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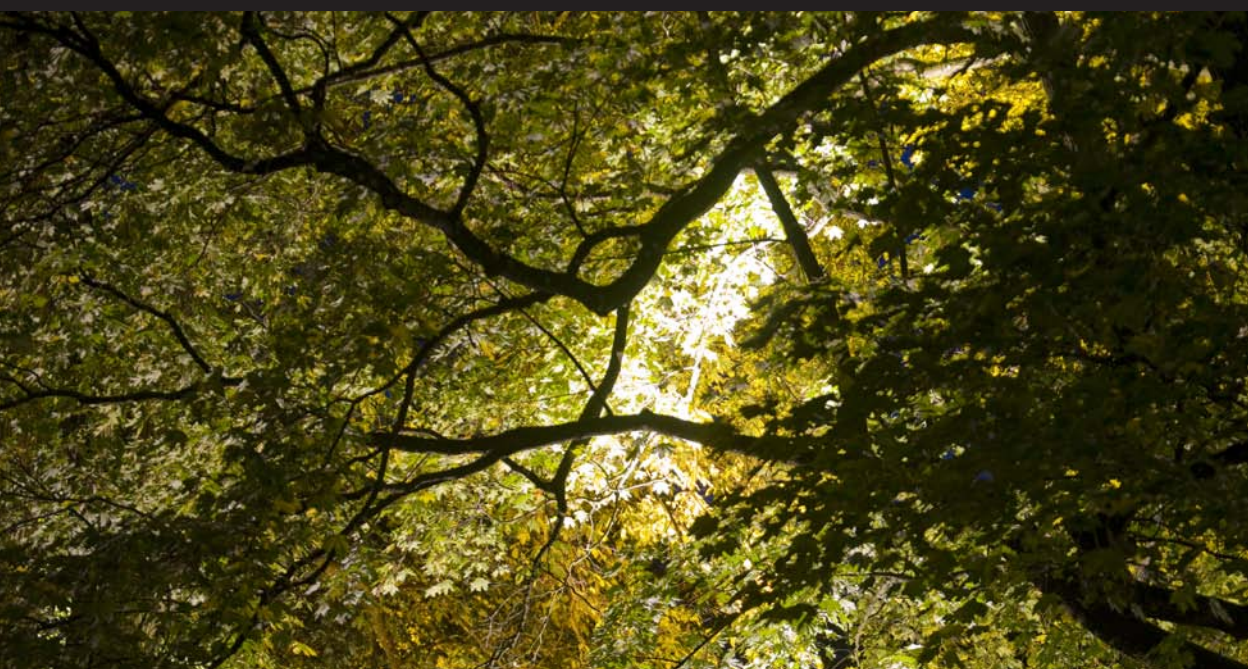

Light Shapes Spaces

Experiences of Distribution of Light and Visual Spatial Boundaries

Ulrika Wänström Lindh

UNIVERSITY OF GOTHENBURG

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HDK – School of Design and Crafts
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"Obviously it is because of its reflective nature that light combines seeing and the visible, so that without light there can be neither seeing nor anything visible." (Gadamer, 2004, p. 477)

"The enhancement of the spatial envelope is the reach into spatial aesthetics." (Michel, 1996, p. 121)

To our children that were given to us during my work on this thesis: to Klara in our memory, to Alfred and Truls.

Abstract

Light enables us to experience space. The distribution of light is vital for spatial experience but has not been the main focus of previous research on lighting. The lighting designer's professional knowledge is to a great extent experience-based and tacit. With design practice as the point of departure, this thesis aims to explore spatiality and enclosure in relation to the distribution of light – with the intention of increasing subjects' understanding of what can be regarded as a space, and to show how spaces can be shaped by the distribution of light. By focusing on users' experiences and interpretations, relationships between the distribution of light and perceived spatial dimensions and experienced spatial atmosphere have been investigated. The main contribution of this thesis is to widen the base of knowledge that lighting designers, architects and customers can use as a common reference.

This thesis is based on three studies: the Scale Model Study, the Auditorium Study and the Church Park Study. The thesis includes concept- and method development. The mixed methodologies comprise a range from introspective phenomenological observations to deep interviews and questionnaires. The experimental setups have also shifted from scale models to real-life interior and exterior settings. Consequently, a quantitative approach has complemented the mainly qualitative approach. Through artistically based research, patterns and relationships are dealt with in complex real spaces.

The findings of these studies lead to a discussion of when, why and how patterns of brightness and darkness influence spatial perceptions of dimensions. The findings also show that brightness not only contributes to our experiencing a space as more spacious than it really is, but in certain situations brightness can actually have the reverse effect. Furthermore, darkness can contribute to a spacious impression, which has hardly been discussed in previous research. What subjects regard as a space may shift between the clearly defined physical space and the perceived space, which include light zones. Light zones can create a sense of inclusion or exclusion for subjects, which affects their sense of community and their feeling of safety. Light topography, e.g. the height of luminaire positions, as well as light direction influence the way we experience the private and the public. Enclosure can, if related to visible spatial boundaries, facilitate reassurance and safety.

Title: Light Shapes Spaces: Experiences of Distribution of Light and Visual Spatial Boundaries
Language: English
Keywords: Practise-based design research, distribution of light, lighting design, architecture, enclosure, perceived dimensions, atmosphere, light zones, light topography, visual spatial boundaries.
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Content

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List of Appended Papers

Paper A: Wänström Lindh, U. Distribution of Light and Spatial Enclosure – A Scale Model Study. Submitted to Nordic Journal of Architectural Research. This paper is a revised version of the conference papers from 2006 (see next page).

Paper B: Wänström Lindh, U. Distribution of Light and Spatial Complexity: Appearance of Five Lighting Scenarios in an Auditorium. Submitted to Journal of Interior Design.

Paper C: Wänström-Lindh, U. (2010); Spatial Interpretations in Relation to Designer Intentions: A Combined Strategies Study in an Auditorium with Variable Lighting. In proceedings from Colour and Light in Architecture. International conference in Venice 11–12 November 2010. p. 258–263. ISBN/ISSN: 978-88-96370-04-9 No. 135594.

Paper D: Wänström Lindh, U; Distribution of Light and Atmosphere in Urban Environment. Submitted to Journal of Design Research, Accepted with revisions. Revised version.

Paper E: Wänström Lindh, U. Distribution of Light and Perceived Size and Shape. Submitted to Nordic Journal of Architectural Research.

Paper F: Wänström Lindh, U. (2011); A Full-Scale Light Laboratory in a Public Space. In Convention Proceedings from PLDC 3rd Global lighting Design Convention, 19–22 October, 2011 in Madrid, Spain. VIA-Verlag, Güthersloh, Germany.

Paper G: Wänström Lindh, U. (2011). Lighting Design Research in Public Space: A Holistic Approach to a Complex Reality. In Proceedings from the 27 Session of the CIE. International conference in Sun City, South Africa 10–15 July 2011. International Commission on Illumination. No. CIE 197:2011. Volume 1, part 2. p. 767–776. ISBN 978-3-901906-99-2.

Additional papers not included in this thesis:

Wänström Lindh, U. (2010). Reaching Spatial Complexity through a Combined Method Strategy: Appearance of Multiple Lighting Design Scenarios in a Single Space. In Book of Abstracts from 2nd CIE Expert Symposium on Appearance: "When appearance meets lighting." 8–10 September 2010, Ghent, Belgium. This extended abstract was later developed into Paper B.

Wänström Lindh, U. (2006). Observations of Spatial Atmosphere in Relation to Light Distribution. Proceedings from the 5th conference on design and emotion 2006 (Karlsson, M.A., Desmet, P. and van Erp, J. eds) Department of product and production development, division design, Chalmers University of Technology, 27–29 September, Gothenburg, Sweden. ISBN/ISSN: 91-975079-5-4 No. 48364. Some parts of this paper are included in Paper A.

Wänström Lindh, U. (2006). Spatial Enclosedness & Lighting Quality: Light Distribution Studies in Scale Model Room. This working paper was orally presented at the international conference Wonderground, Design Research Society, 1–4 November 2006, Lisbon, Portugal (abstract published in book of abstracts). This paper was a ground for the later developed Paper A.

1. Introduction

The main contribution of this thesis is to highlight the impact of the distribution of light on a perceived space. It addresses the importance of conceptual awareness and knowledge of informants' pluralistic pre-understanding. It combines and develops research methods that can display complexity in real spaces through patterns and relationships. Additionally, it includes concept development that focuses spatial understanding.

This lighting design research consists of experimental studies within different complex spatial contexts, from scale models to interior and exterior spaces. The importance of visual spatial boundaries and brightness patterns are discussed in relation to enclosure, perceived dimensions and atmosphere.

1.1 POINTS OF DEPARTURE

Light enables us to experience space. The relation between surfaces, three-dimensionality and depth is visualised by differences in surface lightness through shadows and reflections (Liljefors & Ejhed, 1990, p. 37). As Millet writes, "Light is not perceptible without form (…). Conversely, form is not perceptible without light to reveal it" (Millet, 1996, p. 47). The direction of light, proportions of illuminated areas and level of light in relation to other areas in the room play an important role for our spatial understanding. Distribution of light in a room is affected by the position, shape and size of windows and luminaires, as well as the surface reflectance in the room. Within the field of lighting, distribution, colour and level of light are the most important lighting factors for spatial experience. One may even say that distribution of light is the most important quality for spatial experience. By studying distribution of

light in spaces we will understand more, not only about light but also about spatial experience. This thesis is about light, since light is the factor that is added to space, but it could just as well have been about darkness.

Figure 1. This downwardly directed light does not reach any vertical surface such as the surrounding foliage. The vegetation becomes a black spot at night.

There are several reasons to concentrate more light on vertical surfaces (see also chapter 2.1). Focusing illumination on walls, ground and "ceilings" is a way of making a clearly defined and enclosed space (Michel, 1996, pp. 121–122, 177; Millet, 1996, p. 55). A basic assumption for this thesis is that a room with visible walls is easier to judge distances within because it is easier to detect the rear wall, to estimate the width between the walls and to see connections with other surfaces as well as the relation to objects in front of the walls. However, a minimal number of dominant spatial boundaries are needed for a clear spatial envelope. Michel writes that "the more the boundaries share the similar design qualities, the more they will be tied into stable relationships for visual order" (Michel, 1996, p. 117). The value of enclosure of public spaces has attracted attention through Camillo Sitte's theory of spatial enclosure in medieval town planning (Sitte, 1909). Visible vertical surfaces are also important for orientation: it is difficult to recognise the surrounding by looking at the ground. If the goal is orientation, illuminating a black asphalt surface with low reflectance is a waste of resources. If a luminaire is placed so that the light falls onto a vertical surface that reflects

the light instead of standing free in relation to a black sky, it smoothens out the contrasts and reduces glare. Illuminating vertical surfaces may be cost effective because the reflection makes more use of the light resources.

Figure 2. When these luminaires are placed closer to the facade and the tree, more of the light is seen and the surrounding contrasts become softer, reducing the risk of glare.

The large size of exterior spaces has economic implications: we cannot afford to illuminate everything. Instead of a uniform general lighting, we have a pattern of light spots seen against a dark background. Lit indoor spaces, or outdoors spaces in daylight allow for an immediate and clear overview over a space. But outdoors at night the gaze searches for pieces of information that can bring the puzzle together. The exterior space can be regarded as fragmented; some of the space is brought out by light while other parts are left dark. An illuminated object outdoors, such as an illuminated path, often stands out, where the figure–ground relationship becomes clearer from the larger brightness contrasts. In exterior environments a lighting designer can work by using light to dig holes out of the darkness.

Figure 3. A clear view of a space is difficult when only the ground is illuminated.

With light it is possible to emphasise or minimise what people see, and so the designer's interpretation of the architecture is essential. One may wish to reinforce the impression of height or width of the room or to emphasise an interesting element such as a pillar, or a specific function in the space, such as sitting on a bench. This can cause the observer to view the space in a specific way, or support a specific understanding of the space as well as the viewer's orientation within it. With light it is possible to choose which story is being told. We can choose to expose an object or spatial context or to leave it in darkness. With Gadamer's terminology this can be regarded as a *play* with contrasts between light and shadow; like a movement back and forth, to show or hide (Gadamer, 2004, p. 104). The play in light can be seen from several perspectives. Moreover, there are plays with contextual relations. Merleau-Ponty describes how light affects attention: "The lighting directs my gaze and causes me to see the object, so that in a sense it knows and sees the object." (Merleau-Ponty, 2006, p. 361).

Our artificial light installations often vie for our attention, both in varying level and colour of light. When light is added to an object or a space attention is taken away from something else. It is like when adding a new colour nuance to a field in an oil painting, all the other surrounding coloured fields need an adjustment to balance the recently added field. Similarly, lighting design plays with the architecture and the spatial conditions in order to expose, tone down, to make a contrast, to follow or to accentuate. However, to brightly illuminate the key object is not always the solution. The task of a modern lighting designer may as well be to increase contrasts by creating darkness. Merleau-Ponty continues: "When a painter wants to depict some striking object, he does so less by applying a bright colour to that object than by a suitable distribution of light and shade on surrounding ones" (Merleau-Ponty, 2006, p. 364).[1]

1.2 THE PROBLEM

Most of the existing lighting research focuses on illuminance and colour temperature while there have been few studies of the relationship of the distribution of light and spatial perception. Distribution of light is difficult to measure and better suited for visual evaluation, and is therefore possibly not as well researched. The focus on the level of light, visual task and performance may

1. Merleau-Ponty, refers to Katz Farbwelt.

have caused lighting research and the lighting industry to prioritize uniform lighting that works better for the *central vision* (Liljefors & Ejhed, 1990, p. 39). The standards and recommendations from the European Committee for Standardizations (CEN) and the International Commission of Illumination (CIE) are based mainly on the central vision's (*fovea vision*) need for uniformity to facilitate reading details: "In general, the more uniform the distribution of light in the visual field, the better one sees the visual task" (Rea, 1993, p. 98). Traditional light planning and luminaire development have long departed from a distribution of light that is as uniform as possible to support road safety and indoor visual performance.

However, when it comes to orientation in urban space we use the *peripheral vision* (also addressed as *retinal* or *side vision*). The fact that the two types of vision, central vision (corresponding to 2° of the viewing field) and peripheral vision (170° of the viewing field) function in different ways and in different light situations are of great importance to light planners.[2] The primary task of the peripheral vision is spatial understanding aided by surrounding visible contrasts (Liljefors, 1997, 2003, 2005). The ability of the peripheral vision to view comprehensive scenes and indistinct field contrasts is facilitated through variable light. Therefore, an increased focus on light at vertical surfaces as well as larger brightness contrasts – and not uniformity – would be useful for our spatial experience and orientation ability. The fact that the part of our vision that supports orientation and spatial perception works by reading field contrasts and differences in shade shows that distribution of light is of most importance for our spatial experience (Liljefors, 1997, 2003).

2. There are different ways to interpret these concepts. Professor Emeritus Anders Liljefors states that we should call the peripheral vision the "retinal vision" (*omgivningsseende* in Swedish) and the central vision the "fovea vision" (*detaljseende* in Swedish), so that the spatial task will not continue to be a secondary concern. I support Liljefors, who struggled to change the concepts of central and peripheral vision, but chose to use the established terminology until new concepts are accepted by the CIE.

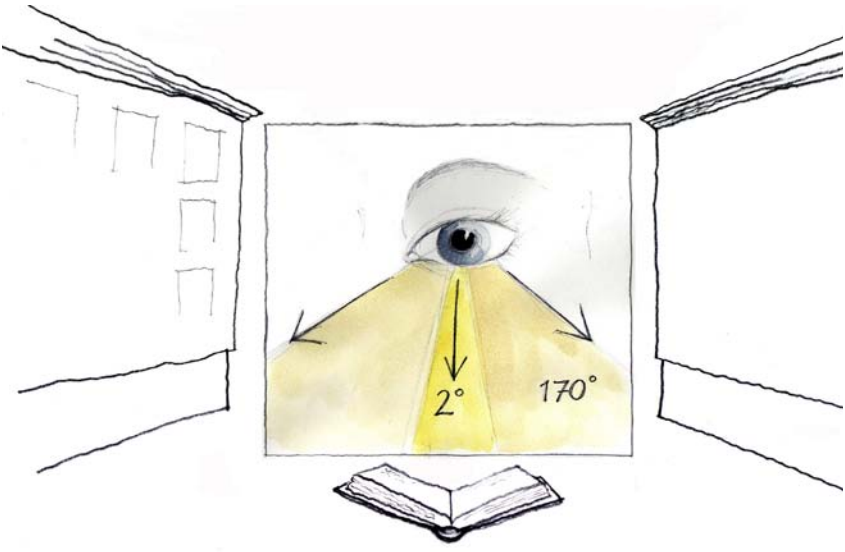

Figure 4. Central and peripheral fields of vision.

It is important to choose lighting principles not only by the street width, type of traffic and speed recommendation. It is also just as important to attend to the architectural experience, street rhythm, the scale of the buildings and the atmosphere. The designer Olle Anderson has clearly expressed the need for contrasts:

> "If a uniform, diffuse light is applied to a whole space it communicates that no part or surface is worth emphasising or more important than any other. A space like this is usually experienced as boring and insignificant since it lacks the clearly defining contrasts, borders and gradients that the gaze always searches for." (Andersson, 1988, p. 27)[3]

Another side of the problem is related to the profession. "Lighting designer" as an occupation is a young profession and area of research, with an educational tradition of only about 10 years, though growing rapidly. Earlier, light

3. Swedish quotation: "Lägger man ett jämnt diffust ljus over hela rummet så har man samtidigt tagit ställning och sagt att ingen del eller yta är viktigare än den andra och värd att framhålla. Vanligtvis uppfattas ett sådant rum som tråkigt och intetsägande, därför att det saknar tydliga kontraster, gränser och gradienter som ögat hela tiden söker."

planning was mostly the task of an electrical engineer or an architect with a special interest in light. In Sweden, urban lighting designers primarily have an architecture background or they are experienced theatre or stage lighting designers. A considerable part of our professional skill is tacit and practical knowledge based on our own experience (Molander, 1996; Polanyi, 1966; Schön, 1983). Despite the previous limited research, architects and lighting designers have many theories about the spatial experience of light. That there are gaps in the knowledge base supporting the lighting-design profession does not prevent designers from making well-founded decisions. A reflective practitioner may develop a huge knowledge through experience (Molander, 1996; Schön, 1983). Hence, it is difficult to discuss it with other members of the lighting field and to validate it. Some of these theories come from research while others may come from conventions and fashion trends. Examples of professional praxis are the widely accepted rule-of-thumb that it is important to illuminate vertical walls to create a more defined space, and to use a vertical pattern to raise a perceived room height or a horizontal pattern to make a space appear wider (Michel, 1996, pp. 118, 133–134; Neufert & Neufert, 2000, pp. 24–25). However, not all of this praxis is substantiated by research.

Fortunately, lighting design can draw from other established professional and research fields. We can find knowledge that is useful for lighting design from perception research, environmental psychology, medicine, physics, electric engineering, architecture and other areas. However, most existing lighting research is based on technical laboratory studies and not from real-life, complex spatial contexts (see chapter 2.6). This gap was an important reason for starting this research. The practise-based architectural knowledge (Hansen, 2010) will be the point of departure for this dissertation.

With regard to the lack of knowledge verified by research, when working as a lighting designer I used knowledge from spatial colour perception and translated it to the field of lighting. For example, that a bright ceiling tends to make a room look higher (Andersson, 1988, p. 27; Oberfeld, Hecht, & Gamer, 2010), that distinct parallel sidewalls squeeze a room and make it look narrower, that dark surfaces make a room look smaller and that a strongly coloured back wall makes the back wall appear closer (Acking & Küller, 1966; Billger, 2006, pp. 161–162) (see chapter 2.3). Even though there are many similarities in perception of light and colour, the knowledge may nevertheless not be fully transferable between the fields. Just like in both the colour and lighting fields, nothing may be taken for granted and everything is context related.

We need to know more about how the final design will be experienced in a real environment and to gain knowledge about others' experiences and interpretations. Lighting designers frequently use test lighting as a working tool, but they seldom have the opportunity to test the effect of a complete lighting design in a complex, real public space. Furthermore, project evaluation is often neglected in the project budget. To summarise, there is not only a demand for studies on the relationship between the lighting designer's intentions and user experience but also for discussions of the designer's specialist knowledge and toolbox.

Figure 5. Vertically and horizontally placed light may influence the perceived width and height of a space.

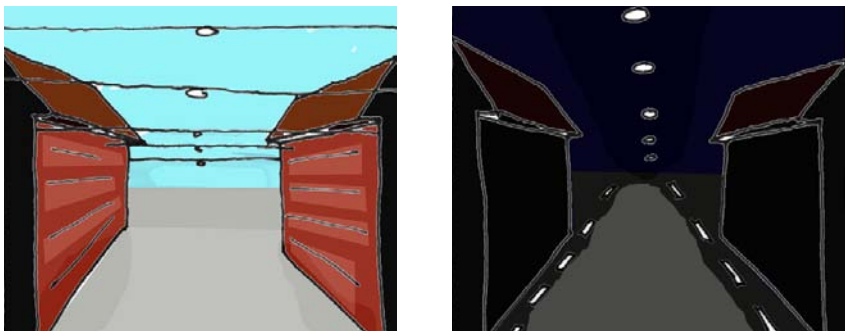

Figure 6. The patterns of luminaires on the left and patterns of light on the right can give a different impression of verticality and horizontality during the day than at night.

The initial assumptions and questions that this thesis deals with were derived from both practical experience as a lighting designer and architect, and from observations and spatial analysis from my master's thesis in architecture about light in urban planning (Wänström, 1998).[4]

1.3 PURPOSE, AIM AND RELEVANCE

This research project aims to explore how the distribution of light in interior and exterior spaces affects how spatiality is experienced, how spatial dimensions are received and how atmosphere is experienced. This research is searching for answers as to what can be regarded as a space in relation to light, and to show how spaces are shaped by the distribution of light.

The target group for this knowledge is other lighting researchers, practitioners, architects, lighting designers, light planners and students within these fields. The purpose of this knowledge is to widen the base of knowledge that lighting designers, architects and customers can refer to. With a better understanding of spatial experience, it will be easier to predict if the final design will achieve the project's intentions. The purpose is also to provide lighting designers with backup arguments about how designed spaces are experienced and interpreted and to facilitate discussions with building contractors and customers. An artistically skilled designer may need more support when communicating a design, whereas a more technical planner may need more information about how people experience designed spaces. An artistically skilled designer can often acquire a considerable amount of knowledge through own practical experience. Still, first it may be hard to communicate an experience, and secondly a designer can never be certain that his/her experience will be shared by others. As such, an important part of this thesis is concept development. The common knowledge of spatial perception of size, depth and shape feels like common sense, something a designer should already know. However, little of this knowledge has yet been supported by research, which means that as designers we have difficulties discussing our spatial experiences.

Another aim of this research is to develop methods by exploring new ways of conducting research through design and by combining quantitative and

4. Translated to English, the title of the master's thesis in architecture is *Light in the city from a spatial perspective* (in Swedish: *Stadens ljus i rumslig belysning*). This study was preceded also by a Master of Fine Arts in Design/Interior Architecture.

qualitative methods. When designers pursue research, new questions are asked. This research differs from lighting research by environmental psychologists, sociologists and engineers or research by art historians about design. This research is somewhere between on one hand the field of basic research and on the other hand applied research for architects. Practitioners can use the knowledge to create an enclosed or open room, to strengthen size or shape proportions or to create a specific spatial atmosphere. The choice of methods will follow the questions. If we can assume that research methods control the results, then new methods will probably lead to new kinds of results; you cannot get answers to questions that you do not ask.

It is important to point out that even if the research discovers usable lighting principles for a specific effect, every lighting design case will need an individual adjustment according to its specific circumstances, such as the function, contrasts and shape of the room. The more we know more about the effects of the distribution of light the better equipped we will be to create well-functioning and appealing environments.

We do not have the environmental or economical resources to illuminate everything uniformly and a non-uniform lighting is more suitable for purposes of spatial experience. It is therefore very important that we know how to put the right light in the right place. This will save both energy and money. Light can be a cost-effective way to increase the spatial and spacious experience. Additionally, this research may contribute to light environments that improve wellbeing, such as counteracting spaces that aggravate symptoms of claustrophobia and agoraphobia.

1.4 DELIMITATIONS

This thesis deals with the visually perceived distribution of light within the context of the space in question. Distribution of light is a consequence of the direction of light into space and the distribution and character of contrasts and reflections from surfaces in a room. The research takes the fields of architecture and lighting design as its starting point. In this case, a lighting designer is a person who works with architectural lighting. Stage lighting is another classical area for lighting designers, though it is not within the scope of this research. It is a conscious choice to not work with more free, artistic light installations or theatrical narrative light. In this thesis, the intention is to learn how the distribution of light of a normal standard illumination can provide opportunities to create character and atmosphere. Other factors that

also affect the total light situation – such as the colour and level of light – will be discussed in relation to the distribution of light, though they are not the focus. The experience of colour in a room can be related not only to colour of light and surface colours but also to the distribution of light in the room.

1.5 RESEARCH QUESTIONS AND QUALIFIED ASSUMPTIONS

The main questions of this thesis are:

- How does the distribution of light affect the visual experience of spatial enclosure?
- How does the distribution of light affect the visually perceived dimensions, shape and size of a room?
- How does the distribution of light affect the experienced spatial atmosphere?

In addition to these questions, there is also the secondary question of whether architects and designers experience light in space in the same way as non-professionals do, or if their experience from increased knowledge, praxis or professional trends differs from non-professionals.

Additional questions are related to conceptual use and the research methods. Since little lighting research is performed in real, complex spaces it is important to investigate and develop methods that are usable for this purpose. What methods can be used for analysing spatial complexity? With a more qualitative approach it becomes important to understand how subjects use and understand the main concepts of the inquiries. Do the informants understand and use concepts in similar ways?

This project began with several qualified assumptions that were developed from my experience as a lighting designer, earlier studies and knowledge from the field of colour research (Billger, 1999, 2006; Fridell Anter, 2000; Fridell Anter & Billger, 2010) (see also chapter 2). Luminaire position affects where light falls, whether parts of a room are reached by the light or not. From my architectural background comes the starting point that walls must be illuminated to be visible, especially in exterior spaces. With visible walls, a room becomes defined and easy to grasp. Millet writes: "Light emphasizes the form of a room by defining its boundary surfaces with light" (Millet, 1996, p. 55). Additionally, she states that "the definition of architectural space is the definition of enclosure, in which light plays a major role" (Millet, 1996,

p. 93). Similarly, Michel states "How is architectural space defined? By its boundaries!" (Michel, 1996, p. 102). There is a relationship between a clearly delimited and a tangible space. As a consequence, a room without illuminated walls is less spatially enclosed than a room with illuminated walls. Illuminated walls contribute to creating a more delimited space that is easier to grasp. Furthermore, a light zone can appear as "the space", which sometimes is more important than the physical space. Nevertheless, one wonders in what situations this hypothesis of illuminated walls becomes evident, since it is related to the context and the whole situation of contrasts.

The studies are designed with the assumption that the luminaire placement and distribution of light have a large impact on the perception of the depth and height of a space. The more precise initial assumption based on my experience of perceived dimensions are that a dominantly illuminated surface seems to either come closer to or farther away from other room surfaces. It is also assumed that brightness and lightness generally increase size (Acking & Küller, 1966; Flynn, Spencer, Martyniuk, & Hendrick, 1973; Houser, Tiller, Bernecker, & Mistrick, 2002; Matusiak, 2004), while darkness most often shrinks a space to the area closest to the observer that is still visible. It follows the assumption that the perceived depth can be manipulated with light, for example increased with a highlighted landmark in a tangible line of sight. Upwardly directed light is assumed to emphasise the height of an object or surface. Luminaire position is expected to influence the experienced size of a space, so that a lower luminaire placement makes the ceiling appear lower. Concerning the relation between distribution of light and spatial atmosphere, this thesis research is based on the assumptions that a lower-placed light and a smaller light zone reinforces intimacy and a private atmosphere (Flynn, et al., 1973). A spatially enclosed room is more intimate than a less enclosed room. Distribution of light can also influence the experience of rhythm, calmness and activity: a patchy and confusing light pattern is experienced as less calm than a regular pattern that follows the building structure. An additional assumption is that an illuminated area or a light beam can be regarded as a space within the space, such as a light zone (Madsen, 2004, 2006) (see chapter 3.4).

1.6 APPROACH AND POSITIONING AS RESEARCHER

For the artistic research context at our faculty it is important to begin from one's own design, in this case with a central design process and research

closely linked to practice. This research project should both exhibit an artistic quality and start from questions posed from a design perspective.

Different contextual settings are used within the research, which consists of three projects: the Scale Model Study, the Auditorium Study and the Church Park Study. The questions of spatial enclosure, experienced room size and shape in relation to distribution of light have been the focus of all three studies. Different research methods and experimental setups have been developed and used. In the first study, different luminaire placements in scale models were observed and compared using a phenomenological method. The second study was conducted in an auditorium with five different lighting scenarios, where different kinds of luminaires were used with varied levels and colour of light. In this study, method development was also a goal. Answers were collected through a questionnaire and in-depth interviews. In the third study, the church park, several objects were illuminated according to the research questions. Spatial enclosure and spaciousness were studied by illuminating trees and facades. The impact of the height of luminaire placement (light topography) was studied through changes in the street lighting. Data was empirically collected through a questionnaire, interviews and focus groups.

Methodology sketching and design planning have been important parts of the research, primarily in the Church Park Project. The intention with the lighting design of the Church Park was, besides providing an experimental setup for the research questions, to create a lighting design that included the whole public space as a functional and well-defined architectural experience. The design process of the Church Park Study is described in the appendix. This work does not really accomplish the third phase of research-by-design since this it does not aim to produce any concrete design suggestions. Since design through my own professional knowledge is used within the research, it is addressed as practise-based design research (Candy & Edmonds, 2010).

This research is part of several research traditions, but it can also be regarded as a new field of research that originates in visual experience. Traditionally, lighting research is mainly scientific, based on quantitative methods. A human-centred approach is found in the social sciences and humanities, where qualitative methods are standard. The new expanding field of artistic research stands close to the humanities and social sciences though is still developing new methods and traditions. As researchers in lighting design, we must have knowledge of existing lighting science while still working through our own designs and combining methods from these different fields. There are tensions between all these fields that must be attended to. Similar to other

architectural research, we also need to relate to a local context.

Whichever leg one chooses to stand on, there will always be contradictions and questions from other fields of research. Qualitative researchers question what useful data could possibly be gained about subjects' experience through the statistical analysis of the questionnaires. Pro-positivists wonder if it is really possible to find any solid answers in these complex studies, where so many questions and interrelated factors are studied at the same time. Researchers outside of the artistic research field question if researching one's own designed, empirical material is too subject to bias. And finally, designers are puzzled about the outcome of a research study like this since they believe that they already have this knowledge from their experience. However, this thesis aims to show a possible method of research that gives a rich study using both empirical collection *and* interpretations in a way that has not been done before.

Within the research school of the Faculty of Fine, Applied and Performing Arts at the University of Gothenburg, where this work is conducted, there is an ongoing discussion of how artistic research compares to research within the artistic field. My interpretation is that artistic research primarily addresses an artwork as the research results, while the research within the arts regards the use of artistic research as an approach, which has more in common with applied art, such as design. When designers research themselves, they ask different questions than when others research *about* design. R. Rocco describes research-by-design with reference to Biggs and Büchler as a non-traditional form of art-based or practise-based research. Rocco discusses three kinds of Research-by-Design: "1) Exploratory practice within the traditional model of academic research. 2) Practise as generator of relevant questions explored within structures provided by traditional models of academic research. 3) Problematic view [sic] that claims that design practise IS academic research [emphasis in the original text]" (Rocco, 2009). One may also more clearly define the difference between research *by*, *in* or *through* design, as Finn Thørbjorn Hansen has done.[5] Hansen and others also often call research that begins from inside the design practise as practise-based research (Hansen, 2010). This research project should both inherit an artistic quality and begin with questions posed from a design perspective. Both sketching methodology and design planning have been important, primar-

5. Based on a PhD seminar with Finn Thørbjorn Hansen at HDK, School of Design and Crafts, University of Gothenburg 2011.

ily in the Church Park Project. The intention with the lighting design of the Church Park was to create a lighting design that included the whole public space as a functional and well-defined architectural experience, as well as provide an experimental setup for the research questions. The design process of the Church Park Study is described in the appendix. However, this work does not really accomplish the third phase of research-by-design, since this research does not aim to any concrete design suggestion.

In his book *The new production of knowledge*, Gibbons describes two mayor research contexts as *Mode 1* and *Mode 2* (Gibbons, 1994). Mode 1 is a traditional approach, mainly within universities, where individual researchers take the initiative for the research and examine self-formulated problems within a discipline. Mode 2 is context dependent, interdisciplinary and controlled by task and finance from outside the academic sphere. Recently, several researchers have proposed a *Mode 3* that either includes emotions and social responsibility (Jimenez, 2008, pp. 48–56) or focus on well-being and sustainability (Frühmann, Omann, & Rauschmayer, 2009), or both. This thesis research seems closer to Gibbons' Mode 2. This thesis examines my self-formulated problems, uses interdisciplinary methods and reports its studies within specific contexts constituted by the experimental sites. Referring to Dunin-Woyseth (2002) and Lundeqvist (1997), Nyström describes the "making disciplines" as problem-oriented research fields rather than traditional object-oriented research. Design research is usually inter- or transdisciplinary and presents a synthesis were the object is seen within its contexts, and the object becomes a subject (Nyström, 2007).

Through art-based research it is possible use a non-linear structure to cope with complexity (Dyrssen, 2010, pp. 223–239). This connects to both design thinking and architectural thinking, areas that deal with spatial and contextual complexity involving the body–space relationship. According to Dyrssen, architectural thinking means "to think in three dimensions regardless of scale and to deal with complex spatial situations that are constantly changing over time". Design thinking, on the other hand, often talks about "wicked problems", such as problem solving in complicated situations (Buchanan, 1992, pp. 5–21). Art-based research includes performativity, staging explorative experiments, modelling and simulation, critical construction and reflection and assemblage (Dyrssen, 2010, pp. 223–239). This methodological framework consists of thinking-acting-composing. It does not address any specific user, as design thinking often does. Through art we can, referring to Dyrssen, see hidden connections, switch perspectives, formulate complexity

and reach new understandings. She refers to the researcher as playing and dancing in a choreography that involves both material and situation. Within assemblage, key points, links and relationships are made up in a composition of relevance dealing with the basic research questions: what, where, when, for whom and how (Dyrssen, 2010, p. 235).

Within art-based research and design research it is unusual to combine the frequently used qualitative methods such as interviews, spatial analysis and phenomenology, with quantitative methods such as statistical analysis of questionnaires and use of test subjects.

It is common to use the first person perspective within qualitative research, architecture, design and artistic research, but not within quantitative lighting research. This complicated issue is consciously addressed by using primarily third person references in the papers and first person references in the main thesis text.

1.7 OUTLINE OF THESIS

Chapter 1 introduces the research, problems, aims, focus and delimitations, research questions, previous assumptions, theoretical frames and positioning as a researcher.

Chapter 2 maps out the field of previous research that this thesis relates to.

Chapter 3 describes the definition and use of main concepts and concept development.

Chapter 4 describes the methodological framework and the research process.

Chapter 5 provides a list of abstracts to summarise all papers.

Chapter 6 provides a summary of the main results and discusses the results between the studies.

Chapter 7 discusses methodological issues and the experimental setups.

Chapter 8 concludes the thesis and presents contributions, improvements and future research proposals.

This compilation thesis is based on of seven research papers, which are included in the appendix:

Paper A, "Distribution of Light and Spatial Enclosure" (about the Scale Model Study). This paper discusses the relationship between the experience of spatial enclosure and illuminated surfaces; how the play of contrasts and light patterns influences perceived spatial size; how compound

illuminated areas can increase depth; how broadly separated illuminated areas can increase size; how perceived width, height and depth of spatial surfaces effect each other and describes the difference between patterns created by luminaires and patterns constituted by light.

Paper B, "Distribution of Light and Spatial Complexity: Appearance of Five Lighting Scenarios in an Auditorium" (about the Auditorium Study). This paper discusses focus and attention created by distribution of light; the relationship between the experienced light zone and the built space and how the perceived size, shape and experienced atmosphere of the auditorium shift in relation to the scenarios.

Paper C, "Spatial Interpretations in Relation to Designer Intentions: A Combined Strategies Study in an Auditorium with Variable Lighting" (about the Auditorium Study). This paper compares the designer's intentions and user evaluation.

Paper D, "Distribution of Light and Atmosphere in Urban Environment" (about the Church Park Study). This paper deals with the relations between a tangible, clearly defined space, spatial coherence and the feeling of being safe as well as power relations and a safe atmosphere.

Paper E, "Distribution of Light and Perceived Spatial Size and Shape" (about the Church Park Study). This paper focuses on perceived change in size, depth and shape of space.

Paper F, "A Full-Scale Light Laboratory in a Public Space" (about the Church Park Study). This paper concerns the role of the lighting designer as researcher and discusses if architects and designers may have a spatial understanding that differs from non-professionals.

Paper G, "Lighting Design Research in Public Space" (about the Church Park Study). This paper provides an overview of the Church Park Study, based on information that was developed further in papers D and E. Paper G includes some extra diagrams and quotations.

Appendix: The appendix includes a description of the design of the Church Park Study illumination. The appendix also includes the questionnaires from the Auditorium Study and the Church Park Study.

1.8 GLOSSARY

This is a short description of concepts that will help you read the text if you are not familiar with the lighting vocabulary. A more thorough description and discussion of the use of the concepts are found in Chapter 3.

Illuminance: a psychophysical (photometrical) concept.[6] Light measured at a point of a surface, measured in lux (Swedish: *belysningsstyrka*) (CIE, 2011).

Luminance: a psychophysical (photometrical) concept. Light measured in a given direction, at a given point of a real or imaginary surface, measured in cd/m2 (Swedish: *luminans*) (CIE, 2011).

Brightness: a visual concept. The perceived intensity of light radiating from a surface. Defined by CIE as "Brightness: attribute of a visual perception according to which an area appears to emit, or reflect more or less light." (Swedish: *ljushet*) (CIE, 2011).

Lightness: a visual concept. The perceived value of a greyscale at a surface. Defined by CIE as "Lightness: (of a related colour) – brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting." (Swedish: *ljushet*). (CIE, 2011).

Colour temperature: a psychophysical (colorimetric) concept. Defined by CIE as "temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus" (CIE, 2011). When this theoretical black body is glowing it emits differently coloured light depending on its temperature (expressed in Kelvin), from warm red, to white to bluish. (Arnkil, et al., 2012). In daily speech, the colour temperature tells if a light appears warm or cold (Swedish: *färgtemperatur*).

Reflection: Defined by CIE as "process by which radiation is returned by a surface or a medium, without change of frequency of its monochromatic components" (CIE, 2011).

Spacious, spaciousness: roomy, the experience of a larger spatial volume or a large ground area (Swedish: *rymlighet*).

Spatial, spatiality: an issue that relates to space and room (Swedish: *rumslighet*).

Spatial enclosure: the experience of a tangible, clearly defined space. (Swedish: *omslutenhet*)

Spatial distribution of light/distribution of light: in this thesis context how light is visually distributed within space, the spread and direction of light. (Swedish: *rumslig ljusfördelning*).

Light zone: a tangible spatial unit created by light within a space (Madsen, 2004, 2006). (Swedish: *ljusrum*)

6. Illuminance and luminance are photometrical concepts referring to "electromagnetic energy weighed against a theoretical model about sensitivity of the human visual system to radiation within the so called spectrum", the V(λ) curve (Arnkil, Fridell Anter, & Klarén, 2012).

Dark zone: a tangible spatial unit created by darkness and shadows within a space (Swedish: *skuggrum*).

The experienced space: what you as an observer regard as the space. It can also be a combination of several spatial units within a space. A light zone is an experienced space (Swedish: *det upplevda rummet*).

The physical space: the built space, with physical limitations. It can also have spatial boundaries of trees or bushes (Swedish: *det fysiska rummet*).

Visual spatial boundaries: the visually observed limitations of a space. It can relate to walls, the ceiling and floor of a physical space, but can also regard the experienced transition between a light zone and a dark zone (Swedish: *rummets visuella gränser*).

Light topography: created by the height of luminaire positions (Swedish: *ljus-topografi*). A concept developed in this thesis.

Spatial hierarchies: Spatial relations, arrangements and orders of spaces related to power (authority) impression/empowerment. For example, to a private or public atmosphere impression (Swedish: *rumsliga hierarkier*).

Uplight: light directed upwards (Swedish: *uppljus*).

Downlight: light directed downwards (Swedish: *nedåtriktat ljus*).

General lighting: Ambient lighting, "substantially uniform lighting of an area without provision for special local requirements." (Swedish: *allmänbelysning*) (CIE, 2011).

Raking light: light sweeping close along a surface to emphasise its texture and grain. Raking light on walls is sometimes called *wall-grazing* (Michel, 1996, p. 179) (Swedish: *släpljus*).

2. Existing Knowledge in the Field

This chapter presents an overview of research primarily related to distribution of light and spatial experience that focuses on the main topics: spatial enclosure, importance of illuminated vertical walls, perceived spatial size, depth, shape and distance and experience of spatial atmosphere, including safety. The need for more research in this field is discussed, and is the point of departure for this dissertation.

2.1 ILLUMINATED VERTICAL SURFACES AND ATTENTION RESEARCH

The eye is attracted by the viewing field's brightest areas, demonstrating the importance of light distribution (Liljefors & Ejhed, 1990, p. 37). In 1964 Piaget showed that even a week-old baby responds to the attraction of light (Michel, 1996, pp. 163–164). "The 'spotty' high contrast environment produces visual direction in a space. (…) The use of high brightness contrast is well established in the theatre as a technique for gaining and holding attention" (Flynn & Mills, 1962, p. 41). Attention can also be drawn by a "shimmering" surface or an illuminated object that functions as a dominant element (Flynn & Mills, 1962, p. 43). Flynn writes that "the highly illuminated central area causes the people and activities in the space to become the dominant features; the structure itself appears as a secondary factor" (Flynn & Mills, 1962, p. 42)

Flynn, Spencer, Martyniuk and Hendrick, have shown that study subjects prefer spaces with illuminated walls (Flynn, et al., 1973, p. 94). Subjects selected seats in the darker part of a room, facing a brighter area, where activity was more easily seen (Flynn, 1973, p. 18). Flynn's conclusion was that,

"For individuals who are unfamiliar with a space, attention tends to be attracted (involuntarily) by areas of brightness that contrast with the visual background" (Flynn, 1973, p. 17). In these experiments, the intensity, colour and distribution of light were studied simultaneously, making this a complex study in real space. Flynn also refers to an experiment by Sucov, et al. who found that a subject's choice of path was affected by brightness conditions and that subjects preferred the more brightly illuminated path in an unfamiliar room (Flynn, 1973, p. 17).[7]

These findings are supported by researchers at Bartlett School of Architecture at University College London. Loe, Mansfield and Rowlands investigated the importance of luminance on walls at a field of 40° in eye-level height for a degree of visual interest (Loe, Mansfield, & Rowlands, 1994, 2000). There is a proven preference for a light pattern on walls that appears bright and interesting (Loe, 1997). Additionally, Hawkes, Loe and Rowlands studied distribution of light in an office interior with 18 lighting scenarios with different combinations of uniform lighting, wallwashing, downlighting, local desk lighting and spotlighting. They found that interest was created primarily by directed light, with focused sources like spotlights, while uniform fluorescent light was considering uninteresting. Furthermore, they conclude that a uniform dim situation cannot be made better just with brighter level of light (Boyce, 1981, pp. 269–271).[8]

Veitch and Tiller have found that subjects regard a non-uniform illumination on walls as brighter than a uniform illumination on the same walls. 10% less horizontal brightness on the working plan was needed in the non-uniform setting. The non-uniform light in the study reached just the lower two thirds of the walls while the more uniform light reached the entire walls from top to bottom (Veitch & Tiller, 1995).

A non-uniform light with low illuminance can, according to Sanders, Gustanki and Lawton, be associated with less noise than a uniform light pattern. Their study observed subjects talking while waiting in a room. The non-uniformity in this case was created by switching off two thirds of the ceiling lighting in an irregular pattern (Sanders, Gustanki, & Lawton, 1974).

Govén, Laike, Pendse and Sjöberg found evidence for illuminating walls

7. The study Flynn refers to is L. H. Taylor and E.W. Sucov1974. The movement of people towards lights. *Journal Illuminating Engineering Society 3(3): 237–241*
8. Boyce refers to: R. J. Hawkes, D. L. Loe and Rowlands, E. 1979. A note towards the understanding of lighting quality, *Journal Illuminating Engineering Society 6(111).*

considering that the retinal third receptor (the photosensitive ganglion cell, related to the human biologic clock/circadian rhythm) is especially sensitive to vertical light (Govén, Laike, Pendse, & Sjöberg, 2007). In the study, there was a preference for a higher background luminance level (100 cd/m² with 500 lux on the horizontal plane as average), yet not the highest one tested. Interestingly, informants judged 100 cd/m² as brighter than 350 cd/m².

ART, "Attention Restoration Theory," connects attention and visual focus to restoration and stress reduction (Kaplan, 1995). The four interrelated factors of *fascination*, *being away*, *coherence* and *compatibility* are important to recuperating from mental and attentional fatigue (often stress related). Illuminated trees and facades can be fascinating, nature is also fascinating. By illuminating spatial boundaries and vertical surfaces, the coherence of a tangible space should also contribute to the restoration effect. Nikunen and Korpela have shown that the illumination of trees and bushes especially increase the restoration value according to ART (Nikunen & Korpela, 2009, 2011). By illuminating vegetation, three aspects relevant for restoration are filled: focus on vertical surfaces, increased depth view and emphasised nature.

Michel refers to findings by Coren from 1969 showing that more brightness contrasts between an object and its background – sometimes a difference of 20% is needed – imply that the object is seen more as a figure than as a background. The concept of "an ambiguous figure paradigm" is used to describe when a sample can be seen either as a figure or as ground. Still, a specific potent figure can stand out also without brightness (Michel, 1996, p. 55).

2.2 SPATIAL ENCLOSURE RESEARCH

Thiel, Harrison and Alden have investigated the experience of spatial enclosure. They found that test subjects arranging images of spaces according to the perceived level of enclosure consistently arranged them on a scale between spatial openness and spatial closedness. The overhead surface (ceiling) in this experiment appeared to be the most important spatial surface for the perception of enclosure, followed by the side walls and the centre (rear) wall. The floor was judged to contribute the least to the perception of enclosure (Thiel, Harrison, & Alden, 1986).

According to Hesselgren, the perception of a restricted space increases when wall screens were added to form a circle with a diameter of 3 meters, and also when the level of light was increased (from 1 lux to 10 lux, 100 lux and 1000 lux) from a pendant luminaire placed in a central position. An ob-

server's perception of a space as restricted increased only up to an illuminance of 100 lux, though beyond 100 lux the observer's perception of restriction decreased (Hesselgren, 1969, pp. 364–365).

> "From this experience we think we have learned that our experimental method works: we *can* measure the intensity of the perception of the restricted space, and we *can* measure contributions from different perception (or sensations) modalities. But we cannot yet draw any practical conclusions how to handle visual form and light perception. For this purpose more complicated experiments must have to be carried out."(Hesselgren, 1969, pp. 364–365).[9]

These experiments focused on light level and illuminated walls. At least in Hesselgren's case, all walls may have had equal lightness since they were placed at the same distance and angle from the light source. Hesselgren's finding that the light level has a threshold where the experience changes is similar to a study by Lau, who found that a room becomes more pleasant as the illumination increases to a certain point before it gives discomforting glare (Lau, 1969, p. 45).

Stamps conducted a study on the relationship between safety and enclosure using computer-generated scenarios of urban settings in daylight. Enclosure was evaluated through five physical factors: percentage of unobstructed view, overall lightness of the scene, depth of view unhindered by obstacles and how many sides are open at the front of the scene. Safety was found most affected by the overall lightness of the scene. According to Stamps, the neurophysiologists Epstein and Kanwisher wrote in 1998 about a region of the brain (the parahippocampal area) that responds more strongly to images showing spatial enclosure than to objects (Stamps, 2005). In another study examining the judging of spatial enclosure in images Stamps found that visual permeability (the ability to see and move through a space) is important and that the level of permeability had the largest impact on the experience of enclosure. However, the level of light (the average amount of daylight from the overcast sky) and the visible horizontal area also had a great impact on the experience of enclosure. Darkness created a perception of a larger enclosure while lighter environments were perceived as more open (Stamps, 2010b). In a study of multiple boundaries Stamps found that enclosure is most related to boundary height,

9. The images from Hesselgren's text are to be found at fig 55:3–7, in *The language of architecture*, Vol 2 (Hesselgren, 1969).

more so than boundary porosity or boundary proximity (Stamps, 2012b).

Several of the researchers that study spaces through images refer to Gärling who compared assessments of openness to closedness, and spaciousness to enclosure in real spaces with assessed environments in photographs and perspective drawings. He found that judgements of images are nearly as reliable as judgements in real settings (Gärling, 1969a, 1969b, 1970a, 1970b, 1972). Sketches that indicated only spatial boundaries were shown to be as reliable for spatial depth judgements as full detailed drawings (Gärling, 1970b, p. 104; Michel, 1996, p. 107). Gärling also found that study subjects may confuse open spaces with large spaces and enclosed spaces with small spaces (Gärling, 1969a).

2.3 SPATIAL PERCEPTION RESEARCH OF DEPTH, SIZE AND SHAPE

More studies have been performed in the field of perception psychology that examine the relationship between the level of light and the perceived room dimensions. In 1898 Ashley had already found that brightness influenced distance judgements (Ashley, 1898). Coules found that a brighter object farther away is equivalent to a dimmer object that is nearer (Coules, 1955). People may perceive differences in size that are not present in the actual space. Epstein, Park & Casey found, when writing a review of the current knowledge of size and distance relationship that there is no equivocal one-to-one relationship between physical distance and apparent size (Epstein, Park, & Casey, 1961). Additionally, Gärling found that subjects judged depth and size consistently (Gärling, 1970a, 1970b).

There are examples of previous research showing that brighter objects are perceived to be closer. In newer experiments Michel demonstrates a finding called "gamma movement," named by Kenkel in 1913, that shows how a bright form advances in space to look both larger and closer (Michel, 1996, pp. 12–13). Oberfeld, Hecht and Gamer write that it has long been known that brighter objects tend to come nearer and also appear larger than dimmer objects seen from the same viewing angle (Oberfeld, et al., 2010).[10] Oberfeld, et

10. Oberfeld, et al. refer to Coules, 1955; Helmholtz, 1867; Mount, Case, Sanderson, & Brenner, 1956, to show that that brighter objects are perceived as approaching. To show that brighter objects are perceived as larger they refer to Ashley, 1898; Gundlach & Macoubrey, 1931; Holway & Boring, 1940; Oyama & Nanri, 1960; Robinson, 1954; Wallis, 1935.

al. also write that a bright object can appear less distant. They explain that this relates to an "irraditation in the ocular media or on aerial perspective" (Oberfeld, et al., 2010).[11]

However, when reviewing literature for this thesis, it seems more common that previous researchers refer to brightness as increasing distance and spaciousness in spaces. Flynn found that a higher and more uniform level of light in a room made subjects experience the room as larger. A wall-oriented "peripheral" lighting or a combination of peripheral lighting and a low level light from overhead lighting seemed to be most beneficial for an impression of spaciousness. Direct light seemed to make the space confining, especially at low levels. Flynn and colleagues tested similar lighting arrangements in both rectangular and irregularly shaped rooms but found no significant difference in judgement (Flynn, et al., 1973, pp. 88–90; Murdoch & Caughey, 2004, p. 71). The IESNA Handbook gives a summary of Flynn's research, where there is a relationship between the impression of spaciousness and brightness. The guidelines say that brightness is a reinforcing factor, but not a decisive one (Rea, 1993, pp. 99–100). Flynn and Mills write that only downward-directed light with narrow distribution de-emphasised ceiling and vertical surfaces, while upward-directed light makes the ceiling dominant (Flynn & Mills, 1962, pp. 17, 19).

Matusiak has conducted several studies on the distribution of light and spatial experience, primarily in relation to daylight, though also with electric light (Matusiak, 2004). The luminance of illuminated surfaces was set to the same luminance as the painted surfaces; either the illuminance on the surface or the reflection factor was increased. These studies show a clear relationship between increased light and an impression of spaciousness. Matusiak found that when borders between surfaces were defined by a strong luminance contrast, observers could more accurately assess the actual size of a space. When there were small luminance contrasts between the surfaces, a higher luminance of a surface made it appear farther away and so the space was perceived as larger. Matusiak writes that "it seems that the human visual system response [sic] a little more to the reflectances than to lighting evaluating the size impression of the room." Another study by Matusiak shows relationships between a horizontal window and a wide spatial impression as well as between a vertical window and a higher spatial impression. Findings

11. Oberfeld, et al. refer to Emmert, 1881; for a critical discussion see Epstein, Park, & Casey, 1961, and for aerial perspective see Helmholtz, 1867.

also showed that a stronger light on a room surface made the surface appear farther away (Matusiak, 2006). Matusiak has also studied whether width or height has the largest impact on the impression of room size. Her conclusion is that one part of the study, with school children as observers, supported the hypothesis that width has a larger impact than height, but this was not confirmed with architecture students as observers (Matusiak, 2008). The findings were much clearer with full-scale rooms in daylight than with dimly illuminated rooms or rooms in virtual reality.

Differences in perceived spaciousness between direct and indirect fluorescent lighting are studied by Houser, Tiller, Bernecker and Mistrick (Houser, et al., 2002). Eleven different combinations of uplight and downlight with the same horizontal illuminance were studied. They found that indirect light most increased the spacious impression and that direct light decreased spaciousness. They also found that the walls and the ceiling contributed significantly to the perceived brightness.

Stamps and Krishnan have studied the relationship between spaciousness and boundary roughness, such as considering the smoothness of a wall surface and the grain size on the surface (Stamps & Krishnan, 2006). Their main finding was that there was an inverse relationship between smoothness and perception of spaciousness: roughness, such as openings in book shelves, increased spaciousness. In other words, boundary roughness is also linked to enclosure. They also tested light conditions in two experiments and found in one case that a darker space was seen as larger and in the other case the opposite, that the brighter room was seen as larger. The difference between these contradictory findings lays primarily in the variation of light level between the studies; the first study where darkness appeared to increase size was generally darker than the second study. Additionally, they found that the floor area was a strong predictor of a spacious impression. Horizontal area (the area one can walk on) is found to have the largest effect on perceived spaciousness (Stamps, 2009), followed by boundary height, while the effect of elongation differed between concave and convex spaces. Colour appeared less important for spaciousness than the other properties (Stamps, 2010a). Fog has been found to increase an open impression (Stamps, 2012a).

There are several examples from the field of colour research that are relevant to studies of lighting. When Billger performed a workshop with architectural students a room with darkly painted sidewalls and a white ceiling, the back wall and floor were either perceived as higher and narrow, or deeper and wider, depending on how the surfaces were perceived together. It ap-

peared that ceilings and floors were most important for judging the height of the space, while the walls either opened up or made the space feel more enclosed (Billger, 2006, pp. 161–162).

Through virtual-reality experiments Oberfeld, Hecht and Gamer discovered that a bright ceiling makes a space appear more spacious and that lightness contrasts on painted walls further emphasise the enlarging effect of the bright ceiling. They also found that floor lightness and the total brightness of the space has less of an impact on the perceived height (Oberfeld, et al., 2010). Furthermore, Oberfeld, et al. point out that the brightness contrast is more important for spatial depth than the level of brightness.[12] If there is a large contrast between an object and the background that it is seen against, it is more likely that the object appears nearer. This relationship seems independent of whether the object or the background is brighter or darker. The given explanation is that aerial perspective reduces both area contrast and the texture contrasts.[13]

The experienced room size has also been studied in models and full-scale rooms by Acking and Küller (Acking and Küller, 1966). Their informants assessed a rectangular space to be higher than a square space with the same volume. They also made similar experiments in spaces with and without windows, yet the lighting situations in both were too different to be really comparable. When Küller and Acking compared a furnished room to an unfurnished room, the furnished room was consistently judged to be smaller (Acking & Küller, 1966). Acking and Küller also concluded that a room with a black floor was perceived as 10% smaller than with a white floor. An additional study dealt with changes in brightness of two opposite walls. One room had dark, long side walls and white, short rear and front walls. In the other room the colours were opposite. The room with long, dark side walls was perceived as oblong. They concluded that dark walls visually contract a space, while bright walls seem to be farther away from each other (Acking & Küller, 1966). Küller writes: "Several attempts show that the lightness at the boundary surfaces in a room, i.e. walls, floor and ceiling, impact the judgement of the spatial enclosure" (Küller, 1975, p. 12).[14]

Hård presented a study where colour, wall patterns and lighting were

12. Oberfeld, et al. refer to Dresp, Durand, & Grossberg, 2002; Egusa, 1983; Farné, 1977; Ichihara, Kitagawa, & Akutsu, 2007; O'Shea, Blackburn, & Ono, 1994; and Rohaly & Wilson, 1999.
13. Oberfeld, et al. refer to Ichihara, et al., 2007; Ross, 1967.
14. Swedish quotation: "Flera försök visar att ljusheten hos de begränsande ytorna i ett rum, dvs. väggar, golv och tak, inverkar på rumslighetsbedömningen."

changed in small full-scale rooms, with the aim of investigating how these things affected the impression of room dimensions (Hård, 1995). The results are not, however, consistent enough to formulate any clear conclusions or hypotheses.

To conclude the literature reviewed in this section, it seems that brightness has the effect of increasing distance and spaciousness in spaces. It appears much more common to generally refer to brightness as increasing distance in space than to decreasing it. Yet, distance also appears to decrease for brighter objects. When reading this, there seems to be a context-related difference between two types of scenarios: the figure-ground relationship of a bright object in relation to a surrounding darker space, and the effect of bright spatial surfaces that often are seen as distancing and creating a larger impression. Michel describes the figure-ground relation theory by Edgar Rubin in 1915 as "how single elements are seen against the ground of other parts of a greater composition" (Michel, 1996, p. 53). However, a similar conclusion is not mentioned in any of the articles that I have reviewed, though there might be more research on this topic that I am unaware of.

2.4 SPATIAL CHARACTER AND ATMOSPHERE RESEARCH

Flynn studied the relationship between distribution of light and spatial experience when he compared uniform lighting to a contrast-rich lighting scenario, and peripheral (wall-oriented) lighting to overhead (ceiling-oriented) lighting. According to Flynn's findings in an indoor experimental space, a spatial experience of *privacy* or *intimacy* can be created with a low intense light near the observer with a varying light pattern placed higher and further away from the observer – and preferably with peripheral lighting rather than overhead lighting (Flynn & Mills, 1962, p. 43; Flynn, et al., 1973, p. 89). Warm, white light and non uniform light with more peripheral lighting is beneficial for a spatial experience of *relaxation* (Flynn, 1977). "High intensity illumination, for example, contributes to a sense of increased activity and efficiency; low intensity lighting tends to create an attitude of relaxation" (Flynn & Mills, 1962, p. 43). An impression of *visual clarity* (*perceptual clarity*) can be reinforced by bright, uniform lighting and some peripheral emphasis. Additionally, an illumination for *pleasantness and preference* can be created through varying contrasts and peripheral emphasis (Flynn, 1977). [15]

15. Flynn's term perceptual clarity, defined as "spatial brightness," is changed to visual clarity in some sources (Flynn, et al., 1973, p. 89).

Similar to Flynn, Manav and Yener conducted a study in an experiment office room where a relationship was found between light on walls and impressions of clarity and order, and where cove lighting (indirect lighting from a ceiling ledge) was associated with spaciousness, while uplighting from torches created an atmosphere of relaxation and privacy (Manav & Yener, 1999). However, the light source in the uplighting was incandescent light, while the rest of the room was illuminated with fluorescent light – a difference which probably interfered with the role of the distribution of light.

Most recent studies of lighting and atmosphere seem to deal with preference concerning a specific function or room type and seldom deal with *how* people *interpret* illuminated spaces. Most of these studies relate to colour temperature and light levels, and not with distribution of light. Vogels, et al. conducted several studies to describe and develop methods to collect the experiences of how an atmosphere created by light is experienced (Vogels, 2008; Vogels, De Vries, & Van Erp, 2008). One of Vogels' studies found that subjects were more attracted to a room with non-uniform lighting (Vogels & Bronckers, 2009). Pelgrim, et al. have investigated the atmosphere in hotel rooms where a combination of coloured light and scents were used (Pelgrim et al., 2006). The overall atmosphere impression seems to have been studied primarily in relation to the colour of light, like Knez who studied cognitive performance in relation to mood created by the colour temperature (Knez, 2001; Knez & Kers, 2000). Nakamura and Karasawa have investigated the relationship between illuminance and colour temperature in a living room for atmosphere preference when drinking coffee (Nakamura & Karasawa, 1999). Atmosphere and retail lighting have been studied by several researchers (Custers, de Kort, IJsselsteijn, & de Kruiff, 2010; K. Gibson, 2001; Quartier, Christiaans, & Van Cleempoel, 2009; Schielke, 2010).

2.5 LIGHT AND SAFETY RESEARCH

Several researchers refer to the work by Hediger from 1959 and 1964 on animals in captivity, where he stated that safety is the most important issue of an environment since it deals with the ability to move and the ability to perceive, both related to enclosure (Oberfeld, et al., 2010; Stamps, 2007). Jay Appelton's well-known *prospect-refuge theory* from 1975 can be described as assessing landscape environments from the ability to see (prospect) yet not to be seen (refuge) (Appelton, 1998). According to this evolution-based theory darkness can be both a refuge and a place for a criminal to hide. Loewen, Steel

and Suedfeld have tested this theory concerning daylight level, openness and access to refuge and they found that light was the most important single variable (Loewen, Steel, & Suedfeld, 1993). Loewen, et al. proposed that the safest environment is one with enough prospects to see the surroundings but not so many that a possible refuge is eliminated. They call the tension between a hazardous or protective potential refuge "a refuge ambiguity". Similarly, the permeability theory generally regards enclosure as a factor that decreases safety since a subject may feel trapped in a closed space and that a danger can be hidden by visual occlusion (Stamps, 2007, 2010b). Additionally, Stamps' study of enclosure, openness and safety in relation to daylight in computer-simulated urban settings found that safety was the aspect most strongly related to the overall lightness of the scene (Stamps, 2005). Hanyu has also found a relationship between safety and well-lit or visible settings in a study of photos of urban settings at night (Hanyu, 1997). Loewen, et al. and Stamps discuss these findings of visibility and safety according to the average level of daylight. However, it is important to study not only uniform light but also non-uniform distributions of light. Moreover, Stamps has also found relationships both between a non-uniform illumination and mystery as well as between mystery and a decreased level of safety (Stamps, 2007).

When Listerborn suggests measures for increasing safety in urban environment, it deals with a graded scale of open–closed spaces: "Openness in the physical design contributes to people feeling safe since the movement in the space is facilitated. Closed spaces are considered better for protecting material property. Sometimes the measures are unclearly defined on that point and different types of crime are grouped together" (Listerborn, 2002, p. 262).[16] Urban projects for increasing the experience of safety in Sweden depart from the idea that illuminating the paths and removing vegetation would increase visibility (Listerborn, 2002). It could be said that this action enhances spaciousness rather than enclosure. Furthermore, this strategy implies that illuminating the path may expose the pedestrian and also makes it harder to see what that may be hiding in the dark surroundings. Jorgensen, Hitchmough, and Calvert found that when subjects rated images of a park, a dense understory was judged as most unsafe with full enclosure, though con-

16. Swedish quotation: "Öppenhet i den fysiska gestaltningen bidrar till att människor upplever trygghet därför att rörelsen i rummet underlättas. Slutna rum anses bättre skydda materiell egendom. Ibland är åtgärderna otydligt formulerade på den punkten och olika typer av brott blandas samman."

trastingly it was second safest with no enclosure (Jorgensen, Hitchmough, & Calvert, 2002). Subjects assessed open spaces as safer than closed spaces. Interestingly, a lack of understory was considered the safest when there was full enclosure while less safe when there was no enclosure. These results indicate that people still need some sort of spatial limitation to feel safe. Jorgensen, et al. refer to Anderson and Stokes (1989) who found that well-maintained vegetation enhances security and attractiveness of urban parking lots in the US. Furthermore Jorgensen, et al. refer to a study by Summit and Sommer (1999) which showed that larger tree canopies provide more shelter (refuge) while smaller canopies allow for better prospect. The vegetation that was appreciated in daytime becomes scary in darkness; added illumination of night can also retain the positive impression. According to Nikunen and Korpela, the restorative effect of illuminated vegetation also has a proven positive impact on reducing fear (see also chapter 2.1) (Nikunen & Korpela, 2009, 2011). The illuminated vegetation not only creates fascination but also constitutes visual boundaries.

Listerborn writes further that places of fear can be created either because characteristics or culture of the physical places or because of power relations between people (Listerborn, 2002, p. 94).[17] Fear can be imagined; women are more scared and less exposed to violence, while the case is opposite for men (Listerborn, 2002, pp. 96–97, 206). Several of the authors that refer to the prospect-refuge theory saw similar differences between male and female subjects. Loewen, et al. explain that men's perception of safety was more clearly enhanced by light since it can help them take action, while women who may not be able to protect themselves did not show the same clear preference for light when judging a scenario for safety (Loewen, et al., 1993).

2.6 THE NEED FOR MORE RESEARCH

Several signs indicate that it is time for a paradigm shift in lighting research and the lighting industry, where the focus is turned from illumination based on uniform "carpets" of light to a more architectonic design regarding quality in non-uniform light. This should logically follow by a shift in focus from level of light to distribution of light, as well as from a general study of spaciousness

17. Swedish quotation: "Rädslans rum är kopplade till rädslans platser, men också till relationer mellan människor. Maktrelationer utspelar sig rumsligt med rummen är också fysiskt utformade utifrån maktrelationer."

to see what actually happens with the different room surfaces in relation to each other. In 1981, Boyce wrote of the need for a more human-centred lighting research that succeeds not by lighting everything plentifully, as was previously practised (Boyce, 1981, pp. 411–413; 2003).

> "Liberal quantities of light are distributed about so that all areas are plentifully lit. In an era of cheap energy this was acceptable. In a world with diminishing energy supplies and consequently increasing costs this practice is not acceptable. Pressure for energy conservation will force lighting to be applied with greater precision than it is at present. Lighting research is necessary to achieve this precision"(Boyce, 1981, p. 413).

Cuttle recently proposed a turn from a light planning based on standards for uniform light towards non-uniformity and lower recommended illuminance levels (Cuttle, 2011). Moreover, the European Committee for Standardizations (CEN) has recently published an updated standard for illuminating workplaces with a larger emphasis on the surrounding vertical surfaces and not only on the horizontal work plane (CEN, 2011). Furthermore, Bullough and Rea argue, for roads with low maximum speeds (less than 50 km/h), for illuminating the road's surroundings more than the road itself, since it is lit up by the cars' front lights (Bullough & Rea, 2004).

Lighting research, with a long tradition originating in physics, has worked almost exclusively with quantitative methods. In 1981 Boyce had already listed several fields where more research is needed that fit well with the topic of this thesis: "Until recently virtually all the studies of the impression created by lighting have been conceived at a very simple level. The concern has usually been either to establish how some variation in lighting appears to people or to validate some proposed new measures of lighting" (Boyce, 1981, pp. 255–256). Boyce writes that most lighting research has used the correlation method, and that more research should try new methods than the traditional, with more variety and imagination. Boyce argues: "At present there are a few studies done in realistic conditions which have indicated how to create an impression with light. But these results only apply to the specific contexts in which they were obtained. What is needed in the future is many more different contexts to be examined (Boyce, 1981, p. 409)." Boyce adds: "The subject of interest should be how people interpret the space they are in, as it is revealed to them by the lighting, not simply how satisfactory or pleasant or comfortable the lighting appears to be" (Boyce, 1981, p. 411). Accord-

ing to Boyce there is also a lack of studies that use room surfaces with colour (Boyce, 1981, pp. 276–277). Boyce also talks about introspection as a useful but forgotten technique for introducing ideas, hypotheses and concepts to be further tested (Boyce, 1981, p. 411). It seems like there is still a need for the research he proposed.

Within the field of lighting research there is an urgent need for studies in real environments. Lighting research has frequently been conducted in isolated laboratory contexts, while few studies have been conducted in real, complex spaces. We know of the principles of perception developed by gestalt psychologists in the middle of last century (Farné, 1947), but we do not really know to what extent these principles work when it comes to experiencing light in a complex space. In the 1960s, perception- and gestalt-research were expansive. The researchers strived to learn more about spatial perception, but most conclusions were drawn without experiments made in spaces. Instead, results from two-dimensional experiments were interpreted as being valid in three-dimensional space (J. J. Gibson, 1950; 1986, pp. 1–4; Liljefors & Ejhed, 1990, pp. 39, 74). On the contrary, researchers such as the psychologists Danford, et al. have criticised Flynn's studies and argued that studies where subjects judge spaces by looking at images, or even imagined spaces, are more reliable than studies in real, complex space (Butler & Biner, 1987).[18] Boyce also discussed the relevance of isolated lighting experiments in abstract contexts: *"To explore higher-order perceptions, it is necessary to put people first, rather than the lighting equipment, and to place them in a specific context, not in an abstract setting"* (Boyce, 2003, pp. 206, 210).

Today, a lot of the perception and lighting research is performed by judging slides showing computer-rendered spaces or photos from real settings. These have been shown to be reliable for their purpose, assessing one variable at a time (Gärling, 1970b; Stamps, 2010a). Still there must be a great difference when a subject can walk around in a space and see it from different angles and distances. Gibson especially talks about different kinds of vision, from *snapshot vision*, where a subject's eye is fixed; to *aperture vision*, like looking through a hole in a fence; to ambient vision where it is possible to turn one's head; and ambulatory vision, when we can walk around (J. J.

18. Butler and Biners refer to S. Danford, N. Starr and E.P. Willems (1979) "The case against subjective, cognitive report in environmental design research," in A. D. Seidel and S. Danford (eds.) *Environmental design: Research, theory and application*, Washington, DC: Environmental Design Research Association.

Gibson, 1986, pp. 1–4). In a study by Holmberg, Küller and Tidblom from 1966–67, subjects were less affected by spatial proportions when they walked around. According to Michel the informants perceived "the boundaries of the total spatial envelope in changing relationship," depending on the distance between the observer and the walls (Michel, 1996, p. 119). Furthermore, the contextual relationship, especially important when assessing safety and reassurance in urban environments, must be very difficult to imagine when assessing photos indoors.

In fact, very little lighting research has been conducted from the designer's perspective, in real, complex environments and with visual experience as the point of departure. However, today we have several examples, especially in the field of colour research, that support the need to study the object in question in the proper context (Fridell Anter & Billger, 2010). Results obtained from studies on flat surfaces are seldom applicable in spaces, as has been shown by Billger. Colours that meet in a space affect each other differently than colours on a single surface (Billger, 1999; 2006, pp. 161–162). Furthermore, Billger points out that we use a different kind of attention when we observe the whole than when we observe parts. Fridell-Anter and Billger have stressed that there is a severe lack of knowledge of colour in the spatially complex situations of real-life architecture (Fridell Anter & Billger, 2010). It should be said that the same statement is also relevant to lighting. Today visual evaluation is more frequently used in the lighting planning process because an increasing number of architects and designers are entering the field that was previously the domain of engineers. However, there is still little research to support visual judgement in real, complex environments.

The present studies of the distribution of light in space have focused on differences between a uniform and a non-uniform lighting and their relationship to an impression of spaciousness at a general level. There seems to be little research that addresses *how* the perceived shape of a space can be transformed by the distribution of light or *how* illumination of different spatial surfaces contributes to perceived changes in depth, height and width. Experiments examining distribution of light and size have primarily been studied in office environments, while those examining the relationship between atmosphere and the distribution of light have mostly focused on retail interiors. Almost all of the studies on the relationship between spatial experience and light seem to have been performed in indoor spaces. Veitch points out that Flynn's studies are rather limited, performed in only one setting and published as an interim report, still these results are taken for granted within

the whole lighting community. She stress that many more contexts and samples are needed (Veitch, 2001). There seems to be a complete lack of studies examining how atmosphere is experienced in real, complex spaces outdoors, with some exceptions in safety research. The results from studies of indoor spaces may have relevance for outdoor space, though a different context may result in different findings. Yet even more seriously, there is too little research about spatial experience and light in exterior environments.

Proposals for future studies based on this thesis are placed in the last chapter.

3. Concept Definitions and Development

This chapter defines the most fundamental concepts of this research and describes how they are used. Further concepts will be discussed as they occur in the text. Concept development is an important part of the thesis results.

Because they can deal with light physically, visually or psychophysically, concepts of light can differ significantly and are used differently, sometimes in contrasting ways. This can make the field of light concepts confusing (Arnkil, et al., 2012; Fridell Anter, 2000; Liljefors, 2010a). Psychophysics, a field established by Gustav Fechner in 1860, is based on the relationship between psychological sensations and physical stimuli. It examines both what is experienced by humans and what is physically measurable (Fridell Anter, 2000). Traditional lighting research is based on quantifiable and physically measurable qualities, described with concepts such as illuminance, luminance and colour temperature. Because this thesis is based on visual perception and experience, visual concepts like brightness, lightness, level of light and colour of light are used when discussing visual experience while physical concepts are used when referring to physically measurable qualities.

3.1 LIGHT

Does light really exist in space and if so, how does it exist? Is light only visible when it falls on surfaces or is it also possible to sense it in mid air, as a beacon of light? Small particles of dust also have surfaces that reflect light. The surfaces can be close to or far from the observer. Light can either shine directly from a source or be indirectly reflected. The light we experience through our senses is not the same as the measurable and calculative physical light radiation.

The common misunderstanding that our perception should be the same as the measurable world has resulted in a severe confusion of terminology and practise (J. J. Gibson, 1986, p. 49; Liljefors, 2003, pp. 2, 115–117; 2005).

> "According to modern physics, electromagnetic radiation is comprised of photon flows, not visible at any wavelength. (…) Any parts of the visual field act as physic [sic] stimuli to the visual qualities of the entire surroundings (space/object)." (Liljefors, 2010a).

In this thesis, *light* addresses the visible perception of light, how we see brightness on surfaces, such as the light radiation that surfaces reflect, not the physical aspect (J. J. Gibson, 1986, p. 54; Liljefors, 1997, 2003, 2005, 2010a). For example, *level of light* in this article stands for the degree of visual light an observer is able to perceive in a space, which is not the same as the measurable level of light.[19]

> "Obviously it is because of its reflective nature that light combines seeing and the visible, so that without light there can be neither seeing nor anything visible." (Gadamer, 2004, p. 477)

This thesis follows Anders Liljefors' definition: "Level of light, in this context, only refers to the relation brightness–darkness, which has similarities to a greyscale with graded steps. It does not say how well or badly one sees in the space or at a specific place." (Liljefors, 1997, p. 15).[20] The perceived level of light, such as the brightness differences we detect, in a space is generally influenced more by the reflectance of the room surfaces than by the luminous flux of the room (Liljefors, 1997, 2005, 2010b).

Especially for non-native speakers of English, it is easy to confuse the difference between lightness and brightness. Several researchers have formulated definitions that differentiate lightness and brightness (Adelson, 2000; Gilchrist, 1980, 2007). Gilchrist's definition:

19. In CIE Standard international lighting vocabulary, CIE S 017/E: 2011 "light" is defined as either "1. characteristics of all sensations and perceptions that is specific to vision," or as "2. radiation that is considered from the point of view of its ability to excite the human visual system."
20. Swedish quotation: "Ljusnivå i detta sammanhang avser endast en bestämning av förhållandet ljust–mörkt, efter en gradering liknande en gråskala, och avser inte hur bra eller dåligt man ser i rummet eller på en viss plats."

> "Lightness is the perceptual dimension that runs from black, through grey to white. The physical counterpart of lightness is the permanent property of a surface that determines what percentage of light the surface reflects. In short, lightness is perceived reflectance. Brightness is the perceptual dimension that runs from dim to bright. The physical counterpart of brightness is called luminance – that is, the absolute intensity of light reflected in the direction of the observer's eye by a surface. In short, if lightness is perceived reflectance, brightness is perceived luminance" (Gilchrist, 2007).

Brightness is the perceived intensity of light reflecting or radiating from a surface. Harald Arnkil clarified several points of Adelson's definition of brightness and lightness: "The term *brightness* refers to the human experience of the intensity of light reflected or emitted by objects and surfaces." (…) "But – as Adelson points out – also surfaces have brightness *in addition to* lightness" (Adelson, 2000; Arnkil, et al., 2012).[21] Note that lightness is not the same as whiteness!

In this text, the concept of *spatial distribution of light* is defined as a visually perceived distribution of light in a space, such as the complex interaction between several light sources (including daylight and electric light) and reflections from surfaces that can be observed visually as differences in lightness and brightness with respect to light patterns and light directions in an entire space.[22]

Colour of light is another important concept for which Liljefors has a useful definition. Liljefors describes colour of light as a tint which can be experienced through the light in a space. This concept, based in visual perception, should not be confused with the psychophysical concept of colour temperature. Colour of light is not the perceived colour of light from the light source,

21. The definitions in CIE Standard international lighting vocabulary, CIE S 017/E: 2011 are "Brightness: attribute of a visual perception according to which an area appears to emit, or reflect more or less light. NOTE The use of this term is not restricted to primary light sources." "Lightness: (of a related colour) – brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting. NOTE Only related colours exhibit lightness" (CIE, 2011).
22. CIE Standard international lighting vocabulary, CIE S 017/E: 2011 addresses distribution of light only in relation to a light source as a measurable physical concept; (Spatial) Distribution of luminous intensity (of a source): "presentation, by means of curves or tables, of the values of the luminous intensity of the source as a function of direction in space."(CIE, 2011).

nor the colours that can be seen on surfaces and objects. Colour of light involves a co-operation with a complex pattern that is still far from physiologically explained. The perception of colour of light is affected by colour temperature, the level of light, the spatial distribution of light, glare and the colours of the room surfaces and furniture (Liljefors, 1997, 2005).

3.2 SPACE AND PLACE

It seems that architects working with spatiality rarely have a clear and coherent definition of what spatiality is. Contrastingly, philosophers and sociologists write quite a bit about spatiality.

The concept of *space* can have several meanings. On one hand it addresses the *physical space*, most commonly a spatial unit enclosed by four walls. *Space* can also address an *experienced space* that doesn't necessarily have a physical delimitation of walls as borders, yet can be experienced as a clearly defined and tangible spatial unit.

What then is a space? In this thesis a space is a delimited cavity (Rasmussen, 1959). A physical space is defined by surfaces with differing positions. These surfaces consist of at least one plane standing in a three-dimensional relation to another surface plane. The surfaces can consist of walls, as well as trees or bushes. If three illuminated objects are close enough together to form a three-dimensional relationship with each other, they can be read together as a room – for example, two pillars and the ground. Spaces can be tiny or huge, yet here it refers to spaces built at the human scale. Interspaces are also just as important as built spaces, though they are not sometimes seen as such. An interspace is not the same thing as an empty space. If we use the phenomenological transcendental artistic view to see the interspace as a shape, the space is not empty (see chapter 4.1). A space can be created by subtracting (digging out, such as a cave) or by adding (building). A space can also be defined by the extension of light beams. Additionally, a lighting designer can model spaces by digging out or by building, either by adding light to an environment, or subtract with darkness and shadow.

In daily architectural practice space is mainly material, experienced with our senses as concrete, physical and geometrical. This thesis deals with limited, open and enclosed spaces. The enclosed, the embraced, the excluding and the inclusive spaces are of special interest. It seems that sometimes this is forgotten in contemporary theoretical discussions. Lefebvre and de Certeau discuss space in a metaphorical way that is useful, though we also need to go

back to basic spatial experience, because at least within the lighting field we have not yet completed all the necessarily research to be able to create well-functioning lighting environments. Lefebvre writes about space mostly as a social construction: the social space. He divides space into three main categories: physical space, mental space and social space (Lefebvre, p. 14–16). Lefebvre also identifies three kinds of spaces: 1) spatial practice, 2) representations of space and 3) representational space (Lefebvre, 1991, p. 33). De Certeau shows that spatiality also can be a modality with passages leading from one to another. A space is defined when one "takes into consideration vectors of direction, velocities, and time variables" (de Certeau, 1984). This sociological view of space is a different perspective of space than what is discussed in this thesis.

In the Auditorium Study, it became clear that the room's function was so obvious that the informants could not avoid addressing the empty chairs as an audience. Ihde's concept of *latent objects*, objects that have the inherent possibility to be regarded from several angles even though we only can see it from one direction at a time, is useful in situations such as addressing the missing public of the empty chairs (Ihde, 2000/1986, pp. 58–59). The concept of the *latent social space* was developed through this research to represent a fourth type of space that we could relate to within the auditorium, in addition to the physical space, the experienced space and the light zone (see papers B–C).

Place can possibly be an urban space defined by its location, while *space* is our experienced room defined by some kind of delimitation, a room that you may be inside of or outside of. One may consider place as a more social kind of space, while the space itself can be regarded more architectonically. To me, place stands for a position on a map, a large official square, a more ceremonial urban space or a central crossway that one refers to. These public places are often marked with light from a higher luminaire placement, such as a centrally positioned mast (Wänström, 1998). Such high, central mast light can be interpreted as signify a feeling that you are watched, exposed in a search light from above. With this, a parallel was drawn to Foucault's "Panopticon" (a prison architectural model) with a central position of surveillance (Foucault, 1975/1987, p. 196; 1991) (see chapter 3.7).

3.3 SPATIAL EXPERIENCE

The concept of *perception* is used to describe how we see and directly apprehend and understand spaces' size, shape, depth and distance. It also addresses experiences such as the level of light and the level of colour as perceived qualities.

Spatial experience includes perception, though also a wider range of interpretations. It is an indirect level of understanding. When describing the experience of being inside a tangible space, it deals more with experience than perception, since feelings are included. Furthermore, it refers to what makes a room's atmosphere seems warm, enclosed, how intense the light contrast is and if the light patterns seem to be active or calm. Even though previous research has shown that it is possible find agreement in the experience and impression of illuminated space (Boyce, 1981, p. 271), all of our perceptions and experiences are still culture dependent.

Spatial experience comprises several sub-categories: a) issues related to space as in *spatiality* and b) *spatial enclosure*, the quality of being surrounded by spatial boundaries, as in the case of vertical walls in a space, and c) the experience of a tangible, clearly defined space. Spatial enclosure does not only deal with where the borders of the space are located and how distinctly these limitations are experienced. It also refers to the experience of a spatial extension and the feeling of being surrounded, like being inside a spatial unit.

In the interviews and the inquiry, the Swedish word *rumslighet*, is frequently used. This word can be used and interpreted in several ways, since it may contain all three spatial experience sub-categories in a single word.

Enclosure is discussed in a slightly different perspective than Stamps, who uses enclosure to describe something that restricts depth and decreases safety because of occlusion and confinement (Stamps & Krishnan, 2006; Stamps & Smith, 2002) (see chapter 2.5). In this thesis, spatial enclosure means being surrounded by clearly visible spatial boundaries that increase spatial understanding and, as a result, safety.

Spaciousness is often mentioned as an opposite of enclosure (Stamps, 2009, 2012b), yet there is an important distinction between regarding a spacious space as roomy or as open. Researchers also address spaciousness differently. They either talk about a space's volume or the extension of the floor area, or both, which can make findings difficult to compare (see chapter 2.3). In this thesis spaciousness is addressed when talking both of volume and ground area extension.

3.4 EXPERIENCED SPACE AND LIGHT ZONES

The *experienced space* has an experienced extension in all directions (depth, width and height) while the physical space has a measurable extension. Sometimes they coincide. It also has the ability to express spatial characters

(closedness–openness) as well as atmosphere and mood.

There are two possibilities with experiencing illuminated spaces:

a. The borders of the experienced space can coincide with the physical space, and the experience of both can be changed by the light. (see chapter 7.2)
b. Light can constitute experienced spatial units that do not coincide with the physical space.

Light influences these experienced spaces (in both cases) by characteristics such as the:

- perceived level of light
- perceived spatial distribution of light
- perceived lightness and brightness contrasts
- interplay between lighting and inherent surface colours
- emphasis of highlighted objects or surfaces

Figure 7. These paintings illustrate visual interpretations of the concepts. From left to right, top to bottom: a light zone, spatiality, atmosphere, a delimited space, spatial enclosure, an embracing space, an excluded light zone, an airy lighting and openness. Do you agree with these visual interpretations?

Madsen has used a phenomenological approach to investigate areas of daylight as spaces within a space. She developed the term *light zones* to describe these spatial units made from light within the space (Madsen, 2004, p. 1; 2006, p. 71). Within this thesis it is shown how a light zone may compete with the *experienced space* and the *physical space*. When walls are illuminated it often signifies that they are visible and tangible. The effect of walls with a high level

of lightness can be created either with illumination or by choosing different colours for the surfaces of these walls. In this study, however, only the effect of illumination is investigated. Similarly, the term *dark zone* could be used to complement the light zone concept: an especially tangible large shadow that creates a spatial unit. Compared to dark zones, however, light zones are usually more clearly defined.

Though we only see light on surfaces, it seems possible to stand inside a light beam as if it were a room by itself. Even if you do not see illuminated dust particles you still see and sense the light falling onto your body. A light beam can be regarded as a space within a space when illuminated areas connect to each other in a three-dimensional relationship and define different planes, *boundary surfaces*. When several *illuminated areas* on a flat surface are positioned in a three-dimensional relationship to each other we can regard them as a spatial unit. What we regard as a space may shift between the light zone, the experienced space and the physical space. When we find that we are inside or outside the light zone, questions related to the atmosphere of a space arise. The shape and size of the light zone and its enclosure or openness affect the experience of being excluded, included or exposed.

Visual spatial boundaries are the visually observed limitations of a space. They can relate to the walls, ceiling or floor of a physical space, but can also be the experienced transition between a light zone and a dark zone.

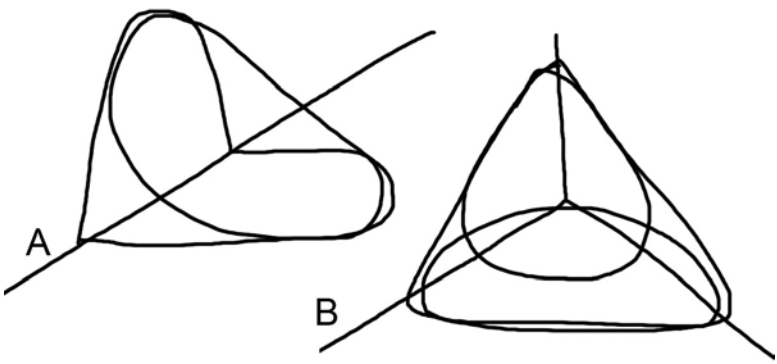

Figure 8. (A) An imaginary tangible space, a light zone created by illuminated areas in a transition where wall meets floor. (B) The shape of a light zone in a corner.

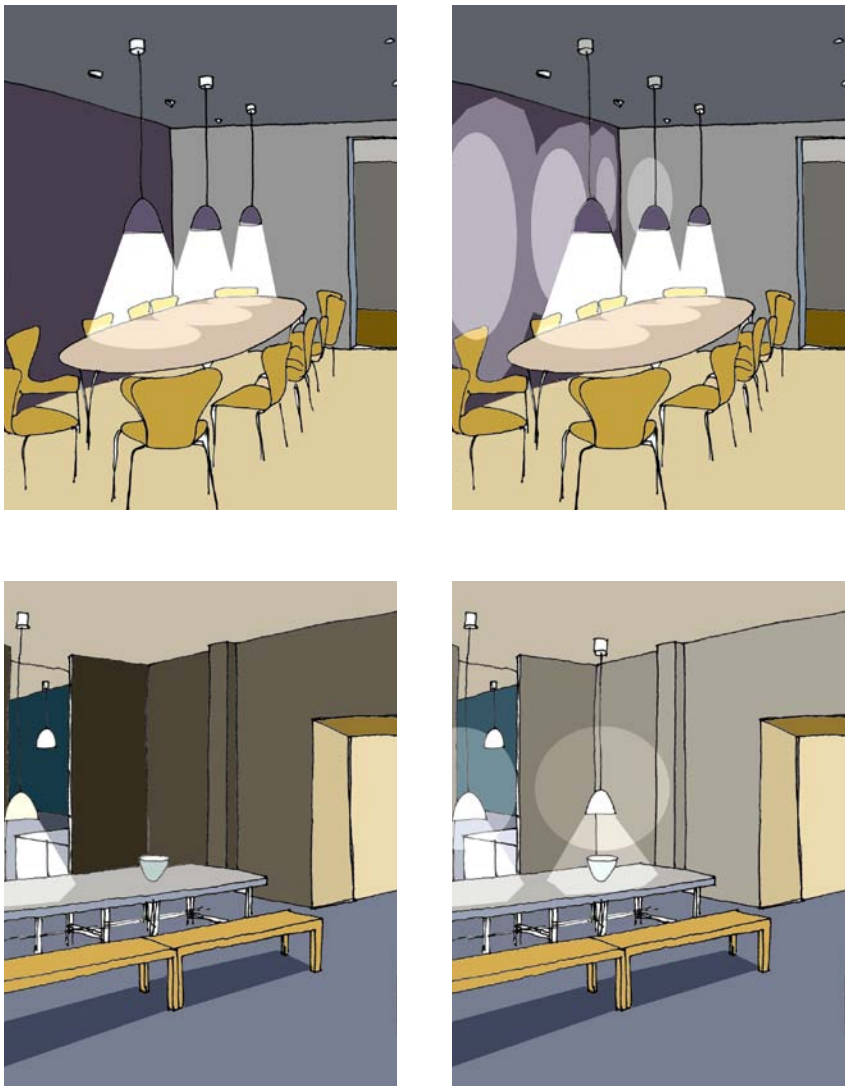

Figure 9. Here the vertical light increases the light zone and the size of the experienced space.

In the earlier conference papers (before 2012), some concepts were used that have been further developed into a more precise and consistent usage (see papers C, F and G). For the concept of *spatial enclosure*, *spatial enclosedness* was used previously.[23] *Tangible space* has replaced the earlier *obvious space*

or *legible space*. Similarly, the use of *delimited space* has changed to *clearly defined space*. Furthermore, the concepts of perception and experience were not treated consistently. Earlier, *continuous illuminated areas* was used, now *compound illuminated areas* is used for the same issue. The concept of *light room* has changed to *light zone* (previously it was *light-zone*, with a hyphen).

3.5 PERCEIVED DEPTH

Depth is an important factor in spatial understanding, since depth is what makes a three-dimensionality that can be considered a space. Those who do not work with the creation of spaces may not even understand the significance of the research questions about depth. However, to create space with light is the very essence of architecture: to make spaces visible, legible and understandable to enhance the experience of feeling safe, to facilitate orientation and the understanding of a room's function.

In order to be able to interpret a two-dimensional figure as three-dimensional it is necessary to have a perception of depth. Merleau-Ponty points out a problem with the traditional perception theory that denies that depth is visible:

> "Traditional ideas of perception are at one in denying that depth is visible. (…) In analytic reflection it is for theoretical reasons that depth is to be judged invisible: even if it could be registered by our eyes, the sensory impression would present only a multiplicity in itself, which would have be ranged over, so that distance, like all other spatial relations, exists only for a subject who synthesizes it and embraces it in thought. (…) In both cases depth is tacitly equated with breadth seen from the side, and this is what makes it invisible. (…) In order to treat depth as breadth viewed in profile, in order to arrive at uniform space, the subject must leave his place, abandon his point of view on the world, and think himself into a sort of ubiquity." (Merleau-Ponty, 2006, pp. 297–298)

Depth perceived in spaces has similarity to and can coincide with perceived *distance*, though they cannot be said to be the same thing. You may say that you feel "a depth", yet nobody says that they feel "a distance". A depth is the opposite of a flat surface, a spatiality that someone can "walk" into, while a distance is

23. Küller used *enclosedness* in the English translation of the Swedish concept *rumslighet* in the SDE method (Küller, 1972, 1975).

considered something that stretches from one point to another. You may measure the distance of a depth, but you cannot measure the depth of a distance.

3.6 SPATIAL ATMOSPHERE

The concept of *spatial atmosphere* addresses the expression or the general character of a room. It can be affected by many aspects, such as the colour of light, surface colours and materials, shape, size, function, symbols, furnishings and memories. Spatial atmosphere is regarded here more as the expression of the space rather than the impression we receive as the result of interpretation, which is more closely related to emotions. In this thesis, concepts like enclosure, privacy, safety and power are used for characterising spatial atmosphere.

Mood is a concept close to atmosphere. The mood concept seems possible to place both at the room level and at the level of the observer. We can also talk about the atmosphere between people, and this can affect our experience within a space. Still, we must be aware about differences between the spatial atmosphere and the human atmosphere. With the concept of *emotion* we take a step further away from the room and towards the observers' reaction, feelings and movement caused by the atmosphere and mood. The spatial atmosphere concept has a great scope with a range from more objective qualities related to spatial expression – like shape, angularity, openness, enclosure, softness and warmth – over to culturally related room-type associations.

There are other concepts that are closely related to atmosphere. The design researcher Desmet defines the affective state as comprising of emotions, moods, sentiments and emotional traits. He writes that there are two traditional ways to distinguish between different types of affective states, either by their origin or by their intensity (Desmet, 2002, pp. 3–5). Desmet sides with the later tradition and identifies two important differences: whether the affective state involves a relation between subject and object – an intentional or non-intentional state – or if the state is acute or the result of an enduring disposition. According to Desmet, feeling is not a distinct affective stage; rather it is a component of the conscious experience of an emotion. "Emotions are intentional since they imply and involve a relation between the person experiencing them and a particular object: one is afraid *of* something, proud *of* something, in love *with* something and so on. (…) Mood tends to have a relatively long-time character; one can be sad or cheerful for several hours or even for several days", says Desmet (Desmet, 2002, p. 5). Desmet describes

emotional traits as a personal character, like a cheerful personality. Sentiments are dispositional states that may persist throughout a lifetime, such as a fear of dogs.

The lighting researchers lead by Vogels define *atmosphere* as "the affective evaluation of an environment". Their research is oriented towards a pleasant lighting environment. Vogels, et al. write further: "In contrast to mood, the perceived atmosphere of sense is expected to be a more stable concept. Atmosphere differs from mood in the sense that it is not an affective state but the affective evaluation of the environment", and also that "it is expected that the effect of light on the perceived atmosphere will be more consistent than the effect on mood"(Vogels, 2008; Vogels, et al., 2008).

Ambient light is a confusing term in the lighting vocabulary since it is so similar to ambiance. *Ambiance* is connected to atmosphere, emotions, mood and feelings. Ambient light has long been used to address general interior lighting, often as uniform "light carpets", which is quite contrary to the variation argued for in this thesis with the focus on distribution of light. Ambient light means background light, which makes the use more understandable and comparable to ambient music that drifts amongst people in elevators and hotel lobbies. J. J. Gibson describes ambient light as the result of illumination with radiant light that causes illumination. He means that ambient light converges to a point of observation and fills the space (J. J. Gibson, 1986, pp. 50–52). According to Gibson, unstructured ambient light gives no information about an environment. Considering this conceptual confusion, the concept of ambient light is avoided both when talking about atmosphere and general lighting. Instead the term *general lighting* is used.

3.7 LIGHT TOPOGRAPHY

The height of luminaire placements is a sorely neglected issue, though important for spatial experience. This topic is emphasised in this research by clarifying it as a concept: *light topography*. The light topography is linked to hierarchies that emphasise a private or a public atmosphere impression. Hierarchies of light can be found indoors (Millet, 1996, p. 117) as well as outdoors. We can observe that different road users and speed restrictions also correspond to different heights of luminaire placements and also by the distance between luminaires. Urban light has a scale comparable to the musical scale, yet the height the light is placed at is relative, relating to functionality, environmental scale and economy. Nevertheless, ordinary street lighting

generally uses a few different heights of poles: masts with heights of 15 m to 18 m, street lighting at heights of 6 m to 8 m, park luminaires for pedestrian paths and pavements at a height of 4 m and bollards at usually around a height of 1 m. Additionally, except for the scale of height one should be able to talk about a scale of width and depth in relation to the street space. These standard heights can be regarded as the interval we have to work with within the scale. The use of different heights has a natural connection to lighting technique as well as for economic and practical reasons. Luminaires on motorways are placed high because they are powerful and can cover larger areas. It becomes cheaper with fewer luminaires and lamp poles to support them. Therefore, it would surely be cheaper to illuminate a park in this way, but the park would become far less pleasant. It seems also likely that a more uniform light is experienced as belonging to a more public atmosphere; often a higher luminaire position gives a more uniform distributed light.

Figure 10. Examples of different luminaire height, light topography.

The hierarchies of urban light can be considered in relation to the measurements of the human body. As Merleau-Ponty claimed, "There would be no space for me at all if I had no body!" (Merleau-Ponty, 2006, p. 117). Without

yet having any scientific basis for this, it is assumed in this thesis that we unconsciously relate to the built environment through our own measurements and eye height. The width and height of luminaire placements may appear more natural if these distances are not too large with respect to our own body. Low luminaire bollards (with heights of 90–120 cm) can possibly by their height and thickness (they are usually thicker than lamp posts) appear as figures indicating a human scale, with a clear perspective appearance.

Power implies a willingness to influence and direct both action and thoughts. Illumination can be used to control, to guide, to delimit, to invite, to expose and to hide next to. Someone chose what should be shown and what sort of room, what sort of atmosphere we will be able to see. Our experiences may vary due to pre-understanding, culture and contextual circumstances, nevertheless the conditions that can be experience can be limited. Design is power. Insecurity can affect the choice of path. With illumination, you can make people stop or continue. The light can control how we use a park bench, if we actually sit on it or just pass by. In our Swedish lighting culture we usually rely on visual guidance of the benevolent order to facilitate orientation, spatial understanding, or for traffic separation in order to avoid collisions because of the confusing road environments. Contrastingly, in the U.S. there are special luminaires for "security lighting" which means that powerful and glaring light is used to dazzle intruders and to discourage violations. This kind of light is not common in Sweden. Highlighting buildings with floodlight is also an exercise of power. With light topography and the amount of light and breadth of light you can illustrate hierarchies, for example between street levels and road user type. It will also likely be possible to find relationships between a "private" atmosphere and a lower-placed illumination, compared to a higher illumination that can reinforce a more public atmosphere. This is an ambiguous relationship. Depending on the context, a private or public atmosphere can either increase or decrease reassurance. Flynn, et al. write that informants described a diffuse overhead lighting with low illuminance as elevator-like while a stronger overhead light gave associations of surveillance (Boyce, 1981, p. 276).

Light topography is also useful for addressing interior lighting. Stidsen, Kirkegaard and Fisker have studied the atmosphere created by the lighting in hospital wards and found that it is beneficial to talk about three levels of lighting: a high light zone in the ceiling (for the staff's needs), a central light zone including wall areas (for patient's needs) and a low light zone with "a horizontal distribution of light floating over the floor level", with a relaxing effect (Stidsen, Kirkegaard, & Fisker, 2010).

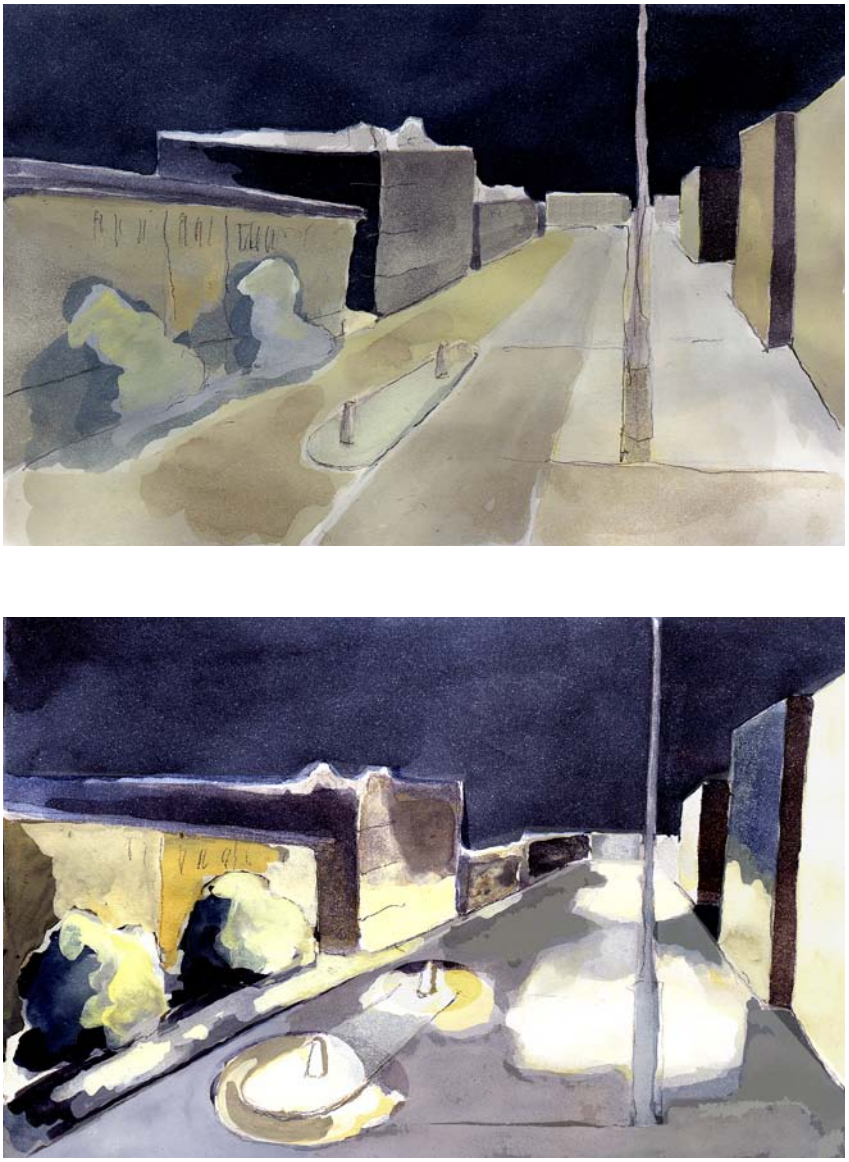

Figure 11. Uniform and non-uniform illumination.

3.8 EXPERIENCED RHYTHM IN SPACE

Uniform lighting does not have rhythm in the same way as non-uniform lighting does. Imagine a night view with a row of streetlights of equal distance between luminaires, illuminating the facades along the street. If some of the facades are darker and less reflective than others or if the row of buildings is broken by a path with vegetation, we will have a pause in the rhythm.

Rhythm is an important tool for artistic expression, not only in music but also in visual contexts. Connections and similarities between rhythm and architecture are described by Dyrssen (Dyrssen, 1995, p. 93). Similarly, Hopsch describes spatial rhythmisation of form sequences (Hopsch, 2008). Repetition of forms creates rhythmic patterns in architecture (Rasmussen, 1959). Lefebvre has developed a theory for rhythmic analysis that deals with repetition of dimensions and frequency in city environments. This theory includes cyclic rhythms regarding place, time and energy. The perception of our five senses provides the impulse to experience these rhythms (Lefebvre, 2004).

Rhythm is usually connected with movement and the passage of time. However, distribution of light creates a rhythm that we experience when walking or driving through a space. In lighting, rhythm deals with distance: the extension of light and distinct pauses of darkness that appear between the illuminated areas. Shadows fade into one another with soft, varying transitions. Repetition of illuminated areas is seen as patterns, with distances in length, width and height.

Figure 12. A repetition of illuminated surfaces creates rhythm.

Distribution of light can create dynamic variations through a more conscious planning that considers differences between bright areas, the spread and direction of light, through distances between light zones, how light zones interact with each other and the light topography. Luminaires can be placed symmetrically, asymmetrically, centred or along a wall. The light can shine from beneath or from above, straight towards a wall or close by so that the wall receives a dramatic raking light. Furthermore, rhythm can be expressed through the width between light sources, with the number of light sources, with soft or hard light and with different colours of light. One can also talk about rhythm in interior lighting in corridors, tunnels and culverts, and especially within large building complexes like in hospitals, shopping malls and airports.

Consequently, Madsen describes dark zones as pauses in an illuminated space (Madsen, 2004, 2006). Lighting designers and architects like Millet and Michel describe rhythm in lighting in similar ways (Michel, 1996, p. 180; Millet, 1996, p. 119). The relationship between rhythm and lighting is also confirmed by Bülow's PhD thesis on light and rhythm in architecture (Bülow, 2007). She primarily addresses case studies where many light sources are shifting over time, or with the variations of daylight, in relation to each other in a complex spatial context, though she also refers to a project where the rhythm is created by a pedestrian walking beneath differently coloured luminaires on a subway platform.

The environmental psychologist Drottenborg found that drivers drive more slow on beautifully streets, such as when the cherry trees are in bloom (Drottenborg, 2002). Regarding this, and the attention-restoration research mentioned earlier (Kaplan, 1995; Nikunen & Korpela, 2009, 2011)(see chapter 2.1), it seems likely that a more varied lighting will also have an effect on traffic speed and driver attention. Additionally, there might be a natural limit between traffic speed and how closely lamp poles can be placed to be able to experience a surrounding as interesting. With a uniform light, there are fewer contrasts that could catch our attention, which may cause an increase in speed. When the surrounding is too dark or when the contrasts are too large, and therefore disturbing, the attention is reduced. Whether a space is experienced as enclosing should be related to how large, high, wide and deep it is with respect to the human body.

The images below show a lighting design project I was responsible for in 2001, at White Design, where the distance between luminaires, light topography and direction of light were used to create rhythm, spaciousness and

increase the feeling of safety in pedestrian tunnels and a car tunnel connected to the railway station in Kungsbacka, Sweden. This project is also described in a book about bridges and tunnel lighting (Westholm et al., 2009).

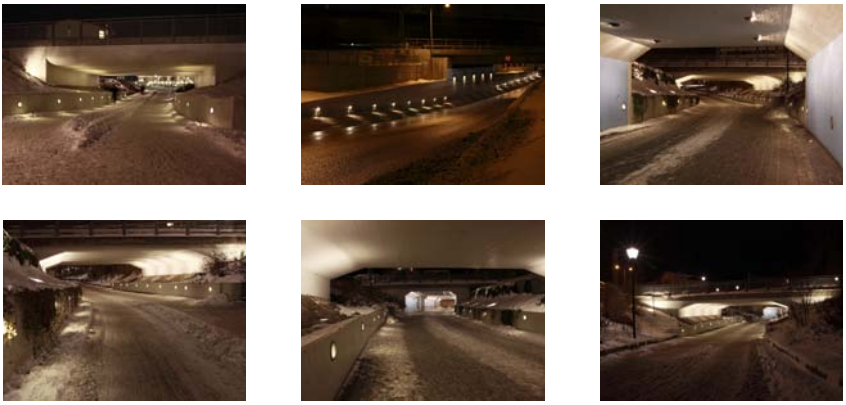

Figure 13. Lighting rhythm in tunnel sequences in Kungsbacka, Sweden. (Photo: Stefan Lindh).

3.9 THE "GOOD" LIGHT AS A METAPHOR

When working with light it is impossible not to relate to the traditionally heavily loaded metaphorical use of light. This biased language is a part of our cultural understanding. Light is a loaded positive word, as well as its opposite of darkness and shadow as negative words. Light is a symbol, a metaphor and a trope. Gadamer talks about the light of words making everything visual, evident and obvious. He points out St. Augustine's interpretation that God speaks for the first time when light is created (Gadamer, 1960/1990, p. 205; 2004). In Genesis 1:3 the climax of creation comes with "And God said, 'Let there be light, and there was light.' God saw the light was good, and he separated the light from the darkness" (*The Holy Bible: New International Version*, 2008). With photosynthesis, light is not only a symbol for life itself but necessary for all growth on earth. Light has long been a symbol for knowledge: we illuminate a problem, we talk about a bright mind and the entire 18th century was named "The Enlightenment".

Since all light metaphors seem to be dedicated to the good, it is important as a lighting designer and researcher to see through the biased language

surrounding light and dark. A good lighting design is not the same thing as a bright room. In a very bright space, it can be better to create essential contrasts by reducing light, adding darkness, instead of increasing the light levels. More focus must be put on creating good contrasts with darkness and shadows so it does not become a light competition that ends with light pollution and visual noise.

As a lighting researcher it is hard to avoid indirectly asking loaded questions since the words are already so loaded. Most words are loaded in the ways that we use them. If we search for a spatial context with the preference that it should be large, enclosed, warm and bright, even words like "narrow", "open", "cold" or "dark" may sound negative. Few words are as loaded and symbolic as light and darkness. Lightness has always represented beauty and clarity while darkness represents the evil and the hidden. Light stands for both bright and easy, as if it were a weight. One can wonder how much of this is culturally taught and what is pure perception. How do subjects respond to questions about light and darkness, when one term is so positively loaded and the other so negative? This is a problem of habit that is discussed further in the findings section (see chapter 6.3.5).

4. Methods

4.1 COMBINED STRATEGIES AND MIXED METHODOLOGIES

Design and architecture are multidisciplinary fields, a fact that is mirrored by the methods used in the studies of this thesis. The Auditorium and Church Park studies use combined strategies with mixed-methodology design (Groat & Wang, 2002) (see papers B–C and D–G). The complex approach of the Auditorium and the Church Park studies can be called *quasi-experimental*: the study object is not seen as a separate entity in an isolated experimental situation (Groat & Wang, 2002). This means working close to the empirical material and searching for patterns and connections when sorting the data. The methods, which concern visual appearance in real and complex environments, are linked to a colour research tradition (Billger, 1999, 2006; Fridell Anter, 2000; Fridell Anter & Billger, 2010; Hårleman, 2007; Hårleman, Werner, & Billger, 2007; Wijk, 2001). If the Auditorium Study and the Church Park Study can be regarded as case studies, the different light scenarios also can be regarded as multiple cases (Stake, 2006; Yin, 2003). An important function of the method is triangulations between the multiple cases and its units of analysis, between the methods and the two groups of informants. The methods of this research are based primarily on a qualitative approach that seeks not only answers to what we perceive and experience but also searches for a wider understanding of how and why we do this.

In the Scale Model Study, the spatial impact of 12 different luminaire placements is compared in two models at a scale of 1:7.5. Lau showed that scale models are appropriate for simulating full-scale illuminated spaces (Lau, 1969, pp. 43–44). Phenomenological observations (Bengtsson, 1988; De-

praz, Varela, & Vermersch, 2003; Ihde, 2000/1986; Merleau-Ponty, 2006) focus on the created light zones according to how these influenced the perception of size and the experience of enclosure. In the Scale Model Study, all observations were made personally. The phenomenological approach strives for an observable richness of variations (Ihde, 2000/1986). The object of the investigation is addressed in the way that experimental phenomenologist Don Ihde speaks about the phenomenological terms of *horizon* and *core* (Ihde, 2000/1986, p. 56), the light zone is the core and the built room is the horizon (see paper A).

All present studies started with my own observations, both to create a comprehension and also to be able to ask the right questions. Through this participatory observation I was able to better understand what the informants saw or described. In the Alingsås church park this meant taking field notes, observing subjects and their movements, walking around without the sites without talking, filming, taking photos and listening to conversations during the guided tours. In the first research study, the Scale Model Study, I was a subject that studied an object: the space (first-person experiences). In the Auditorium Study and the Church Park Study, I was a subject studying an object mainly through other subjects (second-person experiences) (see papers B–C and D–G).

The questionnaire used in the Auditorium Study allowed the 21 informants to first describe the five light scenarios in their own words before assessing open-ended semantic scales concerning spatial dimensions and spatiality. The semantic scales ranged from −3, not at all, to +3, a very high level, with a neutral value of 0. It was a conscious choice to not use *semantic differential scales*, since it was assumed that contrasting concepts could receive positive answers by the same informant: because of different interpretations and spatial complexity, a scenario could be experienced both as limited and open at the same time. The not-at-all option was assumed to work as a control for the answers: a low negative value would indicate that the informants are separating a negative value from a neutral value. A seven-grade scale with only positive values was considered for more precision than what was reasonable for the task. However, the statistical consultant later chose to reduce all negative values to zero so that the huge empirical material fit the statistical models and could be displayed in histograms. The use of a questionnaire with free descriptions combined with semantic scales is inspired by the work by Billger (Billger, 1999) and Stahre (Stahre, 2009).

The semantic scales were followed by having the informants circle adjec-

tives that characterised their experience of the spatial atmosphere. After assessing every lighting scenario, one at a time, a deep interview followed (Kvale, 1996). The interview produced answers to the concepts, how the informants interpreted the questions and additional information about their spatial experience. The interviews included a sketching task where the informants drew the boundaries of each scenario's experienced space in both plan and elevation views (Branzell, 1976, 1995). The informants each stayed 2–2.5 hours in the auditorium. The auditorium questionnaire was primarily used as a basis, a manuscript for the interviews. Due to the complexity, the statistical material was analysed through percentage and displayed as histograms (see papers B, C and the questionnaire in the appendix).

The Church Park Study was evaluated with a shorter and simpler questionnaire with 11 multiple-choice questions. Because any passers-by were asked to participate in the study it was assumed that more questionnaires would be completed if the informants were not occupied for too long. 222 questionnaires were collected during a period of 5 weeks. The lighting that they assessed shifted according to a precise schedule. For the analysis of the church park questionnaire findings, the statistical consultant chose a logistic regression analysis. Additionally, over 22 evenings, 27 video-recorded interviews with 39 informants were conducted. Some informants answered the questionnaires and were also interviewed. The interviews helped to understand how subjects answered the questionnaire and why they had answered in the ways that they had. On three separate occasions focus groups were also assembled to discuss the experimental lighting. 18 informants answered the English version of the questionnaire, while the others answered the Swedish version. During the lighting workshop and the following light festival, Alingsås was visited by many international lighting designers (see papers D–G and the questionnaire in the appendix).

4.2 INTERVIEWING APPROACH

Different interview approaches were used for the Auditorium Study and the Church Park Study. The auditorium interviews were 1.5- to 2-hour-long deep interviews that followed a script to understand how subjects answered the questionnaire. In the Church Park Study the length of interviews varied from a few up to 45 minutes. A selection of interview quotations was chosen based on their representative and descriptive qualities and the quotations were arranged in themes as a basis for the analysis (see papers B–G).

Alvesson has identified three main types of interview approaches: *neo-positivism*, *romanticism* and *localism* (Alvesson, 2011). According to Alvesson these interviews follow a mainly romantic view of the interview situation (Alvesson, 2011, p. 13). In the romantic approach the interviewer establishes an open and relaxed relationship with the interviewee, adjusting the manner of speaking depending on the situation and the interviewee (Alvesson, 2011, pp. 11–23). Consciously confirming what the informants say makes them feel relaxed, considered and important. Through this, a warm, encouraging atmosphere is created between interviewer and interviewee. With this approach it is possible to use informants that are already acquainted with the interviewer. It is still important to be aware that the interviewer and the interviewee assume different roles in relation to each other through the conversation. In the Church Park Study the interviewees were encouraged to speak freely in an effort to get them to elaborate and thereby produce richer results. I sometimes discussed and questioned their statements to stimulate further questions and encourage a response that might strengthen their statement. Every meeting was seen as unique. However, the Church Park inquiry related also to a neo-positivistic approach by using questionnaires and a large number of informants, as well as a somewhat localist approach by regarding and discussing the role of the local context.

A reflexive approach was used to further develop the qualitative analysis of the interviews (Alvesson & Sköldberg, 2009). Reflective interpretation is a method that combines several theoretical and methodological schools in order to provide a view of the material from many aspects. This approach consists of an analysis of the interviews through eight metaphors comprising social scene and dynamics, identity work, impression management, application of cultural script, political interest and other motives for talk, language construction work and powers of discourse (Alvesson, 2011). These metaphors visualize the interpretation process and the theoretical foundation. In this case, the interpretation includes phenomenology, hermeneutics, poststructuralist and critical theory. After transcription, the interviews were structured according to themes relating to content and the research questions. A selection of quotations was chosen to illustrate where the metaphors were able to display underlying aspects that might have had an impact on the informants' statements or the interplay between interviewer, interviewees and the local context. The reflexive interpretation was mainly used in the process of analysing the quotations, and led to the methodological discussions displayed in chapter 7.

Table 1. Interview approach, overview (below).

Study	The Auditorium Study	The Church Park Study
Interview type	Structured	Unstructured
Interview perspective	The interview is structured around a questionnaire with several methodological moments.	Interview is used as a complement to a questionnaire with 222 answers, for a deeper understanding of these answers but also to ask other questions than in the questionnaire.
Interview length	Long, between 60 and 110 minutes after the questionnaire was answered. 27 hours of recorded material.	Shorter, 1–30 minutes. 3 hours and 45 minutes of recorded material.
Interview theme	Spatial interpretations, relations between five light scenarios and spatial experience.	Spatial experience and atmosphere according to four illuminated objects that changed with a timed schedule, and two objects that displayed two variants simultaneously, each changed by a button press.
Interview procedure	Face to face, with sound recording.	Face to face, with video recording.
Interview place	In the room of the study In November and December.	In the public space of the study. Outdoor, autumn cold in October.
Interview context	In an empty, real room with existing lighting.	At a light festival with a temporary light installation designed by the researcher.
Light scenarios shift	Changed by a button press by the researcher that allowed the scenario orders to switch back and forth during the interview. When the questionnaire was answered every informant had a specific order of the scenarios, 4 to 5 people had the same order.	The scenarios shifted according to a timed schedule so that the interviews started at different point in the lighting schedule. The informants could enter the space from any direction.
Informant selection	21 subjects that agreed to take part of the study after a request by email. Half of them were architects or designers (11 of 21). 14 were women. Age span around 25–60 years. Most of them were more or less acquainted with the researcher. Only one of the informants was not born Swedish.	Mostly subjects who passed by and agreed to answer some questions on the spot. The interviewees were not asked about their occupation, but 33% of the questionnaire informants were designers or architects. Half of the interviewees were acquainted with the researcher. 21 were women, 18 men. 9 participants are known to live in Alingsås, and 8 were known to be designers or architects, but they were not asked about this. Age span was 25–70 years.
Number of interviews	21 people.	27 interviews with 39 people.
Interview persons	Single	Single and pair

4.3 METHODS FOR SPATIAL ANALYSIS

As well as it's use as an illustration, sketching is a way to test ideas and to strengthen and distil a hypothesis (Häggström, 1997; Molander, 1996; Schön, 1983, pp. 79–93; Skipetari & Nijhuis, 2012). Note that the design planning sketches for the Church Park Study are biased since they express my view of how the planned lighting would be perceived.

From the lighting designer tradition, test lighting is brought into the research. Test lighting is similar to the sketching in that it also implies a way to achieve a desired result by trial and error. The design of the trees and the graves in the Church Park was a result of two weeks test lighting (see papers D–G and the appendix). Some may question the use of one's own design as a subject of research, such as in the Church Park Study. In this case preference questions were avoided; questions about size, shape and atmosphere seem less open to bias form informants trying to please the researcher with their answers.

Figure 14. Sketches from my observations in the Auditorium.

A spatial analysis inspired by a combination of the mapping methods of Lynch (Lynch, 1960) and Branzell's sketching method of experienced spatial extension and directions (Branzell, 1976, 1995) was also conducted (see papers B–D). These methods were used in a pilot study and partly used in the interviewees' sketching task in the Auditorium. The lighting design in the Church Park was planned after an initial Lynch mapping that included finding paths, key nodes, borders, transitions, areas and landmarks. Additionally, Trieb's method for town analysis was used as a guide to find the height for the

luminaire placements (Trieb & Markelin, 1977). Each building was marked by a central vertical line that illustrates the street's rhythm, a horizontal line that gave the topographical contour of the buildings and a cross that marked the proportions. Furthermore, Cullen's *serial visions* method was used to find balance in the variation of the Church Park lighting design (Cullen, 1961). Even if these methods were used mainly for the initial design phase, they also came to influence the research analysis.

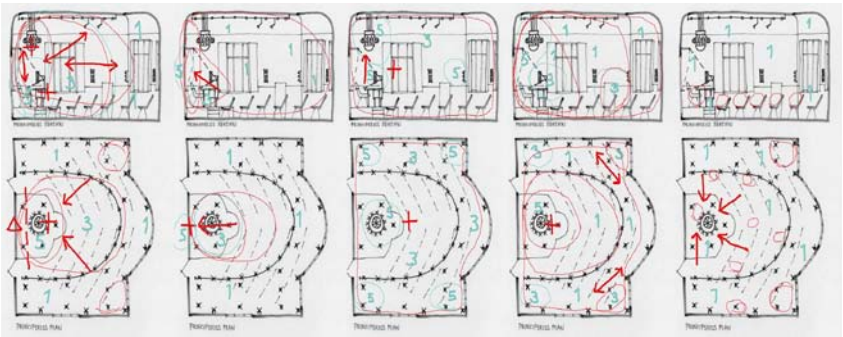

Figure 15. Analysis inspired by Branzell and Lynch.

Madsen formulated the *light zone* as a tool for analysis and as a sketching method (Madsen, 2004, p. 71; 2006, p. 1). She divided the light zones into categories: A) is a single or separate light zone, B) is where light zones are close to each other, while C) is where light zones overlap to create a compound illuminated area. Madsen's observations were the starting point for examining illuminated fields, though the Auditorium Study used artificial light sources and shadow fields, as a play of patterns of contrasts and spatial phenomena. In this thesis Madsen's light-zone concept and analysis are further developed. Søndergaard elaborated Madsen's light-zone concept into a technique for exploring physical spaces based on theatre performance methods (Sondergaard, 2011). The extension of the light zone is "felt" by moving within it while analysing and taking notes, an approach that is similar to the approach in this thesis.

Another new method, *colour-shape interaction analysis*, was used to increase the understanding of perceived size and shape (Häggström, 2009, 2010). The four concepts of *disruption*, *countershading*, *co-shading* and *constructive shading* are used to describe how light and shadows follow and

reinforce the original shape of a building facade (co-shading) or how they disturb and visually flatten the real shape of the space as a false relief (countershading). A disruptive colour pattern is a contrasting surface pattern that conceals the real shape of an object. Inverted countershading (co-shading) follows the shape and enhances visibility rather than camouflaging it. If the shading visually re-shapes the original construction this is called constructive shading (see papers A, D and E).

Additionally in the Church Park Study, classical illusions such as the *Oppel-Kundt illusion* and the *Müller-Lyer illusion* were used to analyse and elucidate the phenomenon observed concerning width perception (Carraher & Thurston, 1966, p. 110; Wackermann & Kastner, 2009) (see paper E).

The *visual evaluation* method by Liljefors and Ejhed (Liljefors & Ejhed, 1990) is used in the Auditorium Study and the Church Park Study as a point of departure for the questionnaire and for my own observations. The *percifal* method is a further development of the *visual evaluation* method that uses eight concepts to describe the spatial experience of colour and light: level of light, distribution of light, shadows, light patches, reflexes, colour of light and surface colours (Arnkil, Fridell Anter, Klarén, & Matusiak, 2011; Matusiak, Fridell Anter, Arnkil, & Klarén, 2011).

4.4 PROCEDURE OF ANALYSIS

This empirically based research uses an abductive procedure (Alvesson & Sköldberg, 2008, p. 198; Johansson, 2000). The path through the three research studies has not been a straight line. The assumptions and the research questions were developed from initial observations and previous research, tested in pilot studies, and again further developed and tested in a hermeneutic circle (Alvesson & Sköldberg, 2008, pp. 55, 269, 480; 2009). Some observations during design practice lead to questions that have been developed through the studies, and are still developing. This research started with three pilot studies, a picture questionnaire, tests with scale models and observations made in the auditorium. These studies were continued back and forth (see figures 16, 17 below and chapter 6.7). After every study the findings have been regarded not only as results but also as new, more developed assumptions. The study findings often produced more questions than they began with. Even so, the main questions were refined through this process. This research produced more dimensions and perspectives than were initially expected. Each study produced new theories and methods.

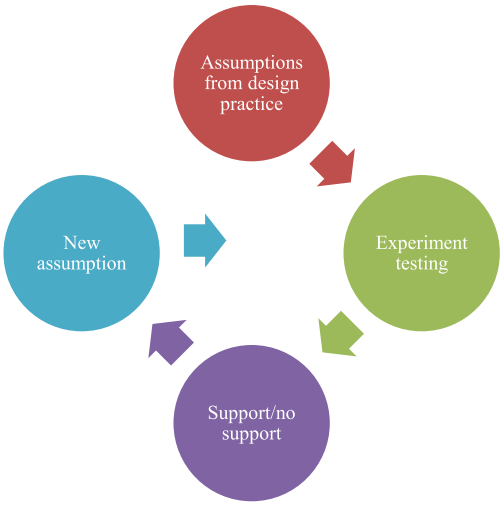

Figure 16: Showing the analysis process.

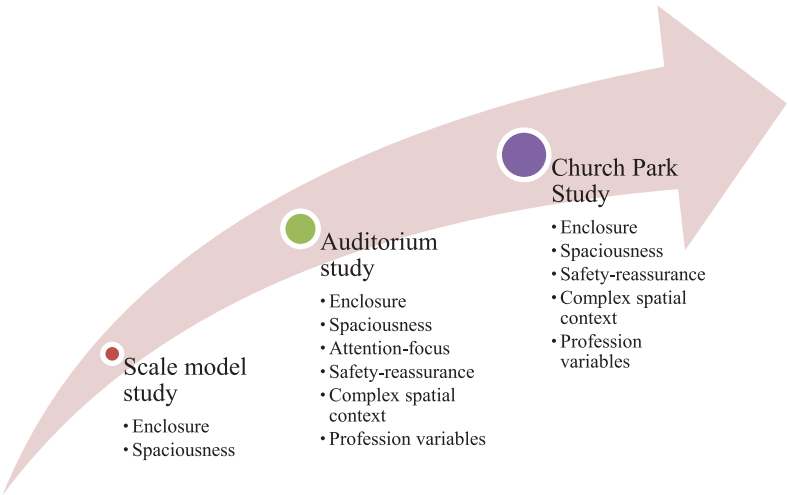

Figure 17: Showing main topics in each study.

Even though there were different contexts and informants in the two later studies, some findings from the first study were repeated in the second and third studies, and between the second and third studies (see table 2, in chapter 6.7). After all studies were completed and documented the findings of all studies were compared with each other, as described in chapter 6.

Questions related to enclosure and spaciousness from patterns of light zones were repeated in all three studies. The real-life studies focused on spatial complexity, the use of informants prompted questions of concept interpretation and professional pre-understanding (see figure 17).

4.5 THE CHOICE TO NOT USE SOME ESTABLISHED METHODS WITHIN THE FIELD

The auditorium questionnaire was created with inspiration from Küller's *semantic description of environment* method (SDE) (Küller, 1972, 1975).[24] It was a conscious choice not to work with factor analysis in this research, even though there were two different methods based on factor analysis that may have been suitable for evaluating spatial experience and atmosphere, Küller's SDE method and Vogels' *atmosphere metric* method (Vogels, 2008). Neither of these methods ask the same questions that this thesis poses. SDE is a method in which descriptive words can be calculated in a quantitative way and transformed into graphs through factor analysis. SDE uses eight categories of spatial characters described with different words. The words and categories are chosen for the method depending on how often subjects in a pilot study used them. However, they were not found suitable for the context and research problems of this thesis. Another reason that these methods were not used is that factor analysis appears to combine words too roughly. The method's categories are *pleasantness*, *social status*, *enclosedness*, *originality*, *complexity*, *affection*, *unity* and *potency*. Of those categories, only "enclosedness" and "complexity" are relevant for this research. "Potency" could have been relevant as a category describing the connection between spatial hierarchies of power and the feeling of safety. Still, it did not seem appropriate when the enclosedness category is described by the words *masculine*, *fragile*, *powerful* and *feminine*. Likewise, Vogels' atmosphere metric method includes words that are similar to those used in this thesis (16 of 38 words), while other words used in this thesis such as *embracing*, *enclosing*, *inclusive*, *excluding*, *inviting*,

24. In Swedish: Semantisk miljöbeskrivning (SMB).

sacred lack a correspondence, making this method unsuitable for this research. Furthermore, the selection of atmosphere terms was too contextual, derived from Dutch and translated to English; they did not seem appropriate in the Swedish context of this research. If factor analysis would have been used in the Auditorium Study, more than 180 informants would have been required for reliability since the method needs 10 times as many informants as semantic scales (Veitch, 2001). For this study, every single question (such as height, depth, angularity, enclosure and airiness) seemed more interesting to explore through the underlying interpretations rather than grouping these into larger categories. Grouping the questions into larger categories would have only discovered if the spaciousness or the spatiality was larger or smaller in each scenario, but would have lacked specific details, such as the nature of the height and depth.

5. Summary of Papers

This chapter summarises all paper abstracts to provide a background for the result discussion. Because the Auditorium Study is represented in two papers, and the Church Park Study in four papers, some repetition and overlapping occur.

PAPER A. DISTRIBUTION OF LIGHT AND SPATIAL ENCLOSURE – A SCALE MODEL STUDY

This study aims to find relationships between the distribution of light and the perception of a space's shape and size. It also tests whether illuminated walls contribute to the experience of a space as enclosed. Phenomenological observations were made by studying and comparing twelve different luminaire positions in two scale models. Spatiality is discussed by examining light zones created by contrasts of light and shadows, and the light zones' relationship to the physical space. The relationship between illuminated corners and dark areas, context, and the surrounding contrasts of light and shadow also contributed to the experience of enclosure in the light zones. Though the study began with the assumption that a space with walls clearly defined by illumination would be experienced as enclosed, it was found that a space with non-illuminated walls also was experienced as enclosed, and that a space that is experienced as enclosed at the same time can be regarded open. The findings show several examples of how the distribution of light influences the perception of the shape of a space: both compound and separated light zones can increase depth or width, depending on how these patterns of light are read together in the spatial context.

PAPER B. DISTRIBUTION OF LIGHT IN SPATIAL COMPLEXITY: APPEARANCE OF FIVE LIGHTING SCENARIOS IN AN AUDITORIUM

In this research, spatial complexity is studied through a combined-methods strategy. 21 informants answered a questionnaire and drew sketches, followed by in-depth interviews in a real-life auditorium with five light scenarios. The purpose of this study was to gain a rich and deep understanding of the relationship that exists between distribution of light and spatial experience. This study shows how distribution of light impacts the perceived space. Prominent, bright walls can, contrary to what most previous research suggests, also contribute to a decreased spaciousness. Simultaneously, a dark room can appear as more spacious when the spatial boundaries become unclearly defined. The wider impression created by wall lighting reduced the high impression caused by indirect ceiling light. The informants assessed the room illuminated by a light with sharp edges and contrasts to be more angular. A uniform light filling a room can be regarded as a more "democratic" light, inviting everybody to participate, while a strong focused light creates a smaller light zone that can be regarded as inclusive or excluding from a community. Furthermore, a focused light was beneficial for an impression of clarity and activity. Additionally, it was found that a strongly directed light in a darker surrounding can make people listen more attentively and lower their speaking volume.

PAPER C. SPATIAL INTERPRETATIONS IN RELATION TO DESIGNER INTENTIONS: A COMBINED STRATEGIES STUDY IN AN AUDITORIUM WITH VARIABLE LIGHTING

From the perspective of a lighting designer, it is of great interest to know if users will experience a final lighting design as it was intended to be experienced. Therefore, the purpose of this study was to interview the lighting designer in charge about his design intentions and compare this to the user's visual observations. The investigation took place in a real-life university auditorium where it was possible to monitor the lighting, comprised of five different scenarios. 21 informants participated in the study. Combined strategies were used in a questionnaire with semantic scales and a verbal description. In addition to these, the inquiry was followed by in-depth interviews. How the various lighting scenarios affected experienced spatiality, size and shape as well as spatial atmosphere were compared to the design

intentions. Discrepancies between the observers' spatial interpretations and the interpretation of spatial concepts are also discussed in relation to the lighting design.

PAPER D. DISTRIBUTION OF LIGHT AND ATMOSPHERE IN URBAN ENVIRONMENT

The relationship between distribution of light and spatial experience was studied using a temporary lighting installation in a real-life urban environment. A questionnaire, interviews and focus discussions collected the experiences of the illuminated space from 222 people. The following assumptions were confirmed: a clearly defined space was created by illuminating walls and trees and visual limits contributed to a feeling of safety in the space because these limits helped establish an overall view of this space. A lower luminaire placement in the street contributed more to a feeling of safety than a higher luminaire placement because the light was closer to the person, highlighted the facades and made the space appear lower. The light topography, e.g. the luminaire height, is discussed in relation to power and spatial hierarchies.

PAPER E. DISTRIBUTION OF LIGHT AND PERCEIVED SIZE AND SHAPE IN URBAN ENVIRONMENT

A full-scale study of changing light scenarios was conducted with 222 observers in an urban space over five weeks. This study examines the effect of the spatial distribution of light and luminaire placement on our spatial understanding. A combined method strategy with interviews and a questionnaire was used to examine the observers' perception of differences in spatial size and shape. The findings show that illuminated surfaces and objects, such as facades and trees, create a perception of increased or decreased depth and distance, depending on context. Additionally, the perceived size of space was found to follow the height of the luminaire placements. The study also found that the distribution of light can influence the perceived colour of light.

PAPER F. A FULL-SCALE LIGHT LABORATORY IN A PUBLIC SPACE

To what extent do we agree about the spatial experience that is created through lighting? Do architects and designers experience space in the same way as non professionals, or do their experiences change as they develop increased sensitivity? This paper, which is based on a full-scale study within a church park, focuses on design as research and cultural script, where designers are used as informants. It also discusses how the use of images between different professional categories can impact spatial understanding.

PAPER G. LIGHTING DESIGN RESEARCH IN PUBLIC SPACE: A HOLISTIC APPROACH TO A COMPLEX REALITY

For a period of five weeks, the park around Christinae church in the Swedish town of Alingsås functioned as a full-scale laboratory. This was a design research project examining how light distribution in a public space is experienced, with particular focus on light direction, light patterns and luminaire height. User experience was collected through questionnaires, video-recorded interviews and focus group discussions. The informants largely agreed on the effect of depth and broadness when they compared the different illuminated facade fields on the church. In this spatial context street luminaires at a height of 4.5 m contributed more to creating a pleasant, delimited and legible spatial experience that gives a feeling of safety than luminaires at a height of 6 m. The informants judged illuminated trees to have higher impact of the feeling of being safe than traditional street- and park luminaires.

This paper displays an overview of the Church Park Study, which was further developed in papers D and E. It includes additional questions, quotations and diagrams that are not in D and E.

6. Results Discussion: Spatial Observations

The starting point of this thesis was to evaluate how the spatial enclosure and distribution of light influence perceived spatial dimensions and experienced atmosphere (see chapter 1.5). The following chapter will discuss the main results of all three studies and compare findings that reoccur in several contexts, starting from the basic assumptions and prevailing research (see chapter 1 and 2). For a complete picture of all studies and findings it is recommended that the papers are read before this section.

6.1 EXPERIENCE OF SPATIAL ENCLOSURE

The assumption that illuminated (visible) walls enhance spatial enclosure and that lack of wall illumination makes a room alienating and poorly defined was a point of departure for this research. Results from all three studies supported this assumption. However, several exceptions contradicting the assumption were found: spatial enclosure was also found to be created in other ways, such as by darkness and contrasts. Several factors were found that impacted enclosure, for example: bright walls and ceiling, tangible inner light zones, compound light zones creating a tangible spatial unit and clearly visible spatial boundaries. In addition, variety interpretations of enclosure were found in relation to the interviewees' different use of the concept of enclosure. These factors will be described in relation to the findings.

6.1.1 Enclosure Related to Surface Brightness

Despite the previous assumption, that illuminated walls emphasise enclosure, the informants surprisingly regarded the brightest scenario in the auditorium as the least enclosing. However, a scenario with a faint light on the walls made the space appear enclosed, whilst a scenario with almost no illuminated walls was regarded as distant and unclearly defined. The scenario with the brightest walls was assessed as less enclosing than the scenarios with weaker wall lighting. This might relate to Hesselgren's findings that the experience of restricted space decreases when the level of light becomes too bright (Hesselgren, 1969) (see paper B).

6.1.2 Enclosure Related to Light Zones

Aspects other than distinctly illuminated walls were shown to contribute to spatial enclosure in the scale models, such as a tangible inner light zone in an otherwise dark space. A space with light zones at the rear wall, and where side walls were closely connected to the rear corners, was also considered as a clearly distinct space even though the major parts of the sidewalls were not illuminated (see paper A).

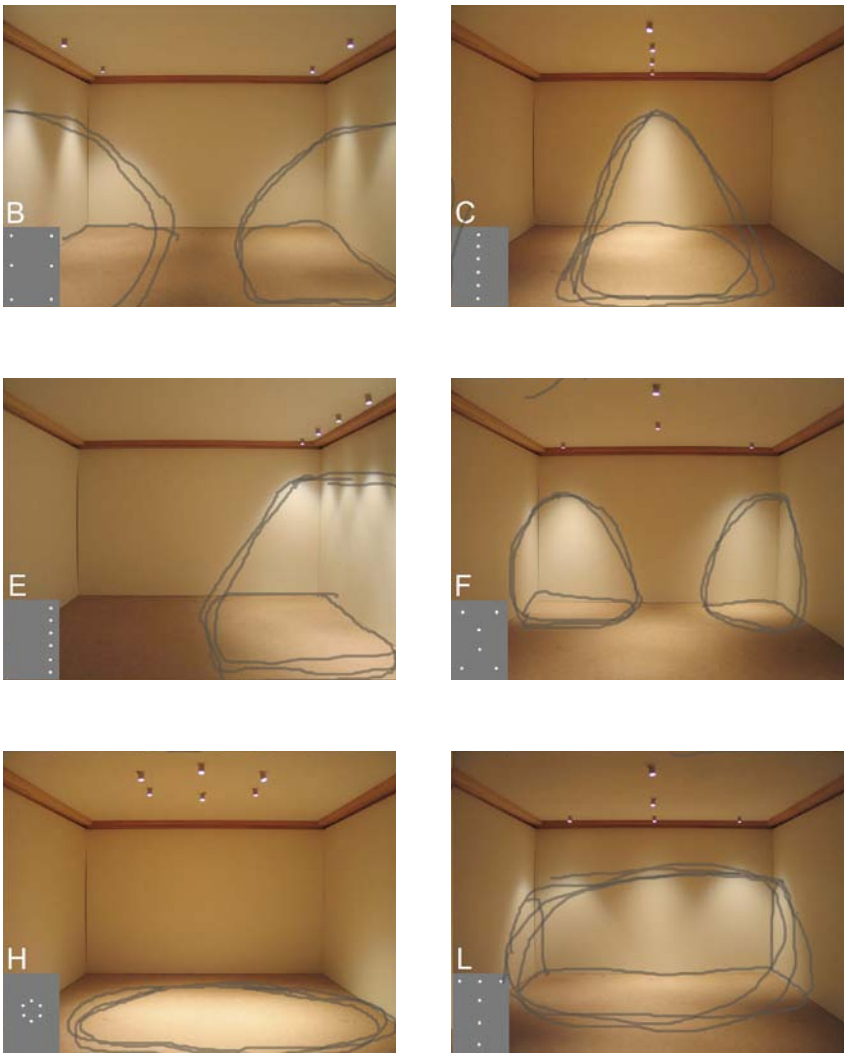

Figure 18. Scale model images showing differently enclosed light zones.

6.1.3 Enclosure Related to Spatial Boundaries

The interviewees were of the opinion that the space of the church park was made more clearly defined when it was limited by visible walls and defined boundaries, in this case constituted by the illuminated tree trunks. This de-

pends on two factors: the vertical illuminated surfaces and the fact that these also provide borders for the space. The reinforcement effect of the tree trunks is greater not only because they are tall, thin and vertical, but also because they are illuminated from below. The light reaches and passes eye level and contributes to creating walls that define the space more clearly. This particular combination resulted in the space becoming more distinct than if the space had been defined by illuminated boulders instead of tree trunks (see papers D–E and G).

Figure 19. The church park's tree trunks without and with illumination.

Also in exterior space, illuminated spatial boundaries created by the "ceiling" can contribute to an effect of enclosure. In the church park, several interviewees stated that the illuminated tree canopies created a ceiling with a sheltering and embracing effect (see papers D–G).

6.1.4 Different Interpretations of the Enclosure Concept

Differences in the use of concepts interfere with the findings. The concept of *spatial enclosure* in the Auditorium Study was mostly associated with a dark scenario with a soft, warm, glowing and spread distributed light from both the ceiling and walls. It was found that spatial enclosure was interpreted in two contradictory ways with emphasis either on embracing or being closed (see chapter 3.3 and papers B and C).

6.2 WHEN BRIGHTNESS INCREASES PERCEIVED SPATIAL SIZE AND DEPTH

Most of the existing research generally addresses brightness as a factor that increases perceived size and spaciousness (Acking & Küller, 1966; Flynn, 1977; Houser, et al., 2002; Matusiak, 2004) (see chapter 2.3). It is therefore logical that examples from all three studies in this thesis show how brightness increases the perceived spatial height, width and depth. Several factors were shown to contribute to a spacious impression or increased width, height or depth: 1) level of light, 2) which surfaces were brightest, 3) the light topography, 4) horizontal–vertical pattern, and 5) patterns of compound or separated light zones.

6.2.1 Surface Brightness and Spaciousness

In the Church Park Study, most of the informants were of the opinion that the illuminated tree trunks enlarged the space because these indicated the limits of the park. The tree canopies illuminated from below also contributed to a higher impression (see paper E and the appendix). Naturally, the illumination of objects that were not originally illuminated increased the total light level, which also can have contributed to a spacious impression. In the Auditorium Study it was found through questionnaires and interviews that brighter levels of light combined with uplighting from a central crown in the ceiling seemed to increase the space's height and size (see paper B). Additionally, when the room was illuminated with less ceiling light and more wall lighting it appeared lower, but wider (see paper B). In these cases, a brighter surface seemed to contribute to a more spacious impression in the direction of the illuminated surface. Both the light direction and the distribution of light appeared to have that effect when light levels were higher.

6.2.2 Light Topography and Spatial Size

Two different levels of street-lighting height were evaluated in the Church Park Study. The findings show that subjects perceive that the experienced spatial size and height followed the height of the luminaires (see papers E and G).

The height that the light reached on the illuminated walls impacted the experienced room height in the scale models and the auditorium, but an emphasised width reduced the height impression (see papers A–C).

6.2.3 Vertical and Horizontal Patterns Impact Size

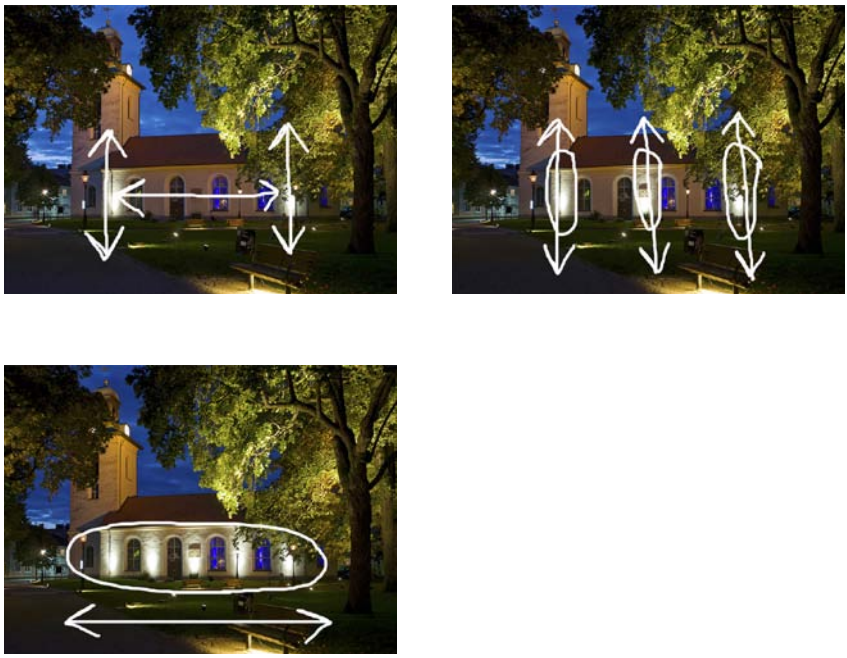

Figure 20. The effect of vertical and horizontal patterns on the impression of size.

The findings from all studies supported the assumption that a vertical pattern of light can emphasise the height and a horizontal pattern emphasises the width. Furthermore, it appears that light from below, for example towards a ceiling, can also contribute to an impression of height.

This was especially clear in the Church Park Study. The church facade was assessed as higher with three illuminated sections and widest with five sections, even though two sections also contributed to a wide impression. More illuminated sections imply an increased brightness, which follows the earlier research, that a brighter object is usually seen as larger (Michel, 1996, p. 12; Oberfeld, et al., 2010) (see paper E). It appears that with five sections the light zones formed a united, large, horizontal, almost compound band of light, while the scenarios with two or three illuminated sections were seen as separate light zones with a more vertical emphasis. This relates to

the architectural praxis that vertical–horizontal patterns reinforce width or height (Michel, 1996, pp. 118, 133–134; Neufert & Neufert, 2000, pp. 24–25), and to Matusiak's study of window shapes (Matusiak, 2006) (see chapters 1.2 and 2.3). These findings concerning the church facade's width and height can also hypothetically be because the figure–ground relation between light and shadow shifts (Michel, 1996, p. 55) (see chapter 2.1 and paper E).

As expected, light directed upwards on the thin vertical pilasters gave, according to the informants, a higher impression of the Town Hall building in the Church Park Study. The direction of light and the illuminated thin vertical objects likely cooperated to emphasise this impression (see paper E).

6.2.4 Compound or Separated Light Zones Impact Size

In the Scale Model Study, a room with more light on the side walls was perceived as larger than rooms with less light on the sidewalls. It was also found that the perceived size increased with light zones forming a united pattern, categorised by Madsen as type C (Madsen, 2006) (see chapter 4.3). When illuminated areas on the floor were positioned so close to each other that they overlapped, this could have been regarded as a compound illuminated area that appeared to increase the spatial depth, provided that it was positioned so that it followed the observer's gaze from the front to the rear wall. The width was similarly reinforced with compound light zones (see figure 21 and examples C, L and K). However, type B separated light zones also increased the perception of size if the light zones were close enough to be read together as a spatial unit (see figure 21 and examples G, J and B, and paper A).

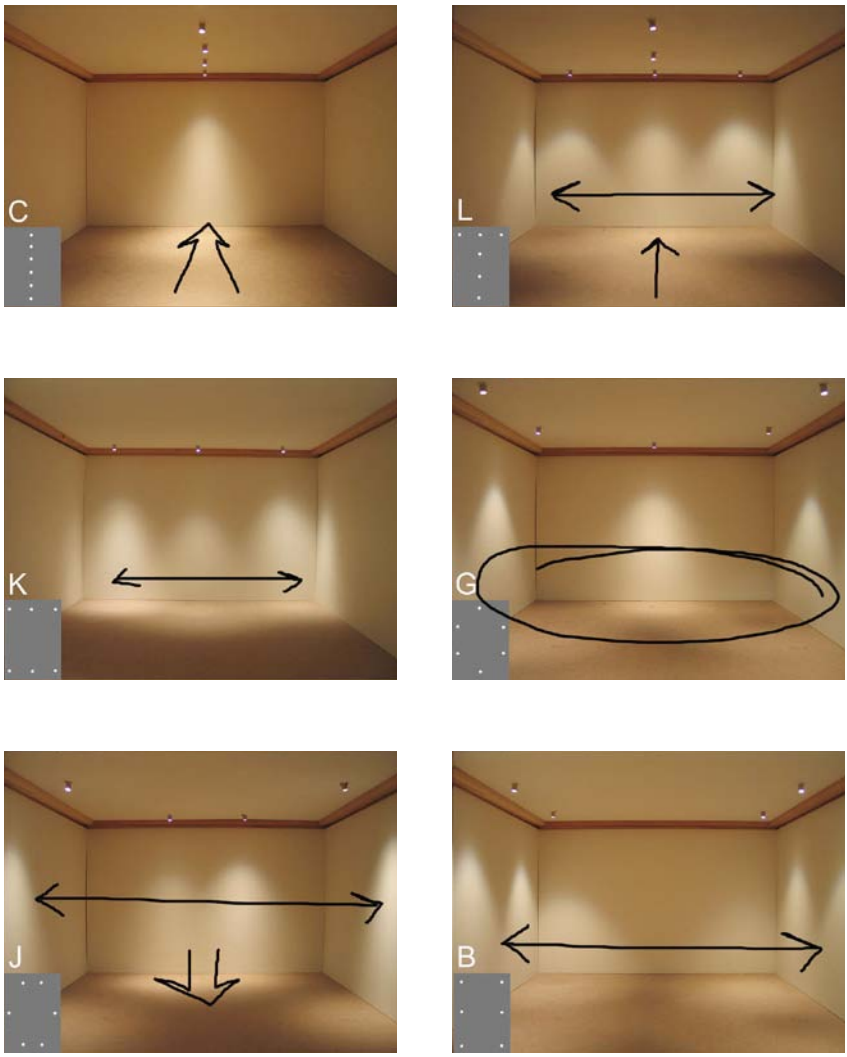

Figure 21. The influence of compound light zones
and the distance between them on the perception of size.

Another observation in the Scale Model Study considered the floor. The perception of size was influenced when the floor was patchy with strong contrast patterns of light, which should attract the gaze; it made the ceiling seem lower (see paper A). In the lighting field it is well known that the gaze is attracted to brightness contrasts (Flynn & Mills, 1962; Liljefors, 1997; Liljefors & Ejhed,

1990; Michel, 1996, p. 163). Furthermore, some of the interviewees in the Auditorium Study spontaneously identified that the gaze's movement influenced the perceived height and width of the space. This shows how strong the effect can be (see paper B).

6.3 WHEN DARKNESS INCREASES AND BRIGHTNESS DECREASES PERCEIVED SPATIAL SIZE AND DEPTH

Contrastingly, findings where depth and size were increased by darkness or decreased by brightness were also found in all three studies. All the surprising answers are understandable when considering the interviewees' interpretations of what they actually referred to when making the judgements. To summarise, five different causes seem responsible for the contrasting findings that darkness in some cases increases spaciousness and brightness decreases spaciousness: 1) unclear spatial boundaries, 2) walls made prominent because they are too bright, 3) ambiguous figure–ground relationship between object and space, 4) a rear wall seen as a cavity or as a body, and 5) conceptual misunderstanding.

6.3.1 Unclear Spatial Boundaries

According to the prevailing assumptions of the Auditorium Study, a room with bright walls was assumed to be more spacious than a darker scenario. Surprisingly, according to the informants the scenarios that gave the largest and deepest impression were the two darkest (see paper B). The findings show that darkness can be experienced as enlarging a space: because there is no visible limit of the space it becomes unclear where the room ends. Darkness often shrinks the experienced space to the area nearest the observer, which he or she can see even in weak light or in the dark. A similar case is when it is foggy, where the space appears more open due to less-visible boundaries, (Stamps, 2012a). As Gärling found out, the relationship between the concepts of openness and spaciousness can be confusing (Gärling, 1969a).

The interviewees in the Church Park Study used the same reasoning to explain why they perceived the illuminated tree trunks as increasing or decreasing the size of the space. They all said it was because of the more distinct boundaries they created when illuminated. These assessments appear to be related to the informants' pre-understanding; they either regarded the darkness as large due to the lack of limitations, or they considered it to be

small because they could only see the area near where they stood clearly in the darkness (see paper E). It is therefore assumed that darkness only gives a clearer experience of spaciousness than what brightness gives if there is enough darkness to make the spatial boundaries indistinct.

6.3.2 Prominent Walls that are Overly Bright Decrease Spaciousness

It was found that brightness can decrease the perceived size when too much light makes the walls prominent. The auditorium scenarios with distinctly bright illuminated walls were judged to have a high level of closeness (see papers B and C). These walls appeared to become more prominent in contrast to the other room surfaces. Note that in this case the wall brightness impacted the presumed spaciousness impression, causing it to be experienced as more cramped rather than more spacious. It did not feel more enclosed as opposed to spacious (for discussion about enclosure and spaciousness, see chapter 3.3).

Contrastingly, the scenario expected to be most enclosing because of the brightest wall lighting was shown to be the least enclosing. Enclosure was assumed to emphasise the experience of a clearly defined space and was not meant to be an opposite characteristic to less spaciousness, but the informants judged the enclosure concept differently (see chapters 6.1.4 and 6.3.5 and paper B).

Hesselgren found a breaking limit where the experience of a restricted space was changed at a specific level of light (Hesselgren, 1969, pp. 364–365). As such, it is possible that the experienced spaciousness, enclosure, depth or closeness are all related to a certain level of light, and that any of these characteristics may change when the light level is raised above a certain limit.

6.3.3 Ambiguous Figure–Ground Relation

Even though most informants answered that the illuminated tree trunks made the space appear larger, some informants were of the opposite opinion. Oberfeld, Hecht and Gamer write that a bright object can also appear less distant. They explain this as relating to either an "irraditation in the ocular media or on aerial perspective" (Oberfeld, et al., 2010). This relates to Kenkel's theory of "gamma movement" from 1913, repeated in a spatial experiment by Michel (Michel, 1996, p. 12). In Michel's example, a brighter object tends to look closer and larger than a similar object that is less bright, in the

same room and with darker surrounding walls. With this in mind, another explanation for the tree trunks could be that the distance we perceive to the trunks might be crucial because we regard them as singular objects or see the group of trunks as a whole semi-open wall. The informants could walk freely in the church park when answering both the questionnaire and the interview. My own observations gave the insight that when the distance between the observer position and the trees was larger, the illuminated tree trunks made the space appear larger, while when the actual distance was shorter, the illuminated tree trunks made the space seem smaller. The distance might impact how strongly the light is perceived and how many surface details we see, such as the bark texture. Furthermore, it is naturally easier to see the trunks as single objects with a closer distance to the observer's position. If seen as single objects, we will regard them in a figure–ground relationship. Consequently, the repeated patterns by the tree trunks seen from larger distance make them form a background. This is an example of an ambiguous-figure paradigm (Michel, 1996, p. 55) (see chapter 2.1 and paper E).

The different answers from the informants regarding the church facade can be related to whether subjects assess the distance towards the facade as an object (figure) or as a rear wall in a whole space (ground). Most Church Park Study informants were of the opinion that the depth towards the church facade increased when the facade was least illuminated, with just two lit sections in the corners, whereas the facade appeared closer when more lit sections were added. It seemed closest with five lit sections (see paper E). My interpretation is that more illuminated sections smoothen the perceived brightness contrasts, which imply that the whole facade is seen with a stronger relation to the whole park space. With two or three sections the spatial context is fragmented and these light zones may be seen more as figures, as objects on their own in the contrasting darkness.

6.3.4 Cavity and Body in Interior and Exterior Spaces

In the Scale Model Study there are some examples where a light zone appears to reduce the depth of the space rather than enhance it. A wider illuminated area on the rear wall seemed to make the rear wall appear closer, likely because of the total higher level of light on the wall, but also because the wider compound light zone (of type C) emphasised width but decreased depth (see Madsen's method analysis in chapter 4.3). Scenarios with rear-wall-centred illuminated areas seemed deeper than scenarios with correspondingly

centred dark areas, a qualified guess is that illuminations that emphasises something chosen are more common (as a figure), so that the centred light zone seems more important than the dark zone (see figure 22 and paper A).

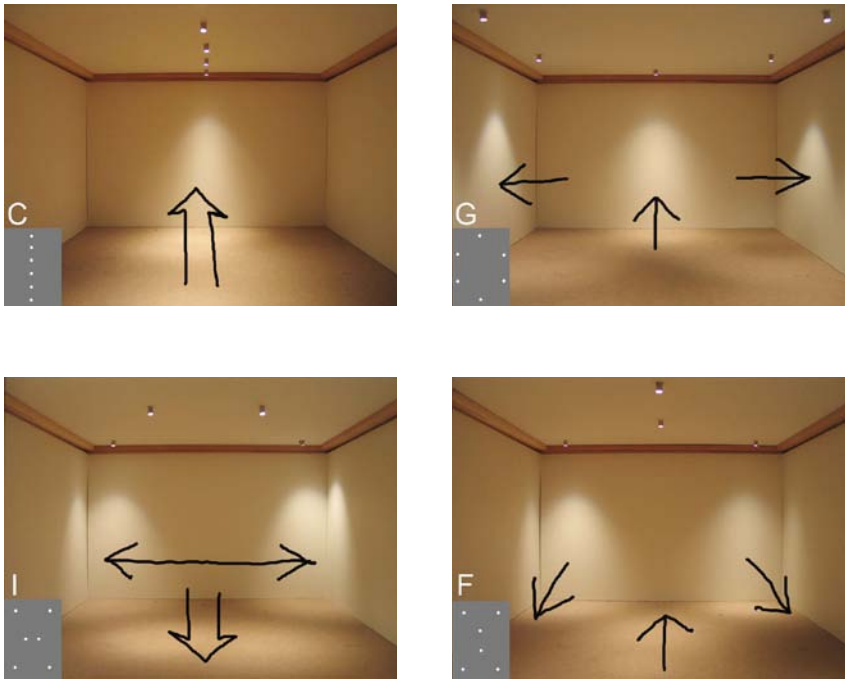

Figure 22. Centre- and edge-positioned light zones in the scale model.

Figure 23. Centre- and edge-positioned light zones on the church facade.

These findings contradict somewhat with the findings from the Church Park Study. Judging depth from the church facade follows the principle that more darkness increases the distance, while more added light reduces the distance. The depth and the distance to the facade were increased when more illuminated sections were added, so the total level of light became higher. Hence, the placement of the illuminated sections on the church facade also seem to be important, since interviewees judged the church facade to be closer when a centre part of the facade was lit, compared to when only the corners of the facade were illuminated and the middle section was left in darkness (see paper E). However, when comparing the findings from these two different studies, this contradiction indicates that the number of illuminated sections of the church facade seem to have a stronger influence than the placement of the light. Still, there are several differences between these spatial contexts that must be studied further, such as their size in relation to the space's scale, the illuminated areas' inherent connection and position, and the distance between the illuminated areas. Additionally, interiors are always convex spaces – cavities – while an exterior facade can be

regarded as either belonging to a spatial cavity or as a solid body of a building. The cavity–body relationship impacts the figure–ground relationship. The church facade can be seen either as a body (figure) or as a part of a cavity (ground). Furthermore, the light zones can, depending on surrounding contrasts, be seen as figures against the darker parts of the rear wall or the facade (ground).

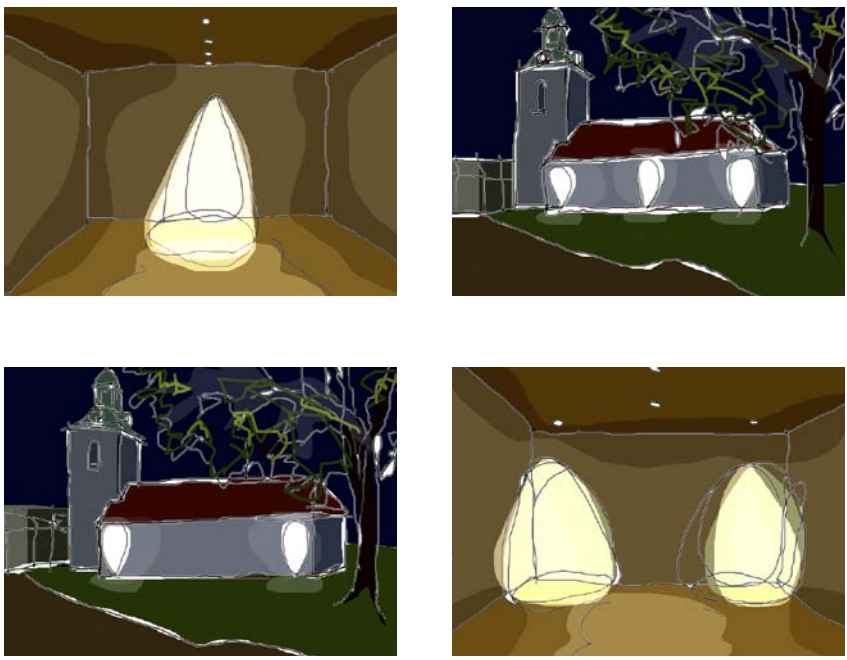

Figure 24. Comparing a rear wall with edge- or centre-positioned light in interior and exterior settings.

6.3.5 Conceptual Misunderstanding

A room without wall lighting was expected to be perceived as distancing and not obviously limited. Nevertheless, in the Auditorium Study the two darkest scenarios were actually assessed as more limited than the brighter ones. It is highly important to understand that the informants interpreted the concept "delimited" (limited) differently. They either felt limited because of the darkness, limited from the outside by the drawn curtains or that they

considered the spatial boundaries as making the space clearly limited (see chapter 7.6 and paper B).

A reason that most previous research has not discussed darkness as enlarging and brightness as making the space smaller may be biased language (see chapter 3.9). Often spaciousness and brightness are more desirable than confinement and darkness. As a result there is more research done on the benefits of light.

6.4 PERCEIVED TRANSFORMATION OF A SPATIAL SHAPE

Surprisingly, all three studies had examples of surfaces that appeared to be vaulted when illuminated in specific ways. No references have yet been found in the literature for similar findings.

It was not expected that the experimental illumination would affect the perceived shape of the church facade. Yet, several interviewees said that they observed a change of the building shape when the church facade was illuminated with only two sections, at the corners. Those who detected this difference said that the facade seemed to be bowed, either in a convex or a concave shape. The observations of the facade as concave are probably related the way that the informants perceived the depth, since the dark middle part in that scenario could be interpreted as farther away than the corners. The ambiguous possibility to also see the bent shape as convex is probably because the two illuminated sections can be perceived as detached from the facade connection, in a figure–ground relationship, depending on the surrounding darkness. The corners can therefore be perceived as either detached from, or as extending, the whole park space. Sweden has a long sunset that, with different weather conditions and moonlight, can change the surrounding darkness. Furthermore, it was not clear whether the tree trunks at the sides of the facade were illuminated or not when the interviewees expressed these observations. If we consider the brightly illuminated tree trunks as increasing the spatial size, the illuminated corners can hypothetically contribute to this increased distance, so they appear farther away than the centre of the darker facade (see paper E).

Figure 25. The scenario with only the edges illuminated was seen by some interviewees as bent.

Figure 26. In this scenario the light caused the ceiling to appear vaulted.

Without prompting, several interviewees reported that they saw the auditorium ceiling as vaulted in some scenarios with indirect uplighting. Hypothetically, when directing an overly bright light towards the ceiling this surface may appear as approaching and as slightly more convex rather than concave. The surrounding brightness contrasts and the shadows on the curved transition between walls and ceiling are crucial for this experience. Another cause for a vaulted impression could be situations where the boundaries between walls and ceiling are not visible and the surfaces seem to merge into each other (see paper B).

A similar phenomenon was shown in the Scale Model Study. A single luminaire row asymmetrically placed along one long side of a room made the ceiling appear convex, and a lighting design with a cross shaped luminaire pattern that emphasised the rear wall corners, similar to the church facade

with only two illuminated sections, made the ceiling appear concave. Experiencing the ceiling in the scale model as either convex or concave may be explained by the phenomenon of a convex shape appearing concave if the light direction shifts from upward to downward (Gregory, 1998, pp. 190–191). In the scale model of space D (see figure 27 below), more light is reflected indirectly from one side of the floor and there is one wall that reflects light up onto half of the ceiling, while the lighting design in space F gives more emphasis to the floor and makes the ceiling appear darker, which creates an impression of a more downward-oriented light, compared to D (see paper A).

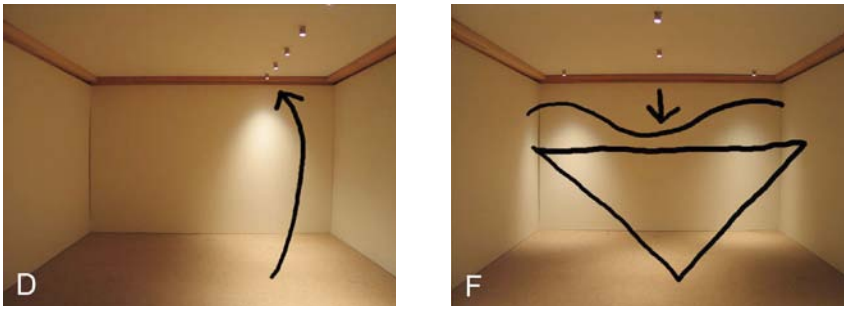

Figure 27. Sketches of possible causes for a convex and concave ceiling impression.

The light scenario with most wall emphasis in the Auditorium Study was supposed to be the most angular. Wall lighting was assumed to create well-defined spatial boundaries and increase an angular impression. Unexpectedly, the darkest scenario with a dominant directed light from an overhead projector towards the podium constituted the largest change in the observed room shape, since the room in this light was clearly judged to be angular, while the room in all other scenarios was assessed as more round than angular. In this case, the informants experienced the character of the light beam and the cold colour temperature, hard contrasts, less-obvious spatial boundaries and the direction of light to create an angular impression in the space (see paper B).

In addition to the pattern formed by light that falls on spatial surfaces, luminaire openings also form patterns. These interior elements often form figures, most commonly on the ceiling, sometimes with a clear shape and sometimes not. The luminaire pattern does not always correspond to the light pattern of illuminated surfaces, or to the shape of the physical space.

In the auditorium, the half-circular lighting track and the wall luminaire placements both contributed to a round impression of the room, especially in the brighter scenarios. In the darker scenarios, the light was seen as more separated from the fixtures (see papers A and B).

6.5 DISTRIBUTION OF LIGHT AND ATMOSPHERE

Atmosphere in these three studies was mostly discussed according to enclosure, inclusive or excluding light zones. Atmosphere also relates to safety, visual and aural attention and speaking volume.

6.5.1 Enclosure and Safety

The interviews and the questionnaire answers in the Church Park Study supported the assumption that a clearly defined space is created when walls are made visible and that visual borders contribute to a person's feeling of safety because they increase his or her general view of the space. This may be one major reason that a majority of the informants reported that the trees in the church park were the illuminated objects that contributed most to their feeling of safety. Naturally, it is important that the trees were not dark as they usually were. When they are bright they are easy to detect and harder to hide behind (see paper D).

In the church park, a lower height of luminaire placement was seen as giving a more enclosed space that was also experienced as safer than a higher light placement (see papers D and G). The interviewees reported that the light is closer to the pedestrian, highlights the facades and makes the space appear lower, all of which contribute to creating a clearly defined and a tangible spatial unit. This in turn can be related to power hierarchy: the atmosphere of a space can be experienced as private rather than public in terms of spatial size (in this case when a space appears lower). In this study, a less uniform street light that formed an area of brightness that strongly contrasted with the rest of the background appeared to be more important for feeling safe than a more uniform lighting spread out over a larger area. According Appleton's prospect–refugee theory one may assume that openness should be more beneficial for the feeling of safety since one does not risk being trapped by enclosure (Appelton, 1998; Loewen, et al., 1993; Stamps, 2005). However, a facilitated overview of a space through spatial boundaries made visible with light is just as important. Another reason for a safer experience with a lower

direction of light is because facial recognition may be facilitated with a light falling diagonally from a lower height. Light falling from a larger distance from above creates harder shadows on faces, which can be experienced as less natural. Light from below can also make a space appear more powerful. In the Church Park Study interviewees reported that the light on the vertical pilasters of the Town Hall emphasised the impression of power (see paper D).

Figure 28. Face recognition is more difficult when the light comes from high above rather than from the side.

Figure 29. The lower street lighting height was experienced as safer and more enclosing.

Though people more often seem to relate comfort and safety to a private atmosphere rather than to a public atmosphere, it is not possible to say that a private space is generally safer than a public space – it is dependent on context. A private atmosphere in a large public space may feel so awkward and strange that it creates insecurity – some interviewees experienced this in the Auditorium Study's "mood scenario". A uniform illumination that does not emphasise anything specific can also be experienced as less safe, according to

some informants in the Auditorium Study. They reported that sitting in the centre of the auditorium in place of an audience with their attention aimed towards the sides of the room created a kind of uncertainty. Some informants described the cold metal-halide light from the overhead projector or glimpses of daylight from slits in the curtains in contrast to the warm room light to decrease the experience of safety (see papers B and C).

6.5.2 Excluding or Inclusive Light Zones

In the Auditorium Study it was found that a focused, directed light was both able to relate to an intimate atmosphere and an excluding atmosphere. The shifting light scenarios showed that a uniform light that covered both podium and public, without specific direction, was evaluated as creating an inclusive, "democratic" atmosphere, inviting the whole audience into a conversation. On the other hand, spotlights directed toward the podium seem to exclude the public from the conversation, and according to the interviewees, make an audience quiet. In this case, the lighting design fulfilled its purpose according to the scenario labels. Informants reported that added overhead-projector light and spotlights created a greater distance to the podium (see papers B and C).

In one interview, an experienced lighting designer claimed that a point of focus is needed to constitute a place to rest one's gaze. Other informants reported that a lighting that lacked a focal point created an atmosphere that gave them the feeling that they were waiting for something to begin, which created uncertainty. It is very important to evaluate if the object that catches the attention really is the intended object. In some of the auditorium scenarios this was not the case, which contributed to a confusing setting. Another finding in the auditorium was that the experience of the surrounding space decreased with a strong focus created by spotlights with a distinct direction (see papers B and C).

6.5.3 Visual and Aural Attention

Flynn found that a uniform, bright light with some wall emphasis created visual clarity (Flynn, 1977). The interviewees in the auditorium related clarity primarily to the focused light, though also to a bright level of light. In this study, clarity was also related to viewable contrasts, to the colour of light, and to the sharp edges of the focused light zone (see paper B).

Several of the auditorium informants said the dark mood light, without any distinct focus, invited silence – "you must whisper here" was one comment. Sanders, et al. found a relationship between a lower level of light and a reduced level of sound (Sanders, et al., 1974). However, a strongly focused light also seemed to increase this effect according to the interviewees. Directed light from an overhead projector[25] and spotlights made the informants feel limited in what they were allowed to do, to be a silent audience, listening and watching. The room was said to be anonymous and the light created a feeling of safety as part of the crowd, a mass of people in full control of the space. This could simultaneously be regarded as an excluding light for those who might enter the room. Several informants said this light provided a good focus on the lecturer. Still, it can only be used as a one-way communication, such as a lecture. A number of the informants noticed that sound became more obvious in the dark picture-showing scenario with one main light source – the overhead projector. This change in attention can be the result of the darkness – when you see less, other senses become more active, when you see fewer shapes and details that helps the concentration for observing – or the sound of the overhead projector itself may activate the ears (see paper B).

6.6 DISTRIBUTION OF LIGHT INFLUENCING THE EXPERIENCE OF COLOUR

An unexpected finding was the relationship between the distribution of light and colour impression. Even though the light sources and the level of light in all the scale-model scenarios were the same, the distribution of light itself appears to affect the experience of the colour of light within the space. Harder contrasts may cause a space to feel cold, and a space with softer contrasts to feel warmer (see paper A). Furthermore, in the church park the distribution of light appeared to influence some of the informants' colour experience. The foliage was seen as warm despite mostly cold light sources used on green leaves. Several factors may have cooperated to create this experience: the background colours, the living materiality and texture of the leaves and because colours in nature are often more yellowish than expected (Fridell Anter, 1996). The light topography also seemed to impact the colour experience. According to several interviewees, a lower street light height ap-

25. An overhead projector for projecting transparencies.

peared to give a warmer light. This could be because the light from a lower position becomes more concentrated and brings out the facade colours, and also because the smaller light zone can have an intimate atmosphere that is regarded as warm (see paper D).

6.7 SUMMARY OF FINDINGS

This thesis shows that the placements of luminaires, the direction of light and focus and the spread of the light each have great importance for the perceived spatial dimensions.

The graphical scheme (see figure 30) and the tables that follow below show another way to display a short overview of the main findings from all three studies. This makes it easy to see topics in common.

Regarding these findings, it seems surprising that many previous researchers have so unanimously reported brightness as a factor that increases spaciousness, while most have not mentioned that darkness can increase spaciousness and that brightness in some cases can decrease spaciousness. Bright walls can either contribute to a spacious or a cramped impression. Most often spaciousness is increased by visible walls. Still, if the contrasts on walls make them more prominent than the surrounding, the effect can be a cramped space. Darkness can likewise either decrease or increase the perceived space. Often the experienced space is reduced to the light zone we see. However, the dark space can also been regarded as without limits, increasing to infinity.

The relationship between the size of a space and the distances between light zones can influence the whole perceived spatial size, a separated pattern that is still seen as an entity may increase size. Moreover, compound illuminated areas may be useful in increasing perceived depth. A number of informants experienced the light zone as a spatial unit on its own within the physical space. The experienced space can change size dramatically and even appear as larger than the physical space. The position of illuminated areas, with placement at the edge or centre, may also influence the perceived size. This may be because we are accustomed to light directed towards that which is most important, and to the figure–ground relationship. An area with brighter contrasts than the surrounding may draw attention that impacts size perception. A gaze that flickers towards the sides because of bright areas can create a wider impression. Brighter areas in the ceiling that similarly attract the eye make a higher impression. A dominant, patchy floor may call for at-

tention to a degree that it influences the experienced spatial size. Furthermore, the relation between width and height is important, since they impact each other: a tall room seems less wide and a wide room seems less tall. The pattern created by light or the pattern created by luminaires are two different things that need to be considered.

This thesis shows that spatial openness is not necessarily more beneficial for safety than what enclosure is. The Church Park Study informants supported the assumption that a clearly defined space is created when walls are made visible and that visual limits contribute to a person feeling safe because they increase his or her general overview of the space. An increased visibility facilitates movement and orientation within space. A clearly defined, tangible space also seems beneficial for a safe experience: it can be experienced as having a sheltering and embracing effect. With regard to the Church Park Study, it seems likely that illuminated borders, landmarks and paths in a space are a way to increase accessibility. In this way enclosure can be beneficial for safety, even though researchers like Stamps are also correct in that openness is beneficial for finding refuge (Stamps, 2005).

The light topography, the height of luminaire placement, is highly important for the atmosphere impression. It was found that a lower street light height contributed to the feeling of being safe even though it was less uniform. A lower luminaire placement comes closer to the pedestrian, highlights the facades and makes the space appear lower, all of which contribute to creating a clearly defined and a tangible spatial unit.

A uniform light filling a room can be regarded as a more inclusive light, inviting everybody to participate. A strong, focused light creates a smaller light zone that can be regarded as inclusive or excluding from a community. Darkness and a strongly directed light focus can influence an intimate experience (even if it is a cold light). A strongly directed light in a darker surrounding can make subjects listen more attentive and reduce their speaking volume. A focused, directed light was found beneficial for an impression of clarity and activity. The empty rows of audience seats were loaded with such an obvious function that the informants continuously addressed the empty chairs as a crowd of people, a latent social space.

In all three research studies some examples appeared when interviewees perceived the shape of a room surface as arched only from the distribution of light. Visible walls and clear spatial boundaries could either emphasise angularity or roundness depending on the level of light and the shadow contrasts in the transitions between room surfaces. A sharp light made informants as-

sess the space as more angular. There were also several examples of how the distribution of light influenced the experienced colours.
Finally, there were differences between professional categories such as architects and designers and non-professionals regarding the use of concepts and what they address when answering a questionnaire about spatial experience

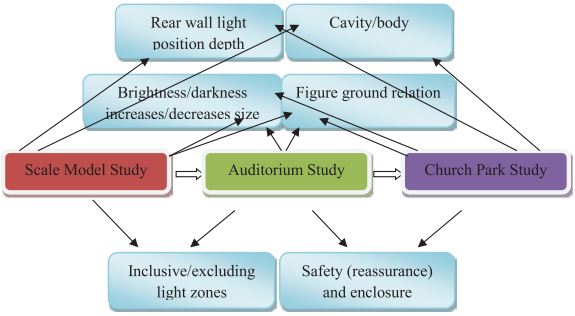

Figure 30: Main research findings in common between the studies (above).

In the tables below, one can follow how several new assumptions developed from an earlier study are repeated and in what way supported in the next study despite the differing context. The tables also display how the different empirical findings were generated. For the content of these assumptions and findings, see this whole chapter and the respective articles.

Table 2. Assumption supported within the studies (below).

SCALE MODEL STUDY (the researchers phenomenological observations) (Paper A)

Supported assumptions:
Enclosure by vertical surface light
Height and width effect each other
Size between illuminated areas influences spaciousness
Size of illuminated areas influences spaciousness

Surprising findings and new assumptions:
Darkness increases spaciousness
Brightness decreases spaciousness
Enclosure is not limited to walls
Continuous light zones influence spatial size: wider or deeper impression
Colour effect
Vaulted ceiling

AUDITORIUM STUDY (21 informants deep interviews) (Papers B–C)

Supported assumptions:	**Documented through:**
Darkness increases spaciousness	Interviews and questionnaire
Brightness decreases spaciousness	Interviews and questionnaire
Indirect uplight – open, airy, high impression	Interviews and questionnaire
Wall emphasis gave a wider but lower impression	Interviews and questionnaire
Height and width effect each other	Interviews and questionnaire
Gaze movement impact height and width	Interviews
Focused light impact attention	Interviews
Inclusive and excluding light zones	Interviews

Surprising findings and new assumptions:	**Documented through:**
Largest enclosure in darkness	Interviews and questionnaire
Intimacy despite cold light	Interviews
Focused light + size of light zone + darkness = intimacy + silence	Interviews
Sound, silence effect	Interviews
Focused light impact visual clarity	Interviews
Vaulted ceiling	Interviews
Enclosure for safety	Interviews
Concept interpretation: delimited/limited, angular	Interviews
Professional differences in understanding depth	Questionnaire

CHURCH PARK STUDY (222 informants in questionnaire, 39 informants in interviews) (Papers D–G)

Supported assumptions:	**Documented through:**
Distances between light sections increases width	Questionnaire
A compound light zone increases width	Questionnaire
Wall light + ceiling by tree tops = sheltering	Interviews
A lower street light was safer	Interviews and questionnaire
Differences in luminaire height reinforce spaciousness	Interviews
Vertical light stripes create a taller impression	Interviews and questionnaire
Professional differences in understanding depth	Interviews and questionnaire

Surprising findings and new assumptions:	**Documented through:**
Lit tree trunks had two possible interpretations, increasing or decreasing size	Interviews and questionnaire + the researcher's own observations
Enclosure for safety – contrasting previous research	Interviews + the researchers's own observations
Vaulted shape	Interviews
Colour effects	Interviews



COMPARING ALL STUDIES

Surprising findings and new assumptions:
Light area positions may impact depth: Cavity–body and figure–ground relationships

7. Results Discussion: Methods

This chapter discusses methodological aspects of the research. Because method development was an important goal in this thesis the methodological reflections are regarded as a component of the results.

7.1 METHODOLOGICAL EVALUATION

If the different moments of the studies' empirical collection are to be compared, the phenomenological observations in the Scale Model Study were useful for developing the spatial understanding and the researcher's observation skills. It also generated assumptions for the further tests (see paper A).

The free, written description in the Auditorium Study was shown to be highly valuable and required less effort, both from informants and researcher. Time-consuming transcription was not needed, and the informants were able to write the essence of their experiences (see papers B and C and the appendix).

The statistical analyses should be regarded as purely exploratory. No claims of statistical significance are made. Such claims would be questionable due to the multiplicity issue and because the same data set was used both for the model selection and the analysis itself. The extensive use of the combined methods, including time-consuming interviews, with limited time and research budgets, limited the possible number of informants. Due to the size of informant groups, it is not manageable to claim a measurable reliability and validity of these studies. Instead, the analysis focuses and discusses the contextual impact (see chapter 7.2 and 7.6). Many more studies and contexts are needed to be able to generalise findings like the ones gained from this

research. However, the mixed methodologies give another kind of reliability; for example, the Auditorium informants had the opportunity to reconsider their answers, and if one informant contradicted him- or herself, this was followed up (see papers B–G).

The negative answer option in the semantic scales were not useful for the statistical analysis, another type of scale would have been better. Still, the semantic-scale findings provided interesting results that could be discussed with respect to the interviews. Questionnaires are commonly regarded as a quantitative method, but in this sense they were analysed with a qualitative approach. The quantitative analysis provided an easy way to have an overview of the empirical material. It facilitated detailed study of some of the variables, such as profession, gender and age. The risk for mistakes in the interview interpretation might have been reduced by the use of many informants in the Church Park Study questionnaire (see papers B, D and E).

The auditorium questionnaire was almost too long and extensive for the informants. The questionnaire was made much simpler for the Church Park Study and just as much relevant information came out of it as the auditorium questionnaire. The simpler questionnaire was designed to be able to catch subjects on the move and to not scare or tire them with too many questions. The statistical consultant also argued that this would benefit processing the data. But the church park questionnaire would have been too limited had it not been followed up by interviews (see papers B, D, E and G).

The questionnaires highlighted causal relationships between distribution of light and perceived size and shape of the space in relation to specific questions. The interviews, on the other hand, provided answers on how and why distribution of light caused these changes. By this, misunderstandings caused by the informants' different interpretations of concept and questions were revealed. Furthermore, the interviews gave explanations that supported the analysis of the findings.

The focus-group discussions with experienced observers in the Church Park Study also provided several valuable quotations, but with group discussions there is always a risk that subjects in a group affect each other, so this material is more valuable for descriptive purposes than for gaining knowledge about majority opinions.

The sketching task in the Auditorium Study was interesting but it will be further analysed in the future. There was a large amount of empirical material and not enough time to continue with all analyses. The informants' sketching task in the Auditorium Study was beneficial for the interview that

took place simultaneously; the drawing task seemed to relax the informants and help them formulate their oral descriptions. The simplicity of this task made it also work well for those who were not used to sketching (see chapter 4.3 and appendix).

The atmosphere concepts that informants could circle in the Auditorium Study questionnaire did not reveal much. Of 45 words, the same five concepts that the informants connected to each lighting scenario reoccurred between the scenarios, only the order of the words changed between scenarios. This indicated that the most-chosen concepts referred more to the physical space than to the five different light scenarios (see appendix). This will be discussed more in a forthcoming article about atmosphere in the Auditorium Study.

7.2 INTERPRETATIONS OF CONCEPTS

It was a great advantage that the Auditorium inquiry was directly followed up by an interview about the answers. The answers had more truth and credibility because the Auditorium informants had the option to reconsider their answers from other perspectives; the positions of seats were changed, and they had the option of adjusting their answers, and needed to defend them. Because of this, it was possible to see how differently questions and answers could be interpreted, individual differences in answering patterns and in the horizon of understanding. This gave a good overview of how representative the interviewees were in relation to the informants answering the questionnaire. Combining the interviews with questionnaires, statistics and a large number of responses created a clearer overview, which hopefully reduced the number of misinterpretations from misunderstood questions. The interview questions may have been asked differently of each respondent and the questionnaire answers balance that. Often the most interesting comments were received from the informants when they reacted negatively to something related to the format of the questionnaire (see papers B and C).

Comparing the answers between the in-depth interviews and the questionnaire clearly showed the limitations of only using questionnaires: subjects interpret concepts and spaces very differently according to their pre-understanding. This was especially obvious in the Auditorium Study were the concepts such *angularity*, *enclosure* and *delimitation/limitation* could relate both to the clearly defined illuminated walls in the built room or to the outer world, outside the room and the building, or the experienced space and the light zones. The explanations for these differences were either related to the

distribution of the light or to the character of the light (such as a cold light with sharp contrasts). It appears also that even if the informants were asked about *delimitation* referring to spatial boundaries, they answered as if the question dealt with how the space *limited* them personally (see paper B).

In the Auditorium interviews several informants claimed that their view of the experienced space changed. In the beginning, they most often assessed the physical illuminated space, while in the following scenarios they shifted focus to the light zones as rooms on their own. Instead of addressing the scenarios, most informants began to talk about them as rooms (see paper B). However, the studies by Flynn, et al. and by Hawkes, et al. show consistent findings even though the informants in one study were asked to assess the room in different lighting and in the other to assess the lighting in the room (Boyce, 1981, pp. 269–271) (see chapter 2).

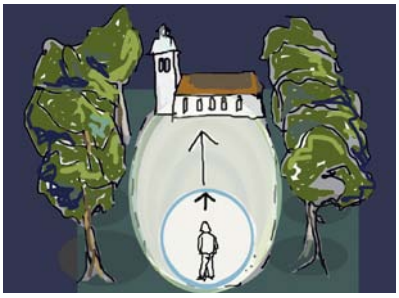

Figure 31. Either the experienced space changed in size or you redefined what the space is.

When talking about enlarging the space with light, this can be regarded in two ways: either the surrounding space is perceived as constituted by the same limitations as before and still you experience it as larger (for example by a rear back wall that appears farther away with less light on the facade), or the physical limitations of the space (the light zone) are experienced as having been moved because you are redefining what is regarded as the space (see figure 31, see paper E).

These differences in concept interpretation show how important it is to combine quantitative methods with a qualitative approach or otherwise prepare the informants in a study so that concepts are interpreted in similar way.

7.3 PROFESSIONAL DIFFERENCES

Findings from the Auditorium Study indicated that designers and architects answer questions about spatial experience, such as depth and openness, differently than non-designers. The professional difference was seen especially regarding the concepts *deep*, *angular* and *large*. This could depend not only on how accustomed they are to understand and use the concepts, but also on the extent of their heightened sensibility from experience and interest in the issue. The use of trained observers (designers and architects) was shown to give more detailed and rich descriptions than with non-professional interviewees (see paper B).

During the coding of the questionnaire answers from the Church Park Study it seemed that architects and designers often answered in a pattern that stood out from the typical response pattern. This may show that designers respond differently than the population at large. Subjects less affected by pre-understanding may answer in a more genuine and "true" way. The Church Park interviews showed that there is an important difference between judging real spaces or images. Professional training appears to interfere with image judging. Light planners that mostly use maps in their planning may think more of the distribution of light at the horizontal plane rather than at the vertical plane. Conversely, architects, who are so accustomed to reduce details when sketching, may "see" real spaces in a simplified way (see paper D).

Matusiak's study on whether width or height has the strongest impact on size impression of rooms showed different results between school children's assessments and architectural students' assessments (Matusiak, 2008). Matusiak explains that the reason may be the unique experience of space that architect students have, and also because the children and students had different eye heights. Gifford, Hine, Müller-Clemm, Reynolds and Shaw, who have compared architects' experiences of architecture to non-architects' experiences, found clear differences in assessment, similar to other researchers such as Herschberger, Nasar and Groat (Gifford, Hine, Müller-Clemm, Reynolds, & Shaw, 2000). In their study it was seen that architects refer to design quality, form, style and historic significance while non-professionals refer to preference and type, and that non-architects made descriptive evaluations while architects' evaluations were abstract and conceptual. Gifford, et al. found that architects preferred buildings with more intricate prototypicality[26] of style and richness of material.

26. "Prototypicality" is a term of Gifford, et al.

7.4 PREFERENCE AND PERSONALITY INFLUENCE ANSWERS

Subjects were never asked for their preferences. Still, preferences interfered with the answers, especially in the free descriptions. Either a subject liked a lighting scenario or not, depending on previous knowledge and references. For example, one Church Park informant said that she preferred less light on the church facade and her husband said that she did not like a powerful church as an institution. Professionally related pre-understanding was evident in the Auditorium Study when a woman with a background as a dancer and set designer interpreted every scenario in the auditorium in relation to the lecture podium as a stage. Another interviewee had a predetermined position that indirect lighting is always the best choice, and judged all the scenarios from this standpoint (see papers B and C). This relates to the article by Veitch, et al. about the beliefs and preferences of end users about lighting (Veitch, Hine, & Gifford, 1993).

The informants in the Auditorium Study had different answering patterns. Some informants consistently answered in outer positions or closer to the middle of the semantic scale. It is easy to make the conclusion that those answering in outer position are more secure in their answers and know the topic better, but it could also be the differences in personality or on how accustomed they are to answering inquiries (see papers B and C). Poulton has, as referred to by Boyce, found the *range effect* and shown that subjects always use something as a reference for assessment: "The effect is simply that observers tend to match the middle of the rating scale with the middle of the range of conditions experienced" (Boyce, 1981, pp. 258, 278).

In the Church Park Study, the video camera in some way played the role of an actor in the interplay of the interview. Latour's actor–network theory (ANT) states that people in social interplay can be regarded not only as actors, but also artefacts – and spaces can be actors (Alvesson & Sköldberg, 2008, p. 93).[27] By recording in a distinctly visible way and also telling subjects that the film was intended to be used in a thesis, some potential subjects will certainly be frightened away, while exhibitionists and the self-confident are in their element. Though the confident subjects may be more sure of their statements; still they may not be more right than any other (see papers D–G).

27. Alvesson and Sköldberg refer to B. Latour (2005) *Reassembling the social: An introduction to actor-network theory*. Oxford: Oxford University Press.

7.5 THE EXPERIENCE OF USING REAL-LIFE SPACES

The use of real-life experimental sites was presumed to help the informants to refer the illumination situation to a trustworthy functional and contextual use. It is difficult to imagine being safe or unsafe in a real space when assessing a laboratory situation in a totally different context. The complexity of real spaces, including the cultural context of the space in connection to a building or a city, interferes with the findings, as has been shown with this research (see chapter 7.6).

The lighting researcher Boyce writes about using real spaces in research: "For example, it is possible, at great expense and inconvenience, to use real interiors, a representative sample of observers and a method of obtaining subjective judgements which diminishes the range effect" (Boyce, 1981, p. 258). The experience from the research in this thesis shows that the use of real environments does not need to be more expensive than building a full-scale mock-up. In Alingsås the experimental site was used as it was: electricity was easily provided through a municipality lamp post, luminaires and other electrical equipment were borrowed or hired for a limited time. The Auditorium Study was even less expensive since it was possible to use the existing control system with five lighting scenarios in a university building. The only extra cost for that study was providing coffee for the informants, who participated without payment (see papers B–G).

7.6 CONTEXTUAL LIMITATIONS

These research studies were conducted in specific spaces, and naturally these findings are not valid for all spaces. Even so, another researcher should be able to reach similar findings if the studies were repeated in the same or similar context. The findings should not be taken as a ready reference for lighting professionals to implement in other contexts, but can be used as a way to increase our understanding of the influence of non-calculable effects of lighting on spatial experiences. When it comes to experiencing light and space, much is contrast dependent, relative and contextual. Light experience depends of many factors, not the least of which is the viewing angle and the observer position. Still it is possible to draw conclusions that can be generalised – such as to say that light can invite or exclude people according to some circumstances – but there is no absolute truth. It is still of great importance to know what in this specific context could interfere with the answers. In a study in a complex

and real space it is important to see the answers from different angles and understand the whole story of why the informants answered as they did. To be able to generalise, researchers and readers must understand the contextual. These research experiments were made in a Swedish lighting culture and the results must be regarded in this context. However, the study raises questions and theories that are possible to test, and must be tested and discussed in other contexts and with larger groups of informants.

Concerning the Church Park Study, the findings should be similar for an urban space of equal size around a park and with buildings of the same size, with similar surface colours, similar luminaire height, street width and distances between the lamp poles (see papers D–G).

This annual light event Lights in Alingsås 2010 was held for the twelfth time. The local public is becoming well educated in lighting design. The informants who participated in the study were already interested in watching light, since most of them had taken the one-hour walking tour at the light festival, where this research installation was the last station of seven light installations. As a result, even the non-professionals in the local audience were more acquainted with observing light installations. When the informants received the questionnaire, they had the task of judging the light. A person passing by would probably have a different approach to the illuminated park. To discover bias related to local context neighbours living in the same block could mark their relationship with the park on the questionnaire, but the number of informants that answered that they lived nearby was too small to be worthy of analysis. It would have been better to ask if they lived in Alingsås (see papers D–G).

The research lighting in the church park was a temporary five-week test installation, and this has consequences for subjects that are accustomed to seeing the park in a different light. Some of the luminaires were obviously mounted in an improvised manner: the tree spotlights mounted with belts around the trunks were used instead of ground-mounted, recessed luminaires. Because of the short duration of the installation and because the luminaires were borrowed from sponsors, there was not much time to fine-tune the glare-protection shields. The result of unshielded ground luminaires was more glare than a permanent solution would have had. The illumination was designed mainly on the assumption that most subjects would walk from one direction that was drawn on maps as a guided tour. Subjects were also encouraged to walk around the park when assessing the light, which could be seen from all angles. The expected effect that the street space would be

included in the whole park space when the autumn leaves fell was not seen because the leaves stayed longer than usual this year. However, the reflection from the leaves was more matted during the data-collection period, which cause the luminaires mounted on the ground to illuminate the tree tops to be perceived as more glaring by the end of October (see papers D–G).

Limitations in the local context and the design of the experimental setup had consequences for parts of the research. The church park is a central and open location that cannot really be said to be unsafe. The vegetation can be described as having a low density of trees and no undergrowth, which is beneficial for safety in an enclosed space (Jorgensen, et al., 2002). There were already several aspects of the park that made subjects feel safe: the place was surrounded with flats with windows facing the park and people from the neighbourhood kept an eye on things – both of these aspects contributed to subjects feeling safe. There were no real places to hide, and during the lighting event many people passed by. However, several informants familiar with the original park illumination reported that the original lighting made the park a dark place that they would usually rush through (see papers D–G).

Contextual limitations were also seen in the Auditorium Study where the informants could identify the function of almost every scenario but not the function of the "mood scenario". The interviews showed that the informants had difficulties relating to the cosy light to this official building and the function of the auditorium (see paper C).

7.7 PROBLEMS WITH THE EXPERIMENTAL SETUPS

An aspect that cannot be generalised was the illumination of a path with light directed inwards at one half, and light directed outwards on the other half. This was done to test the assumption that an illuminated surrounding would contribute more to the feeling of safety than an illuminated path that exposes people in relation to the dark surrounding, where a potential danger can be hidden. The judgements regarding the light direction of the walkway were relatively balanced: 53% of the informants judged the illumination inwards as contributing more to the feeling of safety, compared to the 37% that chose the outward-directed illumination as safer. As bushes and hiding places are missing in this park one can suspect that many who responded that outward light was safer understood the question more generally, while several of the respondents that answered that the inward-directed light was safer considered the question more site specific. Another factor that may

have influenced the uniformly distributed answers was that the raking light on the gravel was more beautiful than the raking light on the lawn, a fact that could have influenced subjects who preferred the gravel effect to consider it safer. The question is interesting, but needs to be studied more on paths that have more vegetation, and needs to be studied with lighting from different heights. In this case, the assumption was not strong enough to be valid when the luminaire height was low, with luminaires at 20 cm, in this open park when bushes and other low vegetation were lacking. Light at leg height cannot be regarded as exposing in the same way as light placed higher. This assumption, concerning ordinary paths bordered with bushes and other hiding places, may still be valid in another context, but needs further testing. Another interesting finding regarding the path lighting was that several interviewees felt that the inward light made the path appear narrow, more emphasised and intimate, and that the wider outreach light was reminiscent of an exit, which was also emphasised by being part of the main direction of the walking tour. The informants spontaneously termed the light on the path as "visual guidance" or "benchmark" (see paper G and the design description in the appendix).

The gateway that bordered the park consisted of a clearly defined and tangible space by itself. The purpose, by varying the existing central row of luminaires with either an asymmetric single row or double rows close to the walls, was to observe the difference between the effects of an asymmetrical or symmetrical luminaire placement. The assumption that a single row next to a wall describes the spatial shape more clearly than a centred row meant that it should also be experienced as more safe. This assumption, however, was not supported. The experimental lighting equipment unfortunately was not similar to the existing lighting. The luminaires that were provided had a glare protection and were more shielded with a more downward-directed light than those that were originally requested for the study. The existing luminaires were more glaring and they spread more light up to the ceiling than the new test lighting. Additionally, the colour temperature was not equal: the central original row had warmer light and more aged compact-fluorescent lamps. Furthermore, halfway through the five-week study the control switch malfunctioned so that the single asymmetric row could not be viewed separately because the central row shone simultaneously. When the double rows along the walls were turned on, the level of light in the gateway was doubled, which also influenced the results. The single-sided luminaire row should have been enough to light the entire gateway, and the wall re-

flectance would have created a distinct space, yet when subjects could chose double rows with more light they did so. In my experience it seems that most people generally consider more light to be safer, up to a certain level. Still, this shows that the assumption was not strong enough to be unaffected by these disturbances. The asymmetric single row worked sufficiently, though it was not a solution that would always be the best for a gateway like this. Even though the questionnaire findings for the gateway were less interesting, the interviews provided new insights that supported the prevailing assumption. Two interior designers, one of them a lighting designer, answered that the space became more clearly defined in the asymmetric single-sided lighting. Their trained gazes observed that the inner yard looked remarkably darker when the gateway's glaring middle, centred row was lit, compared to the single asymmetric or the double-sided lighting. It does not feel safe to walk from a bright gateway towards a dark yard that is difficult to resolve and define (see figure 32 and the design description in the appendix).

Figure 32. The darker rear wall on the inner yard, created by a contrasting frame of centred light. Compare with the side-oriented light at the gateway!

7.8 FUTURE IMPROVEMENTS OF EXPERIMENTAL SETUPS

The omitted daylight apparently had a strong effect in the auditorium, which impacted the judgements, especially on the concept of delimitation/limitation. Most Swedish rooms do not block out the daylight, and only do so for specific purposes like slideshows. A suggestion for future studies is, if possible, to perform these during the evening in winter, when the sun has set

early and curtains do not have to be drawn (see papers B and C).

These studies also provide information about the informants' experience of the scenario orders in the Auditorium Study. Four different scenario orders were chosen. Several of the informants commented that they would have preferred to be able to change the scenarios quickly back and forth by themselves, without restrictions (see papers B and C). Hence, for some informants, a more detailed introduction explaining the expectations of what they should address would be needed. In the first lighting scenario several informants described the room itself more than the effect of the light.

Testing one question at a time in smaller research projects will probably lead to more secure answers, and the questionnaires would have been easier to statistically analyse with fewer variables. The approach in the Church Park Study, with so many different questions and illuminated objects at the same time in the complex space provided other kinds of insights. Still, making projects in complex spaces seems to be a fruitful way of studying relationships of this kind (see papers D–G).

In the Church Park questionnaire there was a box to tick for those who regarded themselves as architects or designers. The purpose of these boxes was to learn about both their professional background and also know who were visually trained observers, accustomed to assessing spaces. In some cases informants added a box of their own and wrote "artist" or "photographer". In future studies this question needs to be refined to those who work with light as a designer or engineer or those who work with spaces. The group of designers can also consist of graphical designers and others who don't work with these questions, whilst the group of photographers and artist also would have been interesting to study separately (see papers D–G).

8. Conclusion

If we return to the original research questions posed in chapter 1.5, we can see that these have been answered in several ways. The way in which distribution of light impacts spatial enclosure was shown by analysing light zones and wall emphasis. Size and shape are affected by patterns of light and the direction of light. Atmosphere – specifically, effect on attention and feeling of safety – was shown to be affected by the distribution of light. The profession of an observer was shown to affect the interpretation of these questions, specifically with respect to different possible understandings of spatial concepts.

The discussion all through this thesis can be formulated as a *theory of visual spatial boundaries*. This theory proposes that enclosure by spatial boundaries made visible by illumination is beneficial for spatial understanding, and consequently for an experience of safety. This seems to stand in contrast to Stamps' *permeability theory*. The permeability theory generally regards enclosure as a factor that decreases safety, since a subject may feel trapped in a closed space and that a danger can be hidden by visual occlusion (Stamps, 2007, 2010b). However, what the discussion in this thesis stresses is the importance of giving hints of the spatial construction by making the spatial boundaries more well-defined. By fully illuminating spaces to create a uniform light that makes everything visible, nothing is emphasised, which may create a lack of visual interest with no support for orientation and spatial understanding. This can also create an uncertainty that makes pedestrians feel unsafe. Still, the two theories do not contradict each other and can be used simultaneously. A large difference between these theories lies in the interpretation of the concepts. Spaciousness can either address openness or a large size of a volume or a ground area, or both. Enclosure, on the other hand, can

relate both to closed walls and to clearly visible spatial boundaries that do not have to be closed. This conceptual confusion describes the complex interaction of many factors in spatial perception. Adding light to spatial boundaries does not impact locomotive occlusion and might not even change the visibility, even though the contrasting surrounding darkness may hide objects that were visible before the light was added. Light does not physically close a space but may still increase the enclosing or embracing feeling within a space. Both theories share the assumption that a clear view of the space is beneficial to finding refuge and detecting possible dangers.

A conclusion to draw from the studies was that distribution of light indeed is an effective tool; a single variable such as luminaire positions in the ceiling can cause large changes in perceived spatiality. The spatial context and subjects' varying interpretations were shown to give rise to contradictory findings. In these studies it was found that it is not only brightness that can have an enlarging effect, but darkness can also increase spaciousness, and brightness can also decrease spaciousness. Comparing findings from these three studies lead to the hypothesis that brightness often increases spaciousness up to a certain level of light, but when spatial surfaces become too bright and prominent the effect can be reversed.

The experienced space, like a light zone, does not necessarily coincide with the built space. Through analysing light zones it was found that their relation to each other also impacted the perceived spatial size: both compound and separated light zones can increase depth or width, depending on how these patterns of light are read together in the spatial context. The figure–ground relationship between a light zone, or an illuminated object, and its background is crucial to analysing whether the lit surface appears closer or farther away. It was also shown that the gaze's movement towards brightness contrasts can impact size perception. Additionally, the distribution of light can contribute to surfaces being perceived as curved.

The concept of light topography was developed through the research studies to demonstrate the effect of luminaire positions on perceived spatial height. It was found that informants felt safer with a lower street luminaire height than with a higher height.

In these studies it was found that light zones can contribute to an inclusive or excluding atmosphere. A focused light in darker surrounding called for attention, reduced interviewees' speaking volume and made them more attentive to sounds. These studies also show that distribution of light can impact colour impressions in a space.

The opportunity to test different approaches, methods and spatial contexts with the same research questions makes methodological comparisons between the studies possible. It was shown to be very valuable to combine the questionnaires with interviews; the questionnaires were useful as a manuscript for the interviews. Still, the richest empirical source was definitely the interviews and the free descriptions. The increased understanding of how subjects interpreted the study, the space, the questions and the concepts also increases the usefulness of the questionnaires. The use of the questionnaires made the interview findings easier to grasp. The statistics clearly display majority answers which were beneficial for comparing findings.

Quantitative studies focus on controlling every aspect of the experimental situation, but they seldom discuss interpretation of concepts and questions, and the subjects' pre-understanding. All findings, quantitative as well as qualitative, need to be interpreted. The crucial point is choosing what material to contribute to the text or not. These circumstances are also highly important for the reliability. These research studies show that it is necessary to educate informants and make an agreement about concept use, or to analyse their conceptual use afterwards. There is always a risk with bias related to the researcher in qualitative studies like interviews. Hence, reflexive interpretation provides a meta perspective of the interview situation, which increases the awareness of the interview context (Alvesson, 2011; Alvesson & Sköldberg, 2009).

Furthermore, differences were seen between architects and designers and non-professionals in the inquiries, especially in the ways they used concepts when answering a questionnaire. The use of trained observers (designers and architects) was shown to give more detailed and rich descriptions than with non-professionals.

8.1 CONTRIBUTION AND IMPLICATIONS

The knowledge on distribution of light gained from this thesis shows that more research is needed in this area. By clarifying the significance of distribution of light for spatial perception and experience, in particular the importance of light on vertical surfaces for the experience of spatial enclosure, and the *light topography*, e.g. the height of luminaire placements, this emphasises the need for a research and a light planning that privileges non-uniformity and that uses visual observations in real, complex spaces.

These findings can influence light planners into putting more effort into lighting walls, trees and bushes instead of the ground surface. Spatial un-

derstanding, important for orientation, is easier when walls, which can be constituted by trees, are visible. Furthermore, trees are both beautiful and rewarding reflectors that give so much back when illuminated, instead of being dark and threatening. This should be considered when safety issues are given high priority in the planning of spaces.

This research widens the understanding of when and why patterns of brightness or darkness influence our perception of spatial dimensions, a subject that needs further discussion. It is more common that there is a desire to enlarge a space rather than shrink a space. The ability to make a space more spacious through distribution of light is cost-effective when compared to the alternative of building larger areas or volumes. Furthermore distribution of light can also be useful for dividing a large office landscape into spatial units.

As this research shows, knowledge and awareness of how light zones can be used to create an inclusive or excluding atmosphere are valuable both to designers, researchers and customers. Furthermore, a focused distribution of light can be used to make an audience quiet in a performance situation, and should also be tested in schools and pre-schools. Everyday settings can also be staged and choreographed with care.

Even though several new findings came out of this thesis, the largest contribution is most likely that it shows how methods with an artistic qualitative approach, maybe seen as "inconvenient", can lead to rich, new findings. Through this, several established research findings were questioned and new theories were developed. The qualitative methods in this thesis are unique for the lighting research field, though not unusual in design research and architectural context. However, quantitative questionnaires and statistics are not common in design research or artistic research. This combination is shown to be fruitful when the task is to explore spatial experience in real, illuminated, complex spaces, an area where quantitative methods are too limited (Fridell Anter & Billger, 2010; Kronqvist, 2012). This research shows how several spatial factors interfere with each other in a complex way in real spaces. It also shows the large impact of concept interpretation in questionnaire studies. Since this research combines approaches and methods from various fields, the described spatial observations provide a starting point for discussions between practitioners and researchers with different backgrounds.

8.2 FUTURE RESEARCH PROPOSALS

The findings in this thesis still need to be tested and evaluated in many more contexts and also with other methods and with larger groups of informants. It was found that there is a large gap of research about spatial experience and lighting in contexts other than offices or retail environments. There are hardly any studies about spatial experience, lighting and atmosphere in exterior space, except for a few studies about safety. Qualitative methods can be a major contribution to lighting research in the future, and a good start would be to map and evaluate qualitative studies in the field through a literature review.

Some empirical material from the Auditorium Study is still waiting for future analysis. For example, the Auditorium Study inquiry into spatial atmosphere and the informants' sketches regarding the experienced space, the light zone compared to the built space will be presented in forthcoming articles. The experimental setup and questions from the Scale Model Study will be interesting to repeat in full-scale rooms and with informants.

According to these findings and previous research it seems that darkness makes the space appear more spacious and deep when the general level of light is low, though not in a brighter space. A related issue that is not clearly explored is the threshold at which illuminated walls, by an increased level of light in relation to the surrounding, shift from increasing spaciousness to decreasing spaciousness. Both these relationships should be interesting to study further. The relationship between walls, seen as belonging to cavities and bodies of buildings either as figure or ground, in interior and exterior spatial contexts, is an additional task that needs to be explored further. It is relevant for depth perception where light can be either an increasing or decreasing factor.

Non-uniform illumination needs to be studied further. When is a non-uniform illumination contributing to a positive spatial experience, and when are the contrasts so large and harsh that the experience becomes unpleasant? A further interesting question is whether a uniform light is generally experienced as more public.

Despite the well-known architectural praxis, that a pattern of vertical lines raises a spatial height and horizontal lines give a wider impression, it was difficult to found research studies that really supported these theories. Still, this relationship appears to be a likely assumption which needs further testing in several spatial contexts.

The concept of *light topography* should be further developed and used as

a tool for rhythm and atmosphere analysis. The assumption that inward-directed light increases the feeling of being safe in some spatial contexts, while outward-directed light can probably increase reassurances of safety in other contexts, such as with varying vegetation and different luminaire height, needs to be further studied.

In addition to the light topography tool, it would be interesting to develop a notification system about rhythm in urban lighting that supports planning for non-uniformity in a consistent way that benefits orientation, safety, architectural experience and spatial understanding.

Atmosphere seems to not have been a frequent and extensive issue in past lighting research. This track should be continued for example by exploring what subjects really mean by a sacred light or an inviting and welcoming light. Moreover, the assumption formulated in this thesis, regarding a possible relationship between a warm lighting impression and soft contrasts, and between a cold impression and hard contrasts, is interesting to test.

Finally, the professional differences, regarding conceptual interpretation and spatial understanding among architects or designers and non-professionals, that were indicated in the studies should also be studied further, since these as well as previous research indicate that it is not easy to design an experience that answers the design intentions.

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Appended Papers

Paper A

Distribution of Light and Spatial Enclosure – A Scale Model Study

Submitted to Nordic Journal of Architectural Research

Paper B

Distribution of Light and Spatial Complexity: Appearance of Five Lighting Scenarios in an Auditorium

Submitted to Journal of Interior Design

Paper C

Spatial Interpretations in Relation to Designer Intentions: A Combined Strategies Study in an Auditorium with Variable Lighting

In proceedings from Colour and Light in Architecture.
International conference in Venice 11–12 November 2010. p. 258–263.
ISBN/ISSN: 978-88-96370-04-9. No. 135594

Paper D

Distribution of Light and Atmosphere in Urban Environment

Submitted to Journal of Design Research,
Accepted with revisions. Revised version.

Paper E

Distribution of Light and Perceived Size and Shape

Submitted to Nordic Journal of Architectural Research

Paper F

A Full-Scale Light Laboratory in a Public Space

In Proceedings from PLDC 3rd Global lighting
Design Convention, 19–22 October, 2011 in Madrid, Spain.
VIA-Verlag, Güthersloh, Germany.

Paper G

Lighting Design Research in Public Space: A Holistic Approach to a Complex Reality

In Proceedings from the 27 Session of the CIE International conference in Sun City, South Africa 10–15 July 2011. International Commission on Illumination. No. CIE 197:2011. Volume 1, part 2. p. 767-776. ISBN 978-3-901906-99-2.

Appendix

X. THE DESIGN INTENTIONS IN THE CHURCH PARK PROJECT

This chapter describes the intentions and the design process behind the lighting design in the third research project more closely, since this is an important part of the research made in an artistic context at the Faculty of Fine, Applied and Performing Arts.

A full-scale study was conducted in the park close to the Christinae Church in Alingsås, Sweden from September 24 to October 31, 2010. The temporary installation with 90 luminaires was made in collaboration with Lights in Alingsås 2010, an annual event of the Professional Lighting Designers Association (PLDA). This research project investigated how the distribution of light affects the perception of a public space.

This work did not only involve designing an experimental setup, but also a lighting design that would function well and be experienced as comfortable and visually interesting during the five weeks that the installation was mounted in the park. The illumination was designed with several aims: to create a clearly defined and tangible space; to create a pleasant and inviting atmosphere; to verify if this was fulfilled and to find answers to the research questions, which were changed according to the park space and available lighting equipment. Additionally, there was a pedagogical purpose to illustrate some phenomena to the audience and to let them visually explore the effect of light distribution themselves. The design intention was not to create an event and festive illumination, but to create a lighting design that could have been permanent and functional.

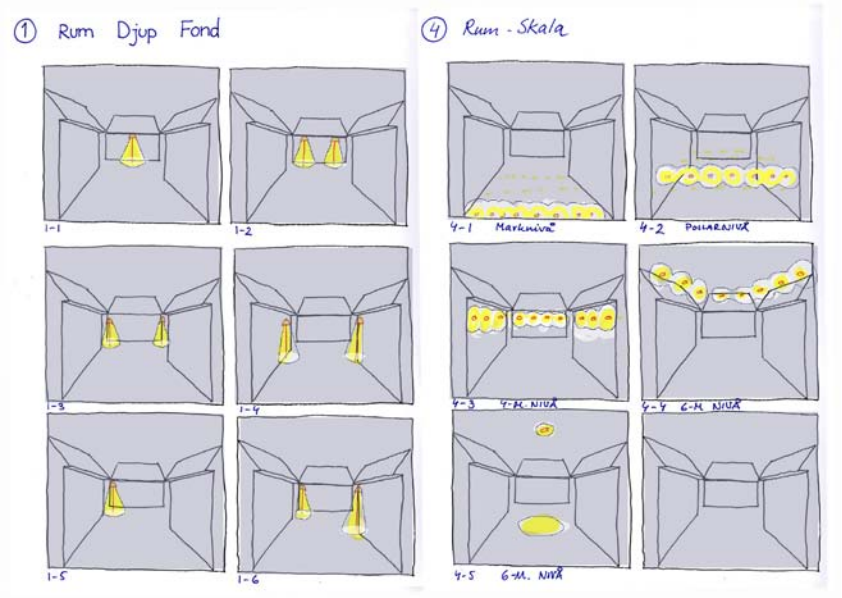

Figure 33. A sample of principal sketches related to research questions.

The design process started by identifying principles from earlier research studies of luminaire placement that would be interesting to test in a full-scale environment (see paper A). The images above show some of these, such as how luminaire relationships to a rear facade influence perception of depth (left figure), and how the light topography, the height of luminaires, influences the perceived size of the space (right figure). The relationship between luminaires in foreground, middle ground and background were also sketched (see figure 33), as well as visual guidance by position luminaires in comparison to wall light and the relationship between openness–enclosure in spaces and the distribution of light. The next step was to find an urban space suitable to apply these principles of distribution of light. Alingsås Municipality was contacted and permission to work with the central located church park was received.

X.I The Spatial Context – Study Opportunities

The experimental site needed to satisfy several criteria. The spatial context needed to be a real-life, urban space with complexity. The church park, (in Swedish: *Kyrkoplan*) was both a public place and a park surrounded by the official Town Hall, private flats and streets, with car as well as pedestrian traffic.

The space was neither too large nor too small to work with. Because there were no bushes, the facades were all visible. The space could be considered both closed and defined, yet it opened up. The bright nuances of the pastel-coloured walls reflect light well. The proximity to the main square makes for easy access for the light festival's walking tours. The streets surrounding the park are similar in their character, with similar building heights and colours, which is an important precondition for being able to compare the streets around the park with each other. This study was chosen to be in a type of urban space that can be found in many Swedish towns. Alingsås is a cute, picturesque and idyllic small town, which may have influenced the results. This park space was chosen as a space with a more general character than many other areas of Alingsås.

Figure 34. Existing illumination.

The existing lighting of the location was in many ways already designed according to the principles suggested in this thesis: street light oriented in close relation to the facades and with a luminaire height that is suitable to the architectonic scale, in this case rather low. However, the existing lighting was not planned with sensitivity to the spatial context. An obvious problem was the use of different luminaries and lamppost heights which created a fragmented impression. The existing lighting was, according to a discussion with the municipality, something that was created out of happenstance. The luminaire heights and placements varied because different streets were planned in different periods, and the street luminaires have different designs that relate to a test lighting that had been done twenty years prior and was left in place and forgotten. Moreover, the existing mercury lamps will soon need to be replaced with new light sources according to EU and Swedish law directives. This situation seems

common and the same conditions are probably easy to find in other towns.

Initially, some problems with the existing lighting were identified where a change would benefit the spatial context. First, the street luminaires at Drottninggatan (the northern street) should be turned towards the street, facing away from the park, leaving an impression that it is the street and not the park that is important. Instead of emphasising the street, wall-hung luminaires could contribute to establishing the fourth wall of the space, marking a pause in the street rhythm and show the street user that something happens here – a space that is inviting. Practical considerations (described below) made it difficult to work with changes of the luminaire placement at Drottninggatan as a temporary solution, so this will be a suggestion to the Alingsås municipality for the future.

The existing lighting at the church is old. The church is illuminated by two large parabolic high-pressure sodium lamp spotlights that do not highlight any three-dimensionality, any architectonic details, building material or colours. The park is dark when compared to the streets. Seven old iron luminaires with clear glass and incandescent light are spread out across the park. They are important as historical references, but the light does not reach very far. These luminaires were not changed during the experimental period at the festival. The Town Hall is equipped with soft, yellow-toned facade lighting from thin fluorescent tubes mounted above the windows.

Figure 35. Plan of the church park.

X.II The Design Suggestion

The experimental setup is described in the attached research articles (see papers D–G) and will not be described in detail here. Instead this text focuses on the choices in the design process as a complement to the articles.

This park was one of the town's green resources and the main focus of the design was on the tree lighting in order to emphasise this function. The park lacked low vegetation such as bushes or flowers. The trees were used as pillars where the tree trunks surrounding the park formed a kind of wall to the streets, and as a ceiling where the solitary trees with huge tops were highlighted. These tree tops were illuminated from below from different directions and with different colour temperature of the light sources to emphasise the tree volumes. Additionally, several layers of shadow and brightness were constructed to increase the depth of the foliage. Some of the branches became dark against a brighter background of leaves while others stood out brighter than their background. The tree tops were illuminated, in contrast to the trunks, which formed a semi-open wall that delimited the edge of the park.

Figure 36. Sketch of trees in the park.

The trunks were illuminated with raking light from below that emphasized the texture of the bark and highlighted some of the foliage. This light was switched on and off every 15 minutes during the experimental period. A choice had to be made between illuminating the tree trunks both from inside the park and outside from the street. To reduce the amount of luminaires and questions for the informants, only inside lighting was chosen. The upward light from ground-mounted luminaires was chosen because of the design and for practical and economic reasons. Sky-lift support was expensive and with the upward direction some light also fell on the foliage, a fact that increased the tree ceiling emphasis. A disadvantage of so much upward light was glaring luminaires on the ground. In a more permanent installation there would be more possibility to reduce the glare by glare-protection shielding and by digging the luminaires down into the soil.

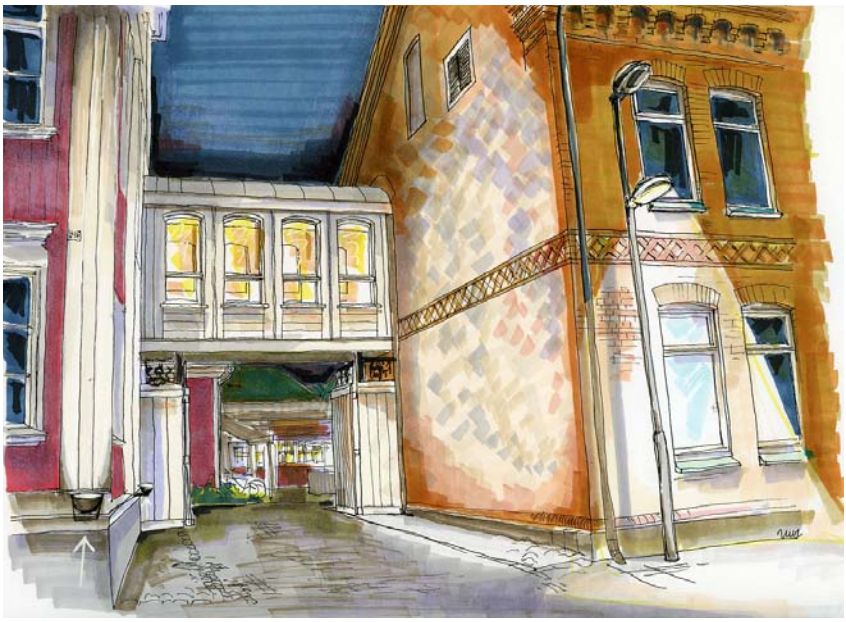

Figure 37. Sketch of facade luminaire at the Town Hall and the lamp pole with two luminaires.

To reduce the risk of glare and waste light into the flats, an effort was made to illuminate the facades while avoiding the windows. The existing place-

ment of lamp poles so close to the facade allowed light to also fall down onto the facade. As a result, street luminaires were chosen that only directed light downwards. However, some especially interesting facade elements like wood or brick roof tops were also highlighted. To test the influence of the light topography, the height of street luminaires needed to vary. There were two possibilities, either to use different luminaire heights on different streets or to change the height of the light by control equipment. The opportunity to work with a radio-controlled LED luminaire enabled the luminaire height to change on all streets every fifth minute. On one street it was not possible to change the height because the roof's eaves were not higher than five meters and the existing lamppost positions were used because it was the most practical and economical solution. For a normal lighting design project the distances between the lampposts would be changed so that they would be closer with more luminaires at lower heights than higher heights. However, this would have been difficult to arrange for this temporary test installation.

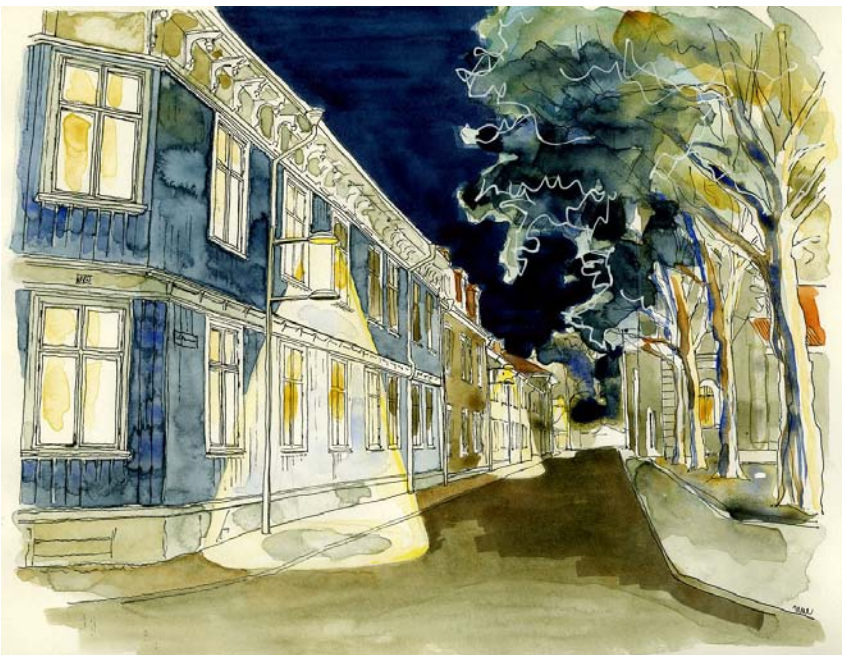

Figure 38. Sketch of a street with variable luminaire height and illuminated tree trunks.

Because the original lampposts were used for the study, but mounted with two new luminaires at different heights, the distribution of light was less uniform for the lower height where the distance between the luminaires was greater. As such, the contrasts were larger for the lower height than for the higher. At the higher height, the light was more uniformly distributed and covered more of the street, though less concentrated and therefore less bright. However, the lenses of these LED luminaires were oriented to reduce this difference. The higher luminaire placement brought more glare than the lower because it was easier look directly into the light source and the light spot was perceived as smaller. The contrasts naturally became larger and increased the glare. In this case, the amount of light that reached the walls was essential because more light softened the contrasts.

Figure 39. The church with event light from the inside.

Standing luminaires on the ground directed the light of the church facade and the Town Hall upward. Both of these were heritage buildings that need to be treated carefully and installations on the facades were not possible. By using grazing (raking) light here the texture of the uneven church facade was emphasised and appeared more lively. Every third minute the light scenarios at the church facade were shifted, as displayed in figure 41. The upward-directed light on the Town Hall, lit every 15 minutes, was also related to the research question of spatial power hierarchies.

Figure 40. Sketch of lighting scenarios on the church facade.

The church had already been very successfully illuminated in earlier lighting workshops by the PLDA and there was no intention to repeat that. However, supplementing the experimental facade light with a warm, glowing, radiating light from the windows and glass parts next to the church doors would make the spatial context more complete. The church is a very important object in this space and the intention was to visualize the interior of the church as a symbol of light, spilling a sacred atmosphere outward like a treasure box in the park. Since the glass parts and windows of the church had characteristic shapes that prominently contributed to the architectural experience, they should not be illuminated with extra care. Fortunately, Lights in Alingsås 2010 included church concerts that were illuminated by a stage lighting designer, and his lighting design actually fit into the Church Park Study by providing the church with a warm red or alternating blue light that shone out from the windows on some evenings. The bell tower was also made more prominent with a saturated green filter added to a spotlight aimed at its green copper opening.

One of the paths in the park was half illuminated by light from low bollards; this light was either directed inward so that light was shed on the gravel, or directed outward and illuminated the surrounding lawn, as on the other half of the path. The low placement of this light (at a height of 20 cm) was another attempt to test the possibilities of working with the light topography. Additionally, raking light was used to emphasise the gravel and the grass material structure.

Figure 41. Path and bench lighting.

Light directions in entrances can have a large impact on the feeling of security and face recognition. In one gateway connected to the park there was a great opportunity to study the effect of changing the existing centred light from above to one side of the ceiling and to both sides of the ceiling. These light changes were controlled by a button panel so the users themselves could choose the light they preferred. In this gateway, security and distinctness were studied, and also how the experienced size and shape of the space constituted by the gateway changed according to the light.

Figure 42. Sketch of gateway lighting scenarios.

The park contained two old memorial stones or possibly graves. One was called "Jonas Alströmer's supposed grave", belonging to Alingsås' "great son" who brought the potato to Sweden. The other was a memorial to a former headmaster who paid for a portion of the church renovation. These objects were highlighted to extend the park's visual direction and depth by using them as minor landmarks. The design intention was to create a mysterious atmosphere with sparse raking light from below and with marked shadows. Furthermore, shadows cast through the iron fence towards the stone created a mysterious illusion that the shadow came from the golden cross of the other grave. The *mysterious* concept was therefore not interpreted in the same way as within Stamps' research, where "mysterious" mainly stands for something hidden, occlusion that hinders visibility (Stamps, 2007). The strength of the light was low, just enough to make the stones visible and its texture materialised. The iron fence was illuminated with a small amount of light directed with precision so every vertical element received three-dimensionality. On each grave only two low-voltage halogen spotlights were used to illuminate both the grave and the fence at the same time.

Figure 43. Lighting on graves.

Five benches were illuminated from beneath and behind so that the illumination clearly defined their position in relation to the ground and emphasised them without exposing people sitting on them. The low-placed light combined with the path light to emphasise the light topography.

Finally, a red cabinet along one street was emphasised as a landmark, illuminated by a spotlight with a red filter. This was done to create something irregular, an accent to make the cabinet visible like the other historical features that were highlighted.

Figure 44. Red cabinet and Town Hall lighting.

The light sources were chosen both for their colour and their ability to switch on and off quickly to facilitate a control schedule where the light changed between 3 and 15 minutes. Less than 15 minutes was not possible on the tree and Town Hall lighting where metal halide lights were used. The trees were mainly illuminated with cold colour temperatures that emphasised the green colours of the leaves. A few high-pressure sodium lamps were also used to contrast with the green leaves and to strengthen the coming autumn colours on some tree tops. Cold white light was used at the church, the Town Hall and in the street lighting, while warmer colours were used in lower positions

for the benches, the path and the graves. These differences in colour temperature were chosen to strengthen the public or private scales set by the light topography (see chapter 3.7).

X.III Design Remarks

This section discusses the outcome of the church park lighting design and experimental setup. One purpose of the church park lighting design installation was to verify if the design fulfilled its intention in the users' experiences. According to the interviews and the spontaneous comments also received, the design seems to have been experienced as expected. There was clear consensus that the atmosphere of the park was holistically experienced as a calm, peaceful, relaxing, inviting, warm and safe place. The spatial envelope was emphasised by creating a legible space through illuminated boundary surfaces such as surrounding facades, tree trunks and bushes. Several informants responded that the designer's intentions of creating spatial enclosure were fulfilled. The distinct spatial enclosure of this illuminated park – with an outer shield of wall-oriented streetlights, an inner semi-open space demarked by illuminated tree trunks and the emphasised foliage ceiling – was highly appreciated by the informants. During the interviews, the informants described their experiences of the spaciousness created by the illuminated trees in combination with the mixed colour temperatures and the low-positioned light on the paths and underneath the benches. However, the beauty of the trees may have diverted attention away from the research questions. It is difficult not to accidentally design a study that achieves the result you expected. In this case the target was to design a spatially defining illumination with a welcoming and safe atmosphere. Still, to design an experience is not as easy as it looks; many factors interfere with an observer's judgement.

A few negative comments were received that a large number of luminaires were used with little regard for environmentally sustainable resources. However, this was not within the scope of the project agenda. The design was planned solely to acquire knowledge about questions of design and spatial experience and perception, and to get as much information as possible out of the study within the possibility afforded by the budget. With a limited time, the intent was to try as many of the research questions as possible without lowering the standard of design quality, and to be able to study the lighting in a complex, real space. Furthermore, control systems were used to shift between different luminaires so they did not all shine at the same time. LED

luminaires with low energy consumption were used for a large portion of the project. The street lighting was especially interesting to study from a sustainability perspective with Prisma Light's Eliott, a new Swedish-manufactured LED luminaire built-in wireless radio control. With this luminaire we also evaluated a shifting level of light for different days, shifting between 5, 10, 20, 30 and 50 W. A number of informants stated that 10 W was good enough with this luminaire for this street space. This can be compared to a traditional mercury light at 125 W or high-pressure sodium light at 250 W. 90 luminaires were used in total, though only 68 luminaires were ever on at the same time. The luminaires were supported with 48 W each, on average.

X.IV Design Proposals for the Church Park

The Church Park Project was initiated as temporary test lighting for research purposes during the event Lights in Alingsås 2010. However, in designing a real lighting design proposal for this space, I would work differently and reduce the amount of luminaires. For a new stationary lighting design, the following would be proposed:

The lower height of street lighting, 4.5 m, is preferable to create visible spatial boundaries (62% of the questionnaire informants assessed this height as safer than 6.5 m). Due to the large effect of spatial emphasis by distinct spatial boundaries, the tree trunk illumination would be prioritized ahead of the tree tops. Only three to four tree tops would be illuminated, from below, in the centre to reinforce the height impression, with one or two spotlights each. 51% of the informants assessed the tree lighting as the most important contribution to a feeling of safety. The tree trunks can be illuminated from above, and this is better when considering vandalism. If this would have been a constant illumination that did not change during the seasons, colour temperatures that emphasised autumn colours would not have been used. The character of the wall-grazing raking light close to the trunks as well as on the church would be kept. The church lighting would be more evenly distributed, without the striped pattern between illuminated and non-illuminated areas as in the experimental lighting. The cold colour temperature of the LED luminaires on the white facade would be kept and combined with a warmer glowing light from the inside, a light that also fills the window niches. An alternative to illuminating the church from below with separate flood lighting would be a strip of LED lights mounted beneath the base of the roof with additional light at the tower. Naturally, the church lighting should continue around the whole build-

ing to emphasise three-dimensionality by contrasts of shadows without the fragmented impression created by the dark areas in the experimental lighting. This would not be a strong light, but a soft light that brings out the texture of the facade and makes the church visible as a sculpture. The graves should be illuminated in exactly the same way as in the experimental lighting, with two spotlights apiece. The path should be illuminated with low inwardly directed bollards, as in the experimental lighting, or only with position luminaires mounted in the ground. It seemed beneficial for a spacious impression to create large differences in the light topography. There is no need to illuminate the Town Hall more than by using its existing soft facade lighting. The experimental uplight was added for research purposes. In total this lighting proposal would require less than half the luminaires used in the experimental lighting.

QUESTIONNAIRE FROM THE AUDITORIUM STUDY[28]

Data collection from a room with a variable distribution of light (Room 10).

Order of light scenarios: Name: Sex: Age: Profession/Education: Date: Interview length:[29]

Instructions: The researcher explains the purpose of the research study, to study the relationship between the light scenarios and spatial perception and experience. Half of the informants sit at position A (in the middle of a central audience row) and half at position B (by a window sill) (see figure 45). The researcher starts by showing one scenario at a time in a darkened room with drawn curtains. The order shifts in one of four different orders for different informants: 1–2–3–4–5, 5–4–3–2–1, 2–4–3–1–5 and 4–3–2–5–1. After a quick show of all five scenarios, the first scenario of the current sequence is shown again. The informant is instructed to take time to adapt to each lighting scenario. Tasks 2 and 3 are answered quietly. When the questionnaire is completed for each scenario the interview phase begins, which includes sketching. In the interview phase, all informants sit next to the researcher at the podium. During the sketching the informants are allowed and encouraged to walk around in the room.

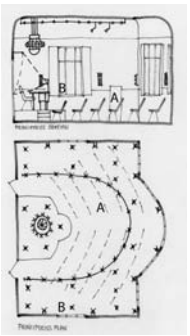

Figure 45. Plan and section to draw on. [30]

28. This questionnaire is presented translated from the original Swedish in which is was administered.
29. In this appendix these questions are squeezed together to save space.
30. The empty sketches to draw on were originally larger.

Tasks:

1. Describe the room (in each scenario) in your own words:
2. Fill in the questionnaire tables below (one for each scenario):

Spatial shape[31]

Estimate	−3	−2	−1	0	1	2	3
High (*Högt*)							
Low (*Lågt*)							
Wide (*Brett*)							
Narrow/Tight (*Trångt*)							
Deep (*Djupt*)							
Shallow (*Grunt*)							
Round (*Runt*)							
Square (*Kantigt*)							
Large (*Stort*)							
Small (*Litet*)							

Spatiality

Estimate	−3	−2	−1	0	1	2	3
Delimited (*Avgränsat*)							
Open (*Öppet*)							
Enclosed/Embraced (*Omslutande*)							
Excluding (*Utestängande*)							
Airy (*Luftigt*)							
Confined/Shut in (*Instängt*)							
Alienating (*Fjärmande*)							
Close (*Nära*)							

31. The inquiry was performed in Swedish. Original Swedish concepts are shown in italics within brackets.

Circle the words you think match the room in each scenario!

Diffuse (*Diffust*), Legible/Clear (*Tydligt*), Dark (*Mörkt*), Sacred (*Sakralt*), Unsafe (*Otryggt*), Rejecting (*Frånstötande*), Simple (*Enkelt*), Safe (*Tryggt*), Complex (*Komplext*), Inviting (*Inbjudande*), Private (*Privat*), Unfriendly (*Ovänligt*), Calm (*Lugnt*), Personal (*Personligt*), Light weight (*Lätt*), Deliberating (*Befriande*), Dynamic (*Dynamiskt*), Unclear (*Otydligt*), Bright (*Ljust*), Intense (*Intensivt*), Harmonic (*Harmoniskt*), Public (*Offentligt*), Friendly (*Vänligt*), Welcoming (*Välkomnande*), Embracing (*Omfamnande*), Subdued (*Dämpat*), Depressing (*Deprimerande*), Cold, (*Kallt*), Deliberating (*Upplyftande*), Active (*Aktivt*), Hard (*Hårt*), Boring (*Tråkigt*), Pleasant (*Trevligt*), Unusual (*Ovanligt*), Lively (*Livligt*), Heavy (*Tungt*), Profane (*Profant*), Ordinary (*Vanligt*), Warm (*Varmt*), Stimulating (*Stimulerande*), Unpleasant (*Otrevligt*), Monotonous (*Monotont*), Soft (*Mjukt*), Impersonal (*Opersonligt*) and Chaotic (*Kaotiskt*).[32]

3. Interview. The researcher asks follow-up questions about the informant's answer. For example: Why do you think this room looks airy? Why is the room more airy in this scenario than in the past scenario? What is it that makes it airy? Were there any words that could have described this room better? All interviews ended with the general questions: What does "atmosphere" mean to you? What does "spatiality" (*rumslighet*) mean to you?
4. Sketching moment (included in the interview, after all the questions are answered before proceeding to the next scenario). The informant is encouraged to draw the experienced space's spatial boundaries, and also to draw experienced light zones in plan and section drawings. Meanwhile, the interview continues with questions such as: What do you regard as the space in this scenario? How large is the light zone that you regard as a space in this scenario? Can you explain why? If you experience any specific directions, can you mark these with arrows?

32. These words were more spread out in the original questionnaire.

Questionnaire – Lighting Design Research in Public Space, Alingsås 2010

It is of great importance to listen to your evaluation of the lighting installation at the Christinae church park! Please answer with a cross in the box!

The date you saw the lighting:

Your age: Sex: female ☐ male: ☐

Make a cross if you live or work in the neighborhood: ☐

Make a cross if you are an architect or designer: ☐

The height of the streetlights and its impact on experienced security, spatial delimitation and perception of spatial size.

1. At which luminary height do you feel most secure (e.g. do you feel comfortable in the darkness)?
   4 meters ☐ 6 meters ☐ no difference ☐

2. When do you experience the space to be most delimited?
   4 meters ☐ 6 meters ☐ no difference ☐

3. How do you experience the park room as a whole, with luminaries at 4 meters compared to 6 meters? Does the 4 meters height make it:
   smaller ☐ larger ☐ no difference ☐

4. Do you detect any difference considering the public room's shape? Does the higher luminaire height makes it:
   a) higher ☐ lower ☐ no difference ☐

   b) deeper ☐ more flat ☐ no difference ☐

The lit fields at the church façade: How do you experience the difference between five, three and two lit fields (the corners) at the church façade? Make a cross when you think the room becomes deepest respectively most broad!

5. Deepest: 2 fields ☐ 3 fields ☐ 5 fields ☐ no difference ☐

6. Most broad: 2 fields ☐ 3 fields ☐ 5 fields ☐ no difference ☐

The pilasters (half columns) at the pink City Council building: Do you experience any difference regarding the height of the building when the up directed light at the columns is lit? The building as a whole becomes:

7. lower ☐ higher ☐ no difference ☐

The tree trunks: Do you experience any difference in room size when the tree trunks are lit? Is it becoming:

8. smaller ☐ larger ☐ no difference ☐

In the gateway: At Östra Kyrkogatan 6-8 you can self change the light with the switcher, so either two rows, one centered row or one asymmetric row of luminaries are lit. Which design do you think gives the most secure situation, when you stand in the gateway?

9. One side ☐ double sided ☐ centred ☐ no difference ☐

The path: One of the paths is lit by bollards. Which direction do you experience give the securest lighting?

10. Inwards ☐ outwards ☐ no difference ☐

Security: Which of the following lit objects do you think contribute most to your security experience?

11. The streetlighting ☐ The church ☐ The trees ☐ The path ☐

Below is some space for own comments if you wish:

The questionnaire that is distributed here should primarily be answered at this spot. You can leave it in a mailbox inside the Light pavilion! However, you may also take notes from the spot and fill in and send the questionnaire at www.hdk.gu.se, or www.lightsinalingsas.se. It may also be downloaded as a pdf. at these webpages. If you wish to mail it, the address is Ulrika W Lindh, HDK, P.O. Box 131, SE 405 30 Gothenburg, Sweden (ulrika.w.lindh@hdk.gu.se). Fax: + 46 (0) 31-786 48 88, marked:"Ulr ika W Lindh". Two design books, *"Ljussättning av broar och tunnlar"* (= Illumination of bridges and tunnels) and *"Design from Western Sweden,"* will be lottery prizes among those who leave their address.

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