Henrika Pihlajaniemi

DESIGNING AND EXPERIENCING ADAPTIVE LIGHTING

CASE STUDIES WITH ADAPTATION, INTERACTION AND PARTICIPATION
HENRIKA PIHLAJANIEMI

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Case studies with adaptation, interaction and participation

Academic dissertation to be presented with the assent of the Doctoral Training Committee of Technology and Natural Sciences of the University of Oulu for public defence in Apaja Auditorium of the Oulu School of Architecture (Aleksanterinkatu 4–6) on 15 January 2016, at 12 noon

UNIVERSITY OF OULU, OULU 2016
Abstract

This thesis explores the design and experience of adaptive lighting. In this research, adaptive lighting is understood as a wide concept referring to lighting which adapts to information about the environment and its users or to other information relevant to intended lighting behaviour. Adaptive lighting is approached as an element of architecture and urban space, which has an influence on the human environmental experience at various levels. The research can be defined as architectural design-based research as well as transdisciplinary research. This research explores design practice by analysing the design processes of three case studies through the research-by-design method. The essential design phases, design tasks and design methods are recognized and presented. In addition, the experiences of adaptive lighting are explored with the help of empirical qualitative research material, which is gained through evaluation of the case studies. The methods used in evaluation include in situ walking interviews and evaluation probes. In the case projects situated in urban environments and in a retail space, different forms of lighting adaptation, interaction and participation were studied.

The design process of adaptive lighting can be theorized, based on the three case studies, as a three-phase process consisting of several subtasks. The design process is guided by several design factors. In the design process, cooperation with experts of interaction and system design is beneficial. The users’ experience of adaptive lighting environments is complex and multifaceted. The experiences emerge in each environment as context-related interpretations or manifestations of the general experiential aspects. Finally, adaptive lighting is conceptualized in the thesis as a holistic design task by formulating a framework for pragmatic-experiential and context-oriented design of adaptive lighting. This defines adaptive lighting as a design task from the perspectives of multifaceted users’ experience and pragmatic constraints of design practice.

Future design processes should acknowledge the complexity of the design task. Then adaptive lighting can offer, besides energy savings, added value for illuminated environments on many levels of experience. The main significance of this study is to help both designers and clients to understand the diversity of the new design task, and to help to approach it from human-oriented perspective—from the perspective of inhabitants of the environments.

Keywords: adaptive lighting, architectural lighting, architecture, design, design process, design method, experience, intelligent lighting, interaction, lighting design, participation, urban lighting
Tiivistelmä


Tulevaisuuden suunnitteluprosessissa tulisi huomioida suunnittelutehtävän monimuotoisuutta. Näin mukaantulona valaistus voisi tarjota energiansäätöjä ohella valaistuhiin ympäristökustaa lisäävää toimintaa useilla kokemuksen tasoilla. Tämän työn päämerkityksenä on auttaa sekä suunnitteluloita että suunnittelun tilaajia ymmärtämään uuden suunnittelutehtävän monimuotoisuus ja auttaa heitä lähdestysemään sitä ympäristön käyttäjien näkökulmasta.

Asiakas: arkkitehtuuri, arkkitehtuurivalaistus, kaupunkivalaistus, kokemus, mukaantulona valaistus, osallistuminen, suunnittelumenetelmä, suunnitteluprosessi, valaistusSuunnittelma, vuorovaikutus, älykäs valaistus
To Aini and Helka
Acknowledgements

First of all, I would like to thank warmly my supervisors, Professor Helka-Liisa Hentilä and Professor emeritus Jyrki Tasa from Oulu School of Architecture, the University of Oulu, for their invaluable guidance and support. With Jyrki I commenced this long journey in the research world and, finally, arrived to this end point (or checkpoint, as more correctly articulated) with Helka-Liisa’s firm support. I am also sincerely grateful to the pre-examiners of my thesis, Associate professor Ellen Hansen from the Aalborg University and Professor Panu Lehtovuori from the Tampere University of Technology. In the last part of this process, they provided me with insightful assessment and constructive advice on how to strengthen the academic argumentation of my thesis. Furthermore, I wish to express my warm thanks to Associate professor Ellen Hansen and Professor Johan Verbeke for agreeing to be my opponents. Also, I would like to thank Professor Anna-Maaja Ylimaula and the late Professor Jan Vervijnen—the leaders of the Future Home Graduate School—for guiding me into the world of academic inquiry and for introducing its relevant methods and procedures.

A substantial portion of my thesis research was done as part of two research projects: the Adaptive Urban Lighting project and the SparkSpace project. I warmly thank the leader of the projects in the Oulu School of Architecture, Doctor Aulikki Herneoja. Besides research collaboration, I thank Aulikki for over-a-decade-long period of teaching together. I would like to thank especially a fellow researcher M.Sc.(Arch) Toni Österlund for an intriguing research cooperation, which has been a really rewarding process and sometimes an exciting "agent story". M.Sc.(Arch) Anna Luusua as well as Doctor Johanna Ylipulli and Doctor Tiina Suopajärvi from Ubi Metrics and Ubi Mingle research projects, and M.Art Minna Teirilä from Department of Art Studies and Anthropology, I wish to warmly thank for collaboration in evaluation of our lighting pilots, even in extreme weather conditions. I am grateful to Doctor Pia Markkanen for research collaboration in SparkSpace project and for helping me in finalizing the dissertation layout according to Acta publication series requirements. I also thank the aforementioned persons for inspiring academic conversations and interesting multi- and interdisciplinary writing processes together. Additionally, I thank M.Sc.(Arch) Tuulikki Tanska and M.Sc.(Arch) Annina Valjus for assisting in the research and pilot processes in numerous ways.

In addition, I would like to thank warmly the following persons from VTT Oulu (research projects SparkSpace and ITEA Emphatic products) for collaboration with a lighting pilot: Senior scientist Vesa Pentikäinen and researchers Esa-Matti Sarjanoja, Satu-Marja Mäkelä, Tommi Keränen, Ville Valjus, Juho Eskeli, Sari Järvinen, Tomi Rätty, and Niko Reunanen. Also, I thank Hannu Kukka, Toni Hakanen, Ossi Salmi, Tommi Heikkinen, and Timo Ojala from the UBI Urban Interactions projects, the University of Oulu, for their kind support and the possibility to use the UBI infrastructure of Oulu. Furthermore, I want to thank research assistant Jarmo Vähä as well as students of Multimedia systems course in the Department of Computer Science and Engineering.

For enabling this research, I would like to express my gratitude to the funders of the research projects—the Academy of Finland and the Finnish Funding Agency for Innovation TEKES. I also thank the business partners of SparkSpace project as well as our pilot sponsors and cooperators: Arkkitehdit m3, CoreFactory, Granlund Kuopio, Helvar, Ruokakesko, SRV, Talomat, Valopaa, Valtavalo, Fagerhult, Philips, City of Oulu and Energy company Oulun Energia Urakointi Oy. In addition, I gratefully acknowledge all the funding bodies and agencies that have supported my research career at some point. These include University of Oulu Scholarship foundation, Tekniikan edistämissäätiö, Valtion rakennustaidetoimikunta, Emil Aaltonen foundation, The Finnish Cultural Foundation North Ostrobothnia Regional Fund, Tauno Tönning Foundation, Arts Promotion Centre Finland, Finnish Cultural Institute in New York, University of Oulu Faculty of Technology, and University of Oulu Graduate School.

Furthermore, I want to thank Professor emeritus Kaj Nyman and Professor Raine Mäntysalo for inspiring conversations and guidance in the early phase of my research. Also, I have been participating in the activities of two fellow researchers’ communities which have provided me valuable peer support. The
first community was the Future Home Graduate School, which offered research training for a multidisciplinary group of researchers from different design-related fields with the challenge of developing design-based research. I would like to thank all the fellow doctoral students, and especially the “tutkijatoverit” of our small group, for delightful academic and non-academic discussions both in seminars and in more informal contexts. The second community was “Verta” group, which we established for peer support in the Oulu School of Architecture. Even though the community has recently been less active, I want to thank all the members of Verta for encouraging sessions with intriguing conversations.

In addition, I want to thank kindly all the study participants, who have shared their experiences and views of the pilot projects and provided me with an extremely rich and interesting research material.

Finally, I would like to thank warmly my parents Leena and Veli as well as my sisters Inka, Elina and Helena for their support and encouragement. My sister Elina, I also thank for the consultation with issues of grammatical correctness. My beloved daughters Aini and Helka, I thank for genuine and trusting encouragement as well as patience towards this thesis project. Thank you for making your wishes, after finding the almond in the Christmas porridge, about completion of your Mother’s thesis. This Christmas, it is finally completed. Last but not least, I thank my dear husband Janne for his time, friendship, love, support and understanding along the years, as well as for his critical and insightful comments. I think we are quits now.

Oulu 7.12.2015
Henrika Pihlajaniemi
**Abbreviations**

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1 Introduction

1.1 Research subject and objectives

The subject of this doctoral thesis is adaptive lighting. The aim of this research is to produce new knowledge of a novel design task—adaptive lighting—from both designer’s and experiencer’s perspectives. My research questions relate to design process and design methods and to users’ experiences of environments with adaptive lighting. In addition, the thesis aims to define the new design task from the perspective of users’ experience.

Due to the recent development of lighting control and sensor technologies, the designers of architectural and urban environments are confronted with new design challenges and possibilities. The concept of ‘adaptive lighting’ is usually defined as an intelligent system, where the lighting dynamically adapts to the presence of people or current environmental conditions, through data transmitted by different sensors (Hughes & Dhanny 2008). Striving for energy savings is quickly introducing intelligent lighting control and adaptive lighting into different contexts: traffic environments, urban spaces and buildings. The application into built environment has been for a great deal technology-driven; thus, the design has been concentrated on technical aspects of the system and optimization of energy consumption. On the other hand, new lighting control technology has been applied in experiential ways in light and media art installations and in media façades and media architecture.

As a phenomenon, adaptive lighting has still been seldom researched. The few research publications that concern interior lighting, focus especially on control of artificial lighting based on daylight availability, user presence or user control (Wen, Granderson & Agogino 2006, Wen & Agogino 2011, Veitch et al. 2008) and concerning outdoor lighting, on optimization of road lighting and control systems (Ekrias et al. 2008, Collins et al. 2002, Guo et al. 2007, Casa & Veroni 1999, Chung et al. 2005). The perspective in the research has been mainly technical and other design criteria besides energy consumption have seldom been covered, although there are exceptions (Magielse & Ross 2011, Ouden & Valkenburg 2012, Figueiro 2008). The users’ experiences of environments lit by adaptive lighting are explored in only few research publications. For example, in outdoor lighting context, the research is concerned with the effects of adaptive lighting on perceptions of safety (Haans & de Kort 2012), and, in interior lighting context, the influence of the light spectrum on sleep rhythm of elderly people (Figueiro 2008).

As a new design and research field, the terminology concerning adaptive lighting has not yet been unequivocally established. There are several parallel or overlapping terms in use, which describe the phenomenon. Later in this chapter, I scrutinize these terms and their definitions. ‘Adaptive lighting’ can refer to, depending on the context of application or research, a rather limited occurrence: for example, to a mere technological system. In this research, adaptive lighting is understood as a wide concept referring to lighting, which adapts to information about environment and its users or to other information relevant to intended lighting behaviour. In addition to sensor-based data, the information can be obtained from different databases, such as meteorological data or calendar information of events. On the other hand, the control of lighting behaviour can be based on some idealized natural process, such as the model of daylight’s temporal changes of intensity and spectral characteristics, which support human biological rhythms and is, thus, employed in biodynamic lighting. Additionally, one approach to adaptive lighting is direct or indirect control of lighting by users of illuminated environments. The essential common features in all the cases described above are, firstly, that lighting is not static but an altering element of
environments, and, secondly, the designer has defined the light’s behaviour to follow some reference information or reference logic.

Fig. 1. Adaptive lighting can be seen as an adaptive system, where environmental and user-related data is fed into and processed according to the rules created by a designer. This results in output control commands to luminaires of the system, which behave accordingly, thus creating a lighting environment. This creates an experience for users and may influence their behaviour, which may again affect the lighting behaviour.

Also stage and theatre lighting can be seen to adhere to the above definition. Stage lighting adapts dynamically according to the narrative of the play: light designer alters the atmosphere on stage with the help of light and highlights with target lighting actors and props in accordance with each scene of the script (Essig & Setlow 2013, Dunham 2011). However, in my research, I outline theatre lighting beyond the scope and concentrate on adaptive lighting in the contexts of architecture and urban environments, especially as part of everyday illuminated environments. Further, temporary event lighting is not specifically in the scope of this research, even though I present in Chapter 2 some projects where adaptive and interactive lighting has been applied as part of events. These well illustrate the possibilities of adaptive lighting in the meeting point of new technologies and art.

In this research, adaptive lighting is approached as an experiential element of architectural and urban spaces, which have an influence on human environmental experience at various levels. On the theoretical level, the aim is to conceptualize adaptive lighting as a design task, taking the multifaceted experience of light as a premise. On the other hand, phases and characteristics of the design process for adaptive lighting are recognized and analysed from the case design projects, and a new design method is presented and evaluated. In addition, the research explores users’ experiences of adaptive lighting environments through study of empirical material from experimental light installations in real-world settings.

In the following, I scrutinize terminology from research related to the subject of ‘adaptive lighting’ and define the meanings for terms used in this research.

In various research articles, the concept of ‘adaptive lighting’ refers to an intelligent lighting system or environment, which is equipped with sensors and actuators, thus allowing lighting to dynamically adapt to current conditions or to needs of individual occupants (e.g., Hughes & Dhanny 2008, Maggielše et al. 2011, Izsó 2009). Adaptation in lighting systems can be achieved through different sensor networks that gather information from the environment, such as natural lighting levels and pedestrians and traffic flow. This information is then fed to a closed-loop adaptive system, the primary task of which is to provide optimal lighting for the user’s needs and secondly to offer cost efficiency through energy savings. (Fostervold et. al. 2009, Ceriotti et. al. 2011)

The term ‘intelligent lighting control system’ is often used for these kinds of adaptive systems. Guo (2008) has defined the difference between an adaptive and an intelligent system as follows: “Lighting control systems can be adjusted adaptively, dynamically or intelligently. In the case when the light levels can be adjusted in real time or according to a predefined time schedule, the lighting system is called adaptive or dynamic. An adaptive or dynamic lighting control system can be intelligent when light levels are adjusted in real time based on predefined parameters.” (Guo 2008: 8) In other words, to be intelligent, the
adaptations should happen in real time not just according to a programmed schedule, and there should be information harvesting with the environment, which is based on parameters. On a highly developed level of intelligence, the communication may consist of two-way feedback loops, so that the system also learns from the received information and responses and adjusts its function (Volosencu et al. 2008).

‘Intelligent lighting’ is often seen as an integral part of an intelligent environment or an intelligent building. Wong, Li and Wang (2005) have presented a thorough review of the definitions of ‘intelligent building’, which vary greatly. Early definitions focused almost entirely on technology aspects—on fully automated building control systems optimizing resources—and neglected user interaction. Later, after wide criticism, the definition widened to cover responding to user requirements and producing well-being and comfort to users, as stated in Derek and Clements-Croome (1997). Kroner (1997) criticises the definition of intelligent building, thus highlighting the need towards responsiveness and widening the discussion to ‘intelligent architecture’. According to Kroner, “intelligent architecture refers to built forms whose integrated systems are capable of anticipating and responding to phenomena, whether internal or external, that affects the performance of the building and its occupants.” (Kroner 1997: 386) The author brings up three “areas of concern: 1) intelligent design; 2) the appropriate use of intelligent technology; and, 3) the intelligent use and maintenance of buildings” (ibid.). These concerns further can be applied in the context of intelligent lighting. Most recently, several authors have extended the definition of intelligent building by adding the capability to learn and adjust its performance from its occupancy and the environment (Wong, Li & Wang 2005: 144, Mozer 1999, Mozer 1998). In the lighting context, this kind of learning and adapting lighting system, which applies artificial intelligence and a learning algorithm, has been recently presented in an office environment by Magielse and Offermans (2013). Also, the term ‘smart lighting’ has been used in research contexts with the same meaning as intelligent lighting: for example, by Bhardwaj, Ozcelebi, and Lukkien 2010.

The ability of the user to interact with lighting and users’ sense of control is essential in defining the concept of ‘interactive lighting’, which can be seen as a subfield of adaptive lighting. On the one hand, adaptive lighting can react to users’ actions without their specific intention or effort, as the case has been in many adaptive street lighting implementations: for example, in van Rijswijk, Haans and de Kort (2012). On the other hand, lighting adaptations can also occur intentionally with users’ control, as a real-time interaction between user and lighting and involve bidirectional communication. This form of adaptive lighting can be called ‘interactive’. For this level of sense of control, users must receive some kind of feedback from the lighting. Lighting communicates with users through changes in light intensity, colour, and distribution of light and the pace or rhythm of these changes. (Pihlajaniemi, Österlund & Herneoja 2011) Boyce, Eklund, and Simpson (2000) present this kind of interactive lighting in an office environment.

However, in human-computer interaction research (HCI), the concept pair ‘implicit interaction’ and ‘explicit interaction’ is used, which may slightly confuse this definition. An adaptive lighting system, which is intelligently controlled and reacts to movements of space users, can be seen as an example of implicit interaction. Schmidt (2000) has defined implicit human-computer interaction as “an action performed by the user that is not primarily aimed to interact with the computerized system but which such a system understands as input.” In a lighting context, this can mean, for example, a control where the system has the capacity to analyze users’ needs according to their behavior through a sensor system and thus, can respond with functions and effects to the needs without any explicit effort or command. On the simplest level, this means a motion detector that turns on lights when someone is entering the room. On the other hand, explicit interaction means conscious efforts in a certain level of abstraction to tell the system what to do. This can be done using a command line, a graphical user interface, a remote controller, gesture, or speech, etc. (Schmidt 2000) Typically, in an indoor context this explicit interaction means use of a control panel on the wall or, more currently, a mobile phone app. Van Essen, Offermans, and Eggen (2012) use in a similar way the term ‘interactive lighting’ for the whole continuum of adaptive lighting behaviour from wholly autonomous system behaviour to full user control and discuss the roles of user and system in intelligent lighting control. A hybrid control approach is proposed.
to create a dynamic balance between user control and system automation (Offermans, Essen & Eggen 2013).

Another term, which is used in some research articles, for adaptive lighting, is ‘responsive lighting’. It has been used with varying meanings covering adaptations to environmental conditions such as wind patterns (Poulsen et al. 2013) and sound levels (Seitinger, Taub & Taylor 2010), adaptations to movement patterns in urban space (Poulsen et al. 2013), and explicit interaction with different actions (Seitinger, Taub & Taylor 2010) and devices (Poulsen et al. 2013).

I want to add still one concept to the subcategories of adaptive lighting: ‘participatory lighting’. It is a concept that we have introduced for defining a form of interactive lighting, which demands creative input from participants or, in another way, meaningful involvement (Pihlajaniemi, Luusua, Österlund and Tanska 2012; Pihlajaniemi, Österlund & Tanska 2012, Pihlajaniemi et al. 2012). Examples of participatory lighting can be found, for examples, in interactive media façade installations (Wiethoff & Gehring 2012).

Figure 2 summarizes the main concepts and definitions of adaptive lighting in the way I use them in my thesis. The definitions form overlapping concepts so that the inner one is always part of the outer one. Adaptive lighting is a form of dynamic lighting that adapts to some form of reference data, for example, to an idealised process of dynamic changes of light spectrum and intensity throughout a day. Intelligent lighting is a form of adaptive lighting that adapts in real-time to data: for example, weather data or movements of pedestrians on a park route. When there is explicit user interaction as part of the adaptation process, adaptive and intelligent lighting are interactive: for example, an office worker adjusts lighting to fit his or her needs. Adaptive and interactive lighting is participatory, when a user interacts with lighting creating something artistic or meaningful, for example, participating in a community art project. Responsive lighting has been left out from the figure, as its use in research has been rather inconsistent. I present an overview of previous research and case projects concerning adaptive lighting in Chapter 2, following these definitions. In my thesis, ‘adaptive lighting’ is used as a general term of lighting with any kind of adaptive behaviour and, specifically, when describing adaptive lighting without explicit interaction.
My thesis research is related to two research projects carried out in the Oulu School of Architecture in the University of Oulu during 2011–2014: Adaptive Urban Lighting—Algorithm Aided Lighting Design Project; and SparkSpace - Adaptive Lighting Control with Multi-channel Ambient Sensing Project.

The main part of the empirical material for this study was produced in the Adaptive Urban Lighting project, which was funded by the Academy of Finland and the University of Oulu. I was employed in the project as a researcher during the length of the project. The aim of the project was to research and develop algorithm-aided design methods and tools for designing adaptive lighting for urban environments. The methods applied in the development were scenario working and real-world demos. Scenarios—Thematically outlined future visions of different applications of adaptive urban lighting—were studied as textual narratives from the perspectives of different user types. Based on the scenarios, three temporary lighting installations were designed and realized in different types of urban environments. The real-world lighting demos studied different implementations of adaptive, interactive, communicative and participatory lighting. With the help of these demos, the solutions of adaptive lighting were tested in reality, and their influence on experiences of inhabitants of urban space was studied. The phases, design components, design factors, and roles of different stakeholders in the design processes of adaptive urban lighting were explored. In addition, the design process of the demos acted as development context for a new, algorithmic design method and a tool. The evaluation of the demos with qualitative methods revealed characteristics of users’ multifaceted experience of adaptive lighting in urban space. In the demos, the ubiquitous technological infrastructure of Oulu, built by the multidisciplinary UBI Urban Interactions research program of the University of Oulu, was applied. It included the free open-access municipal wireless network (PanOulu), public touch screens of the city centre (UBI screens), and trace data from a sensor network. Evaluation of lighting demos was carried out in cooperation with the multidisciplinary UBI Metrics project, which has developed qualitative methods to evaluate users’ experiences of ubiquitous technology in real urban contexts (2011–2014, funded by the Academy of Finland and the University of Oulu). In addition, students from the Faculty of Information Technology and Electrical Engineering participated in realization of the demos.

In my doctoral thesis, I use as a case study two lighting demos from the Adaptive Urban Lighting project: LightStories and Urban Echoes. LightStories was a participatory and communicative lighting project, which invited citizens to devise their own temporary lighting designs into a public space—along a pedestrian-oriented street—and to tell stories with the help of lights. The Urban Echoes project studied different scenarios of adaptive lighting, which reacted to the park-goers’ movements. The lighting installation was also communicative and interactive: the lights in the park conveyed urban information when ordered by mobile devices.

The third case study in my thesis, which approached adaptive lighting in the context of retail space, was conducted as collaboration among the SparkSpace project, Adaptive Urban Lighting project and ITEA Emphatic Products project (VTT Technical Research Centre of Finland Ltd, funded by TEKES). SparkSpace project was a collaborative project by VTT and the University of Oulu, and it was funded by TEKES (the Finnish Funding Agency for Innovation) and a wide consortium of companies. One company participant was M3 Architects, where I am a partner. In the SparkSpace project, concepts for intelligent lighting applications as well as real-time control methods, which utilize multi-sensor data of user activities and environmental conditions, were developed. In the Oulu school of Architecture, two master theses were produced, dealing with adaptive lighting in two different contexts: in retail environments (Markkanen 2013) and in semi-public outdoor and indoor spaces of a housing quartier (Vuojala 2013). As a university teacher in the Oulu School of Architecture, I tutored both of the master theses. The solutions developed in the project were tested and evaluated in a lighting pilot, which was realized in a ladies’ clothes section in a department store. In the pilot, the influence of adaptive lighting on shopping behaviour and experience was researched.

Besides experiential, lighting in an environment is defined in this work as a contextual phenomenon. Experience of lighting—also adaptive lighting—is context-related, and design of adaptive lighting responds to a question defined by the application context. Experiences include both common factors as well as
varying characteristics relating to specific contexts. In this thesis, combining the analyses of the case studies in different contexts with the theoretical background and my previous experiences as lighting designer and architect, I form a framework for the design and experience of adaptive lighting, and theorize the characteristic features on a general level.

1.2 Research questions

Research questions for my thesis are as follows:

Q1. What design phases and tasks can be recognized as essential to the process of designing adaptive lighting? What kind of design methods could be used in designing adaptive lighting?

Q2. How is adaptive lighting experienced by users of building interiors and urban spaces?

Q3. How can adaptive lighting be defined as a design task in general and specifically from the point of view of users’ experience?

I have intentionally formulated the research questions as relatively wide because this research is explorative and aims to understand two multifaceted real-world phenomena: design process and users’ experiences of adaptive lighting. A set of more focused research questions invites risk to create pre-defined categorisations, which would demarcate part of the holistic phenomena out of reach. This is also how designers approach design tasks and problems in design practise and is, thus, applicable in a research-by-design process.

All the research questions are answered in this thesis by reflecting the case study design processes and by analyzing the results from experience evaluation of the case study lighting pilots. The results of the reflections and analyses of the case studies are, naturally, context-related and illuminate these specific cases in great detail. Thus, the knowledge created cannot be seen as a universal model but more as an exploration of contextual aspects, which increase understanding of the phenomena by mapping this new design field. In this way, general features emerge and become gradually visible, creating general research-based knowledge.

There is a hierarchy in the research questions: the new knowledge and understanding of the design process and experience, which is gained by answering Q1 and Q2, are applied and synthetized in order to answer Q3. The intention is to emphasize the users’ experience as an important design factor for adaptive lighting.

1.3 Content of the thesis

The form of my doctoral dissertation is monograph, to which has been appended four previously published articles covering parts of the research. Thus, it is a kind of hybrid between a monograph and a compilation dissertation. The appendices contain results, which might be interesting from the perspectives of other disciplines, such as, HCI discipline. From the appended articles, it is possible to read additional information of the technical realization of the lighting demos, which form the empirical material of the thesis. However, since my thesis approaches adaptive lighting especially from the disciplinary perspectives of architecture and lighting design, I have not highlighted those contents as integral parts of the research argumentation into the thesis, but they are left into supplementary appendices. On the other hand, the articles, which I have written together with the other researchers employed in the research projects, also bring out the context of my work as part of larger research projects and multidisciplinary research collaboration. Appendix V presents a list of researchers and persons who have contributed in the case study projects of this thesis.
The structure of the thesis content is illustrated in Fig. 3. In this first introductory chapter, I have presented the subject of my doctoral thesis and the research questions. In the second chapter, I present the theoretical framework of the study. I commence by describing the internal framework, i.e., I introduce the reader with the earlier and parallel research concerning adaptive lighting as well as interesting realized lighting projects. The presentation follows the three levels of adaptive lighting: adaptive, interactive, and participatory. As the external framework, I go through research concerning design and experience of lighting in separate sub-chapters. Ultimately, I return to the research belonging to the core internal framework, which deals with the design and experience of adaptive lighting.

In Chapter 3, I describe my research process, methods and material. In the first subchapter, I present the methodological framework. In the second subchapter, I describe the research process and the research methods that I have used. The three case study projects, which form the empirical material for my thesis, are presented in the last subchapter.

The research results are presented in Chapters 4, 5 and 6, relating to each research question. In Chapter 4, I analyze the phases and tasks of the case study design processes and describe the use of the new method developed for design of adaptive lighting. In Chapter 5, I explore users’ experiences of adaptive lighting environments, which were realized as case study projects. Finally, in Chapter 6, I present the conceptual framework for the pragmatic-experiential and context-oriented design of adaptive lighting. In Chapter 7, I discuss the research results in the context of earlier and parallel research and assess the contribution, significance, and validation of the results as well as present needs and ideas for future research and a conclusion.
The printed version of this doctoral thesis includes the following previously published articles as appendices:


Table 1 presents which case study the appended articles concern and which research question they are answering to. However, the appended articles do not aim to extensively answer the research questions. Differing from a traditional compilation dissertation, I present in the thesis results chapters a significantly wider review of the case study results than is presented in the articles.

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2 Theoretical framework

In this chapter, I present the theoretical framework of my research. In my thesis, this means an introduction to 1) recent research perspectives and findings concerning adaptive lighting; 2) research on design of lighting; and 3) research on experience of lighting. As adaptive lighting is rather new as a research subject, I can cover in the presentation most of the research done in this field, which is relevant to my topic, and I have even personally met in workshops and conferences a substantial portion of the researchers cited here. For the other two subjects, an immense body of research literature and articles is available as well as professional literature for designers’ needs. My target here is to present an overview of research and professional literature, thus concentrating on classic literature of the field and on recent research articles presenting examples of different viewpoints. In my research, the intention is to present as holistic a view as possible to the subject with my empirical research material and reflect it with a wide body of earlier research from different perspectives and research fields. This is a suitable approach considering the apparent transdisciplinarity of my research subject.

2.1 Research and case projects of adaptive lighting

In the following subchapters, research and case projects of different types of adaptive lighting are presented. I have divided research and projects into three sub-chapters. In the first, I introduce adaptive lighting without explicit interaction with a user. In the second, research and cases, where users have an active role in controlling lighting, are presented. However, I present in the last chapter research concerning those cases, where the interaction can be seen as participatory and having especially creative and meaningful input, according to my earlier definition in this thesis.

2.1.1 Adaptive lighting without explicit interaction

Adaptive lighting system

A large body of research covers the development and implementation of adaptive lighting systems and intelligent control systems. Several different research projects have used wireless sensor networks to gather environmental information and then to use it with an automated adaptive system, which controls lighting levels in roads and tunnels (Guo, Eloholma & Halonen 2008, Ceriotti et al. 2011), in pedestrian street lighting (Volosencu et al. 2008, Hardy & Gafen, 2010), in office environments (Pan et. al. 2008), and in hospital environments (Fostervold et. al. 2009).

In a lighting system, the information processing of the adaptation process can happen in a centralized control unit, which receives sensor data and is knowledgeable of every component that is connected to the whole system. This kind of a centralized approach was used by, for example, Cerriotti et al. (2011), coupled with a wireless motion sensor network, in order to adapt and optimize the lighting levels in a traffic tunnel. Another approach is to use distributed information processing, where the decision-making is divided among different autonomous and intelligent hardware components. In this approach, none of the system components have an overall view of the global configuration of the whole system. Bandini et al. (2009) implemented an adaptive lighting installation using the distributed approach, without a centralized control or hierarchical structuring of controllers. The authors used intelligent lighting fixtures with the adaptation processing distributed among the luminaires. Yet another approach is to use a centralized control system that utilizes aspects of distributed intelligence as a part of the adaptation process. Luminaires
themselves are unintelligent. The aspect of distributed intelligence can be computed in a virtual environment through moving agents and the global system configuration emerges from their behaviour. (Pihlajaniemi, Österlund & Herneoja 2014) Besides system architecture, the research interest in many studies has been in control algorithms (Bandini et al. 2009, Guillemin and Morel 2001, Grigore et al. 2008, Grigore et al. 2007).

In the system implementations, the adaptations have been based on sensor or database data of e.g. interior illuminance and user presence (Guillemin & Morel 2001, Hughes and Dhanny 2008, Fostervold et al. 2009), space users’ position and activity (Magielse 2014), persons’ electro dermal activity and pulse (Grigore et al. 2008), road surface luminance and traffic flows (Ekrias et al. 2008, Guo, Eloholma & Halonen 2007), pedestrians’ presence (Pihlajaniemi, Österlund & Herneoja 2014, Tetri et al. 2014), retail customers’ positions and movements (Pihlajaniemi et al. 2014), and local events information (Pihlajaniemi, Österlund and Herneoja 2014). Besides real sensor data, in some research implementations, a so-called Wizard-of-Oz method has been used to mimic intelligent and dynamic lighting systems. The idea is that a person or group of persons act as a sensor and the intelligent processing and interpret the actions of users of a space and adjust lighting accordingly to match certain predefined rules. Hummels (2000) first presented this method in her thesis about gestural design tools. The method enables testing of adaptive lighting scenarios without constructing a refined intelligent control and sensing system. In this way it is possible to carry out sketchy tests of complex adaptation behaviours which would otherwise demand developed camera vision systems with gesture analyses and a substantial amount of programming. The Wizard-of-Oz method, or similar type of approach, has been in simulating lighting which adapts to pedestrians’ presence and movements (Haans & de Kort 2012, Gonçalves 2013) and to social behavior and interaction of space users (Magielse 2014).

Motivations and implementations of adaptive lighting

Research on adaptive lighting and implementing it in realized lighting solutions has had different motivations. The initial driver has been aspirations for sustainability and energy-efficiency. The need to reduce energy consumption and carbon dioxide emissions is influencing outdoor and indoor lighting solutions and bringing new lighting technology into the market. Street lighting and outdoor lighting, in general, form a significant part of a city’s energy consumption (Volosencu et al. 2008; Navigant Consulting 2010). The EcoDesign directive and commission regulation (EC) N:o 245/2009 are phasing lighting products with low energy-efficiency out of the market in the EU; for example, mercury lamps in the year 2015 (Official Journal of the European Union 2009). Many cities throughout Europe are undergoing large-scale lighting renewal projects within the next years. In addition to more efficient light sources, systems for intelligent lighting control are also being developed and implemented. With the help of different sensors and transmitters, lighting can adapt to prevailing environmental conditions and react to different stimuli and signals, such as traffic or weather data. This helps to reduce the overdimensioning of lighting levels and to improve traffic safety. The concept of outdoor and urban lighting is gradually changing from static to dynamic and adaptive. In The Netherlands, for example, all new public lighting installations must be dimmable. (Pandharipande 2013, Guo 2008, E-Street 2007, Lighting Research Center 2013). Substantial reductions of energy use (for example, 30% and 40 %), due to lighting adaptation to traffic or route users have been both estimated in simulations based on real data (Lau, Merrett & White 2013) and measured in real-world pilots (Tetri et al. 2013, Juntunen et al. 2013). In outdoor street and urban lighting contexts, in addition to energy-efficiency, aspects of traffic safety, sense of security, and visual performance of adaptive lighting are being researched (Ekrias, Guo, Eloholma & Halonen 2008, Guo, Eloholma & Halonen 2008, van Rijswijk, Haans & de Kort 2012, Viliūnas et al. 2014).

In addition to route lighting, office environments are contexts where lots of research and implementations of adaptive lighting systems have been carried out for energy saving purposes. Intelligent systems, where occupancy and daylight levels are sensed and artificial lighting is controlled accordingly, are becoming standard solutions in working and educational environments. The energy savings can reach, for example, up to 70% in comparison with a conventional static lighting system (Hughes & Dhanny 2008). Often, daylight control with
adjustable blinds is integrated into the system, thus decreasing cooling load and adding visual comfort (Guillemin & Morel 2001). Besides this kind of autonomous control, hybrid control approaches, which aim to create balance between user control and system automation, are being studied (Offermans, van Essen & Eggen 2013). I will return to this theme in Chapter 2.1.2., while discussing explicitly interactive lighting.

However, the primary target of lighting design is not only to spare energy but to create suitable working or learning environment for users’ well-being, visual comfort and good productivity. Adaptive lighting should at least maintain as comfortable working conditions as conventional lighting or even improve workers’ performance and well-being. In working and educational environments, adaptive lighting behaviour has been implemented in order to influence in a positive way to biological rhythm, activity levels, behaviour, and learning capacity of workers (Fleischer, Krueger & Schierz 2001, Knoop 2006) and students (Barkmann, Wessolowski & Schulte-Markwort 2012, Sleegers et al. 2013). The concepts of biodynamic and circadian lighting refer to a lighting behavior or lighting system that imitates spectral and intensity changes of daylight (Calcagni et al. 2001). This kind of lighting has been tested to have influence on the biological clock of workers, and it helps, for example, shift workers to be alert during nightshifts and to rest during the day, according to their working and leisure time schedules. Also smaller scale dynamic changes for lighting levels and darkness and coldness of white light can be used during normal daytime work or education to vitalize and to relax workers and pupils when needed (Fleischer, Krueger & Schierz 2001, Knoop 2006, Barkmann, Wessolowski & Schulte-Markwort 2012 Sleegers et al. 2013). The benefits of biological effects of adaptive lighting are being studied in elderly care and living contexts. In the ALADIN project (Grigore et al. 2007, Grigore et al. 2008) the effects of dynamic light levels and changes in the colour of light on daily performance of the elderly has been researched. In addition, the psycho-physiological factors of adaptive lighting have been taken into consideration by Fostervold et al. (2009), who have researched the effects of changing lighting levels in the psychological well-being and health of hospital patients. I will return to this subject while discussing research on experience of light in general and on experience of adaptive lighting (in Chapters 2.3.1. and 2.3.4.).

Adaptive lighting can also be approached from the perspective of social behaviour. The ongoing De-Escalate research project by the Intelligent Lighting Institute, Eindhoven University of Technology, studies means of adaptive lighting to defuse escalation of aggressive behaviour (de Kort et al. 2014). The contexts of the study are an urban environment—Stratumseind, a popular but aggression-prone downtown area in Eindhoven, with cafes and bars—and an indoor mental care facility. Magielse and Ross (2011) have studied social dimension of adaptive lighting in dining situations, using a method they call “interactive sketching”. This means that “interactive concepts are explored with minimal use of equipment and time allowing an idea or concept to be experienced as early as possible” (Magielse & Ross 2011, 173). One of the tests explored the idea of adapting lighting conditions in regard to social information, which was embedded in body posture. Another test explored the influence of adaptive lighting conditions on a group of people having a lunch together (Magielse & Ross 2011; Magielse 2014).

In urban contexts, light is often applied in an informative and communicative function: in traffic lights, signal lights, neon signs, and illuminated advertisements. Recent, and often not so positive, newcomers are advertisement and information screens, which are spreading along entrance roads and in public squares. The penetration of information technology and infrastructure into urban contexts is opening up new possibilities for communicating with urban lighting. Recent ubiquitous computing (Weiser 1991) and HCI research is responding to this call with projects dealing with ambient displays, as the concept of urban display as a means of communicating with light in an urban context has widened its meaning outside traditional screens. Ambient displays use “the entire physical environment as an interface to digital information,” as described by Wisneski et al. (1998). The authors also envisioned that “the architectural space we inhabit will be a new form of interface between humans and online digital information.” Consequently, information is embedded into the built environment, and it “manifests itself as subtle changes in form, movement, sound, color, smell, temperature, or light.”
Seitinger, Perry and Mitchell (2009) have presented a list of earlier strategies of using programmable light in various contexts for communication:

- Using the building as interface
- Appropriating public façades through projection (Fig. 4)
- Interacting with façades through projection
- Deploying individual pixels
- Connecting individual pixels
- Transforming architecture into ambient display (Fig. 5, Fig. 6)
- Creating landscapes with pixels

However, from this list, which can be easily illustrated with various interesting examples of implemented cases, two specific strategies are missing: the employment of existing city lighting infrastructure, and the design of functional lighting to convey meaning. In the case studies of this thesis—LightStories and Urban Echoes—those strategies have been used. (Pihlajaniemi 2013)

The amount of information displayed digitally in urban environments has increased dramatically over the past few years. Many of these systems are private and meant for commercial purposes, thus delivering a deluge of advertisements on passersby without engaging them in any meaningful way (Garcia 2007). There is a risk that public space will be further privatised as a result of this process (Köhler 2009). However, many art installations and projects of media architecture present examples of communicating with light in a subtle and nonobtrusive way, thus creating aesthetic experiences and changing atmospheres in urban and interior contexts. The gathered sensor data from user actions or environmental factors is used to create adaptations of light levels, light patterns and rhythms, and light colours for artistic expressions, for aesthetic pleasure and to convey meanings (Pihlajaniemi, Österlund & Hernejoja 2013).

Fig. 4. Human Beeing media art installation in Helsinki Lasipalatsinaukio square in August 2014 by Christian Zöllner, Sebastian Piatza and Robert Albert. Light as a projection adapted to movements of bees in another time and space context.
Academic dissertations about adaptive lighting

As adaptive lighting is currently an intensely developing area of lighting technology and industry, it has been in recent years a subject of academic dissertations, as well. Some doctoral dissertations have been completed concerning adaptive lighting and there are others in the process to be finalized. Jörg Baumeister (2007) researched the theme of adaptive lighting in urban environment in the doctoral thesis “Adaptives Stadlicht”. Baumeister’s definition for adaptive urban lighting can be described as pragmatic and problem-solving oriented. He defines improvement targets for urban lighting from selected perspectives, which are medical, ecological, security, and economy, and then combines various adaptation processes enabled by different sensor and control technologies to respond to these targets. The different adaptation processes by different technologies are analysed through two scenarios—security lighting, and
event and advertisement lighting—evaluating them from the viewpoints of four selected improvement targets. (Baumeister 2007) The method used provides a wide and analysed view about the possibilities of adaptive urban lighting. Nevertheless, the definition can be seen as slightly technology and device oriented, as technological possibilities and pragmatic concerns are the driving force. This rules out certain viewpoints from the analysis. (Pihlajaniemi, Österlund & Herneoja 2013)

Esben Skouboe Poulsen’s ongoing dissertation project “Responsive Public Lighting” explores, through a series of realized adaptive lighting designs in public spaces in Aalborg, the paradigm of responsive lighting in a smart city. The research, which studies new design techniques and methodologies for lighting in intelligent environments, was done in an interdisciplinary research group. The lighting demos, which were realized, study adaptive lighting without and with explicit interaction, as well as participation, which can occur in public space. The implicit interaction of the experiments was based on tracking of people’s positions and movements in a public square and controlling light accordingly with different kinds of scenarios. The energy use of different scenarios was measured and people’s movement patterns analysed. In one scenario, lighting was also designed to adapt to wind patterns, so that the wave of light over the square indicated the direction and velocity of wind. (Poulsen, Andersen & Jensen 2012, Poulsen, Morrison, Andersen & Jensen 2013)

Still, in an urban lighting context, Eduardo Gonçalves is preparing PhD research of adaptive lighting. I was presenting my work in 2013 in the PLDC Professional Lighting Design Convention in Copenhagen in the same session with him. In the presentation, a test series of adaptive lighting in the urban streetscape context of Lisboa was presented as well as the preliminary results of evaluation of experiences. Lighting adapted to the presence of pedestrian in the streetscape, according to different scenarios of how wide was the illuminated area around the walker and what was the tone of white light. The tests were carried out using the “Wizard of Oz” method. Nevertheless, the results have thus far not been further published, so they cannot be referred to more deeply in this thesis.

Remco Magielse’s doctoral thesis “Designing for Adaptive Lighting Environments—Embracing Complexity in Designing for Systems” (2014) approaches the design of context aware lighting solutions that provide personalized, adaptive, or anticipatory behaviours. His research had three research questions or challenges: 1) Which lighting behaviours are meaningful for people and how these can be designed? 2) investigation of implications on social settings of adaptive lighting environments; and 3) exploration of novel interaction concepts with adaptive lighting environments. Magielse defines ‘adaptive lighting environments’ as “lighting systems that—via information acquired through sensors—adjust their state to fit to specific contextual factors” (Maggielse 2014: 12). In his research, he has used a research-through-design approach. With design-research iterations performed in increasingly realistic contexts and containing evaluation of users’ experiences, he has studied multi-user adaptive lighting environments in dining situations and in different kind of academic working situations. As part of the study, he has developed technologies for adaptive lighting environments, such as a design tool or platform to develop interactive networked environments (Lithne), a modular, flexible lighting system (Hyvve), and a portable, personal light controller (Bolb). As a result, he presents characterizations and insights of the design process of adaptive lighting environments, emphasizing the importance of human, contextual, and social design factors and the balance between automated lighting behaviours and user control. (Maggielse 2014)

Maggielse’s research was carried out in the Intelligent Lighting Institute of Eindhoven University of Technology as part of the Adaptive Lighting Environments project. In the same institute, some other PhD projects are ongoing with the theme of adaptive lighting. The most relevant to the theme of my thesis is Serge Offermans’ thesis project, which focuses on human interaction with light and interfaces that allow users to have quick and intuitive control over lighting. He has studied the relation between autonomous and user control, which I will discuss more in the next chapter with the theme of interactive lighting. (Offermans, van Essen & Eggen 2013, Offermans, van Essen & Eggen 2014)
2.1.2 Interactive lighting

As defined in the introduction, in interactive lighting, the user has an active role, as he or she explicitly controls lighting with conscious and intentional actions. This can be done either with a physical interface or without device, by gestures, movements, or speed (Schmidt 2000). Interactive lighting has been researched from several perspectives. In this chapter, I present research under the following themes: interactive lighting system, user interaction, and implementations of interactive lighting.

Interactive lighting system

In Remco Magielse’s thesis (2014), interactive lighting system is defined, referring to Verbeek (2005), as a composition of people, (interactive) technologies, and the interdependent relationships between them. In this definition, interaction can occur, not only between a human and interaction technology but also between different users of environments. “Interaction is bi-directional: People interact with technologies but these technologies also mediate our behaviour. […] Furthermore, people also interact with each other, and technologies communicate via technological networks” (Magielse 2014, 23).

This makes the system especially complex as a design task. Multi-user aspect is a theme that is often associated with the theme of both adaptive and interactive lighting systems: how to anticipate and enable use situations, where several persons are interacting with lighting at the same time, either implicitly or explicitly? (Aliakseyeu et al. 2012, Magielse 2014)

Interactive lighting systems can be explored from the perspective of control and the role of autonomous system behaviour. There exist systems with full user control (user is active and system obeys) and full system control (system takes actions based on user and context information, user relies on system) (van Essen, Offermans & Eggen 2012). However, Van Essen, Offermans, and Eggen (2012) argue that a hybrid between those two options would be most desirable. “Combined with explicit user interaction, autonomous system behaviour will create intelligent systems, able to adopt to users and contexts” (ibid.). With the help of autonomous control, new complex behaviours of adaptive and interactive lighting can be implemented into lighting environments, which improve user experience, for example, through bio-dynamic lighting or atmospheric characteristics, and give other additional value such as energy savings. Because of the complexity of intended lighting behaviour, full “manual” user control is undesirable and ineffective. The design space of this kind of hybrid control has been researched with implementations and series of evaluations in a living lab context of an academic working environment. The topic relates, in addition to interaction and lighting design, to questions of intelligent system behaviour, artificial intelligence, and machine learning. (ibid., Offermans, van Essen & Eggen 2013)

User interaction

The developed lighting technologies with light sources, which can be individually controlled concerning their intensity and colour, offer a wide range of new opportunities for lighting environment, experiences, and functionalities. This sets needs for new user interaction paradigms. Offermans, Essen, and Eggen (2014) argue that "[...] people have different levels of lighting needs that are highly dependent of context and that also require control at different levels. The context and lighting needs have a large influence on the extent to which people are motivated to adjust their lighting. Moreover, the lighting interface itself has a large effect on this motivation, mainly influenced by the degrees of freedom, the control location and availability, the degree of automation and general interaction qualities.

Several different types of interaction between the lighting system and the user can be defined. Giving instructions means, for example, using a switch or selecting a preset of a lighting situation. On the other hand, there can be a dialogue between a user and a system, i.e., the system and the user interact to find the best option; for example, a system can ask details for a specific context or preferences or give suggestions. In addition, there can be direct manipulation, which means that the user explores the lighting conditions by manipulating
either a virtual and/or physical light environment until he or she finds it satisfactory. (van Essen, Offermans & Eggen 2012).

Additionally, there can be interaction on different interaction layers. This concept is used to describe the relation between user and system. With nowadays user interfaces, users control lighting conceptually through low-level parameters, changing, for example, intensity or colour value. However, the control could operate conceptually on a higher level: for example, controlling lighting behaviour. These behaviours can mean dynamic lighting atmospheres, which are intended to be, for example, relaxing, energizing, providing privacy, and helping concentration. At an even higher level, the user may choose a specific context or activity, and the system selects suitable lighting settings. (ibid.)

Interaction can happen with different kinds of user interfaces, with physical devices or with gestures or voice control. There has been research on improving the effectiveness and user experience of lighting control systems, which has already led to some interesting commercialized products. One theme has been tangible interaction, following the vision of Tangible Bits by Ishii and Ullmer (1997). The idea behind tangible interaction and a tangible user interface is that a person can interact with digital information through the physical environment.

Tangible Bits allows users to “grasp & manipulate” bits in the center of users’ attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. (Ishii & Ullmer 1997).

Lighting can be controlled, for example, by rotating a cube and choosing that side upward where the picture reflects the desired atmosphere or activity to be carried out (Offermans, van Essen & Eggen 2014). Also touch-screen-based devices are sometimes referred to as tangible lighting control (Dugar & Donn 2011, Dugar, Donn & Osterhaus 2011, Dugar, Donn & Marshall 2012). The spreading of mobile devices with touch screens to a wide audience has brought advanced graphical user interfaces into everyday lighting interaction. Philips brought onto market in 2013 a product family called Hue. The system is a collection of individually controllable LED light sources, in a form of a traditional light bulb, and a so-called “bridge” unit, which connects the light sources to the home network. Each light bulb can produce millions of colour shades and different shades of white light. Smartphones and tablets can be used to wirelessly control the light sources, and a wide selection of different apps is available for controlling lighting. These apps let the user control light both on low and high levels: through colour wheels, through selecting atmospheres, according to a colour palette of a photo, through weather data, and so on. (Bui, Lukkien, Frimout & Broeksteeg 2011, Philips Hue)

**Implementations of interactive lighting**

There have been implementations of interactive lighting in various contexts during recent years: in office and academic working environments, in industrial spaces, in schools, in urban contexts, and in artistic installations and media façades. If the concept is widely understood, most private environments allow inhabitants to interact with lighting to a certain level through on/off switches or dimming. Through home automation, also more developed lighting control, for example, with predefined lighting settings and situations as well as remote controlling, is spreading into private homes.

In office environments, a largely researched theme has been the effects of individual lighting control on worker’s mood, satisfaction, and performance (Veitch & Gifford 1996, Boyce, Eklund & Simpson 2000, Newsham et al. 2004). In addition, the reduction of energy use due to individual control has been detected (Newsham et al. 2009). The influence of controllable task-lighting on productivity has also been studied in a factory context (Juslén, Wouters & Tenner 2006). The influence of one’s own control of dynamic, responsive lighting on waiting experiences in an office context has been researched as well (Lemmens & Hu 2013). In addition, technological solutions in connection with machine learning and hybrid control systems, as well as concepts and product prototypes for new types of user interfaces, design tools, and lighting system components,
have been developed (Offermans et al. 2012, Offermans, van Essen & Eggen 2014, Magielse 2014).

In school contexts, Wessolewski et al. (2013) and Sleegers et al. (2013) have studied the effects of variable lighting, where illuminance level and colour temperature of light varies, on students’ and pupils’ concentration and social behaviour. In these studies, the interaction possibility was given to the teachers of the classes, and they could choose the most appropriate setting for each activity and task carried out in the classroom. Hakulinen et al. (2013) have developed audio- and lighting-based physical exercise games for schoolchildren. In their approach, storytelling and dramatic elements, such as interactive lighting, guide and motivate children. In the games, the lights do not directly respond to players’ actions through sensors, but the teacher acts as the intermediary and controls the progress of the game using a wireless controller. Hakulinen, Turunen, and Heimonen (2013) have also developed a framework for designing and controlling interactive lighting, based on the concept of spatial model.

Light’s capacity to affect humans’ biological and psycho-physiological processes has been applied in dynamic lighting systems for elderly in the ALADIN project (Ambient Lighting Assistance for an Ageing Population). The tested adaptive and interactive lighting system has aimed at enabling the users—older adults themselves—to make adaptations to lighting tailored to their specific needs and desires. The intelligent control system was capable of capturing and analyzing the individual and situational differences of the effects of lighting and, in that way, capable of fitting the resulting dynamic lighting environment to their actual needs and wishes. (Izsó 2009, Grigore et al. 2007)

Poulsen et al. (2012) have studied different scenarios in an urban public square setting of adaptive lighting, which responds to the tracked movement patterns of walkers in the square. One of the scenarios, “Red Treasure Hunt”, was designed in order to influence people to stop and confront the lighting in a playful manner, thus creating interactions between users of public space and the lighting.

Though not directly about interactive lighting, Bo Stjerne Thomsen’s (2009) doctoral thesis regarding performative environments included experimental projects that studied interactivity and social dimension of lighting. His four projects investigated the challenges of interactive lighting, as part of event programs and as street lighting in an urban context (Thomsen 2009: 154-173). The interactive street lighting demo, which was carried out by installing one adaptive street luminaire prototype along a street in Copenhagen, had three overall aims: “1) Functionally; to adjust lighting according to activity level and location, 2) Sustainable; to use low-consuming LED fixtures, dimming and potentially photo-voltaic and 3) Social; to introduce emergent light effects stimulating social and playful behavior” (Thomsen 2009: 164). The lighting by the prototype luminaire had a base illumination, which increased when people approached. The colour of light also changed from cold white-blue to white-red indicating potential interactions, according to speed and amount of people in the space.

Applications of this kind of interactivity into functional public lighting have so far been rather rare. On the other hand, interactivity and interactions with light have been studied in various artistic installations and in projects for media façades and media architecture, as, for example, in Aarhus by light and Projected Poetry (Brynskov et al. 2009, Dahlsgaard & Halskow 2010) and in an interaction project for ARS Electronica Center (Wiethoff & Gehring 2012). As these projects include creative input from the participants and engaging interaction, as pointed out by Fritsch and Dalsgaard (2008), I have categorized them into participatory lighting projects and will discuss them more in the next chapter. However, I present here two examples of interactive lighting installations in a gallery context. I visited in February 2007 an interactive light art installation—Target Breezeway by Electroland—which was located on the sixty-ninth floor observation deck of Rockefeller Center in New York during the years 2005–2007 (Fig. 7). The lighting behaviour of colorful LED lights adapted in a complex way to the situations of people visiting the scene, by the system, which was capable of tracking up to 30 individual persons. Visitors to the Target Breezeway space participated in an immersive video game-like environment where human motion is translated into patterns of sound and light (Tyzx press release). Another, perhaps more subtle art project in its expression, is Swarm Light project by rAndom International (2010), where light reacts to the sound of its onlookers.
The installation consists of three cubes of 1000 pc. of white led lights situated in a three-dimensional grid. The art-work translates patterns of collective behaviour found in nature—in swarms of birds or fish—into moving light, following a control algorithm. (rAndom International 2010)

2.1.3 Participatory lighting

In the introduction chapter, I defined participatory lighting as a form of interactive lighting, which demands creative input or in another way meaningful involvement from participants. Fritsch and Dalsgaard (2008) also relate this type of interaction to the affective and engaging experiences and see there the possibility to advocate for long-term interactive experiences. The authors present as examples two participatory, temporary media installations using light in digital images or projections on building façades. In Aarhus by light, camera tracking translated participants’ presence and movements into digital silhouettes on the Concert Hall façade. Visitors could, with their bodily movements, caress, push, lift, and move these digital creatures, which would respond with own behaviour, thus “creating a relation to the visitor which is not only physical and embodied but also affective and emotional” (Fritsch & Dahlsgaard 2008, s. 2).

Another installation, the Climate Wall, was in operation during the climate conference, Beyond Kioto, and provided citizens of Aarhus with the opportunity to participate in the ongoing climate debate. Passersby could move projected words on the façade of Ridehuset, and create sentences relating to climate and carbon emission. (ibid., Dalsgaard & Halskov 2010)

Participatory lighting can be seen as related to participatory design or co-design, to citizen participation and participatory art projects. Participatory design is presently an emerging design practice that involves different non-designers in various co-design activities throughout the design process. By non-designers it is referred to potential users, other external stakeholders, and/or people on the development team who are from disciplines other than design. Participatory design spans across a broad spectrum of domains and makes use of a broad repertoire of tools and techniques in commercial, community-oriented, and research contexts. (Sanders, Brandt & Binder 2010: 195)

In HCI, participatory design is rooted in movements towards democratization at work in the Scandinavian countries in the 1970s. Participation had an important role in the introduction of new technology into working environments. As Ehn (2008, 94) notes, “participatory design started from the simple standpoint that those affected by a design should have a say in the design process.” In addition to this value, the other argument for participatory processes
can be seen in the importance of making use of participants’ “tacit knowledge” in the design process (Ehn 2008).

In the existing multidisciplinary literature on participatory design, participation is usually seen as having two guiding rationales or arguments: an ethical-political argument and a pragmatic argument. According to the former view, participation enables the empowerment and activation of those in weaker positions of power within organisations or communities. From the latter point of view, participation can be seen as a tool to harness the latent knowledge of those affected, thus broadening the base of available knowledge to its largest possible size. (Pihlajaniemi et al. 2012)

Participatory design methods are used not only to achieve solutions that are functionally better but also to arrive at more “creative” solution (Bratteteig & Wagner 2010). Related to this, participation has been an important strategy in art, even since the 1920s tracing back to the authorial experimentations of Dada. In contemporary participatory art, three main aims can be named: 1) the desire for activate and empower audiences; 2) the will to cede authorship in pursuit of a more egalitarian form of art; and 3) restoration of the social bond in a crisis in community. (Muller & Loke 2010, Bishop 2006). Participatory art projects can be seen to have a phenomenological emphasis, which values the experience of the participants (Muller & Loke 2010). This aspect is frequently present in those projects, which employ light as a medium in urban contexts. Interesting examples of this kind of participatory art are Touch (LAB[AU] 2006), Forest of Light (Totem Collective 2009), and the research on interactive media facades (Wiethoff & Gehring 2012).

2.2 Research of lighting design

In the two following chapters, I introduce the reader to lighting as a design task in general and to the earlier and ongoing research of the design of adaptive lighting.

2.2.1 Research and literature about lighting design in general

Currently, lighting design is being established and developed as a discipline that moves beyond mere professional education into the area of academic research (Osterhaus & Dugar 2009). There has been a gap between lighting research and lighting design, as indicated by lighting researcher Peter Boyce (1987):

*In an ideal world there [...] would be a smooth and obvious transfer of knowledge from lighting research to lighting design. Researchers would be the producers of knowledge and understanding. Designers would be the consumers of that knowledge. But this is not an ideal world. [...] anyone examining current lighting practice might suspect that lighting researchers and lighting designers inhabit different planets.* (Boyce 1987: 10, cited in Osterhaus & Dugar 2009: 14)

The middle part of this citation—even though it is already couple of decades old—reflects the fact that lighting research is mostly done by researchers who themselves are not lighting designers. Perhaps this is the reason for the current situation in which there is not much available academic research about lighting design itself, i.e., reflection and theorizing about its processes and methods. Lighting research has largely been concerned of the effects of lighting and lighting technology to produce new forms of lighting in innovative ways. One of the rare recent meta-level reflections of lighting design process is by Hansen and Mullins (2014), who discuss the need for an integration of scientific, technical, and creative approaches to light as a design element. Authors have developed a theoretical framework and a procedural model to demonstrate how diverse research traditions can be integrated in transdisciplinary practice. The model is implemented in a problem-based pedagogical application for a graduate program.
in lighting design, which synthesizes lighting, media technology and architecture. (Hansen & Mullins 2014)

Nevertheless, there is a large body of professional literature aimed to educate and inform lighting designers and different types of professionals of how to design lighting, what is a good design process, what methods can be used, and what are relevant design factors and design criteria. These publications are often based heavily on case studies and project presentations and reflect practical knowledge of the authors, who may be practicing designers themselves. However, several authors also base their insights on the topical findings of research of their writing time, concerning human experiences of lighting: for example, the visual perception process or biological effects of light. Thus, the foci of the books from different authors and different decades vary and also reflect the prevailing attitudes and values as well as the development state of lighting technology during the writing time. Historian and scholar of cultural studies, Wolfgang Schivelbusch (1988) has in his book, *Disenchanted Night—The Industrialization of Light in the Nineteenth Century*, described the development of artificial light in the nineteenth century—from candles and oil lamps to gaslight and finally to arc lighting and electric incandescent lamp. The author interestingly connects the changing lighting technology to the ideals of illuminating and to changes of nocturnal city life, domestic living, and stage performing. The development of artificial lighting is related to the emergence of modern consciousness. Perhaps we are at the moment in a middle of similar kind of paradigm change in lighting than that change from fire to electric lighting was. Now, the change is, due to the development of controllable and networkable LED lights from static lighting to dynamic and intelligent lighting. This fast development process and application into real world solutions will presumably have reflections on life and conventions in different contexts as well as to human behaviour, experiences, and ways of thinking.

Table 2 in page 35 shows examples of significant literature that represent different approaches to lighting design. The table also presents the main concepts and themes of each book, as well as indicates which contexts of design it explores and what kind of project examples it includes.

### 2.2.2 Research of design of adaptive lighting

As adaptive lighting is still an emerging design field, there is no specific practical or research literature available of the subject. However, some academic dissertation theses and recent research articles are dealing with the theme. I have collected a representative selection of the publications in Table 3 (p. 36) and present there the main viewpoints concerning design of adaptive lighting, following the same thematics that are used in Table 2. The research examples are already referred to in the subchapters of Chapter 2.1.
Table 2. Main approaches in the core literature about lighting design.

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<tbody>
<tr>
<td>CONTEXTS</td>
<td>Interior lighting day lighting</td>
<td>Interior lighting</td>
<td>Interior lighting, urban lighting, daylighting</td>
<td>Interior lighting urban lighting</td>
<td>interior lighting</td>
<td>interior lighting</td>
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<tr>
<td>DESIGN FACTORS / DESIGN GUIDELINES / DESIGN CRITERIA</td>
<td>Focal glow make it easier to see Ambient luminescence make surroundings safe and reassuring Play of brilliant stimulate the spirit Intensity Brightness Diffusion Spectral colour Direction of light relative to eyeline Real and implied movement Real and relative values Cultural and psychological effects Physical techniques Activity needs for visual information Biological needs for visual information Visual perception attributive stage expectations affective component Sparkle &amp; glare Visual glow Dull vs. interesting Order in the visual environment Security and insecurity Feeling of intimacy Light’s behaviour &amp; materials Luminaire types &amp; light sources Illuminance Illuminance levels re assurance conservation energy Luminance reflection material contrast &amp; hierarchy sparkle &amp; glare Colour and temperature technical measure visual impression identity natural &amp; artificial light Height intimacy function &amp; dis pense Density number of fixtures grouping of fixtures hierarchy &amp; power rhythm &amp; movement narrative navigation &amp; depth Direction and distribution permutuations &amp; effects transformation of space architecture as lantern Light, visual system &amp; non-image-forming system Work Human performance Cognitive, task &amp; motor performance Visual performance Visual discomfort Perception of spaces &amp; objects Lighting for offices Illuminance light sources, systems &amp; controls Lighting for industry Escape lighting Lighting for driving Lighting for pedestrians safe movement security comfort &amp; attraction Lighting and crime Lighting for elderly visual capacities and tasks circadian timing system Light and health relation visual system circadian timing system Lighting pollution Lighting and energy</td>
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<tr>
<td>DESIGN PROCESS / DESIGN PHASES</td>
<td>Critique of the conventional design process based on calculations New design process based on visual perception Preliminary inquiries Pre-design Design development Detailed design</td>
<td>Proposal design alternative lighting solutions lighting calculations &amp; visual investment cost evaluations General design specified lighting solution Detailed design</td>
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<tr>
<td>DESIGN METHODS / DESIGN TOOLS / DESIGN OUTCOME</td>
<td>Relation of visual information needs to object surface characteristics and illumination qualities Design process aids actures and new tips programming schematic design: diagrams and models models &amp; mock-ups renderings cost-benefit studies CAD Lighting calculation tools 3D-visualization tools L.E.D.S. Light, Energy Optimization and Service Image processing applications Samplings and lighting tests Design documents: Explanatory text Design plans Index of luminaires Costs Construction documents Design documents: Drawings and textual descrip. Visualizations and calculations Cost estimations</td>
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<tr>
<td>CASE STUDIES</td>
<td>Buildings with different spatial configurations Offices, retail &amp; restaurants Conference &amp; concert halls Libraries &amp; museums Urban spaces, master plans Park Restaurant Art museum</td>
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<td>CONTEXTS</td>
<td>urban lighting</td>
<td>urban lighting</td>
<td>urban lighting</td>
<td>media façades</td>
<td>urban lighting media installations</td>
<td>interior lighting</td>
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<tr>
<td>DESIGN PROCESS / DESIGN PHASES</td>
<td>Technology level of feedback Representation level of association Relationship level of attachment</td>
<td>Key data collection</td>
<td>User research Data analysis Design concepts Prototyping &amp; evaluation</td>
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<tr>
<td>DESIGN METHODS / DESIGN TOOLS / DESIGN OUTCOME</td>
<td>Scenario working Assessment rating</td>
<td>Design environment based on cellular automata celle simulator lights view system configurator</td>
<td>Lightbox: Prototyping toolkit iRIS: System for remote interaction with media façades</td>
<td>Design criteria Programming Simulations &amp; scenarios</td>
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<tr>
<td>DESIGN FOR SYSTEMS</td>
<td>Designing for systems Mediating interaction concept (MIC) 1st and 3rd person perspectives Licht: Design platform to develop interactive networked environments</td>
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<tr>
<td>CASE STUDIES</td>
<td>Security lighting Event and advertisement lighting</td>
<td>Urban underground path Street lighting Art installation</td>
<td>Media façade installation Participatory lighting Street lighting Media installations Participatory lighting</td>
<td>Academic multi-use working environment Interactive lighting Dining space Academic multi-use working environment Office</td>
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</table>
2.3 Research of experience of lighting

2.3.1 Research of experience of lighting in general

A large amount of research concerning the experience of light and lighting is available. In Table 4, I have collected experiential aspects which were studied in recent lighting research. Table 4 further presents the references and main concepts used in the articles for each aspect. The context of lighting that the study concerns is presented with colour coding.

Table 4 notes that, for example, safe movement and sense of security are widely studied aspects of urban and outdoor lighting (e.g., Herbert & Davidson 1994, Painter 1996, Boyce 2000, Nikunen 2013, Uttley, Fotios & Cheal 2014). In office and work environments, there have been lots of lighting studies. The research has been based on light’s effects of psychological experiences and creativity, cognition, and performance. Especially after the discovery of the third photoreceptor in the retina of human eye (Brainard 2001), which influences the production and secretion of the hormone melatonin, there has been active research on the biological and psycho-physiological effects of light (e.g. Boyce 2014, Smolders, de Kort & Cluitmans). In the research, besides the previously noted aspects, the perspectives of visual experience, social experience, lighting-related meanings, and experience of atmosphere have been studied. However, it can be noted that there are no researches, at least to my knowledge, which combines in the inquiry different aspects of experience into a holistic view. Different aspects of experience are studied as separate, limited viewpoints.

From the year 2009 onwards, a series of conferences have been arranged in Eindhoven (2009, 2012, and 2014), with the name Experiencing light—International conference on the effects of light on wellbeing (http://www.experiencinglight.nl/). The series of proceedings offer a wide overview of present research themes concerning lighting experience. However, after looking through the content of the papers presented in the conferences and taking part in the last one, I have made an interesting observation. Based on this material, it could be stated that, at the moment, lighting research is largely dominated by research that is either done in laboratories or which, if carried out in a real-context, follows largely the same methods as those used in laboratory tests. The experience, which is under research, is in most cases reduced to a certain set of limited and well-defined questions, which can be answered in strictly controlled ways. This keeps the variables of research in easily controllable limits and aims into reliable results. The results are quantified and studied with statistical analyses. The methods used are near the methods of naturel sciences and are based on the existing methodology of psychological research. Within this field, the results can be easily discussed and compared.

However, from the perspective of design-based research and design-related academic fields, such as architecture and lighting design, this raises several questions. The results of each study seem to be quite fragmented, covering a singular fraction of experience. In addition, what is the relation of the results from a laboratory test, which might be achieved, for example, through looking at visualizations of lighting (e.g., Beute & de Kort 2014) instead of real lighting situations, or in an unnatural test arrangement walking on a treadmill and looking into a box, eyes following a moving target on a screen (Uttley, Fotios & Cheal 2014), to experiences in the real life, with varying factors and ongoing actions? For a designer, it is clear that a small change of detail in an environment can have a crucial effect on the experience. In an experience, different aspects are interrelated and influence each other. A protocol of asking questions about one aspect of experience in a test might cause totally different answers, if the context and research setting would be slightly different. The complexity of architectural lighting environments and, thus, the multifaceted quality of experiences set large challenges to inquiries of experience and demands new, more holistic research methods.
Table 4. Main aspects of experience presented in research publications.

<table>
<thead>
<tr>
<th>EXPERIENTIAL ASPECTS</th>
<th>REFERENCES &amp; CONCEPTS</th>
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</table>
2.3.2 Research of experience of adaptive lighting

There has not yet been wide research of the experience of adaptive lighting in different contexts, as the lighting solutions are still in the process of development. However, some research exists and it is presented in the Table 5 in a similar manner to Table 4. I have not presented our published research in this table.

In the field of urban lighting, especially, it is not meaningful to present that research collected in the table as preceding research, which my research is building upon, as most of it has been done parallel and partly later than our case studies were carried out (LightStories, February 2012; Urban Echoes, February and March 2013). Instead, all the research projects, including ours, have been and still are presently establishing together this new research field, and we have shared our thoughts and developed things also together in several workshops and conferences during recent years.

The research concerning experiences of adaptive urban lighting has covered aspects of safety (Viliūnas et al. 2013, Haans & de Kort), social experiences (Casciani 2014, Poulsen et al. 2013, Seitinger 2010), meanings and values (Poulsen et al 2013; Seitinger 2010), atmosphere and aesthetic experience (Casciani 2014; Poulsen et al. 2013), participation (Poulsen et al. 2013; Seitinger 2010) and communication (Seitinger 2010). Most of those aforementioned aspects have been relevant in experiences of media architecture and described for example in research by Wiethoff and Gehring (2012) and Fritsch and Brynskov (2011).

Research about adaptive retail lighting has not yet, to my knowledge, been published, except our own articles (Pihlajaniemi et al. 2014a, Pihlajaniemi et al. 2014b). In office and working lighting contexts, however, there is already an established research field from the two last decades about individual lighting control and its effects on workers’ mood and performance. I have just presented a few examples of that research area (Veitch & Gifford 1996, Boyce, Eklund & Simpson 2000, Newsham et al. 2004, Offermans, van Essen & Eggen 2014, Magielse 2014). In office context, Magielse has also studied social experiences of lighting interaction (2014).

In educational environments, the experiences of variable and dynamic lighting systems have been studied, from the activity-related perspectives of performance and motivation (Barkmann, Wessolowski & Schulte-Markwort 2011), learning (Mott et al. 2012) and concentration (Sleegers et al. 2013). Effects on social behaviour have also been studied (Barkmann, Wessolowski & Schulte-Markwort 2014). Keskinen et al. (2014) have studied how interactive lighting can motivate school children to exercise. In addition, there has been research on the effects of dynamic lighting on visual performance and, on the level of psycho-physiological experience, research on activity and subjective feelings of elderly (Izsó, Laufer & Suplicz 2009, Izsó 2009).

It appears there are no preceding attempts to theorize the experience of adaptive lighting in general and as a holistic concept. My thesis aims to contribute to filling this research gap.
Table 5. Main aspects of experience presented in research publications about adaptive lighting.

<table>
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<tr>
<th>EXPERIENTIAL ASPECTS</th>
<th>REFERENCES &amp; CONCEPTS</th>
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<tbody>
<tr>
<td><strong>BIOLOGICAL &amp; PSYCHO-PHYSIOLOGICAL EXPERIENCE</strong></td>
<td>Hoffmann et al. (2008) variable lighting biological effects mood, activity, fatigue concentration</td>
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<td></td>
<td>Izso, Lauffer &amp; Suplicz (2009) dynamic lighting activity, performance, subjective feelings</td>
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<tr>
<td><strong>SEEING &amp; VISUAL EXPERIENCE</strong></td>
<td>Izso, Lauffer &amp; Suplicz (2009) dynamic lighting visual performance</td>
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<tr>
<td><strong>ACTIVITY-RELATED EXPERIENCES</strong></td>
<td>Boyce, Eklund &amp; Simpson (2000) individual lighting control task performance</td>
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<td>Newsham et al. (2004) dimming control performance</td>
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<td>Justsen, Wouters &amp; Tenner (2000) controllable task lighting productivity</td>
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<td></td>
<td>Barkmann, Wereszczynski &amp; Schulte-Markwort (2011) variable lighting performance &amp; motivation</td>
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<td>Motl et al. (2012) dynamic lighting learning</td>
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<td></td>
<td>Sleegers et al. (2013) dynamic lighting concentration</td>
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<td>Keskinen et al. (2014) interactive lighting exercise motivation</td>
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<td><strong>SOCIAL EXPERIENCES</strong></td>
<td>Casclans (2014) social lighting re-active lighting</td>
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<td>Poulsen et al. (2012) social qualities play</td>
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<td>Poulsen et al. (2013) social qualities play</td>
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<td>Seilinger (2010) social practices</td>
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<td>Hispanhol &amp; Tomitsch (2012) social interaction performance</td>
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<td>Weihoff &amp; Gehring (2012) group experience</td>
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<td>Magelsee (2014) social experience</td>
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<td>Barkmann, Wereszczynski &amp; Schulte-Markwort (2014) variable lighting fitness &amp; social behaviour</td>
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<tr>
<td><strong>SAFETY &amp; SECURITY</strong></td>
<td>Viluñas et al (2013) intelligent outdoor lighting subjective evaluation of luminance distribution safety subjective well-being environmental properties</td>
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<td></td>
<td>Haans &amp; de Kort (2012) dynamic street lighting perceived safety, prospect, concealment &amp; escape</td>
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<td>de Kort et al. (2014) defusing escalatory behaviour (lighting research)</td>
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<td></td>
<td>Weihoff &amp; Gehring (2012) security</td>
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<td><strong>MEANINGS &amp; VALUES</strong></td>
<td>Poulsen et al. (2013) city image, ownership towards the city</td>
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<td>Seilinger (2010) image of the city private lights</td>
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<td>Fritsch &amp; Brynaskov (2011) affect</td>
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<td><strong>AESTHETIC EXPERIENCE &amp; ATMOSPHERE</strong></td>
<td>Casclans (2014) atmosphere reactive lighting</td>
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<td>Poulsen et al. (2012) aesthetic qualities</td>
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<td></td>
<td>Poulsen et al. (2013) aesthetic qualities</td>
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<td><strong>PSYCHOLOGICAL EXPERIENCES</strong></td>
<td>Westhoff &amp; Gehring (2012) self-esteem self-esteem strength pleasure stimulation</td>
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<td></td>
<td>Boyce, Eklund &amp; Simpson (2000) individual lighting control mood relaxation satisfaction</td>
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<td>Newsham et al. (2004) dimming control mood &amp; worker satisfaction</td>
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<td>Lemmens &amp; Hu (2013) boredom, relaxation, flow pleasure, arousal &amp; dominance</td>
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<tr>
<td></td>
<td>Fletscher, Knauger &amp; Scherz (2001) pleasure, arousal &amp; dominance</td>
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<tr>
<td><strong>CONTROL, INTERACTION &amp; PARTICIPATION</strong></td>
<td>Poulsen et al. (2013) interaction &amp; participation designing light scenarios</td>
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<td>Seilinger (2010) participation</td>
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<td></td>
<td>Hispanhol &amp; Tomitsch (2012) interaction &amp; participation</td>
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<td></td>
<td>Westhoff &amp; Gehring (2012) interaction &amp; participation self-esteem, autonomy, competence</td>
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<td></td>
<td>Brynaskov et al. (2000) interaction patterns</td>
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<td>Velich &amp; Gifford (1996) choice &amp; perceived control</td>
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<td></td>
<td>Boyce, Eklund &amp; Simpson (2000) individual lighting control</td>
</tr>
<tr>
<td></td>
<td>Offermans, van Essen &amp; Eggens (2014) user interaction, user interface</td>
</tr>
<tr>
<td><strong>COMMUNICATION &amp; INFORMATION</strong></td>
<td>Seilinger (2010) interactive pixel low-resolution display communication</td>
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<td></td>
<td>Fritsch &amp; Brynaskov (2011) communication &amp; information</td>
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3 Research process and methods

3.1 Methodological framework

In the following subchapters, I describe the methodological framework of this thesis. I validate my research approach by linking it to practice- and design-based architectural research and to transdisciplinary research.

3.1.1 Practice and design based architectural research & Research-by-Design

In their book Arkkitehtuuri: teoria, tutkimus and käytäntö (Architecture: theory, research and practice), Aura Katainen and Suoranta (2001) have outlined a new form of architectural research and doctoral thesis research in architecture, based on practice. The aim in this approach is to achieve a direct, reflective relationship with the practice of the field. The research approach also takes into account the special nature of architectural practice—multidisciplinary design practice containing creative form giving. Discussion about the nature of architectural research and design research has been going on over the last decades in several international conferences and conventions around Europe.1

As a background for practice-oriented research approach, Aura, Katainen and Suoranta (2001) raise the discussion about “practice turn” (Eskola1997) within many fields, which can be even seen as a new paradigm penetrating several disciplines. As multifaceted and rich in meanings, practices can be seen as inherently theoretical. On the other hand, this complexity of practices makes them interesting as research subjects. There are always in the background of practices different kinds of theoretical preconceptions, which determine how they are understood and how people operate in them. The theoretical commitments and presumptions, which define practice and guide its forming, are often tacit and taken for granted. For that reason, theoretical examination of practice is necessary. (Aura, Katainen & Suoranta 2001: 33-34, Eskola 1997: 154, Karjalainen & Siljander 1997: 67)

In research, renewal of practice can be aspired through practice–theorizing–practice circles, which can be constructed in different ways. Concrete making—praxis—should always have a counterbalance—systematic and scientific analysis of practice; theorizing, thus, aims to reflect, analyze and structure practice and the underlying theoretical commitments and presumptions. Aura, Katainen and Suoranta prefer using here ‘theorizing’ from ‘theory’, since theorizing as a term refers to the active, critical, and creative skill of thinking. (Aura, Katainen & Suoranta 2001, 36)

In the book, two different approaches to practice-oriented architectural research are presented: a practice-based research approach and architectural design-based research approach. The differences between the approaches are related especially to the role of design in the research process. My doctoral thesis research has points of resemblance to both of the research approaches.

In the practice-based research approach, the interest is in the practice, which can be approached, for example, with ethnographic research methods. The research subject can be, for example, theoretical structures of practices of the field, routines and conventions, as well as cultural forms and social structures. An architect can, as a researcher, approach his or her own practice—the work of architect—thus analysing its theoretical and other commitments or conventions to solve a design problem in a certain way. Basis for contemplation can be the

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general reflections concerning, for example, the philosophy of science and the former research and special knowledge of the field, relating to a specific design problematic. The actual research, then, consists of these reflections and theorizations. In addition, a design component can be attached to a practice-based research, in order to demonstrate what kind of practice can be founded on the research. In this way, the knowledge that is abstracted from the research subject can be returned back to practice, as practical knowledge. (Aura, Katainen & Suoranta 2001, 36-38)

The main difference between design-based research approach and practice-based approach is that in design-based research, the “architect as a researcher is not only concentrating in theorizing the practice of the field and in concretizing its results with a possible design component, but uses the design component as a tool, as a research instrument, to gain a primary relation to the phenomenon under research” (ibid., translation to English by the thesis author). In the research process, the design functions as a method to test different, theoretically justified possibilities. Aura, Katainen, and Suoranta (2001) validate their argument of using design as a research tool with the sociological viewpoint to knowledge: scientific research is constructed of both conceptual elements, which can be, for example, theories in textual form, ideas and thoughts, and of material elements (for example test laboratories, research instruments and questionnaire formulas), and the complex interaction of these two elements. In the same manner, knowledge and knowing are formed in a design-based research in a dialogue of conceptual elements, i.e., the elements theorizing practice, and material elements, i.e., experimental or concrete designs. (Aura, Katainen & Suoranta 2001: 38-40, Miettinen 2000: 278)

The design-based research can be described as a reflective process—like hermeneutic cycles—between conceptual and material elements. A problem in architectural practice is leading to study different alternative solutions, rationales, and theoretical foundations behind the problem. The conceptual element, theorization of the phenomenon, is bringing the problem back to a question, which demands material conceptualization and design, which again produces further questions. The cycle theorizing–action–design–reflection can be repeated in a research process several times, as the preceding cycle leads to a new cycle and feeds it. (Aura, Katainen & Suoranta 2001, 40-42)

In both of the aforementioned approaches of practice-oriented research, the aim is, in addition to creating knowledge, to advance knowing within architectural practice, i.e., to return the knowledge into concrete action in practice: for example, to a better mastery of a certain design task. Between the produced theoretical knowledge and practical knowledge and knowing will become a dialogical relationship. It could be stated that only when the knowledge is transformed to practical knowing, it can really become a regenerative agency. (ibid.)

Among the disciplines concerning design, the terms ‘research by design’ and ‘research through design’ (e.g. Nilsson & Dunin-Woyseth 2011, Magielse 2014, Forlizzi, Zimmerman & Stolterman 2009, Verbeke 2008a, Verbeke 2008b) have become established to a wider use. The terms can refer, depending on the case, to a similar kind of research approach as Aura, Karainen and Suoranta (2001) describe in their book.

The concept of tacit knowledge can be closely related to architectural practice and to the research emerging from the practice. The term ‘tacit knowledge’ is initially from the book Personal knowledge; Towards a post critical philosophy by Michael Polanyi from year 1958 (Polanyi 1973). Tacit knowledge is the other dimension of knowledge besides explicit knowledge—unformulated knowledge, which influences people and behind actions, even though it cannot necessarily be described. According to Polanyi, tacit knowledge shows itself mainly in actions of people. (Koivunen 1997, Polanyi 1973, Polanyi 1958)

Explicit or focal knowledge (Polanyi 1959) defines the things that we deal with in each moment and makes them visible. The essential background information in this process belongs to tacit knowledge. It is possible to evaluate critically focal knowledge, as it is expressed in an explicit way, whereas with tacit knowledge, a similar kind of critical reasoning chain is not possible; this is the essential logical difference between tacit knowledge and focal knowledge. Tacit knowledge helps us to process and develop focal knowledge.
“Also in formulating scientific knowledge, we depend on a tradition of that kind of knowledge and science, which we cannot describe verbally. This tradition is influencing scientific data acquisition, setting of hypotheses and selection of coded data. It is impossible to describe explicitly the whole process of scientific knowledge production. According to Polanyi, for example in fields of physics and mathematics, which are heavily based on explicit knowledge, there is an influence of perception manners of unity and beauty: forms and aesthetic traditions of intellectual beauty.” (Koivunen 1997, 80-81; Polanyi 1959, translation to English by the thesis author)

Koivunen states that the borderline between tacit and coded knowledge is extremely interesting, as tacit knowledge can be approached or described only through verbal definitions. Polanyi has described this act of speaking about preverbal knowledge as a small pool of light or an illuminated path in the middle of immense darkness. The fundamental experientiality or truth of tacit knowledge can be approached through art and intuition, but when it becomes conscious, it is already coded and alienated from the initial experience. Creativity, intuition and innovation always demand tacit knowledge. (Koivunen 1997)

What kind of tacit knowledge is manifested in the practice of an architect or of a lighting designer? Jerker Lundequist (1998) has described this designer’s practical knowledge as “knowledge-in-action” (Schön 1983), practical skills, proficiency, and dexterity, as knowing how things should be done. This kind of knowledge is gained through training and social interaction. A designer’s tacit knowledge tells the architect how a building or environment should be constructed in order to be usable. It could be described as a collection of both unconscious and conscious “rules of thumb”, concerning functions, dimensions, climate conditions, and construction methods. However, in order to generate architecture or architectural lighting as the end result, the creative process synthesizing the components of a design task also includes aesthetic thinking, knowledge, and value judgment, which often is difficult to verbalize. (Ojala 2000)

In a practitioner’s mind, there is a repertoire of examples, mental images, insights, and actions, which he or she can use while solving a design problem. Donald Schön (1983) has described this application process as follows:

When a practitioner makes sense of a situation he perceives to be unique, he sees it as something already present in his repertoire. To see this site as that one is not to subsume the first under a familiar category or rule. It is, rather, to see the unfamiliar, unique situation as both similar to and different from the familiar one, without at first being able to say similar or different with respect to what. (Schön 1983, 138)

In his or her work, for example, while designing a building, an architect builds upon the explicit knowledge and the practical knowledge and knowing which is more or less based on tacit knowledge. While researching and renewing the practice, reflection of both forms of knowledge is essential. Schön (1983) has used concepts ‘knowledge-in-action’ and ‘reflection-in-action’ relating to this.

The thought that tacit knowledge could only be described and approached through verbal definitions (cp. Koivunen 1997: 81) can also be challenged: Could it be possible to utilize in the research approaching architectural practices those same tools for reflecting tacit knowledge, which are used in approaching tacit knowledge in the actual practice, in a design process? Perhaps visual and also spatial-material and functional representation in addition to verbalizing might more directly convey those parts of knowledge, which verbal distancing may lose. (Ojala 2000)

Positioning this research

My research is practice-oriented, design-based research. The essential part of the research and the empirical material consists of the design processes of adaptive lighting and the resulting lighting designs, relating to two aforementioned research projects. The significance or the designs in my research has been multifaceted: The design processes have led me as a researcher deep into the problematics of designing adaptive lighting. They have aided me to create an immediate relation to the research subject and specified and formulated my
research questions. On the other hand, the design process has acted as a tool for developing a new design method and design tool. Through reflection of the design-based research material and the documented design processes, as well as discussing it with previous research, I have generated a theory for design of adaptive lighting.

My position as a researcher is of a designer, who has long been interested in lighting-related questions. This doctoral thesis continues my specialization in problematics of architectural lighting, which started with my advanced studies and master thesis (Ojala 1999) for an architect’s degree. Before the aforementioned research projects about adaptive lighting, I worked for several years as a researcher and project leader in research projects concerning daylighting and façade design in a housing context, as well as participatory design and resident-oriented construction (1999–2004). As part of my doctoral studies I have completed a one-year course (2007–2008) of architectural lighting design, Valon arkitehtuuri (Architecture of light) arranged by IADE Institute for Art, Development and Education (nowadays part of Aalto University). As a lighting design consultant, I have done lighting designs ranging in scale from exhibitions, dwellings and public buildings to scale of urban spaces and whole city lighting master plans. On the other hand, educating lighting design in different kinds of scholarly contexts, for example, during the last 13 years in an architectural lighting course in the Oulu School of Architecture, has given me an opportunity to pedagogically reflect, structure and theorize the subject.

Thus, my research approach can be seen as partly subjective and intimate: The researcher has not been artificially distanced from the subject, but rather, in the process the advantage has been taken of the researcher’s close relationship to the subject. The experiences of design work are not only evoking and directing research questions, they are also for their part answering the questions through observations, insights, practical experiences, and understanding via reflections fed by theory. Fundamentally, my designer persona has been included as a debater, together with theoretical background and research materials in dialogue answering to research questions.

The arrangement can, naturally, also be seen as problematic. Thus, are the research and the produced knowledge reliable when the relation to the subject is immediate and personal? The fulfillment of the criteria of a scientific work, the reliability of research and results, has in this work been ensured with criteria, which are often connected with qualitative research. These include presenting the research context, framing of research problem, credibility, and reporting, as well as applicability, transferability, and novelty value of results. (e.g., Aura, Katainen & Suoranta 2001: 54-61)

My doctoral thesis research aims, in addition to new knowledge of design of adaptive lighting, to understanding of experience concerning adaptive lighting. For this task, I have also applied methods of qualitative research, which have received influences of ethnographic research. We have developed these research methods in the multidisciplinary research group during the research processes to respond to the specific evaluation needs of the experimental lighting pilots. I see the evaluations as an essential part of the knowledge production process of Research-by-Design research, as Hansen and Mullins (2014) have stated as well, in connection to lighting design research.

### 3.1.2 Transdisciplinary practice and research

In the Nordic countries, an interest towards developing research education for the making professions, such as architecture, around the idea of transdisciplinarity (Gibbons et al. 1994: vii, 28-29, Kötter & Balsiger 1999: 98-104) has arisen during the last decades (Dunin-Woyseth & Nielsen 2004: 5).

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2 The term ‘making professions’ is a Scandinavian neologism, which was taken into use about two decades ago, when organized research education was developed as a permanent part of architectural and design education in the Nordic countries. Making—understood as form giving of wide variety of artifacts including the scales from “a spoon to a city”—was seen as the common denominator of the professions that are educated in these schools. Among these professional fields are architecture, design, urban design, interior design, landscape architecture, product design, interaction design, and pedagogically oriented professions relating to art and design education. (Dunin-Woyseth & Nielsen 2004: 5)

3 'Transdisciplinarity' does not only refer to knowledge created in the interaction between different disciplines, but, in a research process, there can be actors from practice as well as representatives from business, in addition to representatives from different branches of science. Trans prefix is thus referring to the transcending the boundaries of disciplines and academic world. Gibbons et al. (1994) make a clear distinction between ‘transdisciplinary’ and ‘multidisciplinary’ or ‘pluridisciplinary’. ‘Multidisciplinarity’ as a term refers to a research, which, in parallel, exploits research perspectives of several disciplines; however, proper interactive movement between disciplines, which would
The book *The New Production of Knowledge* by Gibbons *et al.* (1994) presents a new form of knowledge production (Mode-2), which is emerging alongside the traditional scientific and disciplinary form of knowledge production (Mode-1). A typical feature of knowledge production in Mode-2 is transdisciplinarity. In the book, Mode-1 refers to the traditional scientific form of knowledge production, to the system of mental structures, methods, values, and norms, the ideal of which is Newtonian empirical and mathematical physics, and which has spread into ever more fields of research as a criterion of sound scientific practice. The cognitive and social norms of Mode-1 define what is a significant research problem, who is allowed to practice science and what constitutes good science. As a form of knowledge production, Mode-1 is disciplinary and strictly bound to institutions and their hierarchical systems. In Mode-1, separate, self-sufficient realities have been built for science and knowledge production, from where the contact to the surrounding world and reality with its practices and problems has been disconnected. (Gibbons *et al.* 1994: 1-4)

The concern of loss of unity of knowledge as well as the need for the common model of problem solving, which is more than a juxtaposition of different fields, form the inspiration and need for a transdisciplinary form of knowledge production (Nowotny 2004: 10). The fragmentariness of disciplines and specialization to different research fields has led to an increasing inability to have mutual communication and to communicate with the surrounding society. An alarming result of this alienation is the inability of modern science to solve today’s multifaceted problems, which emerge from outside scientific context, and are related, for example, to environmental issues. (Kötter & Balsiger 1999: 90-91)

An essential feature in the new form of knowledge production—in Mode-2—is that research is increasingly being done in the context of application. The research problems are formulated from the beginning in dialogue with different actors, viewpoints, and interests. The research context—a specific problem-solving framework—is set in this communication between different actors. (Gibbons *et al.* 1994: 4, Nowotny 2004: 11)

Another key characteristic of Mode-2, which is closely related to the production of knowledge in the context of application, is transdisciplinarity. Transdisciplinarity differs from interdisciplinary research, which means a cooperation of several autonomous disciplines in order to solve together that kind of a research problem, which one discipline alone cannot solve. Transdisciplinarity is at stake when a research problem arises outside a scientific context, and, for solving it, collaboration between both scientists and practitioners is needed. (Kötter & Balsiger 1999, 102) The explicit formulation of a uniform, discipline transcending terminology or common methodology is characteristic for interdisciplinary research. The scientific cooperation consists of working on different themes but within a shared framework. Transdisciplinarity arises when research is based on a common theoretical understanding and a mutual interpenetration of disciplinary epistemologies. Collaboration leads to clustering of disciplinary rooted problem solving and creates a transdisciplinary homogenized theory or model pool. (Gibbons *et al.* 1994: 29)

In transdisciplinary research, a clear but evolving framework is created for problem solving. The research process includes the creation and updating of research methods by the researchers themselves in the application context. The knowledge production “is characterized by a constant flow back and forth between the fundamental and applied, between the theoretical and practical. Typically, discovery occurs in contexts where knowledge is developed for and put to use, while results—which would have been traditionally characterised as applied—fuel further theoretical advances.” (Gibbons *et al.* 1994: 19) The experimental process is being increasingly guided by the principles of design that have been originally developed in the industrial context. As the solutions contain both empirical and theoretical components, they produce new knowledge, which does not necessarily fit into boundaries of any discipline. (Gibbons *et al.* 1994: 5, 19)

Other characteristics of Mode-2 knowledge production are heterogeneity and organizational diversity, social accountability and reflexivity as well as quality...
control. The quality control is wider than the disciplinary control inside science, and it relates to additional aspects such as market competitiveness, cost efficiency, and social acceptance. (Gibbons et al. 1994: 6-8) Nowotny (2004) mentions the quality control of knowledge production as the Achilles’ heel of Mode-2, because it demands evaluating other aspects besides scientific excellence. Scientific excellence is and remains the basis of good and reliable knowledge. However, the excellence of a work includes other components, which depend on various contexts and which are difficult to define. Also, value-bound societal criteria should be integrated into the process of evaluating the quality of science. (Nowotny 2004: 12-13)

Positioning this research

My research can be characterized as transdisciplinary. The starting point has been a multidisciplinary problem in practice. The solution to the problem has been sought by carrying out research and acting in practice. For solving the problem, research projects have been launched, and lighting pilots have been realized in real-world contexts, with participating actors and experts from different disciplines—architecture; lighting design; information, lighting and sensor technology; cultural anthropology—and representatives from business, users, as well as from construction and maintenance of lighting and urban environment. The starting points, targets, and framing of research questions have been generated in project groups, where different quarters have been represented. The methods have been created, developed, and adjusted during the dynamic research process. Characteristic of the process has been the multitude of methods; thus, the answers to different questions of the complex research problem have been sought with different methods (Groat & Wang, 2013). Considering the result, it is also important to evaluate in the thesis the relevance of the answers—was the used method successful in relation to the targets of framing the question? As characteristic of the transdisciplinary research and Mode-2 knowledge production, the results of the research have already returned back to practice; they have been taken into use in the design and realization processes of lighting. The new practical knowledge has already moved forward by the actors in the research process; for example, I myself have applied the gained knowledge in recent design projects concerning adaptive lighting. In addition, in the city of Oulu, permanent park lighting has been realized and is being realized, where lighting is adaptive. The company partners of the projects have directed their development work and product selection utilizing the results.

3.2 Research process and methods

I present here a short summary of the research process and the methods used in it. The detailed descriptions of the applied, qualitative research methods of pilot evaluations are presented in Chapters 5.1, 5.2 and 5.3.

The subject of my doctoral thesis research and its case studies concern various research disciplines such as research of lighting design and experience, architectural research and HCI. Typical to all of these disciplines is that their research problems are not usually set within a one singular disciplinary framework. In addition, my research problem and the knowledge production operate within a context of practice. This research can thus be defined as transdisciplinary research, referring to Gibbons et al. (1994). In the research process, the framework of methods was developed and modified throughout the process to respond to the needs of research and to the clarified research questions. These developed methods have been, for example, the experience gauging walking interview method, which was inspired by ethnographic research methods, and the evaluation probe method (Luusua et al. 2014), which was influenced by cultural probe method (Gaver et al. 1999). The research followed a mixed-method or combined strategies approach, where multiple methods from diverse traditions are applied in a single research endeavour. This approach is suitable for researching complex phenomena, as in this case a design process and experience of adaptive lighting in real environments. Each method brings with its particular strengths and weaknesses and “combining methods provides appropriate checks against the weak points in each, while simultaneously enabling the benefits to complement each other.” (Groat & Wang, 2013)
Table 6 presents the research methods used in each case study project, divided into the phases of the pilots (design tool and method development and the design and realization of the pilots; experience evaluation).

**Table 6. Research methods used in the case study projects. *Italicics* = the research material is not included in this thesis.**

<table>
<thead>
<tr>
<th>PHASE</th>
<th>METHODS / LIGHTSTORIES</th>
<th>METHODS / URBAN ECHOES</th>
<th>METHODS / ADAPTIVE RETAIL, LIGHTING PILOT</th>
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<tbody>
<tr>
<td><strong>Design Tool and System Development</strong></td>
<td>• State-of-the-art literature surveys</td>
<td>• State-of-the-art literature surveys</td>
<td>• State-of-the-art literature surveys</td>
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<tr>
<td>Design and Realization of Pilots</td>
<td>• Research &amp; Development by Design</td>
<td>• Use Scenarios</td>
<td>• Scenario working</td>
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<td></td>
<td>• Real-world testing</td>
<td>• Research &amp; Development by Design</td>
<td>• Research &amp; Development by Design</td>
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<td></td>
<td>• Video documentation</td>
<td>• Real-world testing</td>
<td>• Real-world testing</td>
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<td></td>
<td>• System data logging and analyses</td>
<td>• Video documentation</td>
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<td>• System data logging and analyses</td>
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<td></td>
<td>• Design tool performance evaluation</td>
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<tr>
<td><strong>Experience Evaluation</strong></td>
<td>• Semi-structured interview</td>
<td>• Semi-structured interview</td>
<td>• Semi-structured interview</td>
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<td></td>
<td>• Questionnaires (online and printed) containing multiple choice and open-ended questions</td>
<td>• Experience gauging walking interview in-situ</td>
<td>• Evaluation probe method used in the test site</td>
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<td></td>
<td>• System data logging and analyses</td>
<td>• Questionnaire (online and printed) containing multiple choice and open-ended questions</td>
<td>• System data logging and analyses</td>
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<td>• System data logging and analyses</td>
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3.3 Case projects

3.3.1 Case 1: LightStories project

This case is presented in detail in the appended Articles I and II, and the description is based for most parts directly on the article texts.

In the LightStories case project, lighting was approached as an experiential, interactive, social, and communicative element of a public urban space. The main concept of LightStories was to appropriate a part of the existing lighting on a pedestrian-oriented street as a forum for personal narratives, messages, and greetings. Through this playful idea of street lighting as social media, people were invited to participate in the lighting design of a public street using an online design tool. Anyone with Internet access could create their own design for the existing street lights, which are equipped with RGB LED stripes, and write a story that would be associated with the lighting design by displaying it on the website and on the public UBI touch screens in the city centre. Each participant booked a suitable time for his or her story and created a lighting design by choosing and modifying different static and dynamic effects and colours. Real-time video of the street was also displayed to illustrate the current story on the website. The LED stripes provided atmospheric lighting, but the functional part of the street lighting, provided through indirect metal halide lamp luminaires, could not be controlled. The LightStories project was designed and realised during the autumn and winter season of 2011–2012. The design tool was in use and the LightStories were displayed in the Pakkahuoneenkatu Street in the city centre of Oulu, Finland, in February 2012. (Pihlajaniemi et al. 2012)

The research aims of the LightStories demo were threefold: 1) On the level of design process the aim was to gain understanding of the design process of participatory and interactive lighting solutions in an urban environment and of the methods and tools necessary for the process. For this purpose, a pilot version of a participatory design tool was developed and tested “in the wild”. Additionally, the aim was to explore ways to employ algorithm-aided design methods in the process. 2) On the level of participant experience the aim was to research how our participants experienced the participatory design process and the interactive urban lighting setting. Our objective was also to get feedback from the users of the design tool. 3) On the level of Adaptive Lighting System, our challenge was to design and build an interactive and communicative lighting system, which allows the inhabitants of the city to participate in the design of public lighting, employing existing street lighting infrastructure. (Pihlajaniemi et al. 2012)
The results of the LightStories demo have been discussed from the perspectives of the participatory lighting design process, tool development and piloting, and algorithm-aided design as well as adaptive lighting system, in the appended Article I. The themes of participation experiences and communication have been discussed, thus reflecting the results of the project in the appended Article II. In Chapter 4.1, I describe and analyse the design process of a participatory and communicative lighting; in Chapter 5.1, I explore the results of the experience evaluation.
3.3.2 Case 2: Urban Echoes project

This case project is presented in detail in the appended Article III, and the description here is, for the most part, based directly on the article texts.

Urban Echoes was a temporary park lighting installation, which studied different scenarios of movement-adaptive lighting from the perspective of a park visitor’s experience. In addition, the installation explored the intriguing potential of communicative lighting.

The movement-adaptive scenarios were designed using a graphical design tool developed in our research project. The design process of demo scenarios acted as a method for developing the tool’s functionalities. For the Urban Echoes demo, the park lighting was designed as a flexible system programmed to produce both even distributions of light and more uneven distributions consisting of different-sized patches of light on the park pathway. The lighting reacted to park visitors’ movements via motion sensors, following the control algorithms graphically designed with the tool. The performance of the design tool could be evaluated by comparing the initial design intentions of different scenarios, the design processes and simulations with the tool, and the experience of the real-world lighting scenarios.
Fig. 11. In the lighting scheme for Activity service, park luminaires were representing the layout of different activity hotspots in the city, receiving the indicating intensity of red colour. These activity hotspots were sensed by the UBI sensor network detecting Bluetooth-equipped devices, and were displayed as red dots with varying intensities of red colour on the map in mobile device. The lighting situation was presented simultaneously by Lighting service as light dots on the park map and as energy consumption graphs.

Another aspect of the Urban Echoes demo was to develop and test a communicative lighting system. The installation provided urban information in the form of colourful lighting. With their mobile devices, people could make inquiries about current events in the city (Events mobile service) and the real-time activity levels of different districts in the city centre (Activity mobile service); they received an answer visualized as light playing on surfaces of the path and surrounding trees. The same information was readable in graphical and textual form on their mobile devices. The third part of the mobile service—Lighting—provided a real-time visualisation of the lights in the park and how much energy it consumed. The Urban Echoes mobile service was accessible from the park through scanning the QR codes on site.

Fig. 12. In Events service, the amount of the ongoing events and the ones that are starting within two hours were displayed in categories with theme colours on a mobile device. In the resulting lighting scheme, luminaires reproduced the amount of different events as dots of thematically coloured lights. The lighting situation was presented simultaneously by Lighting service as light dots on the park map and as energy-consumption graphs.

The Urban Echoes demo can be seen from three different perspectives—as part of a design world, a system world, and an experience world. The threefold objectives of the demo, which stemmed from all these contexts, were: 1) to develop and test a novel graphical design tool for designing adaptive lighting; 2) to explore the process of designing and realizing adaptive and communicative lighting scheme and system in urban context; and 3) to understand user experiences of adaptive and communicative urban lighting in park environment. The two latter targets are in the scope of this thesis and I will explore those results in Chapters 4.1 and 5.1.
3.3.3 Case 3: Adaptive retail lighting pilot

In this pilot project, the aim was to widen the concept of adaptive retail lighting beyond the energy-saving perspective towards light adaptations, which are part of the shopping experience. The pilot was done as a temporary lighting installation in a female clothing section in the Anttila department store in Oulu. It studied how light can enhance the shopping experience and influence customers’ shopping behavior. The aim was to design, develop, and test a system of adaptive lighting, which can attract customers to a certain store section and serve their visual needs in browsing the merchandise. In addition, light dynamics could be used to get the customers more focused on certain products and to lengthen the time they spend in the store browsing the products.

The pilot had several targets. In a system-design level, our challenge was to create an adaptive and intelligent lighting system capable of tracking people’s movement and positions in the pilot area and controlling the lighting based on that data. Another development task was to link lighting control systems with different control protocols together, allowing real-time control messages to be generated. For the Adaptive Urban Lighting project, the design and realization of the pilot was a good opportunity to further develop VirtuAUL design tool after the Urban Echoes project. The tool was developed to take in the complex data coming from the people-tracking system and to create, accordingly, adaptive lighting behavior in real-time.

For my thesis, I could study the design process of adaptive lighting in a different context, this time in an interior space. The pilot setting was also an excellent opportunity to evaluate customers’ experiences of adaptive lighting in a real-life retail environment as well as the effects on their shopping behavior. In addition, the evaluation provided good feedback of the design outcome—the adaptive lighting—which benefits the formulation of design targets for adaptive retail lighting. Thus, what aspects should be considered in the design process from the space users’ perspective?

Fig. 13. Retail lighting pilot setting.
4 Q1 results: Processes and methods for designing adaptive lighting

The first research question (Q1) of this thesis is: What design phases and tasks can be recognized as essential to the process of designing adaptive lighting? What kind of design methods could be used in designing adaptive lighting? To answer Q1, I describe in the following subchapters the design processes for the case projects and recognize and analyse phases and design tasks. I also describe and reflect the used design methods with design process examples.

All of the case projects are not described and presented with the same accuracy, as the processes were organized in different manner. The most detailed description concerning the phases of the whole design process is from the Urban Echoes project, which was the main pilot carried out in the Adaptive Urban Lighting project. The LightStories case employed a ready-made lighting infrastructure, and this fact removed many design phases from the process. The retail pilot was done in collaboration with VTT, and the coordination of the design and realization of the adaptive lighting system belonged to VTT’s role. In addition, the design aims and the design processes were partly different in each case. Therefore, the methods used varied and were developed further in the successive case studies. However, similarities in the processes and methods used can be found in reflection. In the last subchapter, I present a model of the design process for adaptive lighting, where elements of each process have been collected in a coherent diagram and discussed.
4.1 LightStories case: designing a participatory and communicative urban lighting

4.1.1 Workshop with stakeholders and site analysis

The LightStories project was an intensive design and realization process of a participatory and communicative lighting scheme, carried out during December 2011 and January 2012. In May 2011, we had arranged a workshop with representatives from the Oulu city planning office, Oulu city events department and the Oulu commercial centre (Oulun liikekeskus ry) to discuss the targets of our research project, the future strategies of lighting in Oulu, and to gain ideas for our planned first lighting demo. At that meeting, the representative from the city planning office suggested that we could do something on Pakkahuoneenkatu Street, where new lighting with controllable RGB LED strips was installed in 2009. In spite of a controller unit with many functionalities (Pharos LPC Lighting Playback Controller), the lights had only been on with blue or white light for two years.

In the existing lighting setting of the street, only the decorative light elements—RGB LED light strips along the sides of the luminaire poles—were controllable and not the functional street lighting, which was done with indirect metal halide lamp luminaires. Our initial aim was to make a bigger pilot in the spring with that street, where we would have installed new controllable LED luminaires on the side of the pedestrians so that the functional lighting could have been made adaptive as well. The LightStories project was, at first, intended as a preliminary test with the existing lighting infrastructure in order to get into the lighting system’s operation principles. Finally, as the demo was realized, operated, and evaluated, we had gained an abundance of interesting research material to be analysed; thus we abandoned the idea of having another demo in that context.

The site analysis concerned the existing lighting infrastructure, the street character, and surrounding activities as well as the city context. Pakkahuoneenkatu Street is in the core centre of Oulu and is located so that we could see the whole section of the street from our research laboratory situating in the first floor in an old wooden building of the quarter of our department. The street is categorised as a pedestrian oriented-street, as cars are not allowed to trespass. However, parked cars still largely dominate the visual image of the streetscape. Along the street situates many restaurants, which make the street active and the environment visually rich during the night due to its illuminated billboards.

![Night view of Pakkahuoneenkatu Street.](image)

4.1.2 Concept design

As the project was not intended to be the main demo, we did not carry out any brainstorming session with different use scenarios for discerning the design aims for the demo. The main design target emerged from thinking of the common problem of having a developed lighting system in a public space where the authority to use it is somehow undefined: no one has a clear responsibility to
decide how the lighting is controlled. What would be a meaningful appearance for that lighting in that street, instead of that blue light, which is there just because no one bothers to change it? This brought up the idea of making the lights on the public street open to city inhabitants’ own control, thus involving citizens to participate in designing the temporary appearance for that street at night-time. Another aspect, which we found interesting, was the communicative potential of lighting: how to invite people to express and communicate with the light in a public space and how to support this communication with other media, with textual narratives.

To summarize, our **design aims** were 1) to design an adaptive, participatory, and communicative lighting system with a citizen’s user interface for designing temporary, dynamic lighting schemes on the street; 2) to support the communication with textual and visual expressions in other media, using the ubiquitous technology infrastructure of Oulu city. From that starting point, the **interaction concept** of a web-based design tool was created. In addition, the LightStories concept included sharing the stories as texts and real-time videos in the LightStories web site via the Internet as well as publishing the texts in the public touch screens in the city centre.

### 4.1.3 Lighting system design

Different design tasks, which were needed to create the participatory and communicative **lighting system** of LightStories, are listed as follows. A more detailed description of the design process and technical solutions is in the appended Article I.

- Designing a citizen’s web-based user interface to control street lighting
  - web page
  - design tool
  - lighting effect templates
  - database of user created lighting designs and narratives
  - LightStories application on UBI touchscreens
- Programming of the lighting control device
  - designing the lighting effect templates
  - scripting the interactive lighting effect templates
  - in situ testing of the lighting effects
  - defining and building the system functionalities for linking the web-based design tool and the lighting control unit
  - defining system functionalities for maintaining and running the LightStories service
- Constructing the necessary communication links
  - connecting the lighting control unit to the city’s communication network
  - direct VPN connection to the lighting control unit for the research team
  - web servers
  - server for the webcam
- Employing existing infrastructure for the adaptive lighting setting
  - lighting fixtures
  - lighting control unit
  - Ubi touchscreens
  - free Pan-Oulu wireless Wi-Fi network covering the city centre

Besides the Adaptive Urban Lighting research group, an IT engineer was employed to develop the web page according to our design and to construct the necessary communication links. In addition, we had assistance from University Oulu Data administration personnel and the city of Oulu and Oulu energy company Networks sections. The design and realization tasks were carried out more or less simultaneously due to the very tight time schedule.
4.1.4 Designing for participation: participatory design process

In this case, however, the end result as a finalized lighting scheme on the street is not solely the result of a design process by a professional designer but a result of a participatory design process, where the input of a layperson participant has a central role. The flow chart presented in Fig. 15 (page 59) describes in parallel the design processes in the LightStories project from the perspectives of different actors of participatory design process—the professional designer and the layperson participant. These processes are presented as actions in a simplified system context of LightStories. The description is from the appended Article I.

The professional designer starts by framing the user’s design task in order to ease the process of the layman participant designing dynamic lighting within the streetscape. With the lighting controller’s software, the designer defines the participant’s possibilities through devising, scripting, and testing different effect templates to be used in the lighting designs. This framing is also done in parallel in the process of devising the functionalities and principles of a web-based design tool, with which the participant approaches the design task.

A major part of the professional designer’s task is related to designing the participatory and adaptive lighting system, which brings the user-generated designs into the streetscape. The designer devises the functionalities of the interactive lighting system; these make the lighting system operate according to choreography suitable for the requirements of the participatory project in question and link users’ design data with the interactive lighting system.

The complicated system level is deliberately kept out of the participant’s sight, as his or her contact point to the system is the easy-to-use web-based design tool. This design tool is used in the creation of the detailed lighting designs, starting from time slot selection and the actual design task—carried out by combining and modifying effect templates—all the way to writing the narrative text. On the web site, people can also read stories and messages other users have written, watch real-time video of the street, and receive information about the project. Public UBI screens are also part of the system, as they provide a venue for reading the stories and advertising the participation possibility.
Fig. 15. Participatory lighting design process in LightStories case.
4.1.5 Concluding summary

Here, I conclude the analysis of LightStories case design process by summarizing and discussing the design phases, design methods and tasks, and design results as well as design factors.

Site analysis and meeting with different stakeholders helped us to understand the design task and context and to formulate the design aims for the LightStories project. The concept design phase was, in this case, rather straightforward and intuitive: obtaining the strong idea of creative citizen participation based on the contextual needs—the missing or vague authority of the luminous appearance of the central and active streetscape—and then devising an innovative interaction concept for that, which resulted in the LightStories concept. In this case, as we could employ an existing lighting setting, the main tasks were the system design and participatory design tool design, which demanded cooperation with other professionals, in this case with IT experts. Participants completed the last phase of the adaptive lighting design, which resulted in the detailed lighting behaviour onto the street, as they used the web-based design tool and created their own lightstories.

Reflecting upon this case, I want to highlight one specific design method: the application of an easy-to-use design tool in combination with the creation of a narrative text in order to aid the creative process of a layman participant. Of the design factors guiding the process, the anticipated user experience, cultural context, and regulations as well as technology could be mentioned. User experience covered the experience of participation and the experience of the adaptive and communicative lighting on the street. For example, we tested in situ all the effect templates in order to avoid any unpleasant visual experiences. The lighting project had to fulfill the regulations for safe street lighting and we, obviously, decided not to shut down the main lighting of the street, even though we tested what kind of character and atmosphere the street would have with only the decorative RGB LED stripes. We were also considering the cultural context of the street in the core centre of the city and the activities—many restaurants—along that street. For example, the restaurants with the free Pan-Oulu Wi-Fi provided suitable places for citizens to devise their own lightstories in warm inside locations and also see the result and follow stories created by others. An important design factor was the existing technological infrastructure, which we employed. In this case, our main considerations did not include economic or ecological aspects, as the lighting setting was an existing one. The only decision partly related to ecology and energy use was to make the RGB stripes without any light when there were no lightstories presented. This, of course, uses less energy than having them burning white as a default mode. However, a more important motivation for that decision was the conceptual idea of letting the citizens themselves switch on the lights with their lightstories.
4.2 Urban Echoes case: designing adaptive and communicative park lighting

In the initial stage of Urban Echoes project, there were two main research targets concerning the design for adaptive lighting:

- To develop the functionalities and properties of VirtuAUL design tool with the help of the design process of different adaptive lighting scenarios.
- The design outcome should be several different scenarios of adaptive lighting behaviour, which then could be tested in a real-world situation to gain feedback from the interviewees of their experiences concerning each scenario.

As previously described, the design brief was rather open in the beginning. In a normal design project, financial and time resources are usually limited, and the scope of the design aim is usually more focused; thus, there are no opportunities to explore different kinds of design concepts and solutions in the same way that it was possible in the scope of the Adaptive Urban Lighting research project. Anyhow, this special situation gave an opportunity to thoroughly explore the design process and to obtain multi-sided insight.

4.2.1 Meeting with stakeholders and site analysis

The Otto Karhi Park was chosen for the site of the demo after a meeting with representatives of city planning office (the city architect) and city energy company Oulun Energia Urakointi Oy (head of street and traffic lighting department). The park’s central situation in the active core area of the city with a contradictory reputation, as a result of some past crime incidents (Kaleva 2006), made it an interesting site for our tests. We had an opportunity to study, for example, ways to enhance the experiential quality and the feeling of safety in the park. Analysing the site was the next step: A diagonal, largely used pedestrian route goes through the park leading towards the railway station couple of quarters away. Besides that, two narrower, more seldom used routes go through the park. The park itself is rather beautiful, especially during the summer, with its birch tree alleys, a selection of trees and shrubs of various types and a stream running through the park. Otto Karhi Park extends over one city block of the Oulu grid plan area and is surrounded by busy streets on three sides and on one side with a mixed-use street reserved for taxi and service traffic only. Along that street, there are located many restaurants with summertime terraces on the street side. Many restaurants and shops situate along the other adjacent streets. The surrounding buildings are, in Oulu city centre scale, rather high, ranging mainly from five to seven floors, and even to eleven floors.

4.2.2 Concept design with scenario writing method

To explore different ways to implement adaptive lighting in a park environment on a conceptual design level, a scenario writing method was used—writing short narratives of situations with adaptive lighting from the perspectives of various park visitors. The scenario writing method is commonly applied in the interaction design field. Rosson and Carrol (2002) describe scenario-based design as a family of techniques in which the use of a future system is concretely described at an early state of the development. Short stories of envisioned usage episodes guide the development of the system, which will enable these use experiences. As a user-centred method, writing scenarios changes the focus of design work from defining system operations to describing how people will use a system for their activities and anticipates their user experience. One benefit of scenario-based design is that making these kinds of simple narratives—rough sketches of use—is a relatively lightweight method and allows designers and other stakeholders to consider many design options before choosing the one to develop further. (Rosson & Carrol 2002)
Fig. 16. Figure collage of Otto Karhi test site. From upper-left corner to lower down corner: Situation of Otto Karhi park in the city grid. Aerial view of the park and nearby quarters. Park path selected for the testing area. Oulu city free Wi-Fi network PanOulu and sensing network by UBI project detecting Bluetooth activity. Lighting fixtures of the Urban Echoes installation as a light map presentation.
Writing these scenarios led us to empathize different kinds of use situations where adaptive lighting behavior brings about various experiences for park-goers, trying to put ourselves into the position of different users. Altogether, the research group wrote 19 short stories, which were then analysed together to discover different thematic elements of experiences and lighting behavior. Below, three short narratives, which I have written, are presented as an example and analysed as experience features and adaptation principles.

**A cyclist, 29-year-old male**

I drive through the park every day to work. Light is nice and even on the route, but I can see that it brightens around me following as I drive along the park path. In the distance, I see that light is dimmer. I suppose this has something to do with the energy-saving contract that the city of Oulu has signed. Of course, it’s a good thing; I like green values, and so I cycle a lot. Now I dismount from the bike, as I notice that I’m early. When I walk with the bike, light around me dims a little. That feels quite suitable, as, when I move slowly, I don’t need so much light on the route. At the same time, I notice that some trees on the other side of the path are brightening up. Light is caught by the frosted branches in a beautiful way. A bit further, I also see illuminated shrubs. I have really not noticed how beautiful they are. Those would suit well to the front garden, perhaps Tytti would like them?

Experience features:
- seeing route
- seeing environment
- safe moving
- positive values: energy efficiency
- atmosphere
- aesthetic experience

Adaptation triggers and factors:
- movement/position
- pace of movement

**Primary school boy**

On the way home from school, I take a shortcut through the park—this is my favourite route. It took quite long in the football practice, and it’s already dark now. It’s excitingly shadowy on the park path. When I step on it, I see ahead a string of small light dots, which stipple the paved surface of the path merrily. When I move forward into the park, something starts to happen: I notice that light brightens up when I walk on. Anyhow, the light is not brightening up everywhere, but it’s like the small patches of lights would play with me. They are like waking up and starting to live, they come around me like a swarm, but then again, they seem to be escaping, when I try to catch them. When I try to step on the light dots, they usually move aside. I continue trying and I feel that I manage at some points to get into middle of the most powerful rippling of light. Suddenly, I notice that the white light patches turn gradually blue. I know, then, that there will be somebody coming towards. Now a man goes past, and light is gradually turning back to white. It is exciting to guess which colour will appear next time. I think it has something to do with how many walkers will meet. Well, now I have already walked through the park. I have still one look back and see how the rippling of lights gradually fades away and finally stops.

Experience features:
- play
- interaction with light
- activating
- entertainment
- social experience
- excitement/wow
- atmosphere
- communication

Adaptation triggers and factors:
- movement/position
- number of people present and their proximity
A couple having an evening walk in the park

I walk with my boyfriend in the park. There is only little light on the path, and it feels like it would be following our walking politely. We start walking deeper into the park, and, along the route, gradually colours are lighting up, illuminated trees and shrubs blend into a layered scenery. It looks like the play of lights would be random, but I have read from the newspaper that the changes of colours and their movement between different parts of the park reflect somehow sound levels in different areas of Oulu. So there is visible in the park coloured echoes from the district centres of the New Oulu: from Haukipudas, Kiminki, Oulunsalo and Yli-Ii, which will join Oulu next year. The echoes of Oulu are directly from the park itself. It looks really beautiful and we sit down on the bench to watch the changing scenery. On the path in front of the bench light dims down and we can see better the colours around. A fire engine drives past sirens wailing and the trees around turn intensely red, starting slowly to change into magenta shades and gradually into shades of blue. Different trees have a slightly different rhythm.

Experience features:

- seeing route
- seeing environment
- atmosphere
- aesthetic experience
- communication/meanings
- entertainment/art

Adaptation triggers and factors:

- movement/position
- environmental information: sound level

In addition to the examples above, other experience features, which emerged in the rest of the scenarios, were:

- orientation and guidance
- safety and sense of security

In the scenarios, adaptation triggers and factors affecting lighting properties and behavior were movement or position detection, monitoring of movement speed, and number of people and their proximity, as well as sensored environmental data such as sound levels. Other types of sensor data could be easily linked to lighting systems to cause changes in light characteristics. This communicative potential of adaptive lighting, conveying of environmental or urban information in the form of visual expressions of light, was chosen to be one specific design aim for the park lighting demo. All of the scenarios were dealing with lighting that reacted somehow to movement or the presence of people in the park and presented good and applicable concepts for different kinds of experiences. They included concepts for lighting that were serving park visitors by enabling them to see ergonomically, move safely, and guide them, as well as concepts for lighting schemes that would make park more inviting and atmospheric. Lighting could entertain and attract park-goers to play and interact with light and enhance their sense of security in the park. Thus, at this design stage, we decided to target in creating a flexible lighting setting, which could be used for creating various kinds of adaptive lighting behavior reacting to people’s movements, so that we could test different scenarios and obtain feedback from real-world experience.

4.2.3 Design of adaptive lighting setting

The next step was to design an adaptive lighting setting. A rather seldom-used path which goes along the stream, was chosen to be the test site, as we could see if the altered lighting situation could invite more users to use the path. It was also possible to make the lighting scheme along the whole length of the path, so that the walking experience through park would be realistic and coherent and not just an extract of the experience, as in a laboratory setting. Birch trees surrounded the path on both sides, which provided us with an atmospheric element to illuminate and an easy and reasonable priced method to install the
necessary amount of lighting fixtures for illuminating the path surface by suspending them with steel cables running from tree to tree across the path. For creating a flexible lighting installation with several types of light distributions, four main elements were chosen: 1) an even light distribution on the path surface; 2) a dotted, uneven light distribution on the path surface; 3) accent lighting to birch trees along the path; and 4) accent lighting for selected trees and shrubs in the vicinity from the path. Those light elements could achieve most of the previously written scenarios. In addition, these elements would create—thinking with architectural terms—the floor, walls, and ceiling (suspended path luminaires as illuminated dots) to the sensed space of park route in the nocturnal urban environment. The final layout was discovered in an iterative process, which was affected by the amount of available luminaires from the sponsors, project budget, and the final arrangement and installation design and detailing of suspending the luminaires between the trees. The first intention was to get all the luminaires as RGB spotlights so that the tone of white light as well as the colour of light could be controlled for all the light elements. In the final solution, the even light distribution was achieved with luminaires using a wide bicycle route optic and giving only 3000 K light, which slightly restricted the variety of scenarios. The final layout of the luminaires in the lighting setting is presented in Fig. 16. Reaction of light to walkers’ movements was realized through the design of motion sensors installed to the sides of birch trees with more or less even intervals, so that they could cover most parts of the route.

The suitable distances between both the spot luminaires and the wide optic luminaires as well as suspension height, optical properties and needed luminous flux were tested with visualizations and lighting calculations with 3DS Max and Dialux programs. The same procedure is done in a normal lighting design process for static lighting to discover the visible effect of lighting solutions in an urban space as well as how it fulfills the standards for different route types.

In our case, the starting point was that the lighting scheme with the wide optic, which was especially suitable for narrow bicycle routes, would provide sufficiently bright and even light distribution to the route on the maximum level of light. A local LED-luminaire manufacturer Valopaa Oy lended us the controllable luminaires to create route lighting with even light distribution. Two different types of optics were tested by calculations with a reasonable distance between the luminaires. The selected one was then calculated with different light outputs to discover how many LED modules would be tailored into our test luminaires. The optic, which is optimized for a narrow route, was so effective that, even with one module, both the overall uniformity (Uo) and longitudinal uniformity (Ul) values were fulfilled for the highest street illumination class (A1), according to the standard SFS-EN 13201-2 (Tiehallinto 2006: 14-19). Mean luminance value remained obviously below the requirements of all the street illumination classes. For pedestrian route lighting, the uniformity requirements are much lower. In designing pedestrian route lighting, K-classes with requirements for mean illuminance (Em) and minimum illuminance (E) are used. The calculation results and the corresponding, fulfilled illumination class are presented in Table 7. Even though two modules would have provided sufficient illumination for a park path and met K3-class requirements, a set of luminaires, which would fill K1-requirements, was ultimately designed to be used. K1 is recommended for city centre squares and walking streets with allowed service traffic. The park situates in the core centre with surrounding brightly lit AL2-class streets. This over-dimensioning of light levels provided us with a wider control range of light levels in adaptive situations.

Table 7. Results of lighting calculations with optic V12, 18 m distance between the luminaires and 5 m installation height. Further, optic V6 was tested, but the light distribution pattern was not sufficient. The selected luminaire for the installation was Valopaa VP1401-M8-V12, street luminaire for wire rope assembly, 24 W, light output 3600 lm.

<table>
<thead>
<tr>
<th>Tested luminaire: VP1401-V12</th>
<th>AL class requirements: values / class fulfilled</th>
<th>K class requirements: values / class fulfilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light output</td>
<td>Lm (cd/m2)</td>
<td>Uo</td>
</tr>
<tr>
<td>450 lm</td>
<td>0.10 / -</td>
<td>0.47 / AL1</td>
</tr>
<tr>
<td>900 lm</td>
<td>0.21 / -</td>
<td>0.64 / AL1</td>
</tr>
<tr>
<td>1800 lm</td>
<td>0.40 / -</td>
<td>0.46 / AL1</td>
</tr>
<tr>
<td>2700 lm</td>
<td>0.59 / AL4b</td>
<td>0.54 / AL1</td>
</tr>
<tr>
<td>3600 lm</td>
<td>0.78 / AL4b</td>
<td>0.58 / AL1</td>
</tr>
</tbody>
</table>
Fig. 17. Figure collage of Urban Echoes test installation. From upper-left corner to lower down corner: Existing lighting situation of the test area park path with spherical light distribution and mercury lamps. A lighting scenario with new luminaires producing an even light distribution on the path. A lighting scenario with dotted, uneven light distribution on the path. The new luminaires installed with cables above the path; snow hides well the veneer boxes of the tree luminaires. The suspension of RGB LED spotlights from three to three. Three and shrub illumination. Test area as seen from other side of the bond.
The visual effect of light dots on the path surface was calculated and visualized with the 3DS Max program, checking the right suspension height, suitable beam angles, and distances between luminaires and sufficient lumen output. This was done to see if the resulting light patterns on path surfaces were powerful enough to create a clearly visible and beautiful effect. The matching to illumination classes was not checked, as this kind of lighting was not specifically meant for that kind of evaluation. Anyhow, the situation on light spots with two different angles (14° and 24°) was so dense, and the light output in the maximum level so high that in snowy wintertime situation with lots of reflected light, the K-class requirements would most likely have been met if measured on site. The visual effect of tree lighting was checked as well, and an 8° beam angle chosen for the right effect. The luminaires were designed to be located by the foot of the trees, in veneer boxes covered with clear acrylic boards. The boxes could be fastened with steel chains around the trees and covered from sides with snow so that they were barely visible.

4.2.4 System level design, interaction design and coordination of the design and realization

A substantial and time-consuming part of the overall design and realization process was the system level design of the intended adaptive and communicative lighting system and the coordinating of the design and realization. In this phase, the interaction design for the communicative lighting was accomplished, too. A web-based mobile application was chosen as an interaction technology for the communicative lighting services. The technical description of the implemented lighting system is described in the appended Article III. Different design tasks and elements are listed and categorized in Fig.18. Even though our research group made the “big picture” design for the system and interaction, numerous co-operators from academia, companies, and city authorities with IT expertise were required to produce component solutions for the overall system. I was responsible for coordinating the realisation and connection of each element into a real-world functioning system. In Fig. 18, the responsibilities of different collaborators are marked as number coding associated with each design element.

4.2.5 Design tool development

Design tool development was part of this specific design process; in a normal process, a ready-made tool could be applied. This tool development process is described in the appended Article III. Here, in the following, I present a brief description of the development and the basic principle of the tool (VirtuAUL © Toni Österlund & Henrika Pihlajaniemi), so that the reader can follow the design process with the tool, which is described later. The tool and developed design framework itself is a subject of another doctoral thesis, which will be completed by a fellow researcher Toni Österlund. Further details of the design tool are published in Österlund and Pihlajaniemi (2015) and in a forthcoming article and patent (Österlund and Pihlajaniemi 2016b, 2016a).

The development combined practical and theoretical knowledge from two separate fields—computational design and lighting design—and the development process could be seen as a progressive discussion and interactive process of learning between two disciplines and professionals, whose perspectives to the development task were different but partly overlapping (Pihlajaniemi, Österlund & Herneoja, 2014).

The VirtuAUL design tool used a graph-based coordinate system (Österlund 2013) by allowing the designer to freely define the virtual network of lights and sensors. The control method was based on the developed, computational model of network-based agents, where virtual agents move within the network topology. This creates a virtual environment of multiple acting agents that interact with the physical environment through lights and sensors in a multi-agent system (Jennings, Sycara & Woolridge 1998, Macal & North 2009). The global configuration of the dynamic lighting patterns emerge from the interactions as complex adaptation and distributed intelligence (Waldrop 1992, Holland 1998). (Pihlajaniemi, Österlund & Herneoja, 2014)
The basic tool functionalities were based on both theoretical and practical knowledge of the lighting design process and adaptive urban lighting. Additionally, they were based on use scenarios of adaptive lighting in a park experienced by various users (demographics, activity, time). Using VirtuAUL, the designer graphically creates lights and sensors on top of a 2D map of the simulation view. These are represented as individual nodes in the design view, and the network topology can be defined by creating links between them. All relevant design parameters can be modified by accessing right-click menus through each node. Sensors act as emitters that release agents that move and operate within the network of lights. Agents have distinct properties, such as colour, speed, lifespan, etc., and those can also be controlled directly from the menus. Modifications to the simulation and displaying additional relevant information can be done through the control pane. (Pihlajaniemi, Österlund & Herneoja, 2014)
After the first version of the tool, iterative design tests and brainstorming were used as a method for developing tool functionalities that would respond to the lighting designer’s needs. During the design tool development process, I conceived and designed several scenarios of detailed adaptive lighting behavior. In all the scenarios, light adapted to park-goers’ movements. This scenario design process aided in developing the tool functionalities: each scenario brought up new ideas and needs for the functionalities, which would help us to achieve the aspired lighting behavior. These were then developed and coded as a part of the tool. After several iterations, the functionality of the VirtuAUL design tool allowed for the creation of a wide variety of lighting schemes.

A central issue was adding functionalities that would raise user’s level of control of the end result, so that rational and linear adaptation patterns could also be created. Most design iterations and functionality developments of the tool focused on these aspects. The underlying agent-based computational process naturally veered towards seemingly random patterns of adaptation. From the perspective of a lighting designer, a design tool should ideally allow for the creation of designs containing linear or logically perceived adaptation as well as more non-linear patterns of adaptation. The former fulfills the functional needs of illumination (so that the light is at the right place at the right time for visibility and safe movement) and the latter the aesthetic, atmospheric, meaningful, and social needs for adaptive lighting (light creates aesthetic experiences in urban space, arouses meanings, and enhances the feeling of security). In a design scheme, the adaptation patterns can be combined to create a coherent experience, which fulfills both lighting needs. (Pihlajaniemi, Österlund & Herneoja)

4.2.6 Detailed design of lighting adaptation

Even though the members of the research group had already been writing scenarios about adaptive park lighting, I decided to start this design phase again with writing scenarios of movement-adaptive lighting. This helped to continue from more conceptual scenarios to detailed lighting behavior. I wrote scenarios from the perspective of a park visitor and of a more professional perspective of a lighting designer, who commented different design viewpoints and control factors. Altogether, I wrote 10 scenarios, which I then designed with the design tool prototype. The technical solution of the motion detection resulted in some limitations to the scenarios. When detecting movement, the sensors triggered an immediate response from the lighting control unit and continued to do so for as long as they kept detecting movement and 5 seconds after motion had ceased. Because of this delay, I had to abandon those concepts that would have given explicit interaction possibilities and needed real-time two-way feedback between the system and the user. In addition, the number of motion detectors in the installation was limited to seven. For the detailed designs of the adaptation scenarios, several design iterations with slightly different types of design processes and solutions were needed to obtain a desired result. The target was, besides the tool development, to create a useful selection of different adaptive lighting behaviours, which could be used in evaluating park users’ experiences. This increased the amount of needed design iterations, as I wanted to create lighting patterns that could be clearly distinguishable and characterized to represent certain design aims. Finally, after in situ testing in the real-world installation, a selection of scenarios, which were to be used in evaluation interviews, could be chosen from a larger amount of ready-made designs. During the evaluation process, the reactions and comments of the interviewees aroused new ideas for detailed lighting behaviour, which I designed, and then they were added to the testing protocol. In Table 8 and figs. 59–74 in Chapter 5.2, the interview scenarios are presented. Two of the interview scenarios (scenarios 10 and 11) were not designed with the tool, and they were not reacting to the movements, but the lighting dynamics were animated with the controller unit’s design program. In addition to these scenarios, two communicative lighting schemes were designed, and they were presented to the interviewees as well. Those were the Activity and Events lighting schemes, created for the corresponding mobile services (see p. 53, 82 and 83).
Fig. 19. VirtuAUL: Design view.

Fig. 20. VirtuAUL Simulation view.
In the following, I describe the design processes of a selection of scenarios (Scenarios 2, 4, 7A, 8A, and 9B). These illustrate well the design process and considerations and design decisions, which are essential to the process. Each description begins with design aims in the form of a scenario narrative from the perspectives of a park-goer and a professional designer. The design was done using the first version of VirtuAUL design tool, and the process follows a procedure defined by its functionalities and properties. In the end of this subchapter, I summarize the features of the process with the developed design method.

Scenario 2

Main design intention: Supports perception of the route and safety of movement

Park-goer

When I am approaching the park, I see that park path is lit dimly. When I enter the path, light brightens softly ahead of me and around me. Light on the route is sufficiently bright and even, and it seems to follow me softly as I move on the route and to guide me further. The rest of the route is clearly dimmer, but not totally dark.

Designer

My target is to design an adaptive lighting scheme that supports good perception of the route so that a walker moves safely and feels comfortable walking in the park. Adaptive lighting serves park-goers walking by brightening softly ahead, guiding further. The lighting scheme should also spare energy by reducing the energy consumption on lighting while the park is unused, and there is no need for high levels of light. Anyhow, the park should not look totally dark when there is nobody but have some lighting on the routes to look inviting and indicate the situations of the route. The waiting mode of lighting as well as the low presence mode can be rather low so that energy saving potential is large. The brightening and dimming of light happens in the vicinity of the walker and with a short enough length to be noticed. Anyhow, the transition between darker and lighter mode should be soft so that it feels pleasant and not too abrupt.

Design process

For designing the scenarios, a design template file was created where all the luminaires and sensors of the installation were situated as nodes in their right location on the design map. As the design method is based on the idea of leading a flow of light, virtually depicted as agents, to the place where it is needed in the right moment of time, I commenced with defining the network topology between the sensor nodes and light nodes. I chose to use the luminaires that had wide optics in this scenario, so that the light would be even, such as in the expression of ordinary path lighting. There were four luminaires of that kind in the installation, along with a motion sensor located on a tree trunk in the location of each luminaire. In addition, there were two sensors situated on both ends of the path, one on each end. In order to make the first luminaire to brighten softly when a walker enters the park path, I made a link between the start sensor node in the lower end and the first path light node. Similarly, I made a link between the last sensor node and the last path light node, so that lighting also serves walkers from the other end. I continued building the network by adding links between each four middle sensor nodes and the corresponding path luminaires. In order to obtain the light brightening always ahead a walker, I added duplicate sensor nodes to correspond to each one of the middle sensors in the installation, and linked each one of them to those two light nodes that situate just before and just after the sensors. Now the network is ready, and there are configured routes for light to flow in advance to each luminaire before a walker approaches it and when a person is in the closeness of it.

The next phase was to define agent properties, which, in a way, define the quality of the flowing light in the network. The four middle sensor nodes should generate agents of different families than the start sensor nodes and the duplicate sensor nodes, so that their properties could be different. For example, I made those agents, which were achieving the light always to be brightened before the walker enters below the luminaire, to have a shorter life length so that they would never reach the luminaire but come near. This made the light not to
brighten up quite to full intensity before the walker reaches the region of the actual sensor by the luminaire. To make the light behave in a logical and linear manner, I defined the agents to move always forward and not to turn back when they reach a luminaire. In the design scenario, I wanted the light colour to be warm white, so I defined the agent colour to be a responding RGB value (255,240,110). In this case, with the wide optic luminaires, this was important mainly for simulation, as the luminaires had only 3000 K colour and only light-level control option. Thus, only the first number 255 was read by the system and would, in this case, allow the luminaire to give 100% level of light if necessary. Lower value would have cut down the maximum level. By testing different parameters and simulating the end result in the simulation view, I gradually obtained the dynamic alterations of light to follow the movements of a cursor (“walker”) along the path in an aspired manner, softly and sufficiently ahead, fading slowly away after the walker. I still made one more definition to the design: locked the minimum light level of the luminaires to be of 10% of the maximum. This ensured that the path would not be totally dark when no one was walking along it.

From the design of Scenario 2, I did another test scenario—Scenario 1—just by changing the locked minimum value of the light level from 10% to 60%. The design intention for the Scenario 1 was, again, to create good and even path lighting, which would save energy. In this scenario, however, the intention was to make the change of light levels so subtle that the walker would not experience it but, instead, consider it as a static lighting.
Scenario 4

Main design intention: To create lively lighting for the route

Park-goer
When I approach the park, it seems a bit dark. It does not matter, as I know that the lights will go on when I enter there. Why would we need to have light in the park when there is no one; in this way we can save energy. When I enter the park, on the path, ahead and around me, a series of small dots of light is lighting up and following me softly, brightening and dimming in different rhythms. When I turn to look back, I notice that the lights will stay glimmering a while behind me, before fading away. Even though the light is not even, I see well to move safely.

Designer
My target is to design a lively route lighting, which follows the walkers and guides their movement as playful animation of illuminated dots of light ahead and around. The adaptations of light should be perceivable so that they would enhance the atmospheric experience. The amount of dots that are on at the same time varies, and they should brighten and dim with a moderate speed so that it is not irritatingly fast but is a noticeable effect. The lights should not go on in a logical order but slightly randomly, so that it raises interest of the walker with a feeling of surprise. In this scenario, there is a big contrast between the location where lights are on and the rest of the path. This makes the effect of guiding light stronger and more dramatic than it would be when there would be some stand-by lighting where no one is present. However, this contrast and the darkness waiting further may evoke some feelings of insecurity. This could be prevented by adding there, for example, low-level (10%), evenly distributed lighting on the path.

Design process
I start again by opening a design template file where all the luminaire nodes and sensor nodes of the installation are situated in their right locations. This time, I chose to use for the lighting scheme the RGB spot luminaires, which give relatively small dots of light on the path surface, in order to create lively route lighting. I commenced making the network topology for the light to flow. I begin from the lower end of the path and connected the first sensor node with a link to the first luminaire node. The sensor situates in the real world before the first luminaire so that the light can be brightened in front of the walker, inviting one to enter. I continued making the network by creating links between all the path light nodes, from the first one to the second, from the second to the third and so on, until the end of the path. Then, I connected the last path light node with a link to the last sensor node, which is in the upper end of the path. Now, the first lights will brighten up as well when a walker enters the path from that direction. However, I wanted to add more playfulness to the possible movements of agents in the network and to the play of light in the real world. This could be achieved by adding extra links between the luminaire nodes so that agents can make “short-cuts”—move, for example, from the second light node to the fifth, and from the fifth to the eighth, and so on.

In order to make the light follow the walker as a swarm around the walker, I linked the four middle motion sensor nodes, which situate with approximately equal intervals between each other, to the network. I created links from each sensor node to four or five luminaire nodes near it. To create lively lighting behaviour, I did not connect systematically all the luminaire nodes near each sensor but picked randomly the ones to link and the ones not to link with each sensor node.

Now, when the network was ready, the next phase was to define the agent properties. I made the start sensor nodes to generate fewer agents per time frame than the middle sensor nodes, as there was only one link starting from them. However, I kept the number of agents generated for the middle sensors reasonable low, so that there will be randomness in the selection of routes from the sensor, which will cause desired nonlinearity in the end result in the real world. Every time a person walks through the route, the lighting will be slightly different as, the luminaires will brighten and dim in different order. I started testing with simulation different parameters for agents’ speed, energy, life-time, and fade time and finally ended up with a lighting behavior that is like my design intention. Only one type of agents’ behavior is enough for this scenario. By testing, I saw that since I want the lights to follow the walker as a living swarm, I
had to define the agents to move always forward and to die when it reaches the last node of the network. In order to create a warm and comfortable atmosphere for the winter scenery, I chose warm white light (3000 K) for the light colour. I set the agents’ colour to the responding RGB value 255,240,110.

Another test scenario—Scenario 3—could be done just by adding to the design a locked minimum value of the light level of 60%. The design intention for that scenario was to create lively route lighting with moderate energy-savings potential. In this scenario, the intention was to have the path illuminated in the whole length all the time and to add some playfulness with the dynamic and adaptive behavior of light, which could be perhaps noticed like movement of tree shadows on path by sunlight in the wind or similar types of small changes of light in nature.
**Scenario 7A**

**Main design intention:** Experiential lighting for the route, highlighting elements of the scenery and supporting visual detection of other people

**Park-goer**

When I enter the dim park, a series of light dots brighten ahead me, inviting. I notice that, at the same time, the trees get illuminated along the path. I have not noticed before how beautiful the birch trees are in the winter and how they form a corridor through the park. When I go further, the lights on the ground guide me brightening and dimming around me. Then, I notice that by my sides, the light on the trees is changing to blue colour. I realize that there are other walkers in the park further away, as I also see there blue light gradually moving from tree to tree.

**Designer**

In this scenario, I want to create an experiential route lighting where the lively, guiding play of light dots on the path is combined with highlighting the natural elements of the park. The entering into the park is made to an event by brightening all the tree luminaires at the same time, so that the space is framed with light and opens up until the end of the path. All the changes of light should happen with slow speed and gradual change, so that it is not distracting, even though it takes the attention. Another aspect that is studied in this scenario is how adaptive lighting could make people to perceive other park-goers, and, would that perhaps make them feel more comfortable and secure walking in the park in the evening time. The most effective way would be to show the presence of other people as changes of light in vertical surfaces and using colour makes the effect more visible than using only white light. The gradual change of colour in trees from warm white to intensive blue is also an atmospheric effect in winter scenery, and, as it happens around the walker, it is perhaps sensed as a kind of courtesy from the park.

Design process:

I could now start the design by taking the Scenario 4 file as a starting point because I want the path lighting to behave in that manner. I continued with building a new network section for the light to flow to the trees. I created duplicate nodes for each sensor node so that the same sensors in the real world can trigger agents of different properties to path luminaires and to tree luminaires. I connected the duplicate starting sensor nodes from both path ends with a link to all the tree light nodes along the path. This made all the tree luminaires to brighten when a park-goer enters the path. Then, I created four links from each duplicate middle sensor node, one to each of the four nearest tree luminaire nodes. This made the route for coloured light to flow to the trees around a person as one walks along the path. In addition to making the links, I had to define which light nodes would allow access to agents from the duplicate sensor nodes. In this design scheme, it was only the tree light nodes.

After finishing the network, I continued with defining the agent properties for the duplicate sensor nodes. Those in the two ends of the path had to generate a large amount of agents per time frame so that all the tree luminaires would be brightened more or less at the same time, so I set the value to 10. I tested different options for the agents’ movement direction. From the simulation, I could indicate that the right choice was to make the agents to continue after arriving to a node with a random selection to the return direction or to some of the forward directions. This made the tree lighting behave in a playfully nonlinear manner—separate trees dimming and brightening with different rhythms—after the lights went first on at the same time. The RGB value for those agents was set to the same as the path lighting, 255,240,110, responding to warm white 3000K. For the duplicate middle sensor nodes, I set an intensive blue colour, RGB value 64,98,234. Those sensor nodes had only four links each, so the amount of agents generated per time frame could be lower. For the movement direction, here the right solution was always to return after arriving to a node. This made the blue light behave linearly, so that it logically followed the walker and prevented the blue light from leaking out from the nearest trees of the walker to trees further away, which would have spoiled the presence-indicating colour effect. I defined the lifespan for the agents generated from the path end
sensor nodes to be three times longer than the ones from the middle sensor nodes, which made the white light last longer in the trees and the intensive blue to enter through a beautiful transition of darkening shades of pale blues and fade away in a reasonable short time span.

From Scenario 7A, I created another version (Scenario 7B) where a stand by light with a low light level on all the spot path luminaires was added, now locking the minimum light level for those luminaires to 20%. I also lowered the maximum light level to 70% to make the scenario even more atmospheric. In Scenario 7B, magenta (RGB 255,0,200) was used as the effect colour.

Fig. 25. Scenario 7A: Network configuration with agents’ flows and simulation in VirtuAUL.

Fig. 26. Scenario 7A: Series of real-world photos from the installation.
Scenario 8A

Main design intention: Experiential lighting for the route, highlighting elements of the scenery

Park-goer
When I am approaching the park, I see that park path is lit very dimly and evenly. When I enter the park, on the path, ahead and around me a series of small dots of light is lighting up and following me softly, brightening and dimming in different rhythms. I see that the trees along the path are also brightening and shine white. I notice suddenly that a magenta dot of light appears among the white dots. It moves to another location and fades gradually to pink and to white. I see few new magenta dots appear further away, with some animating white light dots. Coloured light looks refreshing in the winter scenery against white snow, I go further, and magenta colour is moving to the trees nearby. I notice that, in some distance from the path, an alone standing tree is coloured pink, and a group of shrubs change colour from white to pink. I remember that yesterday, the coloured dots were having a different shade, probably it was blue then. I wonder if the colour has some meaning while I step out from the path to the street. I turn to have a glance back and see that the lights’ play continue for a while and fades then slowly away.

Designer
The main design intention in this scenario is to create an experiential route lighting, which highlights beautiful elements of the park scenery, such as trees along the route and some shrubs and trees further away. The adaptations of light should be perceivable so that they would enhance the atmospheric experience. In addition, the aim is to create nonlinear dynamic patterns of light so that there would be positive elements of surprise in the lighting behaviour and emerging lighting patterns would be different every time a person walks along the path. Even though the general behaviour of lighting is intended to be nonlinear, there should be some logical linearity in the behaviour to fulfil the functional needs for path lighting: the lively play of light on the park path should follow and even anticipate each park-goer, so that one could see the route where one is heading to and move safely. I want the tree lights to go on softly along the whole route when a walker enters, but then the play of light can continue with random patterns and interacting with the play of light dots on the ground. The possible view directions of the walker are anticipated so that the light will also emphasize more distant objects of the scenery in the visual field as the park-goer proceeds in the park. In this scenario, the base tone of the colour effect is reflecting the outdoor air temperature so that warmer tones of magenta are representing higher winter temperatures, and cooler tones of violet and blue are representing lower temperatures. To make the park not to look totally dark when there is no one and also to make the whole length of the path route to have some light on when a walker is in the other end of the route, so that it feels all the time inviting, a very dim, constant layer of evenly distributed light would be a good addition to the design.

Design process:
I took the Scenario 7A file as a starting point but removed the links from the four duplicate sensor nodes along the path. Now I had a design template of lively path lighting with an event of brightening all tree lights along the path when a walker enters to the path.

Then, I made one or two additional links from most of the tree light nodes towards the luminaire nodes that were illuminating the path near them. This was done to make some of the agents to leak from the path lighting network to the tree luminaire nodes and vice versa, as walkers are walking along the path. I wanted to add some more interest to the design with a colour effect, which would attract the park-goer’s attention occasionally while walking along the path and to guide his or her eye towards beautiful trees and shrubs in the vicinity of the path. I changed a magenta colour (RGB 255,0,200) for the agents generated by the four duplicate sensor nodes along the path. I made new links from those sensor nodes to the more distant tree and shrub luminaire nodes, which were still unlinked, and also made some links to the shrub luminaire nodes. I had to define those light nodes so that they would allow access to agents from the duplicate sensor nodes, and the respective trees and shrubs in the real-world installation would become illuminated by magenta tone light. However, occasionally, their
tone of light would fade to pink and warm white, as warm white agents will find access through network towards those luminaire nodes. I also added a couple of new links from those sensor nodes to tree luminaire nodes along the path. I also defined most of the path luminaire nodes to allow access to the colour effect agents. This would bring some magenta colour to trees along the path and in the form of coloured dots on the path surface. However, I left a certain amount of path light nodes without access in order to prevent the whole pathway surface to get coloured by magenta. In addition, the agents creating the main path lighting of warm white colour would fade and over wash the excess magenta, so that most of the resulting light would be pure or slightly tinted shades of warm white.

By testing and adjusting the agent parameters, I was finally pleased with the simulation result of the finalised lighting design. I still made one more definition to the design: I locked the minimum light level of the wide distribution path luminaires to be 10% of the maximum. This ensured that the path would not be totally dark when no one was walking along it.

Fig. 27. Scenario 8A: Network configuration with agents’ flows and simulation in VirtuAUL.

Fig. 28. Scenario 8A: Series of real-world photos from the installation.
Scenario 8A was the default scenario in the park when we were not doing the interviews, or neither of the two minutes long communicative lighting schemes was on. For the interviews, I created an extra scenario without the even, low-level lighting on the path to see how the interviewees compared it with the same scenario with low-level stand-by lighting. Besides the magenta colour option, colour versions with different temperature scale colours, such as violet and blue, were created just by changing the RGB value for the effect colour. A different colour version of the default scenario was changed to be on according to the measured outdoor temperature of the day.

Scenario 9B

Main design intention: Experiential, colourful lighting for the route, highlighting elements of the scenery

Park-goer

When I enter the park, on the path, ahead and around me a series of red dots of light is lighting up and following me softly, brightening and dimming in different rhythms. Also the trees along the whole route are getting highlighted by a bright pink colour. What a surprise! When I go further, the shade of red is altering a bit. Also the trees around me are changing their colour, now to a cooler tone, blue. I walk on and turn to look back, I see that the colours of the trees are changing to violet and purple, the whole scenery is full of colour and creates a feeling of space. I see that gradually the colours start to fade and the dots to disappear from path, one by one. I go further and follow the lights. Even though the light on the path is not even and white as usual, I see to walk safely. The nice atmosphere makes me feel secured.

Designer

My main design intention is to create a lively, atmospheric path lighting by using only coloured light. This is a lighting scheme, which perhaps would not be on every day and on every park path but on special periods or events and on limited areas of park. I want to play with changing of colour tones of the same family and complement that with a contrasting colour on the trees. The colours can start living together and mixing, creating in that way new colours and new combinations that will emerge every time different as a park-goer walks the park. The change of light levels and colours should not be too rapid but soft, and it follows the walker. To make the scenario more dramatic and a bit theatrical, there is no stand-by lighting of white, even light there. This could be added there, if there is a need to lessen the contrasts.

Fig. 29. Default Scenario 8A with the colour-temperature scale.
Design process
I commenced again from the Scenario 7A design file. I modified the design by changing the agents’ colour definitions. For the path end sensor nodes, I changed the colour to warm red (RGB 252,117,64), and for the middle sensor nodes to different shades of red (warm red 252,117,64; magenta 228,16,117; and bright red 255,0,0). Then I changed colours for the duplicate sensor nodes, which gave light to the trees along the path. For the path end sensor nodes, which trigger the highlighting of the trees along the path, I chose magenta, and, for the four middle sensor nodes, I left the intensive blue tone (RGB 64,98,234), which was already defined in the design file. By testing with the simulation, I could indicate that the light was behaving like I wanted, and the result was a rich colourscape of slowly altering tones around the walker and in the length of the path.

From this scenario, I made another colour version (Scenario 9A) with different shades of green, having in mind the concept of summer scenery along the park path with green trees and living dots of sunlight on the ground.

Fig. 30. Scenario 9B: Network configuration with agents’ flows and simulation in VirtuAUL.

Fig. 31. Scenario 9B: Series of real-world photos from the installation.
**Summary of the detailed adaptation design**

Reflecting the process of the detailed design of adaptive lighting in all the example scenarios, I can articulate the following steps:

- Conceiving the users’ presumed behavior and activity (arriving, proceeding in path, viewpoints)
- Conceiving the aspired users’ experience and the corresponding lighting behavior (e.g., seeing well, enjoyment of atmosphere, surprise → softly and linearly following light or playful lighting behavior)
- Defining the aspired light distribution and where lighting is situated (choosing the luminaires to be employed and where they are located)
- Defining in which locations lighting behavior is triggered to happen in certain locations (linking sensors and luminaires)
- Defining the linearity or nonlinearity level of the lighting behavior (agents’ movement direction, amount of links, amount of agents, agent properties)
- Defining the colour of light (setting the RGB value for agents)
- Defining the starting and return level of lighting intensity (stand-by level) and targeted level
- Defining the rate of lighting level or colour alterations (agents’ speed, energy, lifespan, fade time, amount of links and ghost nodes)
- Defining the interval of light level and colour alterations (agents’ colour and other properties, settings for minimum and maximum light levels)

The final part of the design process was in situ testing of the lighting scenarios, when the installation was built. This helped to finalize the design tool properties and to refine some of the scenarios to the interview versions. This testing also revealed that the simulation responded rather well real-world lighting behaviour and was, thus, a useful tool in making the design. In the appended article III, a wider selection of scenarios is presented from the point of view of performance evaluation of the design tool. The evaluation results reveal interesting aspects about the process of detailed design of adaptive lighting with the tool. For that evaluation, I redesigned all the scenarios, measuring the time spent. From those results one can indicate that even designs with a considerable complexity can be created with the tool within tens of minutes and that the graphically usable design tool with network-agent-based control method and simulation in the form of a dynamic light map functioned as a reliable and usable tool in creating detailed designs of adaptive lighting. (Pihlajaniemi, Österlund & Herneoja, 2014).

![Fig. 32. Lighting scheme for the Events mobile service.](image)
Fig. 33. Lighting scheme for the Activity mobile service.
4.2.7 Concluding summary

Here in this subchapter, I conclude the analysis of Urban Echoes case design process by summarizing and discussing the design phases, design methods and tasks, and design results as well as design factors.

The process commenced with a meeting with stakeholders and site analyses, which helped to formulate the preliminary design brief. A more advanced design brief was developed in the concept design phase. The main method was the scenario writing method, which helped to envision and analyse different kinds of applications of adaptive lighting from various park users’ perspectives. In this way, we could, in a reasonable amount of time, go through different options and finally formulate the main concepts for the pilot design. These were, in this case, different types of scenarios of movement-adaptive lighting as well as lighting that communicated urban information.

In the Urban Echoes case project, the next phase was to design an adaptive lighting setting for the pilot. The methods applied were sketching the positioning of lighting fixtures and sensors, checking the outcome with lighting calculations and visualizations, as well as designing details for construction. In addition, cost estimates for the purchase and construction of lighting infrastructure were prepared, in order to stay in the limits of the project budget. These are similar to the tasks and design methods that are used in the design of traditional static outdoor lighting. To go beyond that level, multidisciplinary cooperation was required to create system level design for the adaptive lighting system and interaction design to enable users to interact with the system. Coordinating those design tasks and the realization of the system were also time-consuming tasks. In the end, the adaptive lighting setting with the required system and interaction elements was constructed.

In this case, design tool development was an essential task. An iterative and transdisciplinary development-by-design method was used, which applied scenario writing, brainstorming, iterative design tests, and coding. This process partly overlapped with the detailed adaptation design phase. That phase began with scenario writing, which resulted in several scenarios to be designed with the tool. In this case, the detailed design of adaptive lighting behaviour for the movement-adaptive scenarios was done with the VirtuAUL design tool prototype. The design process with the graphical tool was an iterative process. The task began with positioning the lighting fixtures and sensors on the 2D map according to the adaptive lighting setting design. After mentally conceiving the targeted user experience and lighting behaviour, the designer iteratively made design actions, thus creating network topology and defining control settings, along with testing the outcome by simulating it on a 2D simulation view. Design actions were repeated and the outcome simulated until the end result—the simulation of movement-adaptive lighting behaviour—seemed to visually respond to the intended lighting behaviour on the park path. This ready-made lighting adaptation design for a scenario could then be saved as a control file and tested in situ in the ready-made lighting installation by the researchers. This in situ testing helped to make final adjustments to the design tool and control system as well as to refine detailed lighting adaptation design and to choose the scenarios for walking interviews. In the evaluation phase of the pilot, participants experienced and evaluated the scenarios, and further refinements and extra scenarios could be made to the designs according to the comments.

In the design process, several design factors guided the decision-making. The central factor in the process was targeted user experience, which was studied and developed with the help of the scenario writing method. More direct involvement of the users as participants was carried out in this case only for research purposes as part of the evaluation phase. Natural and cultural contexts were considered in the design. The pilot setting was designed in order to emphasize the natural elements of the park, and the chosen season for the pilot provided us with snow cover to reflect light and act as a good background for the coloured light to be used. In addition, the installation boxes and wirings of the luminaires could be hidden in the snow. In the wintertime, in the northern latitudes of Oulu, the dark period of the day reaches the active hours, which makes February and March suitable times for piloting adaptive lighting outdoors. The luminaires were turned off during the daylit period of the day. The cultural context of the park as an active transit route but not a place to spend one’s time (partly due to the reputation with past crime incidents) affected the design. A more seldom used path was chosen for the test site, in order to see if the new lighting design would have an effect on the use of the park. Two benches for
sitting, which normally are taken out of the park during the winter, were left there for the winter months. The designs for movement-adaptive scenarios included aims to enhance the feeling of safety in the park. The Urban Echoes mobile services (Activity and Events) were designed to communicate contextual information: where in the city centre people were and what kind of events were going on and starting. The default scenario in the park path expressed the local temperature.

In designing the targeted light levels on the path, the compliance with the regulations was checked with calculations. Because one central driving force for adaptive lighting is the need to reduce energy consumption for lighting, the developed design tool was made to include the means to estimate the energy use of each design. Ecology as a design factor also means considering methods to minimize light pollution. In this case, the existing, spherical luminaires were replaced with LED lighting fixtures directing light effectively towards the path. However, highlighting trees from downward creates lighting pollution. By designing scenarios, where lighting was brightened up only when there were park-goers, could light pollution as well as the energy consumption be minimized. This also reduces life-cycle costs of a lighting installation. In the Urban Echoes case process, investment costs were estimated and considered and economy could be seen as one design factor. Overall, the available sensor, lighting control, and IT technology are essential design factors in the design process, which can lead to certain solutions. For example, the characteristics of the applied motion sensors restricted full development of the scenarios, as previously described. In addition, in our case, the development of the VirtuAUL design tool and control interpreter brought us the freedom to create that kind of control abilities we found necessary. However, the applied agent-based control methodology had its own characteristics, which guided the design process and outcome.
4.3 Retail lighting pilot: designing adaptive lighting for shopping experience

The description of the design process of the third case study is partly based directly on the appended article IV. The design of the retail lighting pilot started with a meeting with the research groups, store manager, and area manager of Kesko. The suitable location for the pilot installation was selected together. Because the initial aim was to discern whether adaptive lighting could influence shopping behavior, attract customers to a certain store section, and possibly increase product sales in that area, the store manager suggested a part of female clothes section, which was situated in the upper floor of the two-floor department store. This Oulu Anttila department did not have as good sales figures as female clothes departments in other Anttila stores in Finland. A well-selling cosmetics department situated next to the test site, and the idea was that adaptive lighting behaviour could, for example, attract customers from there to the test site.

Analysis of the site reveals that the chosen test area was clearly separated from the surrounding space by existing walls and dividers. The space had rather low ceiling height for a commercial space, only 2.4 m. The existing lighting consisted of neutral white (4000 K) general lighting, achieved with fluorescent tube luminaires integrated into the grille false ceiling, and with warm white (3000 K) target lighting by metal halide spotlights in tracks. The site before the demo is presented in Fig. 35. The existing lighting was not dimmable and appeared to be rather bright, even over-scaled. Spotlighting caused some glare. Besides the actual test area, the surrounding access areas were part of the whole test environment, as the lighting control was based of the movements of the customers in those areas, in addition to their movements in the test area (figure 32).

4.3.1 Concept design

The next step was to formulate the concept for adaptive lighting in the test environment. At this point, we did not have to carry out an extensive use scenario study of potential applications of adaptive lighting in retail spaces to
discover a suitable concept. This was done already in the SparkSpace project as part of Piia Markkanen’s Master Thesis *Intelligent and Adaptive Lighting in Retail Environment* (Markkanen 2013) and we could apply its elaborated upon and theorized scenarios. The research group generated a concept design for adaptive lighting, based on test site properties, research aims, and control method, which was based on tracking of customers’ movements with networked depth camera sensors. The concept was a three-mode strategy of adaptive lighting behaviour in the retail environment. The adaptation modes were “Attract”, “Focus”, and “Keep in the Area”. The Attract mode was intended to draw customers’ attention in the test area vicinity in order to attract customers into the area itself. When a customer stopped in front of the site, she triggered the Focus mode. The design aim was to focus customers’ attention to products in the front area of the site and to make her enter for a closer look. Finally, when a customer entered the test site, the Keep in the Area mode was launched. In that mode, lighting was intended to serve the customer by increasing the illumination of the products near the customer to enhance their visibility. In addition, adaptive lighting was applied to make her notice other products farther away and stay longer in the area browsing them.

Fig. 37. Areas where each adaptation mode was triggered. In the approach areas, only customers moving towards the test site triggered the Attract mode.

**4.3.2 Adaptive lighting setting and system**

The *adaptive lighting setting* was designed as a temporary installation. For the pilot, small alterations were done to the test area furnishing: five mannequin figures were placed there in front of the white background boards and in front of an existing white concrete pillar. The illuminated mannequins and backgrounds were intended to create visual focal points to the area. The luminaires for general lighting were changed to new, controllable LED luminaires with neutral white light (4000 K). New DALI lighting tracks were attached under the false ceiling to support target lighting. Tunable white LED spotlights (30 pc.) were tuned to

**Fig. 38. Arrangement and lighting of the pilot area.**
the warm white (3000 K) setting, so that the test area appearance would not contrast too much from surrounding store sections. Luminaires had three different beam angles: 24, 30, and 40 degrees. Besides tunable white spotlights, DMX-controllable RGB spotlights (10 pc.) were installed under the ceiling in strategic positions for colour effects, pointing towards the backgrounds of the standing mannequin dolls and wall-leaning torso figures at the back and the left sides of the area. The white LED spotlights were directed towards clothes hanging from the racks on the walls and standing on the floor. The spotlights were directed always towards near-laying objects so that amount of glare would be minimized. Especially from the entering direction, this aim was sufficiently reached. Anyhow, due to the low ceiling height, glare effects could not be completely prevented.

The sponsor for the pilot, Fagerhult Oy, provided us with the lighting fixtures. We did not calculate the sufficient light output for the installation luminaires but trusted the luminaire manufacturer’s suggestion for the suitable luminaire types. RGB spotlights were not own products of the sponsor but rented from a show lighting company. The position drawing, which showed the luminaires and the targets of the spotlights, helped to estimate the suitable amount of luminaires. The exact positioning in the tracks and final direction of the spot luminaires was done on-site in the furnished test area with the garments, mannequin figures and background boards.

The system level design for the pilot’s adaptive lighting system was coordinated by a VTT researcher and carried out by researchers of collaborating projects which were responsible for different parts of the system. As briefly described, the system consisted of three different software working together to make lighting respond to customers’ behaviour. PeopleTracker detected people in the pilot area and tracked their movement. MessageBroker handled message transfer between the two other applications and processes, and extracted information out of the raw data. VirtuAUL interpreter generated lighting control messages based on the preprocessed tracking data.

4.3.3 Design tool development

The VirtuAUL design tool was further developed to respond to the needs of the people tracking system, and to give new design possibilities as well as to ease the design process. A new virtual sensor, which could react to the presence and direction of movement of people, was developed. In addition, a new type of node—a control algorithm node—was developed. The node was a trigger connected to a sensor, and it defined the agent’s family and amount of agents emitted per time frame as well as on which link layer the agent resides. (Österlund & Pihlajaniemi 2015, Österlund & Pihlajaniemi 2016b). As the people tracker system was capable of recognizing different customer types, which we had defined according to their movement patterns, the control algorithm node was also made to react to this kind of information.

4.3.4 Detailed design of lighting adaptation

As the aim of the pilot research was to gain knowledge of the effects of adaptive lighting on customers’ experiences, three different lighting schemes were created. One scheme, “Static White”, was created to provide a point of comparison: a good, basic retail lighting situation. For dynamic and adaptive lighting schemes, I created both a scheme containing only changes in light levels, “Adaptive White”, and a scheme containing light level and colour changes, “Adaptive Colour”. This was done in order to see if there were differences in experiences and shopping behavior between the dynamic scheme with only white light and the scheme with added colour effects.
I designed the dynamic and adaptive lighting schemes with the VirtuAUL design tool, and again, this process aided in developing new functionalities for the tool. This design phase could be termed as a *detailed design of lighting adaptation* as in this phase, all the detailed aspects of lighting behaviour—light levels, exact situating of dynamic light effects, the pace and rhythmical patterns of dynamic changes of light, and so on—were defined. As I had discovered in the Urban Echoes project, writing short scenarios in the form of narratives worked well as a method of conceiving both design aims as user experience and design factors, I once again applied that method. I wrote a set of short scenarios of the lighting modes, which were needed in the lighting controlling, and studied different versions with creating design files and simulating them. In addition to Attract, Focus, and Keep in the Area, also a standby mode “Empty”, for the periods when there was nobody present in the test area, and the approach area sensors did not detect movement. Finally, also a “Many” mode was created for the periods when there were more than five customers in the test area to ensure that the system would not get overloaded with control messages. Here, in the following, I present scenario examples of the three main modes and describe the design process with the design tool. The examples are all from the Adaptive Colour scheme, and the three scenarios concerning Attract, Focus, and Keep in the Area modes form a coherent story of one shopping experience and how the designer is intentionally guiding the experience with adaptive lighting behaviour. Design process is described as a whole after the scenarios.
**Scenario: Attract**

**Main design intention: To attract the attention of an approaching customer**

**Customer**
I arrive upstairs with escalators and walk along the passage. I am heading to the lingerie department. When I proceed, the brightening of light on the back wall catches my eye. Now I can see also some red light, the colour is quite intensive. Well, now it’s soon Christmas time, so red makes nice and warm atmosphere. Light on back wall seems to be heaving gently, as different parts of the wall are brightening and dimming slowly. I walk further and see that the mannequin figures are brightening. I did not notice them before. There is some magenta light behind two sitting dolls, on the white background. The colour is fading slowly to white and then to red. When I approach the crossing of the passages, I notice that the garments on the table start almost to shine in the light; there is some glitter in the fabric. Light fades a little bit and then another dress, a pink one, starts to glow. At the same time, I register that in front of me there is nice-looking knitwear on a mannequin figure; the colour seems to brighten up as I look at it. Perhaps I should stop there to have a closer look?

**Designer**
My aim is to attract the attention of a customer already from the distance. When there are no customers in the test site or in the approach areas moving towards it, the general lighting level is kept very low, in 10% of the maximum. This is done to save energy. However, there are always some spotlights brightened in the area so that it does not look dark from the distance. All other spotlights are on with 10% light level. The amount and location of illuminated spotlights varies slowly. When the customer is entering to one of the approach areas and moving towards the test site, the general lighting level is raised slowly, within 10 seconds, to 33%. At the same time, the spot luminaires on the back wall, which can be seen already from a distance, start brightening up, not all at the same time, but with a nonlinear pattern. There are slight variations in the light levels on the back wall and slow but noticeable dynamic change or the brightness level makes a wavy effect to the wall. The general lighting level is still kept reasonable low, so that the highlights with spot lights are effective due to the contrast. Since coloured light, and especially dynamic coloured light, is a very powerful attention catcher, I use colour effect besides warm white light in this scheme. I choose shades of warm reds and magenta as colours, which would fade to pastel shades with white. These match with the colour palette of the clothing collection of the late autumn and Christmas. When a customer comes nearer and can see more of the site, the warm white spot luminaires directed to mannequin figures and RGB luminaires directed to their backgrounds start brightening up and dimming one after another in different rhythms. Coloured light is used on background boards and pillar walls behind the mannequin figures, which emphasizes the attention-catching effect. Light is also brightened on the products situated on the table in front, which makes them stand out.

![Fig. 40. Attract adaptation mode as simulated in VirtuAUL.](image1)

![Fig. 41. Real-world photos of the Attract adaptation mode. Adaptive white scheme.](image2)
Scenario: Focus

Main design intention: To focus customers’ interest on products and to make them enter into the product section

Customer
I slow down my walk and stop by the table in front of the department. I see that all clothes racks beside me brighten up gradually. I also notice many nice-looking clothes hanging on the side walls. The space seems to widen as the side walls become illuminated, and it looks inviting. Especially that blouse on a torso figure has a lovely colour, the red is glowing warmly. I move on to the department to check it.

Designer
Here, my design aim was to focus customers’ attention to products in the front area of the site and to make her enter for a closer look. In this phase, the spotlights pointing towards the garments in the front section of the area and on the side walls were brightened with slow dynamic changes. There are still some colourful effect lights behind the mannequin figures, which add interest to the space.

Fig. 42. Focus adaptation mode as simulated in VirtuAUL.

Fig. 43. Real-world photos of the Focus adaptation mode. Adaptive colour scheme.
**Scenario: Keep in the Area**

**Main design intention:** To serve customers while browsing the products and to attract them further in the area

**Customer**
I enter between the clothes to see the blouse better. It is quite nice, but it does not have the right size. I see with the corner of my eye that light is brightening by my side, and I turn. There is a piece of knitwear with fuchsia colour that looks interesting, and I go to look at it closer. I notice that all the clothes near me brighten up, so I can see them better. I see that a white shirt further away starts to glow and get interested in it. I go forward and notice that, every time I move, new clothes around me start brightening up. I wonder about it for a while, but in the end it feels nice, as the change of light is soft and not too rapid. I go back to the white shirt, take it from the rack and start looking for a fitting room.

**Designer**
In that mode, lighting was intended to serve the customer by always increasing the illumination of the products near the customer to enhance their visibility. Simultaneously, a few spotlights illuminating merchandise farther away were brightened in order to make her notice other products and stay longer in the area browsing them. As good colour rendering is essential in making successful purchase decision, in this mode, all the light, which is brightening around the customer and directed towards the products, is warm white, even though it would be coming from a RGB spotlight.

![Fig. 44. Keep in the Area adaptation mode as simulated in VirtuAUL](image1)

![Fig. 45. Real-world photos of the Keep in the Area adaptation mode. Adaptive colour scheme.](image2)
**Design process:**

For making the detailed design for this lighting scheme, a template file, where all the luminaire nodes were situated on the plan drawing in right locations, was created. In this retail lighting pilot case, the control was not based on actual, physical presence sensors but on the people tracking system, which could cover, in principle, all the locations in the test and approach areas and also recognize the direction of movement and a predefined type of a customer. For that reason, any existing sensor nodes were not located in the template, but it was part of the detailed design phase to conceive the correct situations and properties for virtual sensor nodes, which would be needed for the aspired lighting behavior, and to create them.

I commenced by creating the needed virtual sensor nodes for the Attract scenario. I made sensors to all the approach areas, so that the areas could be well covered by them. It was in the main approach coming from the escalators, where the largest amount of virtual sensor nodes was needed, altogether six pieces. In the far end of the two-lined passage, I used wider sensors, which covered both lanes. Near the test area, I made my own sensors for each lane, so that the movement of different sides of the passage could trigger different effects.

I started to create the network for light to flow into space. I wanted that, when a person enters to the escalator end of the passage and moves there towards the test site, the lights start brightening on the back wall. Thus, I connected with links the first two sensors to the light nodes on the back wall. For this pilot, where the intended lighting behavior was much more complex than in Urban Echoes, a new system for defining agents’ movement direction had to be developed. In this version, it was defined by link layers, which were open to either one, two or no directions, thus allowing the movement of the agents on that layer, respectively. Now I opened those links to allow movement towards the luminaires.

I continued by creating a control algorithm node, linking it to the first two sensor nodes and defining the agents’ properties. In the control algorithm node, I could define that those sensors react only to those customers, who are walking towards the test site. Because I did not want all the lights to become brightened at the same time but gradually one after another, I defined the amount of agents generated by time frame to be substantially lower than the amount of luminaires. Besides that, I added bidirectional links in between the luminaires. By an iterative process of changing parameters and testing the effect with simulation, I found the right values for energy, speed, life span and fade time. For colour, an RGB value 255,50,19 responding warm red was defined. This would, however, make only the light from the RGB spotlights to emerge as red. All the other spotlights would produce warm light, and the intensity of light would be based on the first number of the RGB value.

Then, I continued by making links from other virtual sensor nodes in the approach areas. This time I opened them, besides the back wall, towards the light nodes representing the spot luminaires illuminating the focal points, mannequin figures, and their backgrounds. I also added some bidirectional links between the light nodes. However, as the amount of links in the configuration was growing, I wanted to make the configuration clearer. Thus, I did not connect all the luminaire nodes on back wall directly to the sensor but created one ghost node more near the luminaires and made the first link from sensor node to there, and then a set of links to the luminaire nodes.

To the virtual sensor nodes in the passage from the escalator, I connected the existing control algorithm node. I also created a new one with magenta colour (RGB 255,70,190) agents and defined by using link layers that this new colour could enter only in the light nodes for focal point boards. There, they would create a nice effect, thus causing the blending of two types of reds. I had to create a set of new control algorithm nodes with definitions responding to the wanted movement direction in different approach areas. The agents to be created were red, magenta, and warm white, which would also cause pastel colours to appear through blending. By testing different agent parameters and simulating the result, I became satisfied with the result of Attract mode lighting behaviour.

Besides lighting behaviour for the Attract mode, I had to add configurations to Focus mode and Keep in the Area mode into the same design file. In this way, lighting could react simultaneously in real-world situations to different types of customers, and there could be several processes of adaptive lighting behavior simultaneously going on. Thus, the next step was to create the network for the Focus mode. I added to the virtual sensor node, which situated in front of the test...
site, the capacity to recognize focus-type customers by creating a new control algorithm node with a corresponding setting and linking it to the sensor. I connected the virtual sensor node with unidirectional links to the light nodes representing spot luminaires directed to products in front of the space as well as the focal points in the front area. I also created links to side walls’ light nodes, with the help of a ghost node, and some links between them. I defined the agents’ properties for the aspired end result, this time using red as the colour.

In order to create the network for adaptive lighting behaviour of the Keep in the Area mode, I commenced by creating a four-by-four grid of virtual sensor nodes, which covered all the corridors between the clothes racks in the test area. I then connected each virtual sensor node to three or four nearest light nodes, which would, in the real-world, always illuminate the clothes near the customer as she walks in the area. In addition, I created one or two extra links to some more distant light nodes, so that there will be tempting light on a few spots farther away. I created a new control node and connected it to all the virtual sensor nodes in the test area. I defined the virtual sensor nodes to react to the Keep-type of customers, moving to all directions. I chose warm white as the agents’ colour, so that light would always display the products’ real colour around the customer. I defined all the agents’ parameters and tested the end result.

Summary of the detailed adaptation design

Reflecting upon the described process of the detailed design of adaptive lighting, I can articulate the following steps:

- Conceiving the users’ presumed behavior and activity (arriving, proceeding in passages, movement directions, shopping behaviour, looking at products)
- Defining the aspired users’ experience and the corresponding lighting behavior (e.g., being attracted to area, focusing on products, enjoyment of atmosphere, surprise, seeing well, finding and noticing new things → lighting, which brightens softly to guide the eye or playful and colourful lighting behavior to catch the attention and give pleasure)
- Conceiving the contents of the above bullet points as separate adaptation processes, which can happen linearly after one another, separately without any relationship, or simultaneously.
- Defining the aspired light distribution and where lighting is situated (choosing the luminaires to be employed and where they are located)
- Defining for the design, in which locations and to which movement directions lighting behavior is triggered in certain locations (creating virtual sensors, linking sensors, and luminaires)
- Defining and enabling the possibly multiple and separate adaptation processes in the design (user type detection and reaction, movement direction detection and reaction, link layers)
- Defining the linearity or nonlinearity level of the lighting behavior (agents’ movement direction, amount of links, amount of agents, agent properties)
- Defining the colour of light (setting the RGB value for agents)
- Defining the starting and return level of lighting intensity (stand-by level) and targeted level
- Defining the rate of lighting level or colour alterations (agents’ speed, energy, lifespan, fade time, amount of links, and ghost nodes)
- Defining the interval of light level and colour alterations (agents’ colour and other properties, settings for minimum and maximum light levels)

The main difference, when compared with the previous case study of the Urban Echoes project, is that, in this case, there could be several different ongoing processes of adaptive lighting behaviour at the same time. The designer has to conceive those processes and to enable them to happen. In addition, the designer has to ensure that multiple adaptation processes are not conflicting and causing undesired user experiences. The detailed design process and end result were significantly more complex and demanded substantially more effort and concentration, as I had to handle all the processes in the same design file.
In the whole detailed design process, I made altogether 10 different scenarios where adaptive lighting behaviour for each adaptation mode varied. This variation concerned, for example, the pace of dynamical changes, the brightening choreography of the wall luminaires (all at the same time or with varying rhythms), and the use of different luminaire groups in each mode. In a test session in the ready-made installation, the research group decided together which one of the scenarios was the most suitable for the test period and evaluation. In this *in situ testing*, a member of store personnel responsible for product placement of the area was present. Also the effect colours for the Adaptive Colour scheme were checked with the product collection and slightly modified so that they matched well together.
4.3.5 Concluding summary

Here, in the following, I summarize the design process of the Retail Lighting Pilot. Again, the process began with a meeting with the stakeholders and analysis of the design site and the design target. For the concept design, we could apply scenarios and concepts, which were developed in an earlier phase of the project. The final concept design was developed in group brainstorming sessions and was based on the characteristics of the test site, the available sensing technology (people tracking), and targeted customer behaviour and user experience. The concept of a three-mode strategy of adaptive lighting behaviour was developed, based on “Attract”, “Focus” and “Keep in the Area” modes. The adaptive lighting setting was designed as a temporary installation. New controllable luminaires were installed for providing general lighting and target lighting, where also colour effects could be used at specific focal point areas and objects. The suitable amount of luminaires was sketched in position drawings, which indicated approximate positions and direction of the luminaires; however, the exact positioning in the tracks and final direction of target luminaires was done on site.

The system level design made three different software work together in order to make lighting respond to customers’ behaviour. The softwares—PeopleTracker, MessageBroker, and VirtuAUL interpreter—were all developed in the cooperating research projects. For this case study, the design tool had to be further developed, so that it responded to the needs of the people tracking system and the new design challenges. These challenges included, for example, mastery of several simultaneous and different lighting adaptation processes in one design. These processes were defined as lighting behaviour in the phase, which I call detailed design of lighting adaptation. In the case study pilot, two different adaptive lighting schemes were designed for the testing, both following the three-mode strategy. These two final schemes were created through designing several scenarios with different lighting behaviour by using the VirtuAUL design tool. Here, again, writing the scenarios helped me to conceive the anticipated user experience and user behaviour as well as how lighting should behave. The design process with the design tool followed the iterative process, as in the Urban Echoes case. However, now there could be several different ongoing processes of adaptive lighting behaviour, which a designer had to enable to happen. This made the design process more complex and demanding, both as a mental process and as a procedure of design actions with the tool. Finally, the ready-made scenarios, which were saved as design files, were tested in situ with a project group, and the actual test lighting schemes for evaluation were selected.

Again, in this pilot, the users’ experience was a guiding design factor, as described. However, this case also illustrates well how there can be clear user-behaviour related targets in the design, too. Even though the three-mode strategy of lighting adaptations will presumably cause, to some extent, those kind of shopping experiences, which were anticipated in the scenarios, the other side of the coin is that the strategy intends to guide shopper’s behaviour as was intended in the design brief. This guiding or orchestrating users’ behaviour in different kinds of contexts is rather a traditional and common approach to use adaptive or dynamic light, the most familiar example being traffic lights. Thus, the cultural context of the lighting as part of an interior, commercial environment had an effect on the design aims. This influence came especially through the needs formulated by the client (the store manager), as the situation in a normal design process as well. In the case design process, the design was done so that the general light levels were kept rather low when there were no customers in the approach or test area. This was intended to save energy. Further, the adaptive lighting behaviour of target lights provided huge energy savings if compared with the “Static” scheme, where spotlight were on all the time with 100% light output. This ecological aspect, which is, at the same time, an economic aspect, is a central design factor in commercial lighting design.
4.4 Design process for adaptive lighting

In this subchapter, I summarize the results concerning the research question Q1. I reflect and discuss the findings of the three case design processes of adaptive lighting, which were explored in the previous subchapters. I have collected different features of the processes, which I found generally applicable, into a coherent diagram (Fig. 47 in p. 98). In the diagram, design phases, design factors, design tasks and methods, and design results are presented. The idea of the diagram is to aid reflection and discussion of the processes by structuring them, not to present a universal model.

The diagram can be read from up downward as a process of three main phases and from left to right, as describing the components of each design phase. On the horizontal levels, different phases of design, which I have recognised to be essential from lighting designer’s perspective, are presented. The main tasks and methods used in each phase, as well as the design outcome, are presented. In addition, on the left side, the design factors, which have to be taken into consideration and guide the design, are collected. This demands naturally the preliminary analyses of the task and meetings with different stakeholders, which could be added to the figure as a preliminary phase. However, this is a normal preparation phase of design in all lighting and architectural design, so I have excluded it from the diagram.

In the right side of the flow chart, there is a section for cooperative tasks. These are essential for realizing a project with adaptive and interactive lighting, but which demand cooperation with experts other than lighting designers or architects. In the following, I discuss the process in detail.

4.4.1 Design phases

The three core design phases are 1) Adaptation concept design, 2) Adaptive lighting setting design, and 3) Detailed adaptation design. Each phase can include several subtasks.

The design of adaptive lighting does not aim to create a static end product; it aims to a process or a set of simultaneous processes in an environment. The designer defines processes of lighting behaviour according to some form of reference information in order to enable anticipated user experiences and actions in adaptive lighting environments as well as to reach other relevant targets, such as energy savings.

In the Adaptation concept design phase, the designer formulates these processes on a concept level, reflecting relevant design factors and answering questions such as: What is happening in the environment? What kind of situations will occur in the environment? What is the user doing and how is he or she experiencing the situation? Which kinds of needs are there for the lighting behaviour and lighting quality? How should lighting behave and what kind of lighting is suitable for different situations, activities, and anticipated experiences? What kind of information is needed in the system to trigger and control the lighting behaviour and lighting quality in each moment and situation? What form of implicit and/or explicit user interaction will there be?

In the Adaptive lighting setting design phase, the designer defines lighting infrastructure, which flexibly enables the user experiences, system functionalities, and lighting behaviour, which was defined in the concept phase, to actualize. In this phase, the potential for adaptive lighting is created. Both the physical and digital elements of the lighting setting and system have to be defined, and there is a need for multidisciplinary cooperation with experts in electric and IT engineering and, possibly, depending on the design case requirements, also with experts of interaction design or design tool development.

Finally, in the Detailed adaptation design phase, the designer defines in detail how the concepts are realized in the adaptive lighting setting as adaptive lighting behaviour. Here again, design factors, such as targeted user experience, guide the design process. In this phase, using a design tool allows the designer to do design decisions without programming skills. Visualisation and simulation abilities of the tool ease the designer to understand the exact characteristics of the lighting behaviour created, however, in situ testing is a necessary phase to gain the best result.
Fig. 47. Design process of adaptive lighting.
4.4.2 Design phase components

Design factors

In the diagram, I have presented important design factors, that guided the design solution being created in the process. These included targeted user experience, regulations, natural and cultural context, ecology, economy, and technology. These design factors can be seen as relevant in all the design phases.

Besides the design factors, I have collected in the diagram different stakeholders, actors, or informants relating to the design factors. Participants, users, and clients relate to the targeted user experience. Authorities and users relate to the regulations and context. Clients of each commission define the economic framework for the design project. Considerations of life-cycle costs of energy consumption are included in economic estimations of a solution. This relates to ecology as a design factor. Technology is also an essential design factor because adaptive lighting systems can be complex technological systems. The level of technology as well as usability aspects have to be considered from the user’s side, if there are means for explicit interaction in the project. On the other hand, also maintenance viewpoints are important: How will the system in the long run operate and how will it be maintained? Who is responsible for the maintenance and administration of the system? This is also an issue of economy.

In the Detailed adaptation design phase, I have also added sensors as an informant, which can give data of the context and users, relevant for understanding the design problematic.

In the case study design processes, understanding of users’ multifaceted experience was sought through empathizing different kinds of use situations with the help of scenarios. However, for creating more direct insight into those experiences, which can guide design solutions as a design factor, our pilots were evaluated with qualitative and participatory research methods. These evaluation processes and their results are presented in the subchapters of Chapter 5.

Design methods, tasks and results

As previously emphasized, adaptive lighting design can fundamentally be seen as designing processes and experiences. Based on the experiences from both the demo design processes and my later professional work, I suggest scenario working as an appropriate method for conceiving, analyzing, and designing those processes. For the Adaptation concept design phase, I propose scenario working as the main method. However, it is also usable in the Detailed adaptation design phase, as presented in Urban Echoes and in Retail lighting pilot cases. Writing and modeling scenarios as narratives and visual, cartoon strip like presentation of changes of light in different situations, have proven to be good ways to develop the design concept and present the design proposals for clients. Scenarios can be written from the perspectives of different users (different age groups, different roles in an environment) and of the designer. The method is light-weighted; thus, many design options can be studied in a reasonable amount of time. Writing stories from the users’ perspectives helps a designer to empathize with experiences and use processes of different types of environments. Even though this method is not yet widely applied in architectural design practice or education, a more or less similar method is used in the field of HCI as studying and presenting interactions between users and systems (e.g., Rosson & Carrol 2002, Magielse 2014). The scenario working can result to use scenarios and adaptation concepts both on the general level and as applications in the specific context of the design site.

In the Adaptive lighting setting design phase, the tasks and methods, which are presented in the flow diagram, are to a great extent similar to those of a normal lighting design process for static lighting. The designer chooses the lighting fixtures and designs their positioning. The suitable lighting levels and visual appearance are checked with lighting calculations and visualisations. Installation details for lighting fixtures are devised, and investment and life-cycle costs, and energy use are calculated. This results in the production documents of the lighting setting. In addition to these normal design tasks, the system and interaction design aspects have to be taken into consideration throughout the design, so that the lighting setting provides suitable frames for adaptive and interactive lighting behavior. This means that the possible sensor devices have to
be defined and located in the design, the arrangement and hardware of lighting control defined, communication links defined and constructed, and possible services for user interaction created. This demands *multidisciplinary cooperation*, which has to be coordinated in order to succeed.

For the detailed adaptation design phase, I could recommend three methods or tasks: *Scenario writing*, *Use of a Design tool*, and *In-situ testing*. As described in the two previous subchapters, I employed the *Flow method* with VirtuAUL design tool as the main method for this design phase both in the Urban Echoes and in the Retail Lighting Pilot case. With the Flow method, the designer guides and controls the flow of light in the virtual network of the adaptive lighting setting, triggered by the presence or movements of the user in the environment. The design is carried out in an iterative design process with designing and simulating the result with the tool. After mentally conceiving the targeted user experience and lighting behaviour, the designer iteratively makes design actions—creates network topology and defines control settings—and tests the outcome by *simulating* it on a 2D simulation view. Design actions are repeated and the outcome simulated until the simulation of movement-adaptive lighting behaviour seems to visually respond to the intended lighting behaviour of the environment. The outcome of the process is the *detailed adaptation design*, which can be saved as a control file and directly transferred into lighting control system. If the lighting installation is already finished, the design can be tested in situ and necessary modifications and refinements can be done. A more detailed description of the VirtuAUL tool, the design framework, and the control methodology is presented in Österlund and Pihlajaniemi (2015, 2016b), and they are the subject of Toni Österlund’s forthcoming doctoral thesis.

In the aforementioned case design processes, the *design tool development* was an integrated part of the process, and I have included it in the diagram in the *design co-operation* section. If a ready-made tool is available and applicable, this phase can be left out, which eases the process. In those two case studies, where VirtuAUL tool was used, lighting adapted only to movement (Urban Echoes) and location, movement direction, and categorized user type (Retail Lighting Pilot). For that reason, no other triggers to lighting reactions were coded into the system. However, the use of other data was ideated on some level, and the tool and the interpreter could be further developed to handle other types of data than those used in the case studies. Reflecting upon common needs for outdoor lighting control, for example, reaction to natural light levels and snow cover through brightness sensors is an important feature from an energy-saving perspective. Also time- and calendar-related adaptations would be useful as basic features. VirtuAUL could also be used in creating participatory installations, where, for example, users colour choices would be transformed into the system as agent colours and make the park lighting to change color according to participants’ wishes.

Depending on the complexity of the design task, the detailed adaptation design can be a rather challenging mental process, as the designer has to coordinate several coexisting lighting adaptation processes at the same time in the same design. These processes may happen parallel or in a sequence. The formulating of these processes may depend on, for example, how many users there are in the design area, what are the activities that can occur there or which atmospheric or communicative needs the lighting has to support. To aid this complex design process, a graphical design tool, which is capable of configuring, defining and simulating these adaptive lighting behavior processes, is required. The design abilities of a tool, if not wide enough, can restrict the design solutions. For example, some of the simple park lighting scenarios of the Urban Echoes demo (Scenarios 1 and 2) could have been done with software, which lighting controller device manufacturers offer for their product. This would have been done, for example, with a Pharos LPC controller of the Urban Echoes case, using trigger commands, luminaire grouping, and timelines with predefined modifiable effects. However, the simulation of the design outcome would have been impossible. In addition, devising of the designs for the more complex scenarios of the Urban Echoes and especially the three-mode lighting schemes of the Retail Lighting Pilot would not have been possible but would have demanded a substantial amount of programming work. Without a design tool, the designer would have to communicate the design content as a textual description of an exact lighting behaviour to a programmer, who then would do
the coding work. With complex and multiple simultaneous adaptation processes, as in the Retail Lighting Pilot case, compiling the instruction would be a demanding and time-consuming task, and the intelligibility of the description as well as transmission of the design intention uncertain. In addition, there would be no change to simulate or visualize the resulting lighting behaviour, and the design decisions would be based only on possible previous experience of suitable lighting behaviour patterns.

Many features of the outcome of the detailed adaptation design can be tested in situ by designers and user groups in the real environment. This is a benefit of a flexible and controllable lighting system, which should be taken advantage of. It is important to include this task in design offers and contracts, as well.

**Design Co-operation**

Mastering the design and realization process of adaptive lighting environments from concepts to a realized lighting system demands multidisciplinary expertise. In our case studies, we cooperated with professionals and students of electric engineering, sensor, lighting, and information technology as well as with industry partners. In the evaluation phase, we also had cultural anthropologists as team members. In the diagram, I have presented as cooperative tasks the system design, interaction design, and design tool design. Already the Concept design phase could benefit from cooperation with experts from other disciplines. This was done successfully with the Retail Lighting Pilot case, where we had close collaboration with researchers from information, sensor, and lighting technologies. The adaptation concept could be developed together and based in a common understanding of technological possibilities and design targets. The adaptive lighting system, as described earlier, was an integration of three different software developed by different research teams. In addition, the close collaboration in all the design phases, gave us good starting points and support for developing the design tool for pilot needs. In the Urban Echoes and LightStories cases, collaboration with the other disciplinary fields occurred after the Concept design phase in the system design and realization.

Communication between collaborators is a critical part of cooperation. Understanding different collaborators’ viewpoints can be challenging. On the other hand, if the communication is not regular, but different partners do their part alone for too long periods of time, problems easily emerge. In our process with the Retail Lighting Pilot case, each group had its own disciplinary terminologies, which were highly specialized. It took time and effort to build common understanding of the targets and shared vocabulary to be used in communication. Writing and conceiving simple scenarios helped us in this process. These scenarios could be further processed together, and research partners could review the situation from their own perspective. The problem-solving process around a concrete pilot design and realization was an effective incubator for common understanding and proved fruitful for the transdisciplinary research process as well.

**4.4.3 Design participation**

If users’ experiences are taken as an essential design factor guiding the design of adaptive lighting, there are two categorical approaches, which can complete each other. The other is empathizing users’ needs, for example, with the help of the scenario method; the other is active participation of users in the design process, which can be termed participatory design or co-design.

I have situated the participants as one actor or informant group in the design process diagram, both in the concept design phase and in the detailed adaptation design phase. Of our case design processes, only the LightStories case included participatory design in the way that the participants were affecting the design outcome with their creative input. This participation of LightStories is in line with my definition of participatory lighting as a branch of adaptive and interactive lighting, where participants interact with lighting using their creative input and obtaining a meaningful relationship with the target of interaction and situation.

The participation occurred only in the last phase of the LightStories design: the Detailed adaptation design phase. Participants were the actors of the process, who defined the final lighting behavior using the design tool, with the design
possibilities, which were framed by us beforehand. In that design process, there did not exist any real time or even delayed interaction between the participants and professional designer. The design processes were separate and also separated in time, as the designer finished his or her task before the participant entered the arena. Ehn (2008) refers to this kind of participation as meta-design (design for design after design). The only communication, which can be found in the process, was not direct and personal, but through a system as one-way instructions in the design tool from designer to participant. The design tool had some brief educational content with the instructions, and it was designed as a user interface to guide the user through the design process and to simulate the design possibilities for the user with no previous experience. The participant as a user of the LightStories service accomplished the design task independently. However, even though no communication existed from participants to designers during the design process, the LightStories system was built so that it functioned as a tool for gaining feedback from participants for research purposes. This enabled us to obtain comments from a significant number of participants and to invite users for further interviews, which made it possible to maintain direct interaction between the layman participants and the designers as researchers.

In the Urban Echoes case, the project did not contain any possibility for self-expression, but, on the other hand, the mobile services provided information after the user’s request. This desire to obtain information then launched the lighting scheme where information had to be interpreted in order to be legible. The users, however, did not have an active role in deciding what the content would be and how it would be presented; they only had the possibility to choose one of the services. Nevertheless, through that act of choosing, they could change the character of the park, even dramatically.

Because adaptive lighting environments can be rather complicated as technical systems, and because their design is dependant of multidisciplinary expertise, in many participatory lighting installations, users can participate and create their expressions and meanings only in the last phase. However, in the processes of designing adaptive lighting, participation could occur in other phases, too. In the Concept design phase, the methods, which could be employed in engaging participants, are interviews, workshops, cultural probes, scenario writing, design games, or different kinds of toolkits (e.g., Rosson & Carrol 2008, Gaver, Dunne & Pacenti 1999, Sanders, Brandt & Binder 2010). Participants, for example, local inhabitants, could inform about specific challenges and needs concerning the design area: for example areas of fright, and use patterns of urban spaces and routes, as well as important places and elements of environment concerning local identity. Besides producing design ideas and solutions themselves as a member of the team, they could evaluate and comment designs by professionals. These types of procedures already exist as part of architectural and urban design processes. In Finnish land use and building act, targets, principles, and procedures for participation and interaction are defined for planning processes (Ympäristöministeriö 2007, MRL 1999).

After the lighting system and setting are realized, an adaptive system allows many different kinds of detailed designs for adaptive lighting behaviour to be accomplished. Participants can be involved in that part of design process, as well. With a design tool or a user interface, participants and users can themselves adjust the final design of lighting behaviour to meet their needs. As was shown in the Urban Echoes and Retail Lighting Pilot cases, making several scenarios with a tool can be quick, which offers the possibility to test optional solutions and to evaluate them with users and participants. In our research processes, we also used participatory methods in our evaluation processes but more for research purposes than for design purposes. We had preliminary interviews, where participants were asked about their attitudes and pre-conceptions of different forms of adaptive lighting. The Urban Echoes pilot was evaluated with participants using a labour and time intensive walking interview method. In the Retail Lighting Pilot, an evaluation probe method was used to obtain feedback from the participants. However, in those processes, the target was to obtain research material of their experiences for analysis and not to make a design. As part of a participatory design process, the methods could be developed towards a more lightweighted form. One approach could be group visits to the test site combined with group discussions afterward.
The second research question asked how users of building interiors and urban spaces experiences adaptive lighting. To answer this question, I explore, in the subchapters of this chapter, the users’ experiences of the case projects. The case projects situate in different types of contexts—in different types of urban environments and in an interior retail space. In each context, the design aims for creating adaptive lighting differ, even though there are some similar intentions. The experiences also have varying premises, depending on the context and design, as well as on the characteristics of persons participating in the case studies. By evaluating and analyzing users’ experiences in different kind of contexts, it is possible to gain general knowledge of experience of adaptive lighting and understand it as a holistic phenomenon.

In the beginning of each subchapter, I describe in detail the evaluation method, the research material gained, and how the results were analysed. After that, I explore the experiences. The focus is in describing the experiences as such rather than in evaluating the success of each specific case design. In the last subchapter, I present a generalised framework of the experiences of adaptive lighting and apply it to two contexts: urban space and retail space.

5.1 LightStories case

The description of the participants’ experiences of LightStories case is based, for the most part, directly on the text and illustrations of the appended Article II.

5.1.1 Evaluation and analysis methods

The LightStories project was in operation in February 2012, during a period of 25 days. Within that time, 105 user-generated dynamic lighting designs were displayed on the pedestrian-oriented street. The participants of LightStories were requested to fill out an online questionnaire, in which the respondents were asked to answer a short set of multiple choice and open-ended questions relating to the experience of participating in lighting design, and basic demographic details about the users were collected. Volunteer participants were also invited for further theme interviews. Altogether, we interviewed seven participants and three accompanying friends. Two of the interviews were group interviews, as we aimed to create some fruitful discussion about urban lighting in general between our interviewees. The semistructured theme interview consisted of three sections and lasted from 1–2½ hours. In the first section, we asked the participants about their attitudes towards urban lighting in general, adaptive and interactive urban lighting, and participatory design. In the second part, we asked about their experience of participating in the LightStories project. The last section consisted of questions relating to the user experience of the LightStories design tool. Participants’ wishes and development ideas concerning LightStories were also collected.

All in all, the research material produced and collected in the LightStories case project included documentation of the design and implementation process; video documentations of the user-created lighting designs; detailed data of the lighting designs and the associated narratives saved to the database; questionnaire results from 83 users (11 entries from members of the research group were removed); and videotaped interviews of seven participants and three accompanying friends. The following methods were used in the analysis of the research material: reflection of the case design process; statistical analyses of the participant’s lighting designs; story texts and questionnaire data; and qualitative analyses of interview material and questionnaire answers. In qualitative data analyses, the videotaped interview material was observed and analysed with the
transcriptions collaboratively among the research group members. The emerging topics were discussed and documented accordingly. Results from different methods were reflected against each other. All interviews were conducted in Finnish; however, for the purposes of publishing, relevant portions of the transcriptions have been translated into English.

In the following, the experiences are explored concentrating on the themes of participation and communication. In addition, the communication, which occurred with LightStories project, is analysed basing on the collected data.

5.1.2 Experiencing participation

At first, participating in LightStories and the concept of being able to design urban lighting seemed quite confusing for two of our interviewed volunteers. They expressed having doubted how it could even be possible to do so and whether they had the abilities required (retired healthcare administrator, female, 60–69; publishing field, female, 30–39). An architectural student (female, 20–29) mentioned that, at first, she was suspicious about whether there was any proper participation involved and whether there would only be limited choices available without any real possibility to make a truly original design. However, besides these initial doubts, there was a keen interest to find out what all of this was about and how it worked.

Interviewees described the idea of LightStories as interesting and innovative. Moreover, it was seen as a fun way to involve citizens in urban lighting and in the design of their own environment. The respondents to our questionnaire reported that participating was easy (although sometimes challenging at first), inspiring, interesting, fun, or exciting. Only six people out of 83 commented negatively and said that they felt that participating through LightStories was complicated, boring, or did not meet their expectations.

Two out of seven interviewees had made on-site visits to see their own lighting design. When asked about what it looked like, one interviewee said he was pleasantly surprised, as the colors were brighter than he had expected (electrical engineer, male, 20–29). Others had forgotten, were too busy, or the weather was too cold or stormy for an on-site visit. Most of the interviewees, however, had read other participants’ texts on the website or watched the street through the web camera.

How did the participation change the experience of that particular urban space, then? It can be safely assumed that all participants were obliged to think about the designated street space from the point of view of someone who is designing. Overall, those participants who had noticed a change in their outlook of the street in question reported positive changes. For instance, one interviewee (female architecture student, 20–29) felt that the street was now more pleasant to be in. Another (male electrical engineer, 20–29) felt that his general outlook towards the area was now more positive because of participation. A third (social worker, male, 20–29) reported that he now thought of the lights every time he passed the area, which made that part of the city more interesting. Others did not think that participating in LightStories had changed their experience of the street in question, as they had not been familiar with the particular street beforehand. For these people, LightStories nonetheless brought the area into their awareness.

Overall, participation was seen as something novel, enjoyable and interesting. For example, several participants were eager to know whether LightStories would continue next winter and asked if similar things had been done elsewhere. Participation was seen as being most meaningful when it concerned the participants’ own daily environment, such as their residential areas or a site of importance in their city (the pedestrian centre of Oulu was suggested).

According to our interviewees, the various motivations to participate in LightStories seemed to be 1) the pure pleasure of playing with light and colour; 2) the pleasure of writing and publishing a story; 3) the curiosity to find out how they can make a LightStory; 4) sending a message to their fellow citizens; 5) to enhance the space visually; and 6) the possibility to have an influence on their environment.

Two of the interviewees, both with design backgrounds (UI designer, female, 30–39; architectural student, female, 20–29), mentioned that they were mostly interested in playing and experimenting with light and colour. However, one male interviewee (social worker, 20–29) and an elderly woman (retired
healthcare administrator, 60–69) described themselves as people who enjoy writing, and the stories or messages related to the lights were important to them. Having an effect on one’s own environment was found motivating: “That I can actually have an effect on my living environment, that’s really interesting and fun.” (Social worker, male, 20–29) Similarly, the electrical engineer (male, 20–29) was proud to be able to control the environment: “I can say that I’ve had an influence on that [...] and that [the street] is mine for an hour.” (electrical engineer, male, 20–29).

Bearing in mind that most of our interviewees had already expressed some interest in participation indirectly through making a LightStory, it was not surprising that most of them expressed a generally positive attitude towards citizen participation in the design of urban lighting. Only one participant (biologist, male, 40–49) had a mostly negative view of participation in the design of urban lighting, stating: “that kind of stuff should be left to the professionals.”

Those who were most enthused about participation in lighting design saw it as a natural extension of their citizenship. In other words, LightStories was not merely imposed on the inhabitants of the city; rather, they were instrumental as individuals in how LightStories finally manifested itself visually on the street level. One participant also thought that participation was important so that different age groups could be better represented in design. Another (a non-participant) even saw participation as having an educational or a consciousness-raising element (business economics, female, 20–29): “Having the chance to participate, I think it makes people think about these things more.” However, many of those who expressed a positive attitude also had some hesitations towards participation in the design of urban lighting. Without exception, those who expressed doubt also said that they had trouble imagining how citizen participation could really be achieved in practice. Some also had a slightly cynical view of organised participation, as they could not believe that citizens’ opinions would be taken into consideration in earnest by the powers that be.

Our interviewees, then, for the most part, saw participation as democratic and empowering; it had a positive effect on them and their fellow citizens. They did not express any strong opinion about whether or not they themselves had any special knowledge that would have been useful to design professionals, and no one expressed any distrust in the professionals’ abilities, either. However, participating in a design task, which is an immersive activity, nevertheless made it possible for these participants to commit to LightStories and spend a considerable amount of time thinking about what kind of a lighting design they would like to see in their city. For the research group, this meant that deeper, more reflective responses could be elicited from our interviewees.

5.1.3 LightStories as communication

In the following, LightStories is discussed as a medium, reflecting upon it from the perspective of how the project was designed to enable communication, how the communication was realised as user-generated dynamic lighting designs and textual narratives, and how the users experienced communicating. Additionally, it is discussed how the user-generated LightStories corresponded with certain times of the day, calendar events, and topical issues. Questions of publicity and censorship are also discussed.

Context and time

The number of stories created and the amount of visits on the website seemed to be connected with the visibility of the project in the local and national media. LightStories appeared twice in the local newspaper, and there were six radio broadcasts related to it (three on local and three on national radio). Additionally, a report from the street was shown four times on television, of which three were on national television. These reports were also published on the website of the national broadcasting company YLE, accompanied by a video clip. LightStories was also promoted through mailing lists, Facebook, and posters and flyers distributed in the city centre.

The three days during which people designed the largest number of LightStories were, or followed, the days during which the LightStories website had appeared in the media, either in print, on radio or on television. These are visible as three distinctive peaks in Fig. 48. The first peak occurred when the
website was launched and was prominently displayed in a local newspaper and on the radio that morning. LightStories began to be displayed two days after (Feb. 5).

Television broadcasts of LightStories were on February 7, 8, 13, and 27. Besides the media-induced peaks, the service received approximately two to three entries per day, a small but steady use. These peaks were apparently not related to the dates during which the stories were displayed, except for February 14, which was both after the TV broadcast and Valentine’s Day (Fig. 49). Due to a technical error, there were no design entries on February 15. More LightStories were displayed during the first half of the test period than on the second half, which may partly be due to waning interest, but is partly related to the fact that there were less bookable hours available in the second half of the month due to the increasing amount of daylight and daylight saving time. The stories made by the research team were removed from the figures describing the use of the service.

The LightStories design tool was used relatively evenly during the day after 11 a.m. (except for slight peaks at 5 p.m. and at 8 p.m.), and the usage dropped at night after 10 p.m., as shown in Fig. 50. The slight peak shown at 11 p.m. might be partly due to the fact that the design system locked the next night for editing at noon. If a user wanted to have a LightStory presented on the same day, he or she had to submit it before noon. The display times for a LightStory between midnight and 6 a.m. were used only zero to two times each (Fig. 51), which could indicate that there is no great need for this kind of service during the night.

![Fig. 48. Number of LightStories designed per date.](image1)

![Fig. 49. Number of LightStories shown per date.](image2)
Fig. 50. Number of LightStories designed per hour.

Fig. 51. Number of LightStories according to starting time.
Use of colour and dynamics

The LightStories online design tool was intended to offer users the possibility to make varied designs and to communicate expressively with dynamic and colourful light. A web-based design tool was chosen as the interaction medium, as the research group saw it as giving the users the most accurate and versatile means for co-design. One central problem in the design of the tool was how to strike a balance between the amount of design choices that were offered to users and how uncomplicated and simple the user experience should be. Making the tool as easy to use as possible has the risk of limiting the users’ freedom of choice, thus discouraging also their design aspirations. A participatory design tool in our case was not meant for professionals but for everybody, and it should attract and encourage people to participate.

Our online participatory design tool was built around the concept of a timeline, which is used in many control device manufacturers’ design programs. Users compile their lighting schemes from different kinds of partially predetermined light events, both static and dynamic, which they can modify to their own preferences. The creative options that a LightStories user could have were carefully designed considering the tool designer’s responsibility to prevent any possible harm to pedestrians or neighboring buildings caused by ill-devised lighting schemes. The choices concerning the speed of change within the dynamic effects were tested to ensure that possible traffic and medical problems were avoided.

However, the LightStories web design tool offered a complete range of 16 million colours for the design of lightstories. The colour picker included a selection tool for the brightness and saturation values of a particular colour and a colour wheel for the hue. The entire hue range is well represented in the colours that selected for the stories, which would indicate that the possibility to freely select colours is important. The used colours, then, were a rather good representation of the whole and continuous colour spectrum (Fig. 52). The brightness and saturation on the colour picker was set by default to be fully saturated and in the middle of the brightness value. Possible influence by the default value can be seen in Fig. 53, as the majority of the colours are located at the most saturated end of the spectrum; however, the intentional use of bright colours was also brought up by several participants in the interviews. There is a significant amount of less saturated colours, too, meaning that the brightness and saturation selection tool has been used extensively. Overall, lighter colours have been used more often than darker tones.

Figure 50 shows the full range of colours in the three-dimensional HSV-colour space (Hue, Saturation, Value), with the size of the cube representing the number of times a single colour was used. White and black appeared more than any other choice of colour. Their abundance can be explained to a great extent by the use of the “flicker” effect, where black and white were used by default among the selected three colours to create the desired effect. The large amount of black is also due to errors by incompatible browsers, where colours were not correctly saved. Consequently, black and white are truncated to 22 instances, because this was the maximum the most popular colour (turquoise) was used.

Fig. 52. Colours used in participants’ LightStories: a continuous colour spectrum.
According to our user feedback, communicating with colours had been seen as important and rewarding by the interviewees as well as essential in expressing symbolic meanings and feelings. Colours were thought to be useful for expressing, e.g., political opinions, calendar events (national day, Valentine’s day, Christmas, Easter), and support for sports teams. Participants wanted to imitate, for example, the look of the northern lights, growing grass, and snow storms. One participant (biologist, male, 40–49) had created a tribute to his recently departed mother. For him, participating in LightStories was part of his grieving process. Another one (publishing field, female, 30–39) wanted to express the joy of moving to a new city, to Oulu.

Experimenting and playing with colours and light were also mentioned as being positive: “It took some time 'cause I changed them around, I didn't get to the end result right away[...] it was nice to design and savour those colours before deciding on an end result.” (publishing field, female, 30–39) A biologist (male, 40–49) commented that, because street lighting usually is monochromatic, colours can create more interest. “I love colours anyway, so it’s an important thing.” Interviewees mentioned intentions, such as to make a design “as colourful as possible” (publishing field, female, aged 30–39), to have colours “as bright as possible and clashing with each other” (electrical engineer, male, 20–29). The need to bring vivid colours into the cityscape seems to be closely related to the cold and dark period of the year (February), as also one of the interviewees stated, he wanted “to bring those springtime colours into this greyness.” (social worker, male, 20–29).

Besides colours, the dynamics, which could be created from customisable predetermined effect templates, were seen as an important and interesting means of expression. One participant spoke of “the dynamics, how to make it come live” (biologist, male, 40–49), another stated that she “certainly altered the pace, too [...] so that it was kind of slowly flowing forward [...] and at some point it was changing a little faster” (publishing field, female, 20–29). Displaying calmness (slow) or being energetic (fast) were among the more popular ways to use dynamics. Those effects, which could be characterized as the most dynamic ones—namely “flicker” and “movement”—were the most commonly used. Moreover, of the three tempo alternatives, “quick” was very clearly used more than “moderate” and “slow”. This might indicate that users really wanted to have as big an impact as possible on the urban space, a sentiment that was also stated by some interviewees (e.g., electrical engineer, male, 20–29).

Fig. 53. Colours used in participants’ LightStories: HSV-colour space.
Additionally, users were able to determine the length of individual events in their lighting designs. Events of shorter lengths were more popular among the users than longer length ones (Fig. 54). Some of our users also wished to have the ability to make even shorter light events than the defined minimum (5 minutes), which would add the expressive potential of the design tool. Moreover, one interviewee thought that there should be an option to make lighting designs that are shorter than one hour; for example, 10 minutes would be a more suitable length for the story to be watched as a whole on the street.

Interviewees’ answers indicate that the offered amount of choice was sufficient; for most of them, it was difficult to invent anything else they would have wanted to do. They felt that they really had the possibility to design for themselves, not just to select from ready-made options. Also the data from user-generated designs suggested that all the effect templates were necessary, as they were all used (Fig. 55).

Fig. 54. Number of LightStories containing (an) event(s) of specific length

Regardless of the wide array of design choices, the tool was considered generally to be easy to use. However, the design task had been difficult for the elderly user (retired health care administrator, 60–69). Surprisingly, also one design professional (UI designer, female, 30–39) considered the design of lighting as quite difficult because of the many choices and the unlimited colour options. She suggested that there could be two options: a more versatile tool for the more experienced users and a simple one for basic users. One explanation for her reaction might be that she was approaching the task in a professional manner, which also set the standards high for her process and results, whereas most of the users, being laypersons, saw the task in a more leisurely way.

We also asked in the questionnaire about how participants would describe the experience of making a LightStory: 67.1% of the respondents described it with positive adjectives (“easy” 31.6%, “fun”, “nice”, “inspiring”, etc.), 17.7% mentioned something positive, but suggested improvements, 7.6% were unable
to form an opinion, and 7.6% of the answers were negative or indicated that the respondent had experienced difficulties.

Fig. 56. Published texts of LightStories could be read on the public UBI touch screens in the city centre.

Narratives

To accompany the lighting designs on the street, users had written texts that could be read on the landing page of the LightStories website at the time the lighting design was presented in the street. All the stories were further displayed on the calendar page and on the public UBI touch screens. During February, 90 texts were saved to the server (11 by members of the research group). Additionally, 15 lighting designs were saved without the text due to a system error. The texts varied from short greetings, narratives, or descriptions to longer stories.

Greetings often marked special dates, such as Valentine’s Day, birthdays, anniversaries, or were just meant to bring joy to some close person or to all the people of Oulu. Stories described, for example, a memorable situation in the writer’s personal history (e.g., the birth of a younger sister, memories of a summer holiday in Oulu in the 1950s, a story of two swans that the writer had taken care of throughout one winter), a topical theme (election day, the birth of Princess Estelle of Sweden), or simply the writer’s current state of mind. The last example could easily be likened to a status update in social media. LightStories was not used to inform of events or for advertising, except for our own invitation to participate, which was the very first LightStory displayed.

Interplay of light and text

The narrative element was intended to help participants without previous design experience to start designing dynamic lighting. In the interviews, attitudes towards the narrative part varied: some participants found it very inspiring, an important part of the process, and also useful as aiding the design. For example, in the questionnaire, one respondent compared telling the story with light to making a narrative with music, a process that was familiar to him. A couple of our interviewees suggested that writing should be done in parallel with making the lighting design, so that each light event composed could be linked with the corresponding part of the written story. This could also be used in the presentation phase of the lighting design as some kind of a manuscript of events in parallel with the lighting. However, as previously noted, for some participants,
the play with light and colours was the primary part, and writing something that would be published on the website was seen as unimportant or even as an unpleasant necessity. However, the minimum length for the story was one character, so the decision about how much to write was left to the user. Consequently, the verbal and visual tools complemented each other as was intended, attracting people with different strengths and abilities, thus enabling users to express themselves accordingly.

All in all, the rich collection of varying lighting designs and texts is a compelling demonstration of the enthusiasm and inspiration the participants experienced. The documented material, then, offers many possibilities for a full content analysis, which is not in the scope of this thesis.

Publicity and censorship

Participation in LightStories required a willingness to make one’s designs and messages public. Attitudes to this publicity varied widely. One participant (architecture student, female, 20–29) expressed some discomfort about the task of writing a story or a message. Despite this generally disdainful attitude towards publicising her own words, this participant had a clear message (encouraging people to vote in the presidential elections) in her LightStory, which had also informed the choice of colours in the lighting design (her candidate).

At the other end of the spectrum, we find one participant (male, 40–49) who wrote arguably the most personal narrative, a tribute to his mother who had recently passed away. Despite the intensely private subject matter, he was eager to express his feelings, as long as he remained anonymous. The act of expressing these feelings implied that the mode of participation was seen as secure and trustworthy enough, and at no point did the interviewee express any doubt about this. Another participant (male, social worker, 30–39) had given a good amount of thought to the publicity his narrative would receive. However, rather than repelling him, the publicity of the story had sparked a desire in him to encourage people to participate in LightStories and to care about the urban environment and that, ultimately, he “got this urge to get that message out there”. Overall, almost all of our interviewees were very much aware that the narratives would be displayed publicly, and most of them wanted to use their LightStory as a platform to tell other citizens something that was important for them. In this respect, LightStories truly was an urban social medium.

As such, our research team carefully considered the question of moderating the content before the launch of LightStories. It was decided that the narratives would be checked afterwards daily. Albeit a somewhat risky choice, this proved to be the right one for LightStories. No messages were removed from the website, as most were overwhelmingly positive in their tone, and even those that were considered somewhat borderline were merely slightly incoherent. Some of our participants also considered moderating important and potentially problematic, especially those participants who were designers. Concerns that the quality of lighting should not be negatively affected were expressed by layperson participants.

During the final analysis of our evaluation materials, we became convinced that the inherently creative nature of LightStories repelled those who only wanted to wreak havoc. In order to vandalise the system, an ordinary user would have had to create a lighting design, write a message, and fill out our user survey. This ensured that the system was not a particularly worthwhile target for disruptive use (notwithstanding more technologically advanced forms of vandalism). Systems that require creativity and more immersive participation, then, are at least potentially more robust against simple leisurely vandalism.

5.1.4 Further challenges and ideas

Our project expanded the idea of social media by bringing it into the urban scenery and by imagining what else could it be than comments and pictures on a two-dimensional screen. In this pilot version of LightStories, the communication with light and text was more or less one-way communication. Even though self-expression in a public forum was important in itself for the participants, the system could be developed further by adding the possibility for two-way communication between the participants in the street and on the web, e.g., with a commenting feature, “like” buttons, or even by the possibility of responding to a LightStory with a LightStory. This latter kind of internal referencing would have
been possible in the current system in principle, but incidents of such use did not occur. The delay in communication due to the time booking system might have prevented this. The texts were accessible on the site through the public wireless PanOULU network, via personal mobile devices, and, with a laptop, one could even compose a LightStory in one of the many adjacent cafés or restaurants. This option could be brought to people’s attention in the future, e.g., with QR-codes attached onto the light poles.

As previously stated, co-design enabled the research team to engage the participants more deeply, and, similarly, our interviewees saw it as a good way for them to participate. Moreover, rather than limiting, the design tool’s set of customisable predesigned effects was seen as a good starting point for participation. The Internet was overwhelmingly favoured as a medium of participation. Ideas revolving around online tools included the possibility to design and preview LightStories in real time on the Internet, the ability to report unsatisfactory lighting conditions on the City website, and a service where citizens could take pictures with their camera phones and send them to city officials. Ideas for more direct interaction with lighting were also presented, for example, controlling lighting via a public touch screen or smartphone in real-time, or even by touching the luminaires themselves. Some participants also wished to play with other types of light, such as projectors, and to influence what is being lit. Some also wished to be able to cast light on different kinds of objects, such as walls, architecturally interesting buildings, and snow. A larger implementation of LightStories, which would span the whole of the pedestrian centre of the city, was also requested by some participants. Many hoped for a continuation of LightStories, especially at Christmas. The choice of site also appeared as an important factor in the success of a participatory lighting system. Some participants had hoped for an even more prominent and central location, but others reported an increased positive awareness of the previously uninteresting locale. The system, then, can be used to improve low-profile or disused areas; however, a more prominent site can attract more users.

As LightStories was well received by our participants and because it also captured the interest of the media, it is interesting to consider whether a similar system would be feasible in the long run. It must be noted, however, that LightStories was not intended as a year-round system. This was partly due to special northern circumstances, and to the restrictions of the research project, but also partly because LightStories was intended to play a slightly different role in the city. By involving participants deeply in a co-design process, LightStories was suitable for educational and awareness-raising purposes as well as for research purposes. As such, LightStories adequately fulfilled its intended task.

As the street lights are maintained by the electricity company, the added maintenance task would be to ensure the smooth running of the LightStories website design tool. The real challenges, then, for the continued operation of LightStories would relate to developing the content and mode of participation, as LightStories is currently best suited for events and shorter periods of time. The added possibility to use multiple platforms, especially the various mobile operating systems, would be a priority. Similarly, more independent, intelligent and responsive real-time interaction might be necessary to lower the threshold of participation in long-term use. Even though an “empty canvas” was preferred in this short-term demo, the system might create its own designs when it is not being used to maintain people’s interest and a lively, attractive cityscape. Furthermore, as media attention cannot last for an extended period of time, participants might be sent a message to encourage them to invite their friends to participate. Additionally, QR-codes, public touch screens, and posters could be used to inform passersby to use LightStories.

However, a continually available system, with added ease of use and a subsequently lower level of engagement, would likely produce a different kind of experience for its users. Interesting research questions would include: How would this affect the sense of control that LightStories participants feel? Would usage fade away with dwindling media attention, or would misuse eventually become a problem? Or would some kind of a culture of usage develop over time? Another interesting way forward would be to use LightStories as the event-based medium that it is. How would people from different demographics, such as school children or convicts, use the design tool and what stories would they tell if given the chance?
5.1.5 Concluding summary

The LightStories case study explored the process of utilising a part of the existing lighting on a pedestrian-oriented street as a forum for personal narratives, messages, and greetings through an online participatory design tool. The LightStories concept of engaging participants through the possibility of visual and textual expression—the design of dynamic lighting and the writing of texts—was found successful.

The service attracted a remarkable amount of participants during the test phase. However, we also discovered that the amount of visitors on the website dropped whenever there was a longer break in media visibility. It can be said, then, that in order to invite participants, indeed, to make participatory lighting feasible at all, visibility in different types of media is necessary.

The combination of a visual and textual task managed to inspire participants with different abilities to participate and communicate. The participants had used the design tool in a creative and versatile way, according to the data from user-generated designs. Textual expressions varied from short greetings to longer stories and status updates. Stories described, for example, a memorable situation in the writer’s personal history or a topical issue. LightStories proved to be robust against vandalism, quite possibly because it required a high level of engagement and creativity from its users.

From a research point of view, LightStories provided the research team with a means of engaging people in a more meaningful way, thus eliciting more thoughtful responses from our interviewees and questionnaire respondents. The method is applicable in other participatory projects, which aim to collect people’s profound attitudes and ideas for, e.g., developing public environments.

How was the LightStories case study experienced, then, according to the interview and questionnaire material? Many participants regarded participation in lighting design positively, linking it to ideals of democracy and inclusivity. However, many also had initial trouble in imagining how participation could generally be achieved on a practical level. The Internet was overwhelmingly popular as a feasible means of participation among our interviewees. Reflecting this specific method of participation through LightStories, the interviewees had valued the many design possibilities of the design tool and many of the users...
found making a LightStory easy, inspiring and fun. Those participants who already knew the area felt most affected by LightStories, and they regarded its effect as positive, reporting feelings of empowerment and increased interest in the area.

Communicating with colour was seen as rewarding to our interviewees, as was the use of colour in expressing symbolic meanings and feelings. Urban lighting was regarded by many as an important way to create a pleasant environment during wintertime in these northern latitudes. Many expressed an interest in the continuation of LightStories.

The publicity of the written messages had a dichotomous effect on our participants; some participants did not consider the verbal aspect important or meaningful, and, for some, it was the main attraction. Nonetheless, the narratives had an effect on the visual aspects of many users’ LightStories.

The prolonged sustainability of LightStories or a similar kind of participatory lighting project could be ensured by the continual development of the system and the modes of interaction. The use of LightStories could be developed further in collaboration with different demographic groups. The analysis of the interview and use data shows that the piloted concept for participation and communication through expressive means was seen as empowering, meaningful, and inspiring. As such, it could be employed for different purposes in further projects.
5.2 Urban Echoes case

5.2.1 Evaluation and analysis methods

The park users’ experiences of the Urban Echoes case were collected during February and beginning of March 2013 on site. In this pilot, the targets were twofold: First, the aim was to understand park visitors’ experiences of the different movement-adaptive lighting scenarios and of the communicative lighting schemes. As the experience of lighting in an urban environment is complex, we were interested in several questions, such as, how lighting enables seeing, how does it affect the feeling of security of park users, and does it create aesthetic experiences? In addition, we were interested in the park users’ attitudes towards adaptive, interactive, and participatory lighting and their ideas about applying new technology to urban lighting. Second, the aim was to employ the users’ experiences in developing the design of adaptive urban lighting from user-oriented perspective.

As our evaluation emphasised the role of experiencing adaptive lighting in a real urban place, we considered it a primary requirement to employ a method through which researchers would be able to share and partake in the interviewees embodied and situated experiences. Moreover, we wanted to respect the participants’ own categorisations concerning the phenomenon, while allowing researchers to access the participants’ internal thoughts and attitudes. This meant employing a mixture of qualitative methods that we call experience gauging walking interview to enable broader knowledge and interpretation of people’s experiences. The experience gauging walking interviews were preceded by a preliminary interview. Overall, we interviewed 16 participants; one participant attended only the preliminary interview but not the walking interview. Our participants consisted of two age groups: young adults (20–29 years, 11 persons) and seniors (over the age of 65, 5 persons). This was done in order to compare two vastly different experience groups, with presumably different visual and movement abilities and readiness to use new technologies.

The experience gauging walking interviews were essentially in situ participant observations coupled with a semistructured walking interview. In practice, we walked in the park with the participants both prior to and during the deployment of the demo. In these walking interviews, one researcher was primarily responsible for asking questions and audio recording, although everybody was allowed to speak freely and ask questions, and one was responsible for video recording. I was responsible for operating the system, i.e., changing scenarios and showing the mobile services and resulting light schemes to the interviewees as well as presenting the questions concerning the mobile services. On the course of the interview, I also asked elaborating questions inspired by either the answers or the specific present lighting behaviour. The interview team consisted of, besides me with the role of designer of the lighting schemes, two independent interviewers in each interview with backgrounds in the fields of architecture and cultural anthropology.
The experience gauging walks lasted approximately 45 minutes to 1.5 hours. The walks were structured by the selection of test scenarios and a set of questions that were repeated for each scenario. For the interviews, I designed a protocol with several dynamically changing lighting scenarios with the VirtuAUL tool. The design process is described in Chapter 4.2. The scenarios represented different manners of how lighting could be designed to adapt to the movements of park visitors. The starting point in designing those scenarios had been the experience of the user in the park, including aspects such as how much he or she notices the adaptations, what kind of feelings the adaptations cause, and what does the dynamic lighting make the visitor see in the environment. The variables changing in scenarios were the light levels, the distribution of light on the path, the use of tree lighting along the path lighting, and the colour of light (only warm white light, warm white light with effect colour, and only coloured light).

It was rather challenging to select the set of scenarios to be used in the interviews for couple of reasons. The amount of scenarios could not be very large not to exhaust the interviewees. The capacity to remain interested in a task of distinguishing and describing different situations might be limited. In addition, the wintertime climate conditions for the interviews were challenging as the temperature ranged at the interview situations between -17 and +1, and sometimes it was snowing so much that the video camera had to be covered with a hat. Another challenge was that, due to the complexity of the research setting and question, the characteristics of presented schemes, as well as the order in which they were presented, could easily influence the answers. Our solution was to present a selection of schemes, where the expression level gradually rose so that the first ones were slow and calm and the last ones intense with lots of colours and quicker alterations. In addition to the selection of dynamic lighting schemes, the interviewees could test the mobile services and see the resulting lighting visualizations. During the process of five weeks of having the interviews, I added more scenario variations to the protocol. One reason for that was that we realised from the interview answers that the choice of colours in lighting schemes had a strong effect on the answers and attitudes. In some cases, the dislike against chosen effect colour substantially dominated the opinion so that it overwhelmed the experience of other features of the scenario. Then, it was necessary to show another version with another colour choice. Also, the interviewees’ comments and wishes inspired further developments and refinements of some scenarios, which were then presented in the following interviews. This enhanced the participatory and dialogic character of the evaluation method. In addition, due to some reliability problems of the system, it was not possible to present the scenarios in a similar way in all the interviews, as, in some occasions the wide optic luminaires did not obey the control but stayed constantly on at 10% light level. Analysing the results, I have taken into account these exceptions to the protocol. The collection of interview scenarios is presented in Table 8 and in Figs. 59–74 in the following pages.
Table 8. Interview scenarios presented in walking interview sessions. Those interviews, where the control of the wide lights was malfunctioning, and they remained at 10% intensity during all the scenarios, are marked with gray shading. The protocol was slightly developed during the test period. More colour variations were added. Also to Scenario 7 and Scenario 8, a low-level standby light was added: to Scenario 7 with dotted lights and to Scenario 8 with wide lights. In Scenario 5, the light level for path lighting was lowered after first interviews, in order to make the tree lighting more visible.

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* Wide lights 10%
** Wide lights 10% - 70%
*** Dot lights 10% - 70%
**** Dot lights 20% - 70%
***** Scenario intermingles partly with scenario 9B

D Lighting scheme did not come on, but it was described and discussed
Fig. 59. Interview Scenario 1. Design intention: Adaptive lighting which supports perception of the route and safety of movement. Unperceivable adaptation, moderate potential for energy savings. Wide distribution luminaires 60%–100%, warm white light, linear adaptation pattern.

Fig. 60. Interview Scenario 2. Design intention: Adaptive lighting, which supports perception of the route and safety of movement. Perceivable adaptation, large potential for energy savings. Wide distribution luminaires 10%–100%, warm white light, linear adaptation pattern.
Fig. 61. Interview Scenario 3. Design intention: Adaptive lighting which creates lively lighting for the route following a park-goer. Unperceivable adaptation, moderate potential for energy savings. Spot luminaires 60%–100%, warm white light, nonlinear adaptation pattern.

Fig. 62. Interview Scenario 4. Design intention: Adaptive lighting which creates lively lighting for the route following a park-goer. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100%, warm white light, nonlinear adaptation pattern.
Fig. 63. Interview Scenario 5. Design intention: Adaptive lighting which supports perception of the route and safety of movement, highlighting elements of the scenery and supporting visual detection of other people. Perceivable adaptation, large potential for energy savings. Wide distribution luminaires 10%–100%, warm white light, three luminaires 0%–100%, warm white light, linear adaptation pattern.

Fig. 64. Interview Scenario 6. Design intention: Experiential lighting for the route following a park-goer, highlighting elements of the scenery and supporting visual detection of other people. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100%, warm white light, tree luminaires 0%–100%, warm white light, linear/nonlinear adaptation pattern.
Fig. 65. Interview Scenario 7A. Design intention: Experiential lighting for the route following a park-goer, highlighting elements of the scenery and supporting visual detection of other people. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100% warm white light, tree luminaires 0%–100% warm white light and blue light, linear/non-linear adaptation pattern.

Fig. 66. Interview Scenario 7B. Design intention: Experiential lighting for the route following a park-goer, highlighting elements of the scenery and supporting visual detection of other people. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100% warm white light, tree luminaires 0%–100% warm white light and magenta light, linear/nonlinear adaptation pattern.
Fig. 67. Interview Scenario 8A. Design intention: Experiential lighting for the route following a park-goer, highlighting elements of the scenery and other parts of the route with surprising behaviour. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100% warm white light, tree luminaires 0%–100% warm white light and magenta light, nonlinear adaptation pattern. In part of the interviews, also wide distribution luminaires 10%, warm white light. The effect colour reflects the temperature of outdoor air.

Fig. 68. Interview Scenario 8B. Design intention: Experiential lighting for the route following a park-goer, highlighting elements of the scenery and other parts of the route with surprising behaviour. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100% warm white light, tree luminaires 0%–100% warm white light and blue light, nonlinear adaptation pattern. In part of the interviews, also wide distribution luminaires 10%, warm white light. The effect colour reflects the temperature of outdoor air.
Fig. 69. Interview Scenario 9A. Design intention: Experiential, colourful lighting for the route following a park-goer, highlighting elements of the scenery and other parts of the route with surprising behaviour. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100%, shades of yellow and green, tree luminaires 0%–100%, green light, nonlinear adaptation pattern.

Fig. 70. Interview Scenario 9B. Design intention: Experiential, colourful lighting for the route following a park-goer, highlighting elements of the scenery and other parts of the route with surprising behaviour. Perceivable adaptation, large potential for energy savings. Spot luminaires 0%–100%, shades of red, magenta and violet, tree luminaires 0%–100%, blue and violet light, nonlinear adaptation pattern.
Fig. 71. Interview Scenario 10. Design intention: Experiential, colourful lighting for the whole route, highlighting elements of the scenery. Dynamic, nonadaptive, moderate pace of changes. Spot luminaires full colour-related intensity, turquoise, red, magenta and violet, tree luminaires full colour-related intensity, red, magenta, and violet.

Fig. 72. Interview Scenario 11. Design intention: Experiential, colourful lighting for the whole route, highlighting elements of the scenery. Dynamic, nonadaptive, fast pace of changes. Spot luminaires full colour-related intensity, red, magenta, yellow, green and violet, tree luminaires full colour-related intensity, red, magenta, yellow, green, and violet.
Fig. 73. Lighting scheme for the Events mobile service. Luminares reproduce the amount of different events starting within two hours as dots of thematically coloured lights (blue = museums and exhibitions, violet = music and dance, magenta = visual arts, red = sports, orange = theatre and circus, green = literature and literary art). The rest of the lighting fixtures produce warm white light. The random positions of the colours change every 15 seconds.

Fig. 74. Lighting scheme for the Activity service. Luminares represent the layout of different activity hotspots in the city, receiving the indicating intensity of red colour. These activity hotspots are sensored by the UBI sensor network, which detects Bluetooth-equipped devices. Neutral white colour indicates that no such device is detected by a sensor.
The walking interview was semistructured, i.e., it followed a question frame informally. The form and order of the question varied slightly in the interviews in a dialogic manner, and additional questions inspired by answers were presented. The situation was intended to be more like a conversation than an interview. During the walk, the interviewees were provided with information of the design intention and details of lighting behaviour, after he or she had had the opportunity to evaluate the lighting scenario him or herself. With this interactive and participatory method, the interviewee was, in a way, taken as a member into the designer-researchers’ team—as a layman expert, who was given gradually vocabulary and background to process and reflect on his or her experiences. In a way, the evaluation interviews as a whole could be described as a two-way interactive learning process, starting with the preliminary interviews, which inspired the participants to mediate beforehand on different themes concerning urban lighting and their preconceptions on adaptive lighting. This was a conscious method intended to ease the rather challenging task of evaluating approximately 15 different lighting schemes in a row. Even though this may have had some effect on the answers, as our interviewees were more knowledgeable than if they would have come to the walking interviews being a raw recruit, we found the results beneficial as we gained more in-depth evaluations and reflections of the complex phenomenon.

The question framework was based on: 1) the pre-comprehension we had gained in preliminary interviews of what the participants saw as a task of urban lighting: enabling seeing and moving safely, sense of security during the dark, and making a comfortable atmosphere and aesthetic experiences in a cityscape, and 2) understanding of essential features of adaptive lighting as a design task, which I had gained during the research and design processes as well as the design intentions of the scenarios.

Mediating the former point was done through questions concerning whether light enabled the interviewee to see well enough in order to move easily, whether there was enough light or how he or she perceived the intended light level, whether the interviewee would feel secure in lighting like that, what kind of an atmosphere was created along the park path with the lighting scenario, and whether the interviewee found it pleasant or unpleasant. The interviewee was first allowed to describe each lighting scenario freely: How does it look like in there? What has changed from the previous scheme? How does this kind of lighting feel to you? What does this bring to your mind? The understanding of acceptance of adaptive lighting was gained through questions: Could you see this as a permanent lighting scheme for the park? Could this kind of lighting be in the whole park?

From the point of view of detailed design of adaptive lighting, the following questions were asked: Did you notice that the lighting reacted to your moving in the park? In which way did it react? Also questions about amount of light in certain situations and in different parts of path, shades of light colour, and dynamics of light were presented. Special questions concerning the design aims were presented with Scenarios 8A and 8B, dealing with perception of environment and communicative content of lighting. With presenting the mobile services and the resulting lighting schemes, the interviewees were asked how they found the concept and whether they would consider using themselves such services or not. Also questions about communicating with lighting in general were presented. In addition, questions concerning privacy issues and the collection of data of city inhabitants were presented as well as questions about the relevance of availability of urban information through mobile services: for example, energy use information as in the case of the Lighting service of Urban Echoes.

After presenting the scenarios, we had an amount of general reflection questions concerning the overall impression and those scenarios that especially made an impact; fulfillment of expectations; aesthetic experiences; interacting with light; the sense of security, and new ideas generated while walking.

The interviews were transcribed by a research assistant. I have made a qualitative analysis of the research material, reading through the transcriptions, and looking through the video recordings of the walking interviews making observations. I have thematised interviewee’s answers from different scenarios with a help of tables organizing the comments. This has helped me analyse the complex research material and raise relevant viewpoints concerning experiences of adaptive lighting. All interviews were conducted in Finnish; for this dissertation, the relevant portions of the transcriptions have been translated into
English. In this thesis, the aim is to discuss the experiences generally and from the point of view of understanding of the new design task. Thus, I will not present an extensive comparison of experiences about all the scenarios but focus on describing different aspects of experiences of adaptive lighting behaviour. In the following, I present the results under subtitles based on different themes of interest.

5.2.2 Values and attitudes

Generally, during the walking interviews, the interviewees expressed positive attitudes towards use of adaptive lighting in park environments. None of them expressed a rejection to the idea, but they saw it as beneficial in many ways. The principle of implicitly interactive lighting, which follows park-goers, was found good. Also the Urban Echoes mobile service, which offered a more explicitly interactive approach to adaptive lighting and included ambient information to park lighting, was found interesting and to have potential, even though there were some doubts presented as well. I will explore these attitudes in more detail in the following subchapters, thus discussing the experiences thematically.

As also in preliminary interviews, many participants saw energy savings to be a positive value in adaptive lighting. It was considered wise not to have lights always on or have lighting with lesser intensity when an environment is unoccupied.

I think it is quite good that this has these sensors and that it reacts to the movements. This way you can also save energy because it's not on all the time. (female, 22 years, student of geology)

For many of the interviewees, adaptive lighting provided a sense of security in an urban environment. In addition, adaptive lighting behaviour was also seen in a positive way as expressive and aesthetic use of light in urban space and to bring additional value in this sense. It was seen to give character and to enliven the environment. It was found to make the city centre more attractive and inviting to both inhabitants and tourists.

Adaptive lighting was seen to have both image value and economical value, as it could bring more people to use commercial services nearby, and in a larger scale, to boost the ICT and smart lighting industry of the region. Some interviewees connected naturally the concept of adaptive and intelligent lighting to the recent brand of Oulu city as an intelligent community. Oulu was nominated among the top seven intelligent communities of the world in the year 2012, as the only European city (Intelligent Community Forum).

I think this lighting is more intelligent. I mean that it gives a smarter impression and it is positive for the image of Oulu as it is supposed to be some kind of an intelligent city, so that lamps are smart as well. It is always good of course. (female, 20 years, student of nursing)

I find it nice that in Oulu this lighting technology has been developed using LEDs. The thing up there on the wall of Raatti sports field is nothing else than a lamp made in Oulu. I suppose you are very well aware of that. [...] now we are living a wonderful era in terms of electronics industry, when this has been developed here [...] Let's develop these further, this could become a product for export! (male, 67 years, retired repairman)

However, besides the mentioned benefits of new technology, a couple of interviewees had doubts about the operation and endurance of an intelligent lighting system: How long would it last without large maintenance problems?

But this really gives life to it, that's the thing about it probably. I doubt they are lit no longer just for safety reasons but like for esthetic reasons. (male, 24 years, student of history)

Well, I think it's great all these different colours! The fact that you can play with them in so many ways, so amazing, and as I said if this existed then the colours would always change and people would even come and watch this. (female, 69 years, part-time retired doctor)

Yeah, I had a positive image of that of course. It would be nice to say that hey we have in Oulu this kind of thing. We have flickering lights and colors in the park. Only positive things to say about this. (male, 24 years, student of history)
Could there be failures in operation? Would un-operating technology with maintenance problems bring new costs?

I was wondering how often there are defects or that the lamps all of a sudden stop reacting to anything or start reacting to falling snow or such? This might arise some questions. (female, 24 years, student of Finnish linguistics)

Last time [in the preparation interview], I wondered whether when there will be more technology, the defects will increase and costs will increase. I have been outside of the working life already for 10 years, but when the technology increased there, problems increased. [...] In my own summer cottage there are many kinds of, I guess at least three different kinds of motion detectors that adjust the light, so that at least one of them is completely [broken], it has been in use for two or three winters, so it doesn’t work anymore. I wonder if these have the same thing, of course, it depends on the manufacturer. There are also those that have been working for twenty years. (male, 67 years, retired repairman)

One senior interviewee (male, 67 years, retired repairman) was also, at first, very skeptical about the necessity of making functional illumination of a park path to be also atmospheric and aesthetic with lively behaviour of light dots. He had difficulties in understanding this mixture of utilitarian and decorative aspects in the same light element. However, after seeing a selection of scenarios, the expressive nature of light gradually increasing, he became, at some level, accustomed to the idea and saw its imago value, and referred it to art. He described himself as not being at all artistic and, for that reason, found it difficult to make estimations of aesthetics. He had worked in local timber mill for supervision work of labour protection and industrial safety. He had from his background a strong emphasis on utilitarian and safety issues as well as on technical aspects.

I think something like this is unnecessary. Total amount of light is falling here and then there are colours. That kind of lights where light is most visible, they are to use. [...] I think this is a bit showing off; [...] It doesn’t irritate me, of course. It only feels a little useless. Light is light, and these are already a bit like decorations. Of course, it should be some decorations, too, but I think they can be then like illuminating trees or as target lights. This is not basically a target light. (male, 67 years, retired repairman)

Maybe, if there would become some really interesting lights so I’d take somebody from outside Oulu to see them. But, of course, I’d come myself to see, so that to know what kind of [lights] there are. [...] Of course there is [attraction value]. You make art with light, isn’t it so. (male, 67 years, retired repairman)

5.2.3 Seeing, moving, safety, and sense of security

In the preliminary interview answers, a central task of urban lighting was to enable moving safely by seeing well enough and to create a sense of security in a nocturnal urban environment. In walking interviews, questions concerning these aspects were asked and different viewpoints were discussed.

All in all, adaptive lighting, which reacted to the presence of park-goers, fulfilled the task of providing a well-lit environment for moving safely. In general, for safe and comfortable walking on a park path, it was not necessary to have the whole path lit until the end, as long as there was good lighting around the walker and for some length ahead. This anticipative behaviour of movement-adaptive lighting was mentioned by many interviewees as important, so that the light would not be just under the walker but a bit ahead so that one would see where one is going. For example, an interview (female, 24 years, student of Finnish linguistics) stated “Maybe these could come on a bit earlier. I’d like to see already there, when I’m here.” In general, however, this kind of adaptive lighting behaviour, where light follows with the walker, was seen as pleasant and a good way of lighting.

And it was nice, when light was there ahead. It doesn’t have to be so very bright, when it goes there ahead. (female, 77 years, retired hospital porter)

The perceptible, dynamic changes and movement of light was mainly not seen as a disruptive element concerning walking safety, as long as the changes of light are not too rapid. It was seen more as a positive feature concerning walking
experience. “It doesn’t matter. It just creates that kind of variety.” (male, 23 years, student of mechanical engineering) One interviewee, anyhow, who had, due to her myopia, some problems with seeing, had some concerns for those scenarios where only dots of light were following the walker, thus creating changing patterns of shadows and light (for example, Scenario 6). For that reason, she would recommend that lighting type for side paths but not to the main path where traffic was intense.

I was just thinking that how much does this affect perception, if there are some lumps in this path. How much do you see them in this lighting? There can be a problem. I find it nice, not practical, but nice. [...] not really quite everywhere. I think that there are now so intense stripes here, that it is hard to conceive it. Particularly if it’s even changing under your feet. (female, 27 years, student of art education and graphical design)

Some concerns or doubts were also presented whether the lighting would be able to react quickly enough to a cyclist who was moving faster than a walker. During one walking interview, one interviewer demoed this successfully by running along the path. All in all, most of the scenarios were found easy and comfortable to walk by all the interviewees. The only exceptions were Scenarios 9A and 11, which many of the interviewees found interfering somehow their seeing. For Scenario 11, this was obvious and expected, as the scenario was designed as a “horror scenario” of adaptive lighting, where bright colours as dots of light on path and on tree trunks were changing with a fast speed. More surprising was how the colour shade of a scenario affected seeing. We had four scenarios with only coloured light on path. The Scenario 9A with dots of pale green and yellow light on the path following the walker caused several negative reactions. Some interviewees saw it as changing the perception of the path and interfering with walking. It even induced optical illusions.

That neon colour jumps a bit to your face. [...] It was notably harder to walk than just before. (male, 23 years, student of mechanical engineering)

It somehow looks like I would sink into this land. Looks soft. It somehow folds this surface. (male, 67 years, retired repairman)

Intrestingly, the same lighting behaviour with different colour shades—Scenario 9B with different shades of red and pink—did no cause similar negative effect. Only one interviewee thought it not to have quite enough light for seeing. One interviewee (female, 27 years, student of art education and graphical design) even described that some of the red shades are highlighting especially well the surfaces for good visibility. Also Scenario 10 with many changing colours was found pleasant for seeing the route. In addition, it provided interesting scenery along the route.

They are not bothering me these colours. One can see with these colours’ light and there is [light] far ahead. There is good visibility and certainly it’s nice here that those colours vary, so then there’s something to see along the journey. (female, 24 years, student of Finnish linguistics)

The aspect of perception and coloured light occurred in also another context than seeing the route: one senior participant was skeptical about using only coloured light for the reason that it would decrease the ability to describe and recognize a criminal in a possible incident of crime occurring in the park.

While describing the walking experience, the interviewees saw the role of lighting not only as to help their seeing and safe moving but also as creating experience of space, movement, journey and atmosphere. The adaptive behaviour of light as well as the situation of luminaires and the chosen lighting type defined elements of the experience.

[Scenario 6] It feels really quite nice to walk. Here, it’s somehow like walking in some kind of a rink, when there comes light to the ground and then it’s in these trees by the side and then above the light sources also border this area. (female, 21 years, student of Finnish linguistics)

[Scenario 13] Well, yes, just like I mentioned earlier, so it was a bit of a feeling of a journey. When we walked, so the floor was changing along [...]

That green then for some reason doesn’t work with my eye just for the reason that it’s difficult to perceive where to step. In principle that there is only coloured light, that I don’t see as any problem at all. (female, 27 years, student of art education and graphical design)
a bit like walking in a changing labyrinth! And in a pleasant manner. When spots were lighting up there, it reacted in a nice way where one is going, so it came there ahead, in a way. (male, 24 years, student of history)

[Scenario 6] It really made steps quicker when I was waiting for the next one “ting-ting-ting” and then it came on. Really nice. Would this kind of thing be always on a jogging route, so I would run faster. (male, 24 years, student of history)

The interviewees had associations of different lighting types and scenarios with walking and moving in different kind of contexts and situations: the Scenario 1 with bright general feeling along the route was associated for exercise on a jogging route, and the scenarios with dimmer general atmosphere and more contrasts, for example Scenarios 2 and 3, were associated with more urban sceneries and night walks.

And here one gets more like an urban feeling than from the last one. The last one looked like a sports route or something like that. [...] Yes quite well [I can see to move around], so I don’t see that there any problems with these, even though it’s a bit dimmer or more atmospheric like this. And, yeah, this would perhaps be a kind of evening walk mode, [...] the first one was that kind of hiking [mode], so this is then for walking hand in hand with a boyfriend here. More this kind of a sentimental thing. (female, 20 years, student of nursing)

For many of the interviewees, adaptive lighting behaviour, which reacted to park-goers following and guiding the walker along the route, enhanced their feeling of security. During the walking interviews, this was specifically asked for only two of the participants, but this notion occurred in several answers while discussing generally about atmosphere or how safe they felt there either walking with the scenarios or in the reflection-part of the interview. The sense of security was associated both with the feeling of light going ahead and with the fact that it reveals the presence of other people in the park.

I think it was quite nice or it made me feel comfortable. It like creates safety, when it goes there ahead. Quite good. (female, 20 years, student of nursing)

Really this, when you think about safety, so I think this even increases safety. If someone would be hiding there under the bridge and then would attack, so then these lamps would perhaps react to it, so that it would be revealed even more easily. (female, 24 years, student of Finnish linguistics)

There should be light, of course, so that it’s safe to walk when it’s dark, and then also, if there is that kind of anticipating light, which lights up 10 meters ahead when I walk there. Would it be even more secure than that kind of totally even one? Someone, who is perhaps planning something notices that no, here is also other kind of life here. (male, 68 years, retired export manager)

The interviewees had varying opinions regarding the relevant factors for feeling safe in the park. For some, it was the amount of light that brought security (male, 23 years, student of mechanical engineering; female, 71 years, retired nurse), or at least they associated the darkness or scarceness of light with fear (female, 77 years, retired hospital porter; female, 69 years, part-time retired doctor). For some interviewees, it was also the comfortable feeling caused by soft and atmospheric lights or the sense of enclosed space through illuminated trees around or suspended lights above, which brought them security. Important was not the amount of light, but the quality of light.

This is important though, this soft change like the northern lights. [...] It even creates almost that kind of feeling of security just this softness. Like pulling a soft blanket over. It’s comfortable. (male, 68 years, retired export manager)

And then on the other hand those [scenarios], where the trees were illuminated, so they form that kind of nice tunnel burrow, when they border also from the sides of that route. [...] there was in a way a roof, so I think it was a clear issue of safety. At least I myself feel high rooms quite oppressive or they have too much air space. Or when there’s a roof made by lights, so it feels nice. (female, 27 years, student of art education and graphical design)

This effect of atmosphere and sense of specific place regarding the feeling of security, especially created by use of coloured light, surprised one interviewee:
Actually, the thing which surprised me, was that maybe those coloured and those spotlights there above felt as the most safe ones. Not that kind of bright, hard lights, which I thought would be safe, but somehow that makes you feel, how to say it, to get a feeling that I am just somewhere. It is somehow so big a contrast to the darkness there, that it’s that which makes the feeling that here I walk in the dark, only here is light, but elsewhere is dark. I was surprised, I’d have thought, that it’s the safest one, when there’s that kind of bright light. Maybe those colours created somehow sense of security, which I perhaps could have thought before. (female, 20 years, student of nursing)

The interviewee also considered the possible influence of amount and quality of light in environments to people’s mood and behaviour. Especially, this could have an effect here in Finland, where we are accustomed to darkness.

[…] could those lamps still affect one’s mood? Just that kind of a peaceful colour. It doesn’t necessarily make you feel so easily aggressive than if it would be a bright spot or bright area. That can perhaps even irritate some people. When we’re this kind of people living otherwise in the dusk. So it could be nicer too, to have somewhat dimmer conditions. (female, 20 years, student of nursing)

One aspect relating to the detailed design of adaptive lighting scenarios was the question of whether it was seen as necessary to always have some light on along the whole route. This was asked from the interviewees, who were shown lighting schemes, where the light was on only where a person was moving, and schemes with a small amount of light along the whole path. Due to an occasional technical problem of controlling the four luminaires giving light with wide distribution, during four walking interviews, those luminaires stayed constantly on with a 10% light level so that there was always some light on the whole length of the path. Anyhow, those interviewees were asked to imagine the situation when the lights would not be activated.

The attitudes towards this aspect varied among participants and during the course of an interview. However, there were more participants, who thought that there should always be at least a small amount of light on, than participants who considered it unnecessary. Differences were noted between two age groups and between genders among the young adults. For all senior participants, it was a good thing to have some default lighting so that one would not have to walk against darkness or see darkness at the end of the route. Especially, female seniors had experienced insecurity during their earlier life; one described herself of having a fear of darkness and the “spooks”. Large and distinct contrast of light levels between parts of the route emphasized the feeling of an intimidating dark part.

It was so evenly, not to say quite dark, but it may make some still older people to feel, I don’t know if really scared, but to feel like not going there, when it’s light and safe looking here and then it’s a clearly different zone there. (male, 68 years, retired export manager)

In the group of young adults, the opinions varied. Most of the male participants did not see it necessary to have a small amount of light always on in those parts of the path where no one was present. All of them enjoyed dimmer lighting conditions in general. Two of them did not, according to the preliminary interview, experience insecurity in environments at all and had more or less an “adventurous” attitude in life. Two participants—one male and one female—had had experiences of insecurity but still did not reject the idea of having part of the route dark. Common characteristics for all of them was that they valued highly the atmospheric and aesthetic features of lighting environment and not just the functional part of illuminating. This made them see the darkness or dimness as a coherent part of overall design, which created atmosphere and emphasized the feeling of being safe in the comfortable, cozy area of surrounding light. Soft transition between light and dark—not too abrupt contrast—was considered a good feature of design. Additionally, energy savings gained through having the lights off was mentioned as a reason for preferring not to have light always on.

I’m myself to some extent a friend of dim lights, so it probably reflects that. […] It’s the homely feeling that appeals to me in them, and what I at least get easily. There is a certain kind of echo in dim lights, which creates pleasant feelings at least in me. (male, 24 years, student of history)
It feels exciting like in a good way, that’s so nice that blue, so there’s not any unpleasant feeling. Just suitable amount of light and a really nice atmosphere. (male, 20 years, student of environmental engineering)

I think it looks in a way nice that, even though it’s dim and dark, so when you see, that these lights here are flickering, so it just adds to the atmosphere. It’s, however, not then perhaps so scary, when you know that the lights will come soon on, and like that. It perhaps suits well here, whereas, if there are really bright lights and then later very dark, so that’s somehow such a big contrast. [...] So yes, so that it gradually changes to more shadowy. (female, 20 years, student of nursing)

On the other hand, yeah, it [light] creates a sense of security, but still I think it’s still somehow better that they go off, so that no electricity is used. I mean, that just for nothing they there alone are burning. (female, 20 years, student of nursing)

The other young adults thought that it would be good to have always at least a small amount of light on. Especially, this was thought to be important in the autumn, when there is no reflecting snow on the ground, which increases the feeling of lightness in an environment. They also recognized the effect of context to the lighting conditions: our test park was surrounded by busy streets with powerful luminaires as well as illuminated buildings, which increased the light in the park. The situation would be totally different in a darker, isolated park environment. In addition, the amount of people present in the park has an effect on the amount of light in the park. Thus, the context—time-related, spatial, and cultural—is an important design factor for adaptive lighting.

Maybe yet somehow that kind of feeling, that if you walk in a dark park, it would be nice to see until the end of the path. [...] of course you see from here what’s there. There comes this light from around [the park], but [...] there could practically be some kind of a basic lighting, a little dimmer. [...] I tried to think that if it would be some other park, say Ainola Park, which is a really dark place, if one turns off the light there. [...] Then, I would feel scared, I wouldn’t feel this pleasant. [...] I don’t walk there alone during the night anyway. (female, 21 years, student of Finnish linguistics)

Surrounding light was valued inviting. If the lighting behaviour for the dimmer part was designed in a beautiful and lively way, as was the case in Scenario 7B, it could also be seen as more atmospheric and entertaining than mere darkness. For an inviting and safe feeling farther along the route, it was, according to some interviewees, enough to highlight only the trees, which made the space comfortably defined and showed elements of environment.

Maybe it would be nice to have some light on all the time there. It looks anyway as more inviting also from farther off. (female, 24 years, student of Finnish linguistics)

Yeah, so those spots remain flickering there dimmer. That’s basically not a bad idea at all. So it would became totally dark, but there would stay light smouldering there. Could be. Certainly this might be more entertaining, particularly if you talk about that autumn darkness. (male, 24 years, student of history)

Seeing half of the route dark could also cause negative associations, if the park-goer is not familiar with the system. This aspect of familiarity and awareness of the lighting behaviour were noted in many answers. It was thought that, when people would become accustomed to the adaptive lighting, they would trust that the lights would go on and walking against darkness would not feel awkward. Some interviewees trusted that people are willing to test and try new things by their nature, and some were more skeptical because there are always those who are not used to that kind of lighting.

Now I of course know that it will be turned on when I will go there. But it could cause [feeling] of unpleasement or perhaps partly of carelessness, when there’s this one burned light [existing luminaires on other route]. (male, 23 years, student of industrial management)

How can one know? How can I know that it will brighten up, if I come here for the first time and think that it’s a bit dark path there, would I walk there? So, yes, I really cannot know if I didn’t know that beforehand. (female, 69 years, part-time retired doctor)
then if that kind of thing would become more common in certain areas and in certain parks, so that [...] people would know that they react to their going, so that it would be an everyday thing, so then it's a different situation.

(female, 69 years, part-time retired doctor)

This aspect of becoming accustomed to adaptive lighting behaviour could well be noticed in the course of the walking interviews. For some interviewees, the negative attitude towards darkness in the end of the route changed into mild acceptance as reactive lighting behaviour became more familiar to them, scenario after scenario in different expressions, and they learned to trust it and saw it working well.

5.2.4 Aesthetic experience, meanings, and atmosphere

While walking in the park with scenarios of adaptive lighting, participants had aesthetic experiences and enjoyed the atmosphere created by lights. On several occasions, they described spontaneously sensations of beauty. In addition, they were asked a reflection question after the walks about aesthetic experiences. With each scenario, they were further asked to describe the atmosphere. The features in lighting behavior, which induced these experiences, were the lively, dynamic patterns of light and reactions to own movements, the constellations of small luminaires above the path reminding of a starry sky, the illuminated trees, and especially the use of colored light in the scenarios.

[Scenario 7] Those coloured lights are so pretty. Even though there’s that bright light so anyway. [...] It’s a little fairy-tale like. (female, 77 years, retired hospital porter)

[Scenario 3] Wow, this looks nice. This really looks nice, totally different than the direct dimness just before. Looks lovely. [...] I think those are marvellous. I like them [the suspended luminaires] [...] when they hang and are situated a bit asymmetrically. It's like a starry sky low. (female, 69 years, part-time retired doctor)

Yes, absolutely [I felt the lights as an aesthetic experience]. Especially those coloured lights and the lights that reacted to movement. They certainly bring there that kind of atmosphere. (female, 20 years, student of nursing)

Most of the interviewees valued aesthetic experiences and atmosphere as important aspects in park lighting. For them, they provided a comfortable feeling and well-being—especially considering the long dark period of Finland in wintertime, which could be seen as an opportunity. Only one senior interviewee (male, 67 years, retired repairman) saw lighting mainly from the utility perspective.

Yeah and particularly aesthetic, I think. It’s not necessarily practicality the thing that I was seeking here, but particularly how it looks like and the pleasant feeling which comes. At least I had that kind of comfortable feelings, when I was walking there. (male, 24 years, student of history)

When it’s dark in Finland, I think it would be nice that the darkness would be in a way exploited and liveliness and aesthetics created with light. (female, 22 years, student of geology)

Coloured light had a significant role in producing aesthetic experiences; nevertheless, different colours also induced varying reactions. The likings and dislikes seemed to be subjective and were often powerful. Even those scenarios, where the design intention had been creating only warm white light using the RGB technology, were seen by many interviewees as containing colours, either in light dots on the path or in light on tree trunks. This was, of course, an obvious reaction, even though we, who were familiar with RGB technology and its method of producing white light through mixing the colours red, green, and blue, became a bit blind to the actual, slight tinting of light to colour shades. Some of the interviewees described light on birch trees, instead of being warm white, as having changing bright colors. This was caused by the uneven surface of the three trunks, which created partial shadowing of the colour components of RGB. This was seen by some as a beautiful effect and by some as too colourful a feature. However, a number of interviewees experienced the same schemes as having warm white light on birch trees and on path surface.
[Scenario 3] Also the colour scheme [...] is a bit different than in the one before. [...] I think this gives a certain nuance slightly more than that blanco light before. I think this nicely tints this route and this also does justice to those parts that don’t have light. (male, 24 years, student of history)

[Scenario 3] It’s nice here that the light is anyway natural, that the colour is not too striking. When it anyway creates quite much that pattern to the path so it’s nice that the colour is then neutral. It’s good that combined impression. (male, 20 years, student of environmental engineering)

[Scenario 5] Maybe that, when it pulsates that kind of green green or red red [on the birch tree trunks], such right basic colours, so it’s a bit like that wouldn’t you invent anything else? It reminds me more of fireworks than of atmospheric lighting. [...] I would prefer more just yellowish. It looks occasionally good, when it stops there. But then every now and then it throws there that colour range, so that’s a bit well… (male, 20 years, student of environmental engineering)

[Scenario 5] That kind of fairy-tale like [atmosphere]. [...] they are those colours which [make the lighting fabulous]. I like colourful. [...] Hang on, wait a moment. Red, blue, yellow. Red is that lowest one, then there’s some bluish and yellowish. (female, 77 years, retired hospital porter)

The walking interviews demonstrated clearly the fact that colour vision, as vision in general, is individual and alters with age (e.g., Boyce 2014: 497–503). We noticed that one senior interviewee had difficulties in recognizing colour shades and another had difficulties also in detecting colours, such as bright blue, when they were used as an effect with warm white light. However, interestingly, the oldest of the participants, the 77-year-old woman, had the most powerful experiences of the colours, due to cataract surgery. She seemingly enjoyed the beauty of colours and, in some occasions, was even dazzled by their brightness, such as green and pure, intense red. A few other interviewees (female, 21 years, student of Finnish linguistics; male, 23 years, student of mechanical engineering; male, 68 years, retired export manager) had powerful visual experiences and even physiological reactions of some colours, of blue and green or yellow, and described visual illusions, dazzling or even feelings of dizziness.

Many times the likings and dislikes towards certain colours or scenarios, in general, were related to the associations that the colour or atmosphere induced. The associations, if being positive, caused sensations of beauty and a pleasant atmosphere. Respectively, if the associations were negative, the interviewees found the scenario not visually pleasing and had feelings of dislike. Many interviewees had positive associations of dynamic lighting behaviour, colours, or some other features of the installation with nature. The starry sky was mentioned by several participants; the aurora borealis was mentioned couple of times as well. Scenario 10 reminded some interviewees of submarine sceneries.

[Scenario 10] Oh! Now there’s turquoise, just like in a submarine world. There’s some red here, too. Actually, this combination I like, even though the colours are really fiery. I personally like this turquoise, so this turquoise and red work well as a combination. I wouldn’t have believed it. (female, 21 years, student of Finnish linguistics)

[Scenario 10] Once again, complementary colours meet here. Light and colour encounters quite nicely. It creates a kind of underwater feeling occasionally, this kind of aquarium-like. Which is not bad at all. It arouses both warm and cool feelings now, the colour scheme. Certainly. It always pleases the eye when there’s a little changing scenery. Now again I feel like staying here and watching that point on the floor where those spotlights meet. (male, 24 years, student of history)

[Scenario 10] This blue towards turquoise. Now we are in the heart of the aurora borealis, it’s that kind of feeling. Also that rippling of colours creates that kind of image here. [...] this is the most beautiful one, I think. For me, this is clearly quite tempting environment, so that one feels like going to walk there around, if one sees something like that. (female, 27 years, student of art education and graphical design)

Other positive associations linked with lighting scenarios were movie, theatre, or literary sceneries and fairy-tale imagery—Alice in Wonderland, Moominvalley and Avatar—were mentioned. The wintertime atmosphere, for example, by cold blue colour tones, and associations with warming fire, proved pleasant for some interviewees. However, some other participants found the natural association of
blue to coldness unpleasant in winter, thus, emphasizing the feeling of being cold. For that reason, those participants preferred the use of warm colours. The living patterns of white light and colours on park path were associated with rag rug, creating perhaps homely feelings, and also with sensations of travel with changing sceneries and with game-like feelings of moving in a constantly metamorphosing labyrinth. Many young adults also associated the aesthetic and lively use of light to Kemi snow castle, which was probably for many of them the preceding context where they had seen decorative use of targeted or coloured light on snow surfaces.

Scenario 8A] Looks nice, when there is in a way gray and white and then different shades of violet. This looks very good when seeing from the distance like this. [...] it's like a rag rug where colours are changing interactively. (female, 24 years, student of Finnish linguistics)

The negative associations with blue light, which occurred to some interviewees, were related to coldness, to scary movie scenes, and to the common use of blue light in public toilets in order to prevent use of illicit drugs. Many young interviewees had from their childhood a negative association of yellow colour on snow, as they had been advised not to eat yellow snow. Yellow light reminded one participant of an industrial environment. However, one interviewee mentioned yellow as a stimulating colour in a positive way. Negative associations could even be linked with political values: a senior interviewee disliked Scenario 10 because the colours reminded him from Soviet occupation in Porkkala.

Scenario 10] [...] These colours now are not quite... It reminds me somehow of Eastern Europe. [...] Or then in the year 1956, when Porkkala district was returned, it was occupied by the Soviet Union, when it was returned back to the Finns. They had painted on the houses all kinds of strange colours, these are a bit similar shades. (male, 68 years, retired export manager)

The atmospheres that adaptive lighting could create in a park environment clearly influenced the interviewees. It was making the park a more meaningful place for them, thus providing a new identity. The atmospheres could be seen as relating to everyday and to events situations and suitable for different uses of the park.

Yeah, absolutely. I noticed that I was living somehow strongly that atmosphere there was. They were an experience as such. [...] as one misses here in the city the northern lights, so it was nice to find that one good shade of green there further at that point. It gave me a good feeling. I myself come from Rovaniemi, so it was quite yes. (male, 20 years, student of environmental engineering)

Scenario 7B] This violet is really nicer than that blue. This gives somehow warmer feeling and this would probably become soon some “Violet park” if these are coloured like this. The name of this park will change quickly. (female, 20 years, student of nursing)

Scenario 9A] One can well colour everyday, too. I am somehow charmed by this that the coloured light shows on the trees and on the path. This looks nice. (female, 69 years, part-time retired doctor)

5.2.5 Communication and information

Communication and information were linked with adaptive lighting in the Urban Echoes mobile services (Activity, Events, and Lighting) and in some of the lighting scenarios (Scenarios 8A and 8B), which communicated with the coldness or warmth of the effect colour outdoor temperature. In general, all the interviewees found the idea of connecting information to visual expressions of park lighting interesting and saw positive values in it, such as adding interest and aesthetic values to the park environment, usefulness of information, and enhancing the brand of Oulu.

Certainly, knowledge is always really nice. Especially when it's displayed in this kind of special form. I like this very much as an idea at least. City of Oulu, as it often wants to profile itself as a pioneer of different kinds of technological applications, so I think it's a good step particularly towards that direction. We are still riding on that development and perhaps
forerunners in particular, as I have not seen that kind of things in other cities. (male, 24 years, student of history)

An interesting and reasonable thought. Brings there something like a trick into the lighting. It’s quite nice, makes you to think. (male, 20 years, student of environmental engineering)

I’m greatly excited about information graphics by the way, so for me visualization of information is a nice idea. (female, 27 years, student of art education and graphical design)

It’s a good thing. I think it’s a very good thing. It’s refreshing. (male, 68 years, retired export manager)

However, the interviewees had varying opinions about what kind of information should be visualized in the park. Most of them liked the idea of temperature data or weather data in general being visualized and saw that as relevant information, which also had common interest. Some thought, however, that the temperature and colour scale should be the other way around, so that there should be warm colours when it is cold to compensate the sensed coldness by weather. In addition, some interviewees preferred the idea of light forecasting weather and not indicating present weather.

[…] of course, if it reacts to the [temperature] in particular […] so it enlivens really a lot. I think it’s a good idea in that sense that we have four seasons and each have their own temperatures and through that their own colour schemes. […] Not only because it enlivens but it’s really nice that people, who perhaps nowadays don’t anymore have thermometer, can look out. (male, 24 years, student of history)

Today, it’s so that one has to check the local weather every hour. So here one could look passing by that “Ah! Tomorrow it will rain!” or “There will be thunderstorm!” […] I believe that it would bring general well-being to the people walking in the city centre. (male, 67 years, retired repairman)

For one interviewee, the knowledge that the colour had this informative meaning changed the whole experience associated with the blue colour of Scenario 8B from negative to positive. For many, it gave additional value to the originally positive experience of Scenarios 8A and 8B with a colour accent.

It’s quite nice that it’s linked with the weather, so there will be an informative aspect, too. If one is not feeling that on their face, that’s quite good. Yeah, it brings still more function to the lighting. If your brain is thinking that it now tells about that [weather] and not about that public toilet, so then [the blue colour] would be quite yes. (male, 20 years, student of environmental engineering)

Well, it would be quite nice, if it would change like that according to the temperature. I think it would be an amusing detail. It would be better like that than without it. […] And then think how cool it would be living like there upstairs, and “I see, blue lights on, it’s a cold day, I’ll put more clothes on.” (female, 20 years, student of nursing)

Only a few interviewees found the idea unnecessary or unpleasant, for either the reason that they thought that everyone gets weather information anyway from another source, or that it emphasizes the feeling of coldness in winter.

Maybe not [the coldness of light colour according to the temperature]. Then you are freezing even more! You are feeling cold both through your skin and through your eyes! And that you sense anyway. Let’s give to human senses something to work out themselves […] no need to go to the speech bubble level. This is my first reaction. […] You see, with frost it feels even colder. (male, 68 years, retired export manager)

The mobile services and data visualized by lighting were mostly seen as an interesting idea, but many interviewees were skeptical about whether they would use the services themselves. However, there were several interviewees, mostly from the group of young adults, who were enthusiastic of the Events service, both for its ability to filter soon-starting events to be more easily found among the abundance of information, as well as for raising personal and common awareness of the offerings of local events through signaling park lighting. For that latter reason, a few interviewees suggested this kind of system to be more widely spread in the city centre and not just on one park path.
This is really great, that kind of an innovative thing, which have been perhaps missing, so that one would not be only depending on the informing of the City of Oulu. Really nice as an idea, I think. [...] Definitely [I would use the service], because it's often quite tricky to follow those things. You have to follow different kinds of mailing lists and so on and also keep an eye on different kind of servers where you find this information. (male, 24 years, student of history)

I'm still quite a fresh as a Oulu citizen and I'm still sometimes astonished that even though this is not a very big city here happens quite a lot and also lots of free things and then it feels often that people are still complaining that nothing happens. I think a little reminding about the good offerings is quite in place! [...] Yes, I think I belong to that group, which would use it. [...] I'm perhaps one of those people who decide to go to see or listen something at a short notice. I'm not planning much weeks or months beforehand. Then it can be those moments that something nice should be now. It's nice that it shows for the same evening those things, for example. (female, 27 years, student of art education and graphical design)

I think it's an interesting idea, that the events of the city and these park lights would be connected. [...] But it could be nice that there would be for instance in every park of Oulu a permanent colour-coded thing, so then it could perhaps attract people to the events. But I think this kind of one stretch of park path will not yet affect people's behaviour or visit of events. (female, 24 years, student of Finnish linguistics)

Very interesting, but I don't see myself using this, as I don't use these events things of the city, either. I don't visit museums or exhibitions as a whole. For my own use, really purposeless, but quite an interesting idea. [...] Of course, as a pilot project, it's operating only here, but if it would be on Rotuaari as well, so then it would be a totally different experience or if the whole city centre would have this kind of lights, so then maybe. (male, 23 years, student of industrial management)

Some of the senior interviewees saw the technology barrier—either unavailability of suitable devices and know-how or just not interest in new technology—as a reason for not using the services themselves or for hindrance for wider use. One senior interviewee (male, 68 years, retired export manager) compared the Events service with a local Plink service (www.plink.fi), which he had been using. In the Plink service, users can mark and comment interesting happenings, experiences or news on Oulu map, to advertise them to other users, with the help of uploading own photos and videos.

I'm not interested. I'm not using those UBI screens either. So this is a still advanced mode so I know that I have not enough interest. (male, 67 years, retired repairman)

Okay, everything is tricky in the beginning. And this works only with young, aware, innovative, nerd-minded people just like me, a 68-year-old young nerd. [...] The whole thing opens up to a certain group, but good if at least to them or when at least to them. (male, 68 years, retired export manager)

In the Activity service, some interviewees saw potential in finding the right bar with company and a good party mood on a Friday night or during city festivities. Some also saw it as a platform for informing other things that might be relevant to users of the city.

But, on the other hand, that's an interesting idea, too, if you don't think that spying would be oppressive. [...] if you would be thinking where to go in the evening and then there would be some certain locations, and then you would see here, where there's crowd. That could be useful. If there would be chosen that kind of meaningful places, so then it would be interesting. (female, 24 years, student of Finnish linguistics)

How about some [service] to see where there's a traffic jam, so then you would see here, for instance, what route is worth taking if you go somewhere. [...] Which [information needs] there could be? Which lakes have thin ice, where one shouldn't go walking or this kind of safety instructions or something could be coded. (female, 24 years, student of Finnish linguistics)

A few interviewees were simply enthusiastic of the idea of visualizing the ambient information of flows of people in the city. The fact of being sensed
and followed by the system was mostly not experienced as being distractive or violating privacy, even though there were some exceptions. Nevertheless, for some interviewees, the service was not providing additional value and seemed unnecessary.

Somehow, I’m even more excited about this thought [than of Events service], as this doesn’t require anything from those who are being visualized here. It doesn’t require necessarily from them that kind of activity, but they can exist without knowing themselves as red light there. I think it’s quite amusing. Or, that we now here are also existing in that map. I like maps, too. I think this is a nice idea. (female, 27 years, student of art education and graphical design)

I’m not fond of that [surveillance], but on the other hand when you think that it’s a question of mobile phone. Roughly speaking everyone has a mobile phone, so it doesn’t matter. They don’t know what else I have in the pocket. They don’t know that I have a mouth organ in my pocket. No one else knows, except you. (male, 68 years, retired export manager)

This is quite high-flown. [...] It’s just one of those that some people are so full of ideas that they invent something like this and play with those things. But then, how many of those is going on to practical life then and stays in life; that’s a different thing. Ideas should one have, of course, and let them fly. Perhaps one of those hundred will be the one, which will remain. (female, 69 years, part-time retired doctor)

Concerning the Events and Activity services, many interviewees took up the legibility of visualized information as an important aspect. Most of them thought that there should be more information available in the park in regards to how to decode the information displayed. It was not enough for most participants to simply find that information with a smartphone and through QR codes situated in the site. There should have been some boards with the information or even a public display screen where the information could be checked. In addition, the project should be advertised more so that the knowledge would spread to a wider audience. It was also discussed that it would take time before this kind of project and service would develop into a local culture, so that people would recognize and knowledge the informative content. Before that, the coloured light dots would simply remain as an aesthetic feature in the park.

It’s quite a good idea, if you then see it also here, what they mean. So that you don’t necessarily have that smartphone. If there would be, for example, a sign next to each tree telling, which place it means in that Bluetooth thing. And maybe that kind of colour chart telling what they mean. That kind of translation. (female, 20 years, student of biology)

[...] then you should somehow learn to know that they mean something and get that knowledge then from somewhere else. [...] I mean that for most part, for 90%, one only looks that “hmm, nice lights!” [...] But after that, what then? What did they mean and stand for? And what kind of knowledge are they giving? For me it could then remain in that level that you don’t go to find it out. (female, 69 years, part-time retired doctor)

The Lighting service divided opinions, as well. Some were greatly interested in obtaining data of the energy use and generally appreciated this kind of information to be available more widely of city’s various functions, and also combined with cost calculations. However, for many participants, this was not personally interesting.

I think that the energy use section there is quite nice, as when you start doing some new lighting, especially if it’s something sensational, so people are surely interested in the energy use. Maybe you could take that still a step further, so that how much it is in euros or something. People are probably interested besides energy use of what they have to pay for this. [...] It is quite interesting. I went to check in the web pages of my energy company. There you can also see graphics about your own energy consumption and see many kinds of comparisons. I spent there about an hour, looking at those things. That’s quite interesting information in itself. (female, 27 years, student of art education and graphical design)

I bet someone is interested. Not me. [...] No, I’m interested only in that aesthetics. (female, 69 years, part-time retired doctor)
Some interviewees had further ideas on how to develop this informative and communicative aspect of lighting. One junior participant (female, 24 years, student of Finnish linguistics) would like to use lights for communicating ethical and ecological values, thus use the visualizing capacity of park lights for personal demonstration. She further saw potential for an advertising business, where a digital screen would support the ambient information given by park lighting, thus helping to decode the messages into more explicit form.

Maybe I’d like to communicate some things related to ethical issues. Like how many people don’t have food in the world or something like that. It would be then a kind of small demonstration. [...] And perhaps also something about friendliness to the environment, that kind of messages I could like to express with lights. (female, 24 years, student of Finnish linguistics)

 [...] it just came to my mind, that one could make advertisement business [...]. Companies could buy advertisement time there and express with the coded colours something, for example, numbers and statistics, [...] I mean that there would be a separate screen, where one could read that this large amount of Finns is using Andiamo shoes and then there would be with a red colour like every second Finn, and then every second light would be red. (female, 24 years, student of Finnish linguistics)

When asked about what interviewees would like to communicate with lights, the answer, by a couple of interviewees, was simply about feelings and atmosphere. This kind of participating and interacting with lights—changing the colours of the park to express personal feelings and to induce a certain atmosphere—was seen as an interesting and natural way of communicating, as colours were felt as powerful tools to influence people’s feelings. However, the legibility of the message was also questioned as people have individual ways of experiencing colours.

What would I communicate? [...] Perhaps that’s quite nice that you could order there then light coming according to your mood. At least to my own purposes it would be quite handy. (male, 20 years, student of environmental engineering)

The experience of light or experiencing some colour as a message is probably quite individual in the end. I’d perhaps get a bit kind of feeling that if the message is only coloured light, how anyone can so to say understand that message. It can be a problem there. Maybe you would need there some ready-made symbolizing about it, so that you could influence with what mood you have today. Orange colour would mean that something bothers and blue that you are in the heart of Zen. With that kind of setting I could communicate my own mood or something, but the colours should be given beforehand. [...] But something like that, it could be funny to notice that in the middle of polar night everyone was annoyed and the park is screaming orange. [...] For many people, polar night is really tiring so then you would notice that everyone else here are really tired. That could be quite a funny message, but I wouldn’t go into any deep waters, to any proper opinions or politics. Maybe more this kind of small-scale feeling communication and something. This was a good day, let’s have little blue. (female, 27 years, student of art education and graphical design)

5.2.6 Interaction and participation

The implicit interaction with lighting—the adaptive lighting behaviour where light reacted to park-goers—was experienced as a positive form of interaction. However, for all interviewees, the relation between one’s own movements and changes of lighting was not always clear, which lessened the sense of interaction. The reasons for this are twofold: there were often many users in the park at the time of the walking interview and the movement sensor had a certain delay in ceasing to indicate presence, as was described in Chapter 4.2.

Yeah, it was that motion sensor, then especially I got that kind of feeling, that “my life’s got a meaning”, ’cause when I walk here, this is just this colour. (male, 20 years, student of environmental engineering)

Yeah, that when I was walking there so it reacted and on the other hand when so many people were walking there so it got blurred. Then you could not wholly see the idea. (female, 21 years, student of Finnish linguistics)
Often I wasn’t quite sure if they really reacted to me really or to what did they react. But I’m not sure if that’s necessarily a bad thing. In the first place, the lights are living and not only illuminating; in my opinion, this is nicer than that they would only stand there. Maybe, or actually it is really nice to notice that they are reacting to yourself. (female, 27 years, student of art education and graphical design)

Scenarios 1 and 3 were designed so that the contrast between the minimum and maximum light levels were moderate, minimum light level being 60% and maximum being 100%, and the change slow. The idea was that the adaptation of light levels could be imperceptible. When asked if interviewees noticed that the lighting reacts to their movements, approximately half of the interviewees did not perceive the movement-adaptation and another half of them noticed it or thought that they noticed it. However, it is not clear how many of them would have been conscious of the adaptation if not asked. On the other hand, in Scenario 10, which was only dynamic and animated lighting with colour changes and not adapting to park visitors’ movements, was, nevertheless, experienced as reacting somehow to the movements by some participants. This clearly demonstrates that people are keen on searching cues and logical reasons for lighting behaviour. One of the interviewees especially enjoyed the act of analyzing the adaptive lighting behaviour and patterns, calculating the formulas and searching for the logic behind.

[Scenario 4] I start so easily to calculate formulas, based on how some [light] is turning on or off singly. This is the first time than I see a reacting and changing light in a larger scale. I’d like to start working out those schemas. (male, 24 years, student of history)

[Scenario 5] I am perceiving now more clearly this route the lights are coming up along. As I make these calculations all the time in my head, I think I was a moment ago a bit confused. But now they are lighting up as we are going along this. I think there just came on the second or third of these farther ones and then one in between and one there farther behind. These do have a pattern! I really can see it again. (male, 24 years, student of history)

Some interviewees would have liked to have a more developed form of movement interaction, including detection of gestures and pace of movement, which would have allowed them to interact with park lighting in a more explicit way and to play with lights consciously.

[...] if I had kids, so then it could be nice if they would react even more to your movements or something, so that you could take the children to play there on the park path. (female, 24 years, student of Finnish linguistics)

[...] it would be nice and funny, if you could control the light more with your own movements. That would really have almost limitless possible applications in that kind of thing. [...] For example, with gestures and waving hands and with that how fast you move and sort of things. (male, 23 years, student of mechanical engineering)

Besides through movement or gestures, many interviewees expressed interest in interacting with light in an explicit way with the help of some device. This was allowed, to some extent, by using the Urban Echoes mobile services and ordering one of those two-minute lighting schemes, by making the inquiry. This possibility was appreciated by many. In addition, most of the interviewees did not find problematic the fact that someone else can change the lighting around you in the park by using the Urban Echoes mobile service. However, one interviewee found the idea also irritating, basing on her previous experience of a participatory installation. She was also wondering the multiuser aspect and its effects on the experience.

I think it’s really nice that without they can break it, they can change it [the lighting] how they like it. This would probably bring again more users to this park and they could get more out of these luminaires. (female, 20 years, student of nursing)

There was a bit same kind of idea in Helsinki, when I was living there last winter. There were tables which went like that in a café. [The height of tables and chairs could be controlled through the net.] Personally, it irritates me that some other person can have an effect like that. I don’t know; perhaps there’s something wrong with me. Then, the thing that how many people will
be using it at the same time, so that then you can’t be sure whether I have lit this [light] or someone else here. As an idea, that this conveys information of those events, it’s quite interesting. But the fact that everyone can order it from there irritates me personally. (female, 21 years, student of Finnish linguistics)

Wider possibilities to interact with light, not only through those two services and in this one park, would also be appreciated. Creating atmospheres with light through interaction was found to cheer up otherwise dull and dark wintertime.

It was nice that you could influence it. The information there was a little bit self-purposeful. But it’s really nice that you can do it yourself, even though they come with a little delay. It could work in a bigger scale, too. That Otto K[arhi] is quite a small area. In a bigger scale it would be still better. […] Creating atmosphere, that cheers up those sometimes quite bleak dark times during January and February, when nothing really happens. Then at least lighting could be that kind of nice thing. (male, 20 years, student of environmental engineering)

It was also seen as important that the interaction possibility should be given to everybody and should not be reserved exclusively to those citizens possessing smartphones. For that reason, the use of public UBI touch screens for controlling park lighting was proposed.

I think it would be really nice if you could with your phone yourself, or if there would be a UBI screen, so then you could do it there. It would also be nice, as not all the people have smartphones, like old grannies who are the ones who have time to walk there in the park, or quite few have them. So that they would have an opportunity to be with them, too. (female, 20 years, student of nursing)

On the other hand, many interviewees were accustomed to using smartphones and found that as a suitable device for personal interaction with lighting. However, also some doubts of willingness to play with lights barehanded with mobile devices in freezing temperatures, was presented. Some interviewees took up an idea of employing the near-by restaurant spaces, which provide warm and cozy interiors with view to the park. The local bars could have some control board, where a variety of pre-made, colourful atmospheres to the park could be chosen, or even designed themselves by the customers. For many, it was important that one could interact with light on the spot, or at least from a near-by locale, where one could see or experience the results oneself.

Smartphone is in itself good, even though the circumstances for using them is at the moment probably hard, but with a one I would have liked to try that application. If I should choose a device, it would be particularly a smartphone. For me it’s already such a big part of everyday life, and surely of many others, too. (male, 20 years, student of environmental engineering)

[…] but I’m not sure if I bothered to dig my phone out of the pocket, if it’s awfully cold, and start playing a while. […] To some of those bars could be installed some board so that you could go and change the lights from there. […] Some kind of a control board. […] You could play, for example, those scenarios with it or something else. Whoever. (male, 23 years, student of industrial management)

Several young interviewees were inspired by the aspect of creating designs with colourful lights, thus playing and composing with colours. This raises aspirations for lighting interaction in the park to the level of participatory lighting with creative attitude and deep involvement. This kind of participation and interaction was also seen, besides personal expression, as social activity and a way of spending time together. One interviewee, who had background in organizing community art projects, contemplated on the interesting concept of democratic lighting: How would the lighting of the park be a result of votes by individual citizens?

I’d certainly enjoy acting as a kind of DJ there. I’m sure it would be quite fun. I was just thinking that those people, who were just dancing there in the park, if they had a change to turn the knobs, it would be great to see what happens! What kind of hassle they would turn on? […] It’s really so that if you give a lighting board to one and allow us to play with it, so everybody starts to play with it. Really even though there would not be any bigger message behind, I believe that everyone likes that kind of thing. What
happens with this button and if I do that, how would it look like? (female, 27 years, student of art education and graphical design)

It would certainly be in that sense funny, and it would really be nice to come with friends also tinkering and playing with those lights. [...] That kind of having fun or entertainment. [...] It would be just handy, if you could do it with your smartphone and it would be nice in particular if you could put there something beforehand and get together with friends to some park. (male, 23 years, student of mechanical engineering)

I am somehow fascinated by the idea that there could be a kind of “light colour battle”. People would be allowed to decide with their small percentage, what colour would the light be and it would be nice to see some kind of visual presentation about, what have been suggested and where the result then settles as a collective opinion. Probably it would become that kind of democratic pink. [...] That famous brown light those [luminaires] hardly can produce. But I think it would be nice to notice, what colours people find pleasant and see some demographic distribution, that all the kids have wanted to make the park green and all persons over eighty years think that light should be white. Or something like that. A screen, which can be used quickly or something like that. To put there one’s age and select colours. (female, 27 years, student of art education and graphical design)

5.2.7 Social experiences and park-use

Adaptive lighting scenarios changed the character of Otto Karhi park concerning park-use. For the interviewees—both young adults and seniors—the park had prominently been a place to walk or cycle through, and an opportunity to take a diagonal shortcut through right-angled city grid in a pleasant park with vegetation and a water element. During the walking interviews, they described several new ways to use park with increased social behaviour. Adaptive and interactive lighting and especially those scenarios which employed atmospheric use of dotted and tree lights as well as coloured light were seen as drawing attention in a positive way and attracting people to use the park.

 [...] I have mostly cycled through here, since I haven’t fancied doing anything else here, but now when there are such great lamps, so then one could come here for an evening walk, for example. [...] The park could be in a more versatile use, if there would be this kind of lamps. (female, 20 years, student of nursing)

I think all this kind of things makes this a nice and inviting park. Just as I said then, this is only that kind of [park], which you walk through. Everybody goes through with great hurry, and most of them walk this [main] route. But if here would be something, so you could perhaps stay a bit, and it could produce some thoughts to you and other. This would not then only be that kind of a transit place. (female, 69 years, part-time retired doctor)

The interviewees could think themselves as spending time in the park, for example, sitting in the bench, changing the colour of the lights themselves with a smartphone, and having there a walk with a girl-friend along a path coloured with special colours to create a romantic atmosphere.

It could be quite good that, if you sometimes come here, for example, with your girlfriend from a dinner in a restaurant or something like, so it would then be quite nice to have there good atmosphere colours. [...] Really, the shade of colour, as I quite strongly feel the colours, so that kind of dim and then this kind of blue and perhaps dark violet. [...] so it would be quite nice that you could snap it on from the other end and it would be with you while you walk. (male, 20 years, student of environmental engineering)

Adaptive lighting in the park was considered as something to come to see for its own sake and to bring friends to enjoy, as one elderly interviewee (male, 68 years, retired export manager) said: “I could now specifically ask some people with me to look these exciting things.” This brings up the aspects of “noctambulisme” (Bell 2009) —walking around in the city at night for its own sake—and “nocturnal tourism” (Narboni 2004). The same interviewee could also see the lighting to benefit the entrepreneurs around the park by bringing there more customers.

Adaptive lighting was also seen as a supporting part of happenings and activities in the park. One interviewee (female, 24 years, student of Finnish
linguistics) also envisioned pedagogic use of adaptive park lighting. The visual capacity of park lighting with changing light levels and colours could be used for communicating information and educational contents. For example, a certain amount of light dots could turn on indicating a percentage value, and so on. This could benefit visual learners’ capacity to remember things.

Yeah, and as nowadays anyway, there is lots of discussion about that school lessons wouldn’t need to be within four walls in class rooms and in school desks, so this kind of a park as a learning environment could be good. […] And, for example, for people with learning difficulties could this kind of visual thing help in remembering. (female, 24 years, student of Finnish linguistics)

The last scenario with rapidly changing bright colours, brought up, besides positive associations with temporary events, music, and disco dancing, thoughts of negative social effects. As the other scenarios were thought to attract more users into the park, the last scenario could drive away park-goers by being visually unpleasant. The restless behaviour of light was even thought to be capable of causing aggressive behaviour.

In the New Years’ time, this would suit perfectly to the city, but this clearly does cause perception problems. It’s hard to realize how one walks here farther. Especially, if you think you are looking at a green spot, and then there’s intense blue next, so that clearly creates after images and that sort of thing. This surely provokes an urge to fight in people, if one has to stay here long. (female, 27 years, student of art education and graphical design)

This comment relates interestingly to the De-Escalate pilot and reseach project in Eindhoven, where different scenarios of lighting behaviour are being tested for their capacity to defuse escalating behaviour in a night-time active downtown area (de Kort et al., 2014). However, during the same interview, we had the pleasure to witness the same lighting to promote positive social behaviour: group dancing in the park with winter boots on. “On the other hand, it’s quite nice to see that in Finland someone starts dancing just spontaneously” (female, 27 years, student of art education and graphical design). Adaptive lighting was thought even to have potential to develop Finnish social culture and outdoor city life, which is normally seen as rather restricted, especially in winter due to the harsh outdoor conditions. “To develop Finnish culture, if someone can get people in Finland to dance on streets in the winter!” (female, 27 years, student of art education and graphical design)

The series of walking interviews provided us with an excellent opportunity to make observations of park use and social behaviour in the park. Altogether, the walking interviews in the park lasted approximately 19 hours. Besides that, I visited the park regularly during the time the lighting was on, as I had to do some checks and maintenance with the installation and the system. These on-site observations and video recordings of the interviews provided good addition to the interview material, as they afforded us a real-life scene to the park use (see Fig. 75). Our interview method with the protocol of walking along the path with each lighting scenario did not allow the participants to use the park in any other way, even though they were told that they could move freely with their own pace and turn and stop as they liked. Thus, in this respect, the interview was not a real-life situation, even though it was meant to be as near it as possible. In real life, one seldom walks in the park with three interviewers holding tape and video recorders, reflecting own experiences.
Fig. 75. Figure collage of observations about park use during walking interviews and the opening event of the installation.
During the walking interviews, we observed that adaptive lighting had clearly activated the use of the park and introduced new and more social ways of using the park. We had observed the park also before the installation, as our preliminary interviews contained one part in the park standing along the same path. During the preliminary interviews, very few walkers were detected, and, when it was a day with snowfall, we could see from the untouched snow that the path had not been used recently. With the new lighting, evidently more walkers were using the route. We observed several times people walking there alone, with a couple and in groups, as well as walking their dogs. People seemed to be interested in the lighting and their behaviour, and many were taking photographs there. We also observed scanning of QR codes of our info-posters and retrieving more information of the installation. We learned that the photos had been shared in social media, but nobody was publishing them in the official Facebook group of our project, even though we invited people to do that in the park. Only one person sent to the Facebook group a message with a link to her photo album in the net, which had a shot from the park. During the walks, we saw kids playing with the lights, even “talking to the lights”, as we heard one mother to tell her child. Kids were peeking to the three light boxes and running from one light to another, jumping over the coloured light dots. After a snowfall, when the park was looking especially beautiful with all trees covered with snow, a family with parents and children had clearly come in an evening walk there just to experience the park with the lights. We observed couple of times people sitting on the bench and having a smoke, a drink, or a picnic, alone and in a group, simply spending time in the freezing cold of February. We also saw people dancing, and once we witnessed staging cos-play.

Several times, passersby commented in a positive way on the new lighting, as they associated us with the realization of the installation. While I was checking the last installation work with electricians, an old lady came to ask who had designed the lights and thanked me for how much they delighted her. She said that she walks along the park every day, as she lives near and that she had wiped off the snow from the tree light boxes every time she walks through, so that the lights will not be snowed under. This gesture shows that adaptive lighting, at least when it is designed to be aesthetically pleasing and atmospheric, can arouse feelings of belonging and positive communal identity and sense of ownership towards public areas. This increases concern of common public environment.

5.2.8 Acceptance and preferences

The interviewees were asked with each scenario if they could consider it to be permanent lighting, and, if so, could it be along all routes of the park. Most of the interviewees found almost all the scenarios suitable for permanent installation. The only clear exception was the “horror scenario” (Scenario 11), with its quickly changing bright colours. That scenario could only be seen as a short-time performance associated with a festival, and perhaps, combined with suitable music, or as an on-the-hour repeating short interlude between more calm lighting expressions, which would indicate passing of time. Scenarios that contained only colours divided opinions and were not as widely accepted as the scenarios of warm white light or of warm white light with one accent colour. One interviewee (male, 67 years, retired repairman) thought that the main lighting should always be white and not coloured. Many interviewees thought that colours should be changed according to the season and events or simply for creating variety and feelings of surprise when entering the park during different times. The variability and flexibility of the lighting system was especially appreciated by a few interviewees who thought that, since the system was capable of making different kinds of lighting schemes, any one of them should not be there as a permanent solution. The chosen colours for Scenario 9A (shades of green and yellow), Scenario 9B (shades of red, magenta, violet, and blue), and Scenario 10 (shades of turquoise, magenta, red, and violet) were not appreciated by all interviewees; however, all of those scenarios evoked strong positive opinions by some interviewees. Scenario 9A caused the most negative reactions in a couple of participants, including strong negative associations, and even physical reactions. This polarization of attitudes and strong personal experiences indicates that, for public environments, coloured light should perhaps not be designed as a constant feature but as a flexible system allowing changes and also absence of colours.
[Scenario 9A] Why not, in a way, that short autumn period that we have, so of course it's nice, if it's enlivened that way and in a way taking all the advantage out of that colour scheme because autumn foliage is quite a short period in the end. Then you will probably get to those cool colours, there's enough of that. Why not? (male, 24 years, student of history)

[Scenario 10] What's good here is this turquoise and then a little violet with it. But then when it is this kind of turquoise-pink-turquoise-pink, so I feel that if I had a bad day I'd say no! In a good day this goes, someone has had fun designing this thing. [...] Too much is too much. [...] Maybe a paradise for little girls, but not for the taste of a grown-up man. (male, 20 years, student of environmental engineering)

[Scenario 10] Actually, this is quite chirpy and lively. Right that turquoise is there, so I like this much more [than the previous one]. It evens up that fiery red and also pink and makes them much more pleasant. This I like. (female, 21 years, student of Finnish linguistics)

Now when I have seen these, I really think that those movements and variations are quite nice. [...] Yeah, they could alternate. It cannot be even any cost issue. It makes then the whole interesting. (male, 68 years, retired export manager)

Only a few interviewees rejected the idea of permanence for the Scenarios 3 and 4 with dotted warm white light. The reasons against the Scenario 3 were that its dynamic lighting behaviour was considered to be too fast (female, 24 years, student of Finnish linguistics) and that it was seen more as lighting for an event than for everyday (male, 67 years, retired repairman). One interviewee (male, 23 years, student of industrial management) claimed that the problem of the Scenario 4 was that those parts of the path and park in general, where no one was present, would remain totally dark.

The most basic adaptive scenarios (Scenarios 1 and 2) could well be on all the routes of the park. However, one interviewee claimed that in regards to the whole park, there could perhaps be something more visually impressive. For the rest of the scenarios, opinions were divided. Some of the interviewees thought that the more impressive scenarios with dotted lights, tree lighting, and colours should only be on one or two paths, thus creating a wow effect or a positive accent in the park; some interviewees liked the idea of having the same lighting solution for the whole park. Some interviewees considered scenarios in which there was no light when no one was present not to be good as the only solution for the whole park, as it would make the park appear totally dark during inactive periods. A few interviewees thought also that there could be, for example, different colour schemes for different paths, which would make the park even more interesting.

[Scenario 8] Maybe this could be like one path only, so that could emphasize it well, it would make that one path to jump out in a positive way. (female, 22 years, student of geology)

[Scenario 4] I think that, in the kind of prime time, when there are lots of people here, this would work quite well. But now, if on a Sunday evening, when there are not many people moving around, so then it would look from a little distance that it's dark here. May not feel like coming here. (female, 27 years, student of art education and graphical design)

Well, it doesn't have to be necessary uniform everywhere. It could be good to have different kinds of combinations, and then they could change always like according to day or hour, [I mean], what kind of a light show there's on each path [...] you would never know what happens, when you walk here! That could be quite nice. (male, 23 years, student of mechanical engineering)

The interviewees were not clearly asked about their preferences in regards to the selection of scenarios. It would have been a rather challenging task to answer that, as the amount of different scenarios was large and the protocol of changing scenarios proceeded with a relatively intensive tempo. However, one question in the reflection session, just after walking, was whether a particular scenario had stuck in their mind, either positively or negatively. Did any of them somehow make an especially powerful impact? Scenarios raised as being positively memorable were Scenario 8A (the chosen default scenario of the park with dotted warm white light and accent colour defined by the temperature on both path and birch trees, with low level of general lighting all the time), Scenarios 9A and 9B and Scenario 10. Also the blue light on birch trees was mentioned as
a positive feature. One interviewee appreciated basic Scenarios 1 and 2. Many interviewees could not mention one favourite but widely described memorable features of scenarios they had enjoyed.

I think it was nice that there were so many different kinds of things here. Besides natural and ordinary light and coloured light, there was light that reacted to movements and flickering lights and whatnot. There were many kinds of variations. I could not really expect anything. I noticed that you can do a lot with lights. Not only that it illuminates, but you can achieve playful feelings and pleasure and jolliness and everything else like that. [...] that starry sky was really lovely, I think. I liked that [...] and then I liked the light that flamed there like that. Not the whole corridor was illuminated in the same way, but it moved, that was nice. And then it was nice that the trees and path were illuminated and how the colour was used. There were many amusing ideas. (female, 69 years, part-time retired doctor)

5.2.9 Concluding summary

Generally, the interviewees expressed positive attitudes towards use of adaptive lighting in park environments, and they saw it as beneficial in many ways. For example, the energy-saving aspect due to the absence of light or lower light levels when park was unoccupied was seen as a positive value. Interviewees valued many of the presented scenarios for their aesthetic character and the atmosphere they created to the urban nightscape. Adaptive lighting had image value and economic value. It was seen as supporting the Oulu’s brand as an intelligent community. The only doubts presented towards this type of new lighting technology were about the reliable operation and endurance of intelligent lighting systems and whether possible maintenance problems would cause costs to citizens.

Movement-adaptive lighting was seen by many to enhance the sense of security. The sense of security was associated with the feeling of light going ahead and with the fact that it could reveal the presence of possible aggressors. Also, the atmosphere and sense of a specific place which was created by adaptive lighting and the use of coloured light, had a positive effect to the feeling of security. The aspect of sense of security was, according to some interviewees, context-related. The quality and familiarity of environment, the surrounding light levels, activities, and social context, in general, were seen to influence the sense of security. This came up in the answers concerning whether there should also be a little light in un-occupied areas. In addition, the attitudes towards this specific feature of adaptive lighting behaviour were in the answers age and gender related to some extent. The interviewees became clearly accustomed to adaptive lighting behaviour in the course of the walking interviews, which affected their opinions. From a designer’s perspective, the safe solution is to include a low level of default lighting in movement-adaptive lighting schemes, as there seemingly is a risk that, for some users, darkness waiting farther ahead might cause uneasy feelings.

Aesthetic experiences were induced especially by the following features of different scenarios: the lively, dynamic patterns of light, reactions to one’s own movements, the constellations of small luminaires above the path reminiscent of a starry sky, the illuminated trees, and especially the use of coloured light in the scenarios. Most of the interviewees valued aesthetic experiences and atmosphere as important aspects in park lighting, especially in Finland’s climate with its long and dark winter. For them, it provided a comfortable feeling and well-being. Even though coloured light had an important role in producing aesthetic experiences, the opinions towards different colours varied greatly. The associations, which certain colours or scenarios induced, influenced experiences. Many interviewees had positive associations of dynamic lighting behaviour and colours with nature, for example, with the aurora borealis. Other associations or
meanings aroused were, for instance, rag rug and game-like feelings of moving in a constantly metamorphosing labyrinth. The suitability of a colour, for many interviewees, also was related to seasons. However, the attitudes towards this season aspect varied: for example, blue light was seen by others to beautifully suit snowy winter scenery and by others as making one to feel even colder in freezing temperatures. The atmospheres created by adaptive lighting made the park a more meaningful place to the interviewees, and they could give it a new, own identity.

In general, all the interviewees found the idea of connecting information to visual expressions of park lighting interesting and saw positive values in it. However, the interviewees had varying opinions about what kind of information should be visualized in the park. The idea of lights communicating the prevailing weather or forecasting it was favoured by many. The legibility of the visualized information provided was an important issue, concerning both the Events and Activity service. Supporting information for decoding the message should be on site, not only in the web-based services. Further ideas for communicating with adaptive lighting were presented as well. These included communicating ethical and ecological values—a personal demonstration—and advertising. Also changing the colours of the park to express personal feelings and to create atmospheres was seen as interesting.

The implicit interaction with lighting in the form of movement-adaptive lighting was experienced generally in a positive way. Some interviewees were also wishing for a more explicit interaction with light through gestures and movements, which would have allowed them to consciously play with lights. Further, many appreciated the mobile-device-based explicit interaction through the Urban Echoes services; however, also wider interaction possibilities would have been appreciated. The idea of creating designs with park lights, playing and composing with colours, was found inspiring, especially by young interviewees, and approaches the level of participatory lighting.

In the interviewees’ comments, adaptive, interactive, and participatory lighting was related to social behaviour and park-use. The installation with adaptive lighting scenarios changed the character of Otto Karhi park in terms of park-use, both in the interviewees’ answers and in real-world observations.

Adaptive and interactive lighting and atmospheric use of light was considered to attract people to spend time in the park, instead of only passing through. Possible activities included sitting in the bench, bringing visitors and friends to see the lights, interacting and playing with lights (for example, with a smartphone), and having a romantic walk with a girlfriend surrounded by self-selected colours. In addition, pedagogic use of adaptive lighting was envisioned. Even though most of the ideas concerned positive influence on social behaviour, the last scenario with quick changes of bright and contrasting colours also brought up some thoughts of negative effects, in form of aggressive behaviour. Different forms of adaptive lighting were considered suitable as a permanent lighting in the park, as a seasonally changing feature, or part of temporary events, depending on the scenario and on the interviewee’s attitudes. The flexible nature of the lighting system and the capacity of creating different kinds of lighting behaviours and atmospheres were appreciated.

As observed during the long interviews, the park had become a more active place, in spite of the harsh winter conditions. The amount of people using the route increased clearly and people were besides walking and watching the lights play, taking photographs, sitting on the bench, having picnic, playing with lights, dancing, and staging cosplay. Furthermore, positive feelings of communal identity and ownership towards this public area were increased, as could be seen from the caring gesture of wiping the snow off from the luminaires on ground.
5.3 Retail lighting pilot

The description of experiences of adaptive retail lighting is based largely on the text published in the appended Article IV.

5.3.1 Evaluation and analysis methods

In the Retail Lighting Pilot, we used an Evaluation probe method in order to evaluate visitors’ experiences of the different lighting schemes. Our method refers to the Cultural probes methodology introduced by Gaver, Dunne, and Pacenti (Gaver et al. 1999), which employs visually enticing and playful material to engage participants in reflection without direct researcher presence and to self-report their thoughts. The benefits and limitations of the developed Evaluation probe method are discussed in a further paper (Luusua et al. 2015).

The study was conducted for five weeks in October and November 2013. Our participants (19 persons) were female and aged from 35 to 55 years. They were recruited through various professional and nonprofessional organizations’ email lists, our personal networks, and through the snowball method, i.e., referred through participants’ friends.

The evaluation probe consisted of a probe package with three custom-designed notebooks and a preliminary, 30-minute semistructured interview. The notebooks included relevant information concerning the assignment, a floor plan of the department store and the test area, and several open-ended questions that were meant to foster participants’ reflection on their experiences. Each participant filled out three notebooks: one for each visit in the department store. Participants were instructed to explore at least the women’s clothing department; otherwise, they were given free reign to wander around the store as they pleased. On each occasion, a different lighting scenario was in operation. Due to commercial reasons, the clothing collection changed somewhat during the study period. The colour palette of the clothing remained similar, however.

The interviews and notebooks provided us with a wealth of valuable qualitative research material for further analyses. The research material that was analysed consisted of observers’ texts and commented drawings in the Evaluation probe booklets as well as their comments in the preliminary, semistructured interview. Altogether, there were 57 booklets, as 19 observers filled one booklet of each three lighting schemes. Because the research material was qualitative of its nature, the analysis was explorative and interpretative. The target of the analysis was to recognize different aspects and elements of a multifaceted experience in a complex real-world situation and to find some relations between separated aspects and different types of experiences. In the
analyses, interpretations and assumptions for the reasons of individual experiences could be made, thus reflecting both the background information of each observer, which was gained in the preliminary interview and also through the comments in probe booklets. In addition, the interpretations were based on knowledge of the detailed design solutions in the adaptive lighting settings, as the designer of the adaptive schemes conducted the analysis. The analyses method could be described as grounded theory method informed by a research-by-design process of the case.

In the analysis, I have thematised the textual research material from the probe booklets and preliminary interviews. The first round of thematising of probe material also operated as transcription of the hand-written texts. It followed the structure of the questions relevant to my research subject. I collected responses and comments answering to each questions, combining and interpreting answers to several questions by each observer. This was also important, as the questions for each lighting scheme varied slightly. This was partly due to an error in the final layout of the booklets and partly due to delivering first nonupated schedule of different lighting schemes to the observers, which resulted in six of them answering the questions of a wrong booklet. However, the evaluation probe method was rather robust, as it was based in open-ended questions, which the participants could answer as they liked, so, fortunately, those errors were not critically lessening the research material. For example, in analyses, I could find clear answers also to the missing questions as the observers described rather freely their experiences. Additionally, the observers also referred to other schemes while answering to the questions and compared different schemes.

In the second round, I recognized different features of experience, which emerged from the research material, and collected those fragments of answers, which described each feature in question. I have read the material both as horizontally (examining and comparing the experiences of certain aspect in all the observers answers) and vertically (reading the different stories of experiences by individual observers).

The research material was qualitative in nature and not intended for quantitative analyses because the sample was rather small, and the formulation of questions and the answering method (open-ended questions) were not suitable for statistical analysis. However, in order to roughly reveal the relative occurrence of different features of experience, I created a matrix of features of experience that appeared in each observer’s probe answers concerning each one of the three lighting schemes of the test. In the matrix, features were presented as positive, neutral, and negative experiences, according to my interpretation of the comments. For example, the participant might have positive, neutral, or/and negative experience of motion detection, or she did not mention motion detection at all in the answers. In the last case, she might have described the patterns of light as random, which was again another category of experience. This matrix helped me to make the analyses, as the research material was very complex with abundance of different features emerging in different answers. In addition, I have collected those features which emerged into a graphical presentation where positive and negative experiences form bars into different directions, thus obtaining their length from the amount of observers who had had that kind of experience. Neutral experiences are in the middle section. Even though this presentation should not be read as a quantitative analysis, it helps the reader to comprehend the complexity of experiences and the differences of experiences between each lighting scheme.

### 5.3.2 Experiences of adaptive retail lighting

In general, the participants had varying and personal attitudes to the lighting schemes and to adaptive lighting. The idea of adaptive lighting was seen mostly as interesting, favourable, and adding many positive aspects to the shopping experience. Only a few clear rejections to the idea occurred in the answers. Interestingly, similar features could be read in different responses both as positive and negative. There are personal differences in the ways lighting is experienced and also the complex research setting in the real world with many changing factors causes variation in lighting situations.
I have divided the different features of experiences, which I have recognized, into five categories: 1) visual experience; 2) atmosphere and meanings; 3) shopping experience; 4) lighting behavior; and 5) values and opinions. The static lighting scheme caused experiences belonging to only the three first categories and the two adaptive lighting schemes experiences from all the five categories. Graphical presentations of these experiences and categories are presented in Figs. 77–79.
While evaluating the Static scheme, the observers’ comments were largely focusing on visual experience and visual comfort aspects of the lighting setting: for example, how much light there was and how well they could see. In most answers, the sensation of glare came up. Besides that, comments about the atmosphere occurred. For one observer, the warm white light was awakening associations of the warm light in summer evenings. This was found revitalizing in mid-November. In addition, some comments related to shopping experience were presented. These included a couple of notions of positive attention, attraction, and highlighting of products as well as missing highlighting of products. All in all, for many observers, the lighting scheme clearly reminded of a basic retail lighting environment, which they were accustomed to see in clothes stores.

Concerning the Adaptive White and Adaptive Colour Schemes, the evaluation revealed substantially wider range of experiences. Obviously, there were large amounts of commenting of the adaptive lighting behavior, which was not present in the Static lighting scheme. However, the adaptive lighting schemes, especially the Adaptive Colour scheme, evoked more comments about atmosphere and aesthetic experience by the observers. Many meanings and associations were described as well. In addition, the lighting was seemingly more seen as a supporting part of their shopping experience, as can be seen by comparing Figs. 77–79.

Those aspects, which were the guiding principles in designing adaptations, emerge in many responses. These themes were attracting, focusing, and guiding the eye farther. Especially the Adaptive Colour scheme was found to be effective as an attention catcher and attractor even from longer distances. Both adaptive schemes were mentioned several times as a feature that made the area more attractive and which gave it an identity that distinguishes it from surrounding areas in a positive way. One part of the attraction was also the atmosphere that the dynamic warm (Adaptive White) and coloured (Adaptive Colour) light created.

Observers mentioned several times that the changes of target lighting made them focus on a certain product and guided their gaze to other products that would perhaps otherwise go unnoticed. Nevertheless, some of them felt that the products, which were emphasized with light, should be somehow special and not ordinary products. Especially, the use of changing light and colours in focal points—the mannequin figures and their background panels—was considered a beautiful and attractive effect.

Many observers noticed the relation of changes of light to their own movements in the space. All observers found it interesting as an idea. It facilitated their sight and brought products to their attention. However, several observers did not mention that the lighting responded to their movements or described the changes of light as random. One observer said she grew tired because she tried to analyse the logic and pattern of light, partly due to her commitment to the task of observing. The variety of these comments can easily be understood while reflecting on the adaptation design. The concept combined three modes so that a part of the dynamic changes of lighting resulting from a person’s movements did not happen near her. In addition, the amount of customers in the area and its access points had an effect, as all of them caused adaptations. This created a mixture of logical but also seemingly illogical patterns in the dynamics of light, depending on what part of the space the observer is looking at. The multi-user aspect can be seen as a further design challenge.

Seeing the colours of products in a realistic way was an important aspect to many observers. This caused some criticism towards the use of colour in the Adaptive Colour scheme. Nevertheless, some observers noticed the whitening of light while approaching a product. Some mentioned the change of light level and colour also as a positive feature regarding colour detection: it showed the customer how the garment looks like in different lighting conditions.

Many meanings were linked to adaptive and dynamic lighting and especially to the scheme that contained colours: for example: in connection to the forthcoming Christmas season with many festivities. In addition, the adaptive lighting schemes altered the brand image of the store and the products for some of the observers.

Furthermore, detailed aspects of visual experience were brought up, concerning, for example, the perception of the dynamics of light (rate of changes, timing) and light levels (contrast in space and in different moments).
5.3.3 Concluding summary

The participants had varying and personal attitudes to the lighting schemes and to adaptive lighting. The idea of adaptive lighting was seen mostly as interesting, favourable, and adding many positive aspects to shopping experience. Only a few clear rejections to the idea were noted. The evaluation of experiences revealed that adaptive lighting has promising potential for design concepts, as it can attract, tempt, and guide customers, facilitate their seeing and enrich their shopping experience. Additionally, it can enhance identity and influence brand image. The results show that a careful design of detailed aspects of adaptation patterns and light dynamics is critical in creating pleasant environments, as dynamic light is a powerful tool for future designers.
5.4 Framework of experiences of adaptive lighting

In the previous chapters, I have explored users’ experiences of the three case study projects. The qualitative analysis of the wide research material from the interviews, walking interviews, observations, and evaluation probes gave me extremely rich and even kaleidoscopic insight into users’ experiences of adaptive lighting in three different kinds of environments. In the previous subchapters, I have presented an illustration of emic experiences, thus letting the participants talk themselves with long extracts of transcripted interviews. This illustration forms a substantial, and the most valuable, part of my answer to the research question Q2: How is adaptive lighting experienced by users of building interiors and urban spaces? This vivid illustration is challenging to be summarized and generalized without losing the richness of experience. However, in the following, I present a generalized framework of experiences concerning adaptive lighting, based on the evaluation results and the theoretical background of Chapters 2.3.1 and 2.3.2. This is answering in the general level to the Q2. This framework should not be understood as the final end result in the form of a general model but more as a summary of the rich mapping of the individual experiences in order to highlight the importance of its complexity and holistic nature.

The generalized framework is presented in Fig. 80. In the experiences, there can be seen both a general level and a contextual level. As the experience of adaptive lighting, as well as the experience of lighting, is complex and multifaceted, on the general level, it can be seen as containing various experiential aspects. All the presented aspects came up in the interview and observations analyses. In addition, each one is mentioned in some form in the published research of adaptive lighting (Table 5). However, in the research articles, the aspects have been presented in separate case studies and publications. Even though the theoretical framework is presented in my dissertation already in Chapters 2.3.1 and 2.3.2, the categorisation was created interactively with the thematic experience categorisations emerging from the case study research material. Thus, it obtained its final form in the last part of the research process. On the other hand, I have been making literature reviews along the long research process and throughout the designing of the case studies, which means that as researcher I have not been a “blank canvas” but resourced with continuously developing preconceptions. This interaction between the background theory, practice and empirical material can be seen as natural part of this kind of a research process, which combines design-based research and qualitative research.

The different sections of experiential aspects are separated with dotted lines, as the divisions or classifications are partly artificial. In real experiences, they are combined and related to in many ways. For example, feelings of security are also psychological experiences, and meanings are closely related to information and communication as well as the experience of atmosphere. Nevertheless, the idea of conceptualization of these aspects is to make them visible and known, thus widen the perspective of experience of adaptive lighting environments to a holistic view.

The recognized general aspects are:

- biological and psycho-physiological experience
- visual experience
- activity-related experience
- social experience
- safety and sense of security
- aesthetic and atmospheric experience
- experience of meanings and values
- experience of information and communication
- experience of interaction and participation
- psychological experience
In real environments, the experience of adaptive lighting is, to a great extent, context-related. One part of this is naturally due to the fact that adaptive lighting may be designed through different design aims for different contexts. For example, a design of adaptive motorway lighting aims to create a safe traffic environment and to save energy. Usually, the targets do not include producing aesthetic experiences or communicating. On the other hand, if the motorway in question is the entrance road to a big city, lighting might be, however, designed to have some visually attractive elements besides functional illumination, which communicates at least city brand-related aspects. In an educational context or in elderly care, for example, the experience of adaptive lighting may be again different, this time focusing perhaps more on biological or psycho-physiological aspects, as adaptive lighting might be used in design in order to employ those human processes.

In this way, *I argue that experiences of adaptive lighting emerge in each environment as context-related interpretations or manifestations of general aspects.* Certain aspects are more emphasized than others, relating to both the affordances of contexts as well as personal characteristics of the users of the environments. The experiences of adaptive lighting are, in their details, rather subjective, as the case studies have presented, even though common characteristics are visible. The subjective experiences can be related to user’s gender, age, and personal history, as well as current situation: for example, the activity on hand and prevailing mood.

Fig. 80. Generalized framework describing experiences of adaptive lighting.
Fig. 81. Framework of experiences of adaptive urban lighting in general and contextual level, reflecting the exploration of experiences from the LightStories and Urban Echoes case projects.

Figs. 81 and 82 (p. 158 and 160) present a collection of those contextual features, which can be seen as actualized, based on the case studies, in urban and in retail lighting contexts.

In the Urban Echoes case study, the different experiential aspects emerged clearly and richly in interview answers. All the aspects were included in experiences or in further discussions on the possibilities concerning adaptive lighting in urban environments. In the LightStories project, due to the nature of the project, the experiences were more or less concentrated on aspects of communication, participation, aesthetic experience, and atmosphere as well as on psychological and social experiences. In the evaluation, the interviewees were concentrating more on the experience of participation with the help of the design tool than on the experience of lighting on the street. In the following, the reflection is based mostly on the experiences from Urban Echoes.

On a biological level, certain light colours induced physiological experiences, such as dizziness, in participants. In addition, participants associated the sensations of cold and warm to the used effect colours and connected on an idea level the use of different colours to the yearly cycle of light and nature.

Seeing the route, other people, and elements of environment became essential parts of the interviewee’s visual experience. Adaptive lighting was seen as a guiding element and as creating them sense of space in a nocturnal environment. Adaptive lighting solutions should maintain visual comfort in the illuminated environment: for example, with suitable light level contrasts and by not producing glare.

On the level of activity, the experiences relating to moving in the park either by walking or cycling were well represented. The following behaviour of adaptive lighting was a powerful experience in general, responding to the participants’ own bodily movements with different rhythms and patterns of lighting scenarios. However, participants brought up several other activities, which could be related to adaptive lighting experiences. These included play, education, advertising, entertainment, and spending time in a night-time urban environment. Furthermore, in the LightStories case, the play with coloured light came up as means of spending time and as an entertaining activity.

On the social level, urban spaces are environments that people occupy alone and in groups and where they meet and interact with other people. Adaptive lighting was seen as potential for introducing social behaviour, such as play with
light, into the environment. It could also create an atmosphere that would be suitable for social interaction. Experiences of adaptive lighting wanted to be shared as well, with a partner or with friends.

In the participants’ experiences, adaptive lighting could enhance the perceived safety in the environment with lighting behaviour following the people. Light around was felt to be a reassuring feature as well as the enclosure and comfortable atmosphere created by light. Indicating other people’s presence by adaptive lighting was also seen as an element that added to the sense of security. The anticipative behaviour of light so that a walker can see the route ahead was essential for safe moving. In addition, adaptive lighting behaviour should not decrease the perception of safety by making the environment totally dark when no one is present.

The aesthetic experiences and atmosphere, which adaptive lighting can create for users of urban environment, were an essential part of the experiences in general. Lively and variable behaviour of dynamically changing light with the use of colours added visual interest and sensations of beauty to a nocturnal environment. These experiences were seen as important during the long and dark winter period of northern Finland because they could increase general well-being. However, attitudes towards and preferences of colours varied greatly and were also related, for example, to seasonal context. This highlights the importance of a flexible lighting system.

As part of the atmospheres created by the lighting scenarios were many powerful associations from living and colourful lightscapes. These have the potential of creating an identity and a sense of place. Adaptive lighting can be part of enhancing the city image and adding sense of belonging to citizens. Adaptive lighting was also associated with values such as sustainability and it was seen as supporting Oulu’s smart city brand.

As both of the case projects had communicative aspects, it is natural that, in this research, the experiential aspects of information and communication are well represented. Adaptive lighting can elicit both ambient information and explicit information. The legibility of information is seen as important aspect. Contextual information, such as weather data or local activities, was seen as enriching and near the inhabitants. However, many applications for different types of information and communication were ideated. These include private demonstrations, advertisements, educational communication, and guidance. Deep engagement of communicating makes the experience participatory as well.

Urban environments can offer many levels of interactive experiences from implicit interaction to explicit interaction and participation. Users of urban environment may prefer a passive role and experience adaptive lighting merely as an automated behaviour which serves their visual needs and creates aesthetic experiences, or, they may have an active role and a will to consciously interact with lighting. In public urban contexts, expectations of different kinds of users as well as multi-user aspects should be considered. Creative expression with light can be deeply engaging experiences and, according to the user interface, even give wide design possibilities. Interaction may occur with many kinds of devices and user interfaces, which have an influence on the experience, or it can be based on gestures and movements.

On a psychological level, adaptive lighting can create many kinds of affects such as excitement and relaxation, attraction, pleasure, and even restorative experiences. However, adaptive lighting behaviour has potential, if not designed well, of inducing negative feelings such as irritation or confusion, if the changes or light are too rapid, or if the lighting behaviour is not experienced as relevant to the context and to, for example, current situation or activity of the users.
When the same framework is interpreted into a retail lighting context, the emerging features are partly different and partly similar. This is presented in Fig. 82.

For participants, biological level was not clearly part of the experience. However, some participants referred to lighting as bringing the sense of daylight or sky light into the interior; it was also described as bringing the warm light of summer evenings into dark and rainy November day. Adaptive lighting has potential in windowless retail spaces for translating the natural changes of daylight into the artificial lighting, thus supporting biological rhythms and experiences.

Visual experiences of the participants concerned seeing and focusing on products, in which the adaptive lighting behaviour was seen mostly helpful. Colour rendering was an important property, which came up in many comments. Adaptive lighting should not hinder customers from seeing the real colours of the products. Nevertheless, some saw possibilities in the dynamically altering colour of light, as it showed the colours of products in different colours. The glary effect of bright light sources of static scheme was lessened in the adaptive scenarios, where the light was visually more interesting due to the colours and lighting behaviour. This was an interesting example of the twofold phenomenon of glare and sparkle. Adaptive lighting had effects on the sense of space and made the test area stand out in a positive way. Thus, adaptive lighting can be used as means for visual guidance.

On the activity level, participants saw adaptive lighting as supporting the presentation of products and helping them to find and browse clothing. Changes of coloured light were seen as entertaining, which works well if shopping is also seen as spending time and leisure activity—not just as picking up necessary products.

Our participants did not express any comments concerning social experiences. This was partly due to the individual task of observing scenarios and because the cramped test area did not encourage social behaviour. However, there could easily be found settings in retail environments, for example in shopping centers, where adaptive and interactive lighting could induce social behaviour, in the same manner as in public urban spaces. Safety was another level of experience, which did not come up in the answers. Whereas a nighttime urban environment might be sometimes associated with danger, a retail space is experienced in the first place as a safe environment. Nevertheless, in dangerous situations, adaptive lighting could be used for guiding customers safely out.
The adaptive lighting behaviour, especially the scenario with effect colours, caused aesthetic experiences and changed the store atmosphere in a positive direction. Adding visual interest was seen as a positive feature, if it was not making the store too restless. Adaptive lighting and changing colours evoked many positive associations: for example, about being in a journey or starting Christmas time. It was seen to give identity to the area and to enhance the brand image. Adaptive lighting was also associated with positive values of sustainability and energy saving.

In this pilot, communication or information of lighting remained on an ambient level, as the lighting behaviour was intended to attract and guide customers to the store section. This could be termed as ‘ambient advertisement’. The observers experienced implicit interactions with light, as it was seen to serve their needs and show them products. However, not all noted the connection between their own movements and the lighting behaviour but experienced it as random. This was partly due to the complex three-phase adaptation design and the amount of customers visiting the site at the same time. The multi-user behaviour of adaptive systems is an important design and experience feature. Further, explicit lighting control for dressing rooms was ideated by one participant.

On the level of psychological experiences, participants were feeling attracted and excited by the lighting, and it gave them pleasure. Lighting behaviour was seen as relaxing, too. Too rapid changes or missing lighting where it is needed could cause irritation and confusion. This is also an important aspect of detailed design of adaptive lighting behaviour.
6 Q3 results and synthesis: Framework for pragmatic-experiential and context-oriented design of adaptive lighting

In this chapter, I answer Q3: How can adaptive lighting be defined as a design task in general and specifically from the point of view of users’ experience? In Fig. 83, I present the synthesis of results from Chapters 4.4 and 5.4, and answering the third research question, formulate a framework of pragmatic-experiential and context-oriented design of adaptive lighting. This defines adaptive lighting as a design task from the perspectives of user’s experience and pragmatic constraints of design practice.

The core part of the framework as an essential design factor is the multifaceted user's experience, which was defined in the previous chapter. This experience is always context-oriented, even though it is the interpretation of the general experiential aspects. Other design factors, which frame the design outcome in the design process and have to be taken into consideration, are natural context, cultural context, ecology, economy, technology, and regulations. These factors are taken into considerations and solved into a coherent design outcome in the three-phase design process, which I have presented in Chapter 4.4.

Fig. 83. Framework of pragmatic-experiential and context-oriented design of adaptive lighting.
Natural context forms the basis of adaptation to environmental conditions, such as weather, snow cover, and daylighting conditions. A designer has to decide which conditions are relevant to the design task in question and to define the technological means to gather data of the environment and to feed it into the adaptive lighting system.

Cultural context concerns both architectural and urban environment and its cultural and social conventions and constructions. A designer has to consider, what kind of lighting behaviour is suitable to the architecture and cultural context, and what kind of social patterns of the space use the environment already has or will have in the ready-made design. How can adaptive lighting take these into account and reflect or support them? What kind of uses the environments have? What kind of sensing technologies can be used and are suitable for the context? Which forms of interaction are relevant to the environment and its users?

Because the need for reduction in energy consumption is an important drive towards implementations of adaptive lighting, the energy-use issue is a central, ecological design factor of adaptive lighting. The design targets to find an optimum balance between the user experience and energy use. With sensor technology, great savings can be achieved, for example, by lowering light levels when spaces are unoccupied or when daylight compensates the light needs. In addition, preventing the excess and unnecessary use of illumination and creation of light pollution (Lyytimäki 2013) are also important design aspects considering the effects of lighting on natural ecosystems.

Economical design factors are partly related to the energy-use aspect, but they form a more complex problematics with all the stakeholders included in each design project. Higher investments as purchase costs for intelligent and adaptive lighting solutions will in many cases in the long run result to reduction in life-cycle costs. However, this depends on many aspects of the designed solution, such as the patterns of use and the scale of the project. If the energy consumption of the luminaires in a small project is already from the start very low, with the prevailing, rather low electricity prices of the Finnish energy market, the payback times for advanced lighting controlling with sensors, communication, and controlling may grow relatively long. In larger projects, however, cost-efficiency is more easily gained. Nevertheless, there is already a large penetration of economically feasible lighting infrastructure into the market, for example, in the field of outdoor lighting, which pass well the life cycle assessment. The evaluation of economical feasibility is, however, made more complex, if the added value of adaptive lighting into the project or even externalities of a design solution are taken into account. The quality of architectural lighting may have its relation to economic value concerning, for example, building prices, as is the case of architectonic quality (Pihlajaniemi 2014).

In many cases, the question of the technology level to be chosen is related to the economical design factors. In addition, it has to be in balance with user needs and maintenance resources of the client as well as the future management and use of the interior and outdoor spaces. This relates to many aspects of interaction design and system design: for example, the design of user interfaces for administrative use and local user control. Furthermore, the division and cooperation between autonomous lighting control and user control is an important design aspect, as suggested by Offermans, van Essen, and Eggen (2013).

The last design factor, which I have recognized, is termed regulations. The design has to fit into regulations set by different authorities. These may relate to recommended light levels according to national or international standards, to estimated energy-use of the building, or to orders regulating the use of artificial lighting in relation to visual image of nocturnal cityscape. At the moment, there is still a lack of standards and recommendations concerning dynamic and adaptive light use in different contexts, though the work has commenced (Commission Internationale de l’Eclairage CIE 2010, Viikari et al. 2012). Formulating the guidelines is a challenging task, if adaptive lighting is understood to be as complex and multifaceted a phenomenon as I have presented in my thesis. It would be desirable that the future guidelines would not be set based on limited viewpoints and, thus, have over-restrictive influence on design outcomes, regardless of the wide design possibilities. Further research on the experiential aspects of adaptive lighting is still deemed necessary in order to set the future standards and regulations.
7 Discussion and conclusion

7.1 Contribution of the research

The realized case projects, as innovative and experimental lighting pilots, have generated new practical knowledge and demonstrated the possibilities of new technology for architectural and urban lighting. The projects have illustrated, inside and outside academia, how adaptive lighting, if designed in a holistic and creative way, can enrich users’ experiences of urban spaces and retail environments. The projects went beyond most of the earlier research pilots by using full-scale real-world environments, which were used for their normal purposes—urban streetscape, park path and retail-space—during the research. In addition, most of the earlier implementations in urban environments have been in art festivals or media architecture installations, for example, the interesting projects presented by Fritsch and Brynskov (2011) and Wiethof and Gehring (2012). Our cases, however, showed in a novel way the potential of adaptive lighting for functional everyday environments and infrastructures, as well as the existing ubiquitous technology of the city. An essential new contribution in the pilot cases was also the perspective of architectural lighting design and a practicing designer’s presence in the whole process: in this way, the projects could genuinely demonstrate the creative and expressive potential of lighting as part of everyday environmental design and ubiquitous technological systems.

With the Urban Echoes project, adaptive lighting has proven its potential for communication and a medium for ambient information, at the same time enhancing the atmospheric quality of urban environment without lessening the illumination function of park route lighting. Urban Echoes managed to change the use patterns of the formerly not so actively used section of the park and made it an attractive and actively used part of the city. In addition, it increased the local identity and common ownership of the park, as was indicated by the inhabitants’gestures to maintain the installation area by wiping snow off the luminaires. The success of the installation further affected city authorities who gave us a permission to have it on during the following winter-time, until the park went under a big renovation project. Perhaps not coincidentally, in autumn 2013, I was commissioned by the city planning office to design, as a lighting consultant in my own office, the new permanent park lighting. By the end of 2015, there will now be realized an adaptive lighting arrangement where lighting reacts to park-goers and is intelligently controlled following the lighting needs of different times of year. On the same path of the Urban Echoes installation, there will be realized an interactive and experiential park lighting. The concept is not totally similar to the Urban Echoes installation, as it will be realized with lighting bollards, but it has some elements in it, which were valued greatly by our interview participants. The beautiful birch trees will be illuminated, and the park lighting will have an intimate atmospheric character. With the RGBW LED lighting, changing lighting scenarios with both white and colourful emphasis on trees can be implemented. The intelligent infrastructure allows creation of interactive and participatory installations, according to the needs of the city and citizens. This process aptly demonstrates the movement between practical and theoretical knowledge, as described by Gibbons et al. (1994) to be essential in Mode-2 research: the results gained through transdisciplinary research are returned back to the world of practice as new practical solutions.

The LightStories project demonstrated that city inhabitants can be attracted to express and communicate with urban public lighting and to create meaningful
beauty in their everyday environment. In this aspect, it is related to earlier participatory projects such as Urban Pixels by Seitinger (2010); however, going further in many aspects. LightStories demonstrated the employment of unused or underused intelligent lighting infrastructure of cities to communal and participatory purposes. In the project, we explored the potential of a web-based design tool for enabling visually rich and versatile expressions through colour and light, embedding personal content as artistic communication. The aim was to give the participant the power to really design themselves and a good sense of control—perceived control—with the ability to predict the outcome of a particular design choice accurately (Barnes 1981). Based on the evaluation, we succeeded in that. The creative process of designing lighting and expressing thoughts through narratives, gave the participants a deeply engaging experience of participation, which also changed their conception of the Pakkahuoneenkatu Street.

This thesis is, to my knowledge, the first theoretical presentation, where the design process of adaptive lighting has been theorized as a whole from an architectural lighting designer’s perspective. In addition, the research relates relevant design factors into the process and describes the collaborative needs of different professionals and experts in the process. The users’ anticipated multifaceted experience has been taken up as the central design factor. The thesis has also contributed by suggesting and describing suitable design methods and design phases and tasks for the process. Scenario working method has proven to be useful in the Adaptation concept design phase and also in the Detailed adaptation design. In the research project, we developed a new design tool and method for the Detailed adaptation design. Its suitability for the design process was tested in two of the lighting pilots—in an urban park and in a retail context. After the research case studies, I have had an opportunity to apply the theory of the design process into practice in my professional work. During spring 2015, I was commissioned to conduct concept-level designs of adaptive outdoor lighting for two new housing areas in Tynävä, a small rural municipality in the Oulu region. In the design, I applied the scenario working method to produce documents and definitions for an innovative type of procurement of public lighting. This again clearly demonstrates the iterative, transdisciplinary knowledge production and application loop from practice to theory and back to practice (Gibbons et al. 1994, Aura, Katainen & Suoranta 2001).

Previous real world studies of adaptive lighting have still been rare; in general, a great deal of lighting research is carried out in laboratory contexts. This research has contributed in lighting research by studying experiences in concrete, real-world contexts. The research has illuminated the experience of adaptive lighting environments by studying them as a holistic phenomenon: the emic experiences of the users have been explored by employing novel, innovative research methods, which have been developed for the pilots (Luusua et al. 2014). The experience-gauging walking interview method is inspired by ethnographic research tradition and combines it with transdisciplinary design research tradition. The Evaluation probe method was inspired by the Cultural probe method by Gaver, Dunne, and Pacenti (1999). This thesis presents a general framework of experiences of adaptive lighting and applies it in the contexts of the case studies, showing how experiences actualize in urban lighting context and in retail lighting context. If added to Table 5, the results of this thesis would cover all the experiential aspects presented in rows, thus creating a holistic overview of the experience of adaptive lighting.

In addition, the framework of experiences has been combined with the results of theorizing the design processes of the case studies. As a synthesis, this thesis has presented a framework for pragmatic-experiential and context-oriented design of adaptive lighting. In the framework, a core design factor is the multifaceted user experience. This experience is always context-related. Other design factors, which frame the design outcome in the design process and have to be taken into consideration, are natural context, cultural context, ecology, economy, technology and regulations. This conceptualizing of adaptive lighting as a design task on the theoretical level, can in practice be applied in framing of design tasks in public and private procurements, for example, in purchasing intelligent public lighting, as well as in design commissions.
7.2 Validity of research and needs for future research

The research results have been validated by applying and documenting rigorously the chosen research methods—research-by-design and qualitative evaluation. The partial subjectivity of the results is seen as a benefit in the context of architectural design-oriented research, as it has allowed the direct and deep relation to the questions under research. However, there are certain limitations in the results, which finely offer further research possibilities both in design research studies and within other disciplinary or transdisciplinary research.

The contexts of our research cases were urban environments and a retail environment. Adaptive lighting should be further studied in applications in other contexts. This is especially important, as the experience is deeply context-related. Several interesting research directions can be established for applications in educational and working environments, and in contexts of elderly care and living as well as in housing in general. In addition, the evaluation periods for our pilot installations were relatively short. With other types of methods, the long-term effects on the experiences of adaptive environments and on, for example, the use of public urban spaces could be gained.

In this study, the research approach to experience was holistic and interpretive, as it applied qualitative methods. The sample of interviews and participants was rather small, due to the methods used being time and work consuming. Intention of this study was to reveal and describe the diversity and multiformity of experiences, so that they can be taken into consideration in future design processes. Based on these results, only suggestive guidelines can be presented for the design. It creates a wide framework within which design decisions may operate. However, other types of research, which analyse the experiences in more detail and with more controlled research protocols, are needed. This would allow, in the future, formulating more specific design guidelines concerning separate design features of adaptive lighting behaviour.

The developed VirtuAUL design tool and method is already being theorized further in Toni Österlund’s forthcoming doctoral thesis, and it will be presented there in more detail. However, there is a need to develop it further into a commercial product, so that it can be applied more widely in design practice.

7.3 Conclusion

In conclusion, I present summarized answers to my research questions.

Q1) The design process of adaptive lighting can be theorized, based on the three case studies, as a three-phase process consisting of several subtasks. The main phases of the process are: 1) Adaptation concept design; 2) Adaptive lighting setting design; and 3) Detailed adaptation design. The design process is guided by several design factors. In the design process, cooperation with experts of interaction and system design is beneficial. The main method suggested here for the Adaptation concept design phase is scenario working, which can be used also in the Detailed adaptation design phase. The Adaptive lighting setting design phase applies common methods of lighting design. The main method proposed for Detailed adaptation design phase is an algorithmic design method with the developed VirtuAUL design tool.

Q2) The users’ experience of adaptive lighting environments is complex and multifaceted. It contains several aspects both on general level and on contextual level. The recognized general, experiential aspects are: 1) biological and psychophysiological experience; 2) visual experience; 3) activity-related experience; 4) social experience; 5) safety and sense of security; 6) aesthetic and atmospheric experience; 7) experience of meanings and values; 8) experience of information and communication; 9) experience of interaction and participation; and 10) psychological experience. The experiences of adaptive lighting emerge in each environment as context-related interpretations or manifestations of the general experiential aspects.

Q3) Adaptive lighting is conceptualized as a holistic design task by formulating a framework for pragmatic-experiential and context-oriented design of adaptive lighting. This defines adaptive lighting as a design task from the perspectives of a user’s experience and pragmatic constraints of design practice. The core part of the framework as an essential design factor is the multifaceted user’s experience. This experience is always context oriented, even though it is the interpretation of the general experiential aspects. Other design factors, which frame the design outcome in the design process and have to be taken into consideration, are 1) natural context; 2) cultural context; 3) ecology; 4) economy; 5) technology; and 6) regulations.
This thesis has demonstrated the multifaceted and context-oriented nature of the experience of adaptive lighting environments and how anticipation of experiences can guide the design process. In addition, many pragmatic aspects frame the design, which is a multiphase process containing collaboration with relating professionals. Future design processes should acknowledge the complexity of the design task. Then, adaptive lighting can offer, besides energy savings, added value for the illuminated environments on many levels of experience. The main significance of this study is to help both designers and clients to understand the diversity of the new design task, and to help to approach it from human-oriented perspective—from the perspective of inhabitants of the environments. It forms one step forward in the process from technology-driven development towards user- and experience-driven development and design of adaptive lighting.
List of references

Publications


Boyce PR (1877) Lighting research and lighting design: Bridging the gap. Lighting Design and Application 17(5): 10–12.


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Appendices

I – IV Previously published articles by the author relating to the content of the thesis


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V Participants and their main contributions in the research projects relating to the case study projects
V Participants and their main contributions in the research projects relating to the case study projects

Adaptive Urban Lighting project
Aulikki Herneoja, Dr.Tech., Architect
-Leader of the research project
Henrika Pihlajaniemi, architect, researcher
-Coordinating the design and realization of the lighting demos (LightStories & Urban Echoes)
-Design of the lighting demos (LightStories & Urban Echoes)
-Design tool development from the perspective of lighting design (VirtuAUL)
-Evaluation of the lighting demos (LightStories & Urban Echoes)
-Analysis of evaluation results (LightStories & Urban Echoes)
-Doctoral thesis about design and experience of adaptive lighting

Toni Österlund, architect, doctoral student
-Design of the Lighting demos (LightStories & Urban Echoes)
-Design tool development from the perspective of algorithmic design
-Doctoral thesis about VirtuAUL design framework and method

Tuulikki Tanska, research assistant, architectural student (at the time of the project)
-Assisting in design of the lighting demos (LightStories & Urban Echoes)
-Assisting in evaluation of LightStories

Anniina Valjus, research assistant, architectural student (at the time of the project)
-Assisting in design of Urban Echoes
-Interview transcriptions of Urban Echoes

Jarmo Vähä, research assistant, IT engineer
-network system and web-service construction (LightStories & Urban Echoes)

Minna Teirilä, student of Cultural Anthropology
-Evaluation of LightStories demo
-Interview transcriptions of LightStories

Students of Multimedia Systems course, Department of Computer Science and Engineering
-network system and web-service construction (Urban Echoes)

UBI Metrics project & UBI Mingle project
Anna Luusua, architect, doctoral student
-Evaluation of the lighting demos (LightStories & Urban Echoes)
-Analysis of evaluation results (LightStories)
-Doctoral thesis about digitally augmented urban spaces and their evaluation

Johanna Ylipulli, cultural anthropologist, doctoral student (at the time of the project)
-Consultation of evaluation methods (LightStories)
-Evaluation of Urban Echoes

Tiina Suopajärvi, cultural anthropologist, PhD, researcher
-Evaluation of Urban Echoes

SparkSpace project / Adaptive Retail Lighting pilot
Aulikki Herneoja, Dr.Tech., Architect (UO)
-Leader of the Oulu university part of the research project

Vesa Pentikäinen, DI (VTT)
-Leader of the VTT part of the research project
-Coordinating the design and realization of the Adaptive Retail Lighting pilot

Henrika Pihlajaniemi, architect, researcher (UO)
-Tutoring the master thesis about adaptive and intelligent retail lighting
-Design of the Adaptive Retail Lighting pilot
-Design tool application to the pilot needs from lighting design perspective
-Evaluation design
-Analysis of evaluation results

Piia Markkanen, architect, researcher (UO)
-Master thesis about adaptive and intelligent retail lighting
-Design of the Adaptive Retail Lighting pilot
-Evaluation design
Anna Luusua, architect, doctoral student (UO)
- Evaluation design
- Evaluation of the pilot

Toni Österlund, architect, doctoral student (UO)
- Design tool application to the pilot needs from algorithmic design perspective

Esa-Matti Sarjanoja, DI, researcher (VTT)
- Retail pilot lighting control system

ITEA Emphatic products project
Satu-Marja Mäkelä, Tommi Keränen, Ville Valjus, Juho Eskeli, Sari Järvinen, Tomi Räty and Niko Reunanen
- People-tracking system used in Adaptive Retail Lighting pilot
   potentials and restrictions - a case study of the living environment for older people in Helsinki
