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Exploring how lighting affects humans' experiences of architectural and social urban contexts.

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Abstract.
This paper explores how lighting and darkness influence human experiences of architectural and social public urban contexts in dark hours. Tram stations in Aarhus, Denmark, are used as cases to investigate how brightness levels influence human sensory experience of the local space, the surroundings, co-presence with other people, and the activities performed in a specific context. Furthermore, this paper describes a transdisciplinary process, where methods from natural science, social science and arts/humanities are combined in three pre-analyses and a main field experiment. Lighting is often related to safety while darkness is related to fear. However, the findings from the main field experiment of this project indicate that lower and balanced brightness levels can sharpen our senses and create a relaxed atmosphere. Additionally, lower brightness levels enrich perceptions of and connections with spatial and social surroundings, thereby increasing perceived safety. We argue for context specific field experiments based on pre-analyses and the use of a transdisciplinary process, for drawing nearer to people's immediate senses when exploring experiences of urban lighting. The ultimate goal of the studies is to inspire to solutions that exploit the architectural and social potential of lighting by lowering and balancing brightness levels, all while reducing energy use and light pollution.

1. Introduction

1.1. Balanced brightness levels

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 at a tram station, n Aarhus, Denmark in the dark hours. During the field experiment test participants experienced first a bright and then 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, dimmed lighting)

We highlight this quotation because it represents an example of the human sensory experience of a balanced brightness level in an urban context. Immediate senses are formulated in response to the dimmed lighting, and both the architectural and the social aspects of lighting are mentioned. The feelings of both the atmosphere in the dimmed lighting setting (being in harmony), and perceived safety in the bright lighting setting (being a target and exposed), can be interpreted due to the choice of words of the test participant.

The field experiment constitutes one out of four studies in a PhD thesis about lighting in the urban

context. The four studies were performed over a period of three years. They consists of three pre-analyses (study 1, 2 and 3) and a main field experiment (study 4):

Study 1 was performed as a literature study of how lighting and darkness are used in scenography to enhance atmosphere and the dramaturgy of a play. The purpose of the study was to compare the use of lighting in scenography and in urban public spaces to collect inspiration for how lighting and darkness can enhance the architectural and social qualities of an urban space [1].

Study 2 was performed as a field study, a qualitative explorative study about the role of lighting at two tram stations in two different urban contexts. The purpose of the study was to investigate if the lighting supported the architectural and social qualities at the two tram stations and to deside a direction for the research in study 3 and 4 [2].

Study 3 was performed as a lab study, a quantitative study of human experiences of six lighting settings. The purpose of the study was to examine human experience of different ratios of lighting between two lit spaces. The two lit spaces were a) one lit local space where the test participant was placed and b) a surrounding lit space [3].

Study 4 was performed as a field experiment and the experiment was based on the results from the three pre-analyses (study 1, 2 and 3). The purpose of the field experiment was to study human sensory experience of two lighting settings, with different ratios of lighting between a local space (a tram station) and the surroundings (the urban context around the station), in a real-life context [4].

This paper describes how human experiences of lighting were collected and how the theme of balanced brightness levels (hereinafter BBL) was formulated in the process of the four studies. The focus of this paper evolves around the main field experiment and how this experiment contributes to the field of lighting design research. The pre-analysis in the field (study 2) and the pre-analysis in the lab (study 3) are briefly described to explain how these studies lead to the main field experiment (study 4). Furthermore, the paper describes how research methods from natural science, social science and arts/humanities were combined in a transdisciplinary process of conducting the four studies. 'The Architectural Experiment' – model [5] was used to structure this process. The four studies are further described in two conference papers, a journal paper, as well as a book chapter [1,2,3,4].

1.2. Urban lighting – understanding the effects of lighting

Research on the experience of urban lighting has a long tradition of utilizing an engineering approach with a focus on visibility and perceived safety [6,7,8,9]. In recent years, interest in how lighting affects human behavior and social interaction has increased in social science [10,11]. Likewise, researchers in architectural lighting design have received inspiration from the notion of social lighting [12]. However, knowledge about the role of lighting in urban contexts as seen from an architectural point of view seems to be lacking. There is a need for a holistic architectural approach to lighting research which combines knowledge about the ability lighting has to; create atmosphere, enhance the visual identity of a space, support design intentions, and to ensure that both the technical and the social properties of lighting are incorporated.

Lighting designer Roger Narboni states that a holistic thinking is needed in outdoor lighting design. He sees the need to change from light urbanism, where lighting is designed to produce visibility. According to Roger Narboni, lighting should be adapted to nocturnal urbanism in the future. The lighting should adapt to '*citizens' needs, new infrastructures, and new ways of using the city after dark*'[13]. To support this change from light urbanism to nocturnal urbanism, we need to study humans' experiences of lighting in different urban contexts and to combine research disciplines. Peter Boyce states: *'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' [14]. Likewise, Yvonne de Kort emphasizes that tests should be done in field studies after the effect of light has been confirmed in the laboratory [15]. Furthermore, she describes that she seeks to gain knowledge about lighting in relation to, for example, vision, comfort, health, performance, the atmosphere, and energy savings, and this requires collaboration between various research fields and combining methods [15]. In line with these statements, this project is aimed at fostering a deeper understanding of how lighting can be adapted to nocturnal urbanism by combining methods from various research fields and conducting a field experiment based on pre-analyses in a specific context.

2. Aim

The aim is to increase understanding of how brightness levels affect the human sensory experience of architectural and social urban contexts, and how these experiences can be explored in a transdisciplinary process.

3. Background

3.1. Sustainable urban infrastructure

Globally, the majority of the earth's population lives in cities, and it is estimated that this urbanization will be further developed in the future. An energy-efficient infrastructure is necessary to support the development of sustainable cities [16]. A political decision in 2013 led to an agreement about a national green transport policy in Denmark, and tram infrastructures in the three largest cities became a part of this initiative. When it comes to increasing the use of public transportation, the pedestrian's experience of using public transportation plays an important role [17]. In Denmark, it is dark for half of the year when people commute to and from work. Therefore, to ensure attractive public transportation, we need to investigate not only how lighting can create visibility but also how lighting and darkness can enhance the experience of architectural and social urban contexts.

Tram stations were chosen as a case for studies of the architectural and social potential of lighting in outdoor spaces for several reasons. The tram represents a sustainable infrastructure and at the time this project started the tram had just been taken into operation. Furthermore, the tram stations are placed in different urban, suburban, and rural contexts and as the project developed it was possible to focus the studies on a specific context. The focus became urban stations, and one specific context were chosen for the final experiment to concentrate on how the lighting and darkness could enhance the architectural and social qualities of this specific context. Additionally, one of the industrial partners of the PhD project, Holscher Design, was in charge for the design of the tram stations. This collaboration gave access to information about design intentions and how the lighting design had been implemented during design and construction phases of the stations.

3.2. Lighting influencing architectural and social urban contexts

The architectural urban context, refers to lighting and darkness in relation to the atmosphere of the space [18,19,20] and the physical context, such as the buildings, objects, space, surroundings, materials, surfaces, etc. With architectural lighting design, one should ensure that the shapes of objects are visible, shadows are present, colors and textures are visible in a local space, and details in the physical surroundings are visible. While, the social urban context refers to people in the urban built environment, the co-presence of people, and their behavior in a public space. The social values of lighting can be described as, being able to see people in a pleasant light in a local space, as well as the ability to see people in the surrounding space. These values also include creating a safe and relaxed atmosphere that provides social enhancement, accessibility, and hospitability [12], as well as creating lighting that supports human behavior and the activities performed in the space [11].

3.3. Brightness, illuminance, and luminance levels

To describe levels of lighting, both unmeasurable and measurable terms have been used, due to the transdisciplinary nature of this project. Brightness is unmeasurable, as brightness describes the

subjective experience of light. Brightness describes the state of the light–dark pattern in the eye and the actual pattern of brightness in the field of vision [21]. Illuminance and luminance are measurable. Illuminance describes the amount of light that falls on a surface, measured in lux [21]. While luminance describes the amount of light reflected from a surface, measured in candela per square meter (cd / m2) [21]. As luminance measures the light leaving a surface in a specific direction, luminance better describes how the human eye perceives a surface's brightness [22]. For many years, existing lighting standards and regulations have relied mainly on the illuminance levels on horizontal surfaces, likely because they are easy to measure (with a lux meter). Current standards also include luminance, although illuminance is still the more commonly used measure in practice [22].

3.4. Human sensory experience

During studies, emphasis is placed on the fact that experiencing outdoor lighting is a human sensory experience, which should be experienced by being bodily present in the urban environment [23]. 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 [14]. Sound, smell, and touch are also human senses that have an influence on how a place is experienced [24]. 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'* [19].

This project seeks to get an understanding of how human sensory experiences of the lighting and darkness can be collected in the urban complex context, where countless factors can have an influence on how the architectural and social context is experienced. Presence of lighting in the urban space can often be taken for granted by people who are not used to talk about experiences of lighting [10]. Therefore, a combination of research methods is used to seek to understand test participants' vocabulary about experiences of lighting and darkness.

3.5. Balance between lighting and darkness – atmosphere and perceived safety

Lighting is often associated with safety and darkness with fear. However, too much light can *'wipe away the sense of a place'* as Pallasmaa describes it [23]. 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'* [25]. Nick Dunn and Tim Edensor explore the multiple meanings and uses of darkness across time and space. Specifically, they look at how darkness has been laden with negative attributes throughout history, forgetting the positive aesthetic and sensory experiences that darkness can create. They draw attention to this historical tradition of relating darkness to danger and lighting to safety in urban spaces without considering the aesthetical values of darkness [26]. 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 perceived safety [26]. Throughout time, phenomenologists have described the connection among light, darkness, and the atmosphere. In his work about atmospheres, Böhme uses the stage as a metaphor to highlight a situation in which light and darkness are tools for producing atmospheres [27]. Similarly, Pallasmaa states: *'Deep shadows and darkness are essential, because when the sharpness of vision is dimmed the unconscious peripheral vision and tactile fantasy is invited'* [23].

Nonetheless, we also need lighting at night. The benefits of light at night are described by Peter Boyce as greater safety for pedestrians and reduced fear of crime [6]. Regulations and standards for lighting provide general rules to ensure that the illuminance level is sufficient in relation to safety and visibility

in urban contexts. At the tram stations in Aarhus, Denmark, the illuminance level was based on two norms: 'Bane Norm BN2-81-1' [28] and 'Danske Vejregler, standsningssteder for letbaner' [29].

This project focus on perceived safety defined as subjective experiences of safety [30]. The investigations focus on perceived safety in relation to the lighting in the local space, where a person is situated, combined with, the importance of being able to perform long-range detection of possible threats, in the surroundings [30,31,32]. Leon van Rijswijk and Antal Haans highlight that there may exist an intuitive or learned association between lighting and safety, such as the mere presence of lighting may directly affect people's perception of safety of an environment [30]. This intuitive or learned association is challenging for studies of perceived safety and therefore different approaches should be used to gain understandings of this. Lighting research conducted primarily in lab studies shows that test participants feel safer if the illuminance level is higher [7,8,9,33]. This project seeks to combine research methods and investigate the balance between atmosphere and perceived safety both in a lab study and in a field experiment in relation to a specific urban context.

To structure the research and to frame the four studies, the following two research questions was asked:

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?

4. Methods

4.1. Research methods – research disciplines

Methods for exploring outdoor lighting vary within research disciplines. Within natural science, research on outdoor lighting is primarily focused on measurable facts and reproducible quantitative tests. Research mainly involves lab studies in controlled environments to eliminate biased findings. The results must be quantifiable through measurements or questionnaires, which can be statistically analyzed. In social science, humans are studied in urban environments after dark with a focus on how artificial lighting is experienced in different situations and how these experiences affect behavior. Research is primarily done through field studies, interviews, and observations. Finally, when it comes to research within the arts/ humanities, the architectural investigation of scale, spatial hierarchy, and the atmosphere is rooted in the architectural design tradition of experimentation in a real context. Methods are combined, and a problem is often examined through field studies; observing spaces and people, and registering through photos, sketches, models, or mock-ups. The three disciplines represent three approaches to research. To understand the complexity of lighting and particularly the experience of brightness levels, we study how to combine the research methods.

4.2. The architectural experiment – a transdisciplinary process model

The combination of methods and knowledge across research disciplines in the BBL project is based on the transdisciplinary process model 'The Architectural Experiment', hereinafter the AE model (figure 1) [5]. The AE model illustrates a transdisciplinary and knowledge-based design process in horizontal steps 1-5. The three vertical criteria represent knowledge and methods from three research disciplines, natural science, social science, and the arts/ humanities, which become part of the design process in each step. The AE model is aimed at crossing research boundaries and refers to theories on innovative processes such as 'knowledge boundaries' [34] and 'knowledge brokering' [35], combined with theories on design research [36]. The AE model has been used throughout the BBL project to structure the process and the implementation research methods for each study.

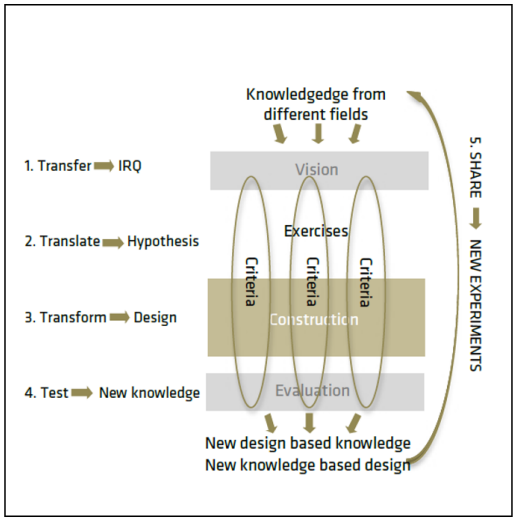

Figure 1. The AE model [5]

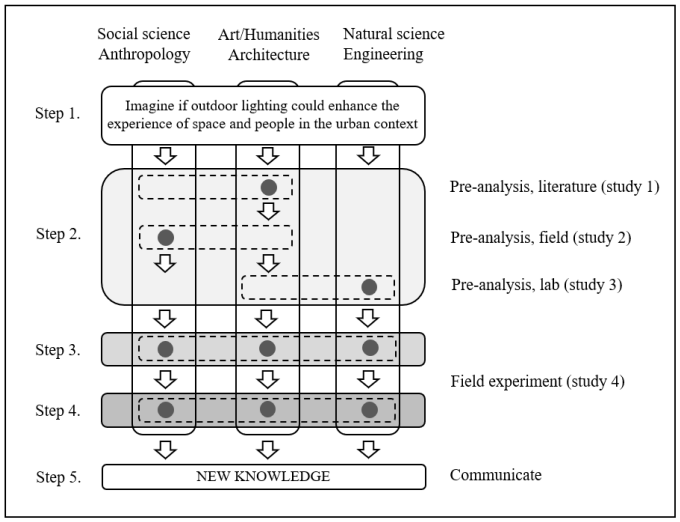

Figure 2. Process model for the BBL project

4.3. Combining disciplines in the BBL project

The horizontal bands in figure 2 illustrate how the four studies of the BBL project are related to the steps of the AE model. The vertical bands illustrate research disciplines. The black circles illustrate the main research approach of each study, and the dotted lines illustrate the fact that methods from other research disciplines have been used during the study. The arrows illustrate how knowledge from one study has been transferred to the next. During the field experiment (study 4), knowledge from the pre-analyses (study 1,2 and 3) was implemented for formulating the research design (step 3) as well as for performing and evaluating the results (step 4). Meanwhile, research methods from natural science, social science, and the arts/ humanities were combined and incorporated into the process. Overall, figure 2 illustrates how the BBL project is aimed at crossing knowledge boundaries by combining knowledge and methods in all stages of the project. In the following two sections, the methods used in the three pre-analyses and the field experiment are described briefly further information can be found in papers about the studies [1,2,3,4].

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4.4. Pre-analyses in the field and lab

Study 2, the pre-analysis in the field [2], was based on ethnographic methods, anchored in social science. This was combined with an architectural approach to analyse space and atmospheres. During three days in January 2019, a total of 20 people participated in short interviews while they were waiting for the tram at two tram stations. James P. Spradley's descriptive question matrix was chosen for action-based data collection [37,38]. The interviews was supplemented with photo registrations and observation of the spaces, people, and activities at and around the stations [39].

Study 3, the pre-analysis in the lab [3], was primarily based on methods from natural science. The study was performed in a period of three weeks in January 2020 in the lighting lab at Aalborg University, Copenhagen. The experiment included 30 participants who experienced six lighting settings with different ratios of brightness levels in a lit zone where the test participant and the interviewer were placed and a lit zone representing the surrounding space. Information where gathered through a questionnaire with semantic differential scale. Through twelve questions test participants were asked about their experiences of the atmosphere in the local space, co-presence with other people, and perceptions of the surrounding spaces during the six lighting settings.

4.5. Field Experiment, Study 4

The field experiment took place in November 2020 at the Nørreport tram station during two weeks. One week with the existing bright lighting setting and one week with a dimmed lighting setting. The existing

illuminance level was measured to approx. 165 lux in the sheltered waiting area and in the surroundings, a level of approx. 1- 6 lux was measured along the facades. The illuminance level was dimmed approx. 80% in the sheltered area in the dimmed lighting setting.

During the main field experiment both methods from arts/humanities, social science and natural science were combined. The research was conducted in collaboration with anthropologist Karen Waltorp from Copenhagen University. Her anthropological methods were combined with the architectural methods of the authors and to measure illuminance and luminance levels, engineering methods were used.

Ethnographic interviews were conducted as comparative go-along interviews with participant-produced pictures. The go-along interviews included 10 participants. The interviewer met each participant at the Nørreport tram station twice, in the existing bright lighting setting and in a dimmed lighting setting. The interview included a tram ride to the nearby station and back again. Each recorded interview lasted approx. 30 minutes. At each interview, the participants were asked to comment on the atmosphere in the waiting area , the experience of the surrounding urban context, the experience of co-presence with other people, and the experience of lighting in relation to activities being performed [24]. Participant-produced pictures were taken before the first meeting, during the first interview, and then during the second interview [40]. During the interview, the test participants were asked to take pictures with an Ipad in relations to the topics discussed.
Architectural methods used on site were observations, sketching, photo registrations and time lapse videos which registered experiences of rhythms of daylight, urban light, traffic, and people [41,42].
Engineering methods were used to gather quantitative data about illuminance and luminance levels, such as lux measurements on horizontal surfaces at ground level at the station and on the pavement in the surroundings. Likewise, luminance measurements were performed on vertical surfaces at the station and on the surrounding buildings (at selected points at eye height), and through luminance maps based on high dynamic range (HDR) photos [43].

5. Results

5.1. Pre-analyses in the field and lab

Study 2, the pre-analysis in the field. Field notes were transcribed and analyzed through qualitative traditional coding [44]. It was found that the brightness level in the sheltered area at the station was out of balance in relation to the brightness level in the surrounding context. The high differences in the brightness levels made the architectural and social qualities of the space invisible, as the contrast could not be compensated for with the human-sensitive night vision [2].

Study 3, the pre-analysis in the lab. Answers from the questionnaires were analyzed separately using Friedman analyses of variance (ANOVAs). For quantifying differences in luminance levels among the six settings, luminance measurements and luminance maps calculations were performed. When the balance between brightness levels was examined in a lab study (study 3), the results showed that the low brightness level in the local space increased the perception of the atmosphere as being relaxed and private. Furthermore, the low contrast in the brightness level ratio between the local space and the surrounding context increased the perception of the area as being relaxed and harmonious [3].

5.2. Field Experiment, Study 4

The recorded interviews were transcribed and coded in Nvivo12. First, a deductive sorting of the data was performed to detect and recognize themes. Subsequently, an inductive coding of the data was performed to introduce new angles and perspectives to the project. The findings from the go-along interviews in the field experiment (study 4) demonstrated that the sensory experiences of space and people in the urban context was affected in the dimmed lighting. The participant-produced pictures (study 4) were effective for understanding the participants' immediate thoughts about the experience of lighting in the urban context. The pictures led to sudden realizations and triggered memories for the

participants [40]. It was discovered that issues that were difficult to describe in words was easier to describe when the test participant explained the content in a picture. During this process, a vocabulary was developed. Dimming and adjusting the brightness level according to the surrounding brightness level created a relaxed atmosphere at the station for those waiting for the tram. A connectedness to the surroundings and the people there was felt, thus increasing the feeling of perceived safety. The adjustments of the brightness levels also helped to ensure the visibility of the architectural and social qualities of the urban context. While waiting at the station, the majority of the people appreciated the dimmed lighting. But when test participants arrived at the station and got off the tram, they perceived the brightness level as too low due to the high brightness level in the tram.

Luminance maps (figure 3) provided measurable facts about the luminance levels in the urban scene as well as a visual hierarchy of the luminance levels. The luminance maps also revealed how the sheltered area at the station became transparent, as intended by the designers, when the brightness level was lowered. By lowering the brightness level, in the sheltered area, the lighting was not reflected the glass panels which divide the platform into two parts and the surroundings became visible again.

Figure 3. Photos and luminance maps illustrating how brightness levels are balanced when the lighting is lowered in the sheltered area at the station; the surroundings became visible when the contrast was lowered (study 4).

6. Discussion

The findings from the BBL project illustrate the fact that by combining methods in a transdisciplinary process, we can obtain a nuanced understanding of how lighting can influence architectural and social qualities in the urban context. In the lab test, general knowledge was produced and proved to be valuable for the design of the context specific field experiments. This revealed that lowering and balancing brightness levels resulted in increased visibility, a relaxed atmosphere, and a higher level of perceived safety.

The American philosopher and pragmatist John Dewey argue that problems and situations in practice should dictate which methods should be used to investigate a problem [45]. One cannot have knowledge about the world without being an actor in it, as bodily experiences related to a topic, or a problem should be gained in the actual context to acquire access to participants' immediate senses [46]. While the specialist in lighting research, Yvonne de Kort, points out that when it comes to lighting research tests should be done in the field after the effect of light has been confirmed in the laboratory [15].

In existing research on urban lighting, opinions about lowering brightness levels are diverse within the research disciplines. When illuminance levels are lowered, some would investigate changes in perceived safety whereas others would investigate changes in experience of atmospheres alone. But can this balance between light/darkness and safety/atmosphere be established? Humans have different needs, and each urban context has different circumstances that should be taken into consideration. Regulations and standards give general recommendations about urban illuminance levels, but the findings about visibility, the atmosphere, and the perceived safety in these studies advocate for the idea that general recommendations should be supplied with context specific recommendations.

7. Limitations

The findings of this study must be seen in light of some limitations. Lowering illuminance levels at a tram station caused security concerns for Aarhus Tram and a permission was difficult to obtain which caused delays. In addition, several limitations were related to the COVID-19 pandemic e.g., recruiting test participants and investigating the social potential of lighting when people had to cover their faces with masks. A week before the field experiment at Nørreport tram station began, restrictions regarding the COVID-19 pandemic were announced. Due to warnings concerning a second 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.

8. Conclusion

The conclusion should be seen in relation to the above-mentioned limitations which caused that the amount of test participants was reduced to ten people. Further studies should be performed to support the conclusions presented below.

The conclusion can be divided into collected knowledge about how lowered and balanced brightness levels affect the human experience of the architectural and social urban contexts and furthermore, knowledge about methods for exploring lighting in the urban context.

First, the BBL project contributes information on how an urban context is experienced when brightness levels are lowered and balanced. Three important findings are presented:

- In the lab (study 3) and the field experiment (study 4), atmosphere was perceived as relaxed when brightness was lowered and balanced.
- Through lowering and balancing brightness levels, an increased visual connection to the people in the surroundings was established, and this led to an increased feeling of perceived safety.
- Spatial connectedness and social connectedness between the space and the surroundings, as well as the humans there, were established when the brightness level was balanced.

Second, the BBL project provides an example of how to explore the complexity of lighting in the complex urban context. Three important approaches are pointed out:

- Through conducting research in a context specific field experiment, it was possible to focus on brightness in relation to spatial characteristics, the humans present, and specific activities being performed.
- Performing ethnographic go-along interviews with participant-produced images gave access to participants' immediate senses. Thoughts about light, space, co-presence with other people, and activities, were described in the situation, in the own words of the test participants, while walking, talking, and taking pictures.
- Luminance maps showed both quantitative and qualitative details about the luminance levels and the ratio of luminance levels in a local space (the station) and the surrounding urban context.

The BBL project indicates that outdoor lighting can facilitate more than being able to see in the dark. It explores how the balance between lighting and darkness, as well as the balance between the brightness level in a local space and its surroundings influence the human sensory experience of the atmosphere, perceived safety, and spatial and social connectedness. The project provides an example of how a lower brightness level can lead to more visibility when the lit urban context is taken into consideration, and when the nature of nocturnal urbanism in a specific context is taken into consideration.

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References
[1] Hvass M & Hansen E K 2019. Potentials of light in urban spaces defined through scenographic principles. *NAF Symposium*, June 2019. Proceedings Series 2021-1
[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. *Proceedings PLEA Conference,* September 2020
[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**, 107680
[4] Hvass M, Waltorp K & Hansen E K 2022 Lights out? Lowering Urban Lighting Levels and Increasing Atmosphere at a Danish Tram Station. In *Lighting Design in Shared Public Spaces* edited by Shanti Sumartojo pp. 151-172 (New York: Routledge)
[5] Hansen E K & Mullins, M 2014 Lighting Design: Towards a Synthesis of Science, Media Technology and Architecture. *Smart and Responsive Design*, vol **2** pp 613-620
[6] Boyce P R 2019 The benefits of light at night. *Building and Environment* vol **151** pp 356-367
[7] Boyce P R, Eklund N H, Hamilton B J & Bruno L D 2000 Perceptions of safety at night in different lighting conditions, *Lighting Research and Technology* vol **32** pp 79–91
[8] Nasar J L & Bokharaei S 2017 Impressions of lighting in public squares after dark, *Environment and Behavior* vol **49** pp 227–254
[9] Fotios S & Gibbons R 2018 Road lighting research for drivers and pedestrians: the basis of luminance and illuminance recommendations, *Light. Res. Technol.* vol **50** pp 154–186
[10] Sumartojo S and Pink S 2020 *Atmospheres and the Experiential World - Theory and Methods* (New York: Routledge)
[11] Slater D, Sloane M & Entwistle J 2015 *Configuring light: Staging the Social*. http:// www.configuringlight.org/. Accessed 10. October 2020
[12] Casciani D 2020 *The Human and Social Dimension of Urban Lightscapes* (Cham: Springer)
[13] Narboni R 2016 From light urbanism to nocturnal urbanism. *Light & Engineering* vol **24** pp 19-24
[14] Boyce P R 2014 *Human Factors in Lighting*, Third Edition. (CRC Press; Taylor & Francis Ltd.)
[15] de Kort Y 2021 Opinion: On becoming smart. *Lighting Research and Technology* vol **53** p 4
[16] United Nations. *World Urbanizations Prospects 2018: Highlights*. New York, USA
[17] Rahm J & Johansson M 2016 Walking after dark - A systematic literature review of pedestrians' response to outdoor lighting. *Environmental Psychology Monographs* vol **26**
[18] Rasmussen, S E 1966 *Om at Opleve Arkitektur* (København: Gads Forlag)
[19] Pallasmaa J 2014 Space, Place and Atmosphere: Emotional and Peripheral Perception in Architectural Experience. *Lebenswelt* vol **4** pp 230-245
[20] Zumthor P 2006 *Atmospheres. Architectural Environments. Surrounding Objects (*Basel: Birkhäuser)
[21] Tregenza P & Loe D 2014 *The Design of Lighting* (New York: Taylor & Francis)
[22] Dubois M C, Gentile N, Laike T, Bournas I & Alenius M 2019 *Daylighting and Lighting under a Nordic Sky* (Lund: Studentlitteratur AB)
[23] Pallasmaa J 2012 *The Eyes of the Skin: Architecture and the Senses* (Chichester: Wiley-Academy)
[24] Pink S 2015 *Doing Sensory Ethnography* (London: Sage)
[25] Böhme G 2017 *The Aesthetics of Atmospheres* ed J P Thibaud (London: Routledge)

[26] Dunn N & Edensor T 2020 *Rethinking Darkness: Cultures, Histories, Practices* (London: Routledge)
[27] Böhme G 2013 The art of the stage set as a paradigm for an aesthetics of atmospheres. *Ambiances* vol **315** pp 2 -8
[28] Banedanmark 2015 Banenorm BN2-81-1. https://www.bane.dk/da/Leverandoer/Krav/Tekniske normer og regler/Banenormer.
[29] Vejregler, standsningssteder for letbaner http://vejregler.lovportaler.dk
[30] van Rijswijk L & Haans A 2018. Illuminating for safety: Investigating the role of lighting appraisals on the perception of safety in the urban environment. *Environment and behavior*, vol **50** (8) pp 889-912
[31] Boyce P R & Gutkowski J M 1995. The if, why and what of street lighting and street crime: A review. *International Journal of Lighting Research and Technology*, vol **27**(2) pp 103-112.
[32] Caminada J F & Van Bommel, W J M 1984. New lighting criteria for residential areas. *Journal of the Illuminating Engineering Society*, vol **13**(4) pp 350-358
[33] Johansson M, Pedersen E, Maleetipwan-Mattsson P, Kuhn L & Laike, T 2014. Perceived outdoor lighting quality (POLQ): A lighting assessment tool. *Journal of Environmental Psychology*, vol **39** pp 14-21
[34] Carlile P R 2002 A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development *Organization Science* vol **13** pp 442-455
[35] Hargedon A B 2002 Knowledge Brokering: Linking Learning and Innovation. *Research in Organizational Behavior* vol **24** pp 41-85
[36] Koskinen I, Zimmerman J, Thomas B, Redström J & Wensveen S 2011 *Design Research Through Practice. From the Lab, Field, and Showroom* (Croydon: Elsevier)
[37] Spradley JP 1980 *Participant observation* (New York: Rinehart and Winston)
[38] Spradley J P 1979 *The ethnographic interview* (New York: Rinehart and Winston)
[39] Cullen G 1997 *The Concise Townscape* (London: Architectural Press)
[40] Pink S 2021 *Doing Visual Ethnography* (London: Sage)
[41] Edensor T 2012 *Geographies of rhythm: Nature, place, mobilities and bodies*. (Ashgate: England)
[42] Lefebvre H 2013 *Rhythm Analysis: Space, Time and Everyday Life* (London: Bloomsbury)
[43] Inanici M 2006 Evaluation of high dynamic range photography as a luminance data acquisition system, *Lighting Research and Technology*, vol **38** pp 123-136.
[44] Bjørner T 2015 *Qualitative methods for consumer Research*. (Copenhagen: Hans Reitzels)
[45] Brinkmann S 2013 *John Dewey, science for a changing world* (New York: Routledge)
[46] Dewey J 1934/1980 *Art as Experience* (New York: Perigee Books)