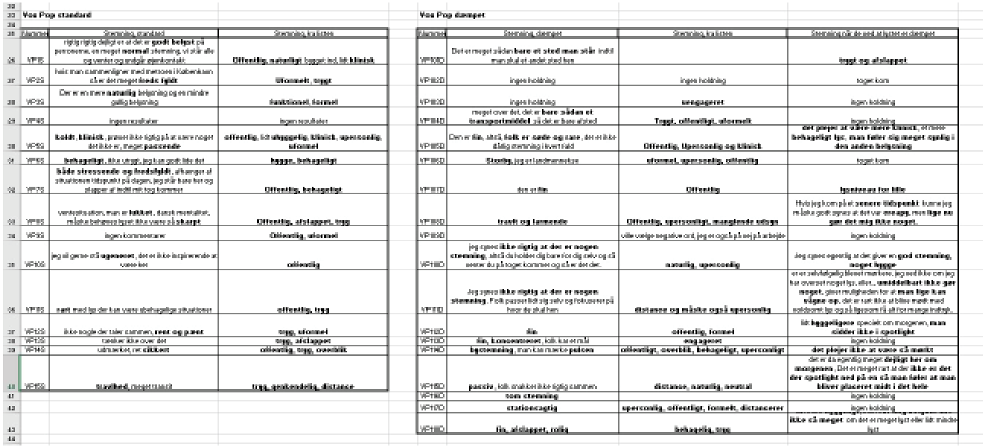
Vox Pop standard

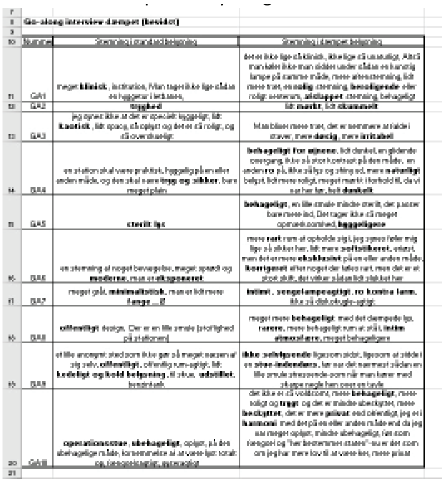


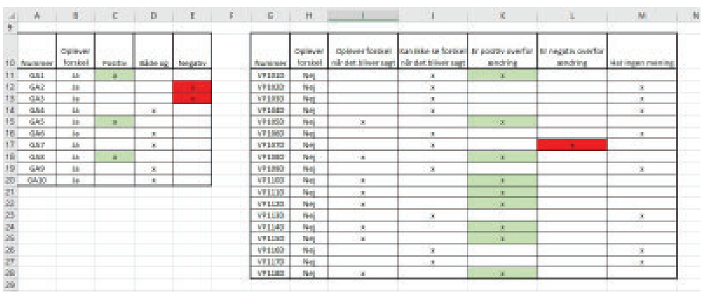
Vox Pop dæmpet



Examples, levels of thematic coding







Examples, levels of thematic coding

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