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## Cover Page Footnote

Thanks to Karin Fridell Anter for great advice. This article was primarily written at The School of Design and Crafts, Gothenburg University. It was continued and finished at The School of Engineering, Jönköping University.

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# Experience of Spaciousness and Enclosure: Distribution of Light in Spatial Complexity

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# Abstract

This study explores how distribution of light impacts perceived space. The purpose of this study was to gain a rich and deep understanding of the relationships that exist between distribution of light and spatial experience. In this research, spatial complexity is studied through a qualitative approach with a combined methods strategy. Twenty one participants answered a questionnaire and drew sketches, followed by in-depth interviews, in a real-life auditorium with five light scenarios. The scenarios varied in light distribution, light level and light colour. All findings were triangulated in the final analysis.

Surprisingly, a dark room appeared as more spacious when the spatial boundaries become unclearly defined. Simultaneously, findings indicate that bright walls can, in contrast to what most previous research suggests, contribute to a decreased spaciousness, if they become prominent enough. The results indicate a relationship between perception of increased width, caused by wall lighting, and reduced height, caused by indirect ceiling light. The experience of room size and spatial enclosure in relation to light distribution did not follow physical room boundaries. Furthermore, interview answers indicate that there can be a relationship between lighting and social interaction.

**Keywords**

*Lighting design, light distribution, spaciousness, enclosure, spatial experience, perception, spatial complexity, qualitative research.*



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## 1. Introduction

Light distribution with emphasis on vertical surfaces and spatial boundaries is of great importance to one's feeling of security and comfort in a room. For example, cramped spaces can increase anxiety (Bokharaei & Nasar, 2016; Okken, van Rompay, & Ad, 2013; Stamps, 2013, 2015). There is a need for knowledge about spaciousness and enclosure.

Lighting research, with a long tradition originating in physics, has worked almost exclusively with quantitative methods, focusing on visibility and visual comfort (Peter R. Boyce, 2004; Calvillo Cortés & Falcón Morales, 2016; Kelly, 2017). This means that lighting primarily has been studied through measurements of the physical environment and by mathematically analysed inquiries. This research has frequently been conducted in isolated laboratory contexts, while few studies have been conducted in authentic, complex spaces. Kronqvist claimed that quantitative methods alone cannot *"explain complex interactions between human perceptions, well-being, visual comfort and performance"* (Kronqvist, 2012, p. 5).

Qualitative research can supplement previous experimental research by offering, as evidence, interviews that provide rich and detailed understanding of how participants think about lit spaces. Just like research methods diverge, the lighting field is clearly separated between science and art (Peter R. Boyce, 2017; Dugar, 2018). In fact, very little lighting research has been conducted from the perspectives of lighting designer and architect.

Light distribution in complex rooms, which is hard to study in laboratories, is largely ignored by researchers (Peter R. Boyce, 2014). Prozman and Houser, as well as Boyce, claim there is a need for complex studies on the relationship between three-dimensional rooms and peoples' impressions (Peter R. Boyce, 2004; Brent Prozman & Houser, 2005). It seems that the number of complex spatial studies is increasing, but there are still few based on user experiences collected using a qualitative approach.

## 2. Theoretical framework

More than a century ago, it was found that brightness influences distance judgements (Ashley, 1898). About 60 years later, it was concluded that dark opposite sidewalls visually contract a space's width, while bright opposite sidewalls increase the perceived width (Acking & Küller, 1966). Several more recent studies support that a bright ceiling increases the perceived height and gives a spacious impression (Houser, Tiller, Bernecker, & Mistrick, 2002; Oberfeld, Hecht, & Gamer, 2010). Furthermore, Houser et al. found that walls and ceiling importantly contributed to the perceived brightness (Houser et al, 2002).

Matusiak has shown a clear relation between more light and a spacious impression. Matusiak and colleagues also found that when borders between surfaces in spaces were defined by a strong luminance contrast, observers were better able to assess the actual size of a space (Matusiak, 2004, 2006; Matusiak & Sudbø, 2008). Veitch's and Tiller's experiment showed that walls with a non-uniform illumination were perceived as brighter than if they were uniformly illuminated (Veitch & Tiller, 1995).

Flynn, Spencer, Martyniuk and Hendrick studied the distribution of light in relation to spatial experience in a complex study when they compared uniform lighting to lighting rich in contrasts and peripheral (wall-oriented) lighting to overhead (ceiling-oriented) lighting (Flynn, 1977; Flynn, Spencer, Martyniuk, & Hendrick, 1973, p. 89). Wall-oriented light and a low-intensity table lamp of varying contrasts contributed to a spacious impression preferable for a pleasant character.

The research group of Flynn et al has been followed by other researchers who drew similar conclusions, when they studied different lighting scenarios in office rooms, with varying degrees of uniform illumination and different directions and distributions. Manav and Yener found, for example, that cove lighting (indirect light from a ceiling ledge) was associated with spaciousness (Manav & Yener, 1999).

In the study of Durak et al a diffuse indirect wall lighting was preferred to increase spaciousness, and Prozman and Houser found that the spacious impression was increased with a higher light level on the walls (500 lux) compared to a lower level (320 lux) (Brent Prozman & Houser, 2005; Durak, Camgöz Olguntürk, Yener, Güvenç, & Gürçinar, 2007). It has also been shown that when all other factors are constant, people prefer a ceiling height higher than the standard height (Baird, Cassidy, & Kurr, 1978).

Spatial perception is complex – perceived longer dimensions/larger room surfaces do not necessarily mean the same as a general increased spaciousness (von Castell, Oberfeld, & Hecht, 2014). One aspect – height, width, or depth – can affect the experience of space more than the others. In particular, the length/depth of the room is important (Bokharaei & Nasar, 2016). Gärling found that people judge depth and size differently and that they may mix up open spaces with large spaces (Gärling, 1969a, 1969b). Furnishings also affect experiences of spaciousness (von Castell et al., 2014). Unfurnished rooms feel larger than furnished, but smaller than half-furnished rooms (Bokharaei & Nasar, 2016).

Spatial perception is highly contextually related. In complex authentic settings there are many factors that work together in a figure-ground relationship (Wagemans et al., 2012). The task of a lighting designer can be described as choosing between what is to be reinforced by light and what can remain in the background. A room's shape can be transformed by shadows. A shadow may either follow the original shape and reinforce it (co-shading) or give a flatter impression (countershading) (Häggström, 2009, 2010; Tantcheva & Häggström, 2011). If a round shape is illuminated obliquely from above, it looks convex, but if the light is shining obliquely from beneath, it looks hollow (concave) (Gregory, 1998).

Spatial enclosures comprise both the spatial boundaries and the experience of being surrounded inside a spatial unit and feeling its extension (Wänström Lindh, 2012). There is actually a specific area of the brain, the Parahippocampal cortex, that corresponds to spatial enclosure, but not to single objects (Epstein & Kanwisher, 1998). Enclosure is sometimes seen as an antonym to spaciousness (Stamps, 2009). But a closed room and a small room are not always related, and a spacious room does not have to be open. According to Bader, *depth* in built environments can be defined through the concepts of *envelopment, overlap* and *enclosure* (Peri Bader, 2015).

According to Hesselgren, the experience of enclosure can be enhanced with a raised light level (from 0 up to 100 lux). Yet, when the room becomes too bright, the enclosure effect decreases (Hesselgren, 1969, pp. 364-365). The scale of a space has no influence on the perception of enclosure or spaciousness (Hayward & Franklin, 1974). Madsen, who investigated spatial enclosing areas of daylight as spaces within a space, introduced the term *light zones* to describe these spatial units made up of light within the space (Madsen, 2004, p. 1; 2006, p. 71).

Additionally, Søndergaard has developed a method of capturing the embodied experience of sensing light when moving through a light zone — one person moves within the zone, another interviews this person and takes notes, while a third person observes her/him and takes photos (Søndergaard, 2011, 2012). Their work strengthens the approach of this article to describe spatial enclosedness in lit rooms.

The purpose of this study is to explore relationships between the distribution of light, illuminated walls and atmosphere experience connected to enclosure and spaciousness. Of special interest is the relationship between the experienced "light zone" and the built room (Madsen, 2006). To this end, the effect of different light scenarios on the participants' perception of, and experience with, the room's shape and size was investigated.

Three hypotheses were defined for this study:

- Because illuminated walls were assumed to define a space and to contribute to a spacious impression, it was hypothesised that a room with lighting emphasis – bright light on the walls – would be perceived as open, high, wide, airy and spacious, while a room with weak wall lighting would be perceived as distinctly enclosing and smaller;
- A room without wall lighting will most likely be perceived as distancing and not clearly delimited, but a room with bright walls would be more regarded as more spacious than a darker room;
- Furthermore, wall lighting was assumed to create well-defined spatial boundaries and to enhance an angular impression of the room.

## 3. Methods

A pre-study based on visual estimation (Arnkil, Fridell Anter, Klarén, & Matusiak, 2011; Fridell Anter & Klarén, 2017; Liljefors, 2005; Liljefors & Ejhed, 1990; Matusiak, Fridell Anter, Arnkil, & Klarén, 2011), and phenomenological observations (Depraz, Varela, & Vermersch, 2003; Ihde, 2000/1986), was undertaken in an auditorium to develop the initial assumptions for this study. A focus group consisting of the researcher and ten students within design education answered questions and discussed them in this setting. The final questionnaire was developed from these observations and discussions.

In the main study, the research questions were studied through the questionnaire, the in-depth interviews and the sketching moment. The combination of three methods allows mitigation of weaknesses in each. For example, the questionnaire, which allowed for participants to give a loose description of each scenario, provided a structure so that the interviews would have more focus. The questionnaire facilitated comparisons between participants, scenarios and themes. The interviews revealed how and why the participants answered the questions as they did. Where the questionnaire was limited, the interviews offered richness. The visual representations, that is the drawings, made the discussion about abstract spatial concepts more concrete and easier for the participant to understand, and it also made it easier for the researcher to understand the participants' thoughts.

### 3.1 Experimental site and lighting scenarios

A real-life room with existing lighting was used for the study. The University of Gothenburg has a main building that was built in 1907. The auditorium, "Sal 10", has 100 seats and an interior characterised by warm beige walls, a white ceiling with stucco work, oak panels and heavy dark red velvet curtains. The room is 18m x 7m and 4.6m high. The auditorium's lighting system was designed in 1998 by an experienced lighting designer and features five different pre-programmed lighting scenarios. Normally, several large windows allow daylight inside, but the room was darkened by thick curtains during the study (see Figures 1 and Figure 2).

The light scenarios represented similarities as well as contrasting designs, including different distributions of light (indirect and direct light, wall-light, spotlights as well as centred light and separated light). Different luminaries and light sources, and various colours of light and light levels, further contributed to a rich, complex, experimental situation. At the time of this study, incandescent light was still used in this historic building. The specially-designed luminaires are inspired by the lighting character this building had 100 years ago.

**Figure 1 – Inventory sketch of the auditorium (by the author).**

**Figure 2 – The auditorium in daylight.**


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**Figure 3 – Photos of each light scenario (left to right): the Lecture, Picture Showing, Auditory, Display and Mood scenarios.**

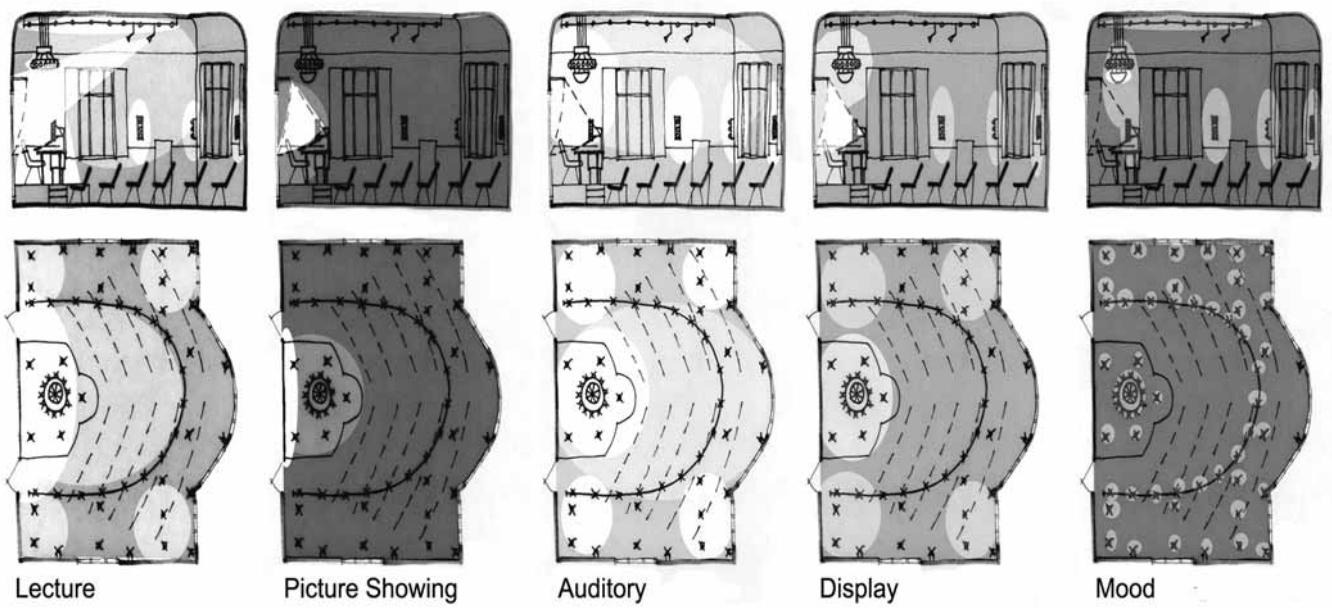


**Figure 4 – Principal sketches of the author's experience of the distribution of light in each scenario (Note: not to scale).**

When the existing lighting was designed in 1998 by a reputable Swedish lighting designer, clear incandescent light was used to create a festive and warm atmosphere. While other light sources gave the main light, the incandescent light added to the spatial impression with sparkling, glowing accents. The retrofit LED light sources were at the time of the study not enough developed to give a fully corresponding lighting quality. Nowadays, the incandescent bulbs are replaced. Luckily, the lighting equipment did not change during the empiric collection of this study.

The general lighting was provided by the combination of 14 recessed downlights of 50W low-voltage halogen lamps; warm-hite compact fluorescent lights inside the ceiling crown for up/down light respectively; clear incandescent 25W bulbs around the ceiling crown; 27 bulbs at the curved lighting brass track; and three at each of the ten wall luminaires. The wall luminaires mainly emitted raking light from the sides out to the wall, but the 300 incandescent bulbs also directed direct light into the room. Six spotlights with low-voltage halogen lamps were directed from this track toward the podium.

There were five light scenarios (see Figure 3 and Figure 4):

- **The Lecture Scenario** is bright but has less ceiling emphasis and greater focus on the podium. The uplight in the ceiling crown is off, while the crown's other light sources are dimmed to approximately 75% (visually estimated, including vertical surfaces). Additionally, the spotlights and the overhead projector are switched on and directed toward the podium;
- **The Picture Showing Scenario** is the darkest of these scenarios, as it uses no incandescent lights and no wall lights. Only the recessed downlights are glowing weakly. The overhead projector is the main light source. The light in this scenario is not sufficient for notetaking.
- **The Auditory Scenario** is the most uniform and brightest of these illuminations. With regard to the visual estimation of brightness, including vertical surfaces, this scenario appears to be the brightest, with all luminaries fully lit. The *Auditory Scenario* feels much brighter than what the measurements indicate;
- **The Display Scenario** has a total light level that is down-regulated to 75-50% of the *Auditory Scenario*. The overhead projector is lit, but there are no extra spotlights.
- **The Mood Scenari**o is similar to the *Display Scenario*, but it is much darker and uses neither the overhead projector nor the spotlights. The light in this scenario is too dark for notetaking.

As a conscious choice by the lighting designer, the room was illuminated with lower horizontal illuminance levels than the levels recommended by international and European lighting standardisation committees (see Table 1). Instead, greater emphasis was placed on the vertical surfaces through the wall luminaires. The designer's intent was to emphasise the podium, which benefits the audience, and to create a beautiful and well-defined room surrounding the podium. Despite the low average level of light, there was enough light for

**Table 1 – Estimated dimming percentages per light source type and scenarios as well as horizontal illuminance values measured the auditorium**

| Scenarios | Lecture | Picture S. | Auditory | Display | Mood |
|---|---|---|---|---|---|
| Ceiling light | 75% | <25% | 100% | 50% | 25% |
| Wall lamps | 75% | Off | 100% | 50% | 25% |
| Brass track | 75% | Off | 100% | 50% | 25% |
| Crown up | Off | Off | 100% | 25% | 25% |
| Crown down | 75% | Off | 100% | 25% | 25% |
| Spotlight | On | Off | Off | Off | Off |
| Overhead light | On | On | Off | On | Off |
| Average illuminance É_avg | 62 lux | 29 lux | 44 lux | 50 lux | 12 lux |
| Median illuminance É_med | 33 lux | 12 lux | 39 lux | 28 lux | 6 lux |
| Maximum illuminance É_max | 252 lux | 141 lux | 83 lux | 165 lux | 26 lux |
| Minimum illuminance É_min | 21 lux | 5 lux | 29 lux | 19 lux | 4 lux |
| Uniformity $U_o$ | 0,6 | 0,42 | 0,73 | 0,68 | 0,67 |

**The estimation of light level dimming is based on visual observation, with the auditorium light being at the 100% level.**

taking notes for a short time, as the designer reported in a follow-up interview.

### 3.2 Procedure

In total, 21 participants filled out a questionnaire and then provided a spontaneous written description of the room for each scenario. Subsequently, they were interviewed by the principal investigator, and the experiment ended with a sketching session. The duration of the experiment and interviews, both held in the room, was between 90-120 hours. Only one participant was in the room at a time, together with the researcher. Every participant had some degree of higher education, 13 were designers and nine were not, 14 were women and seven men, with an age span between 25-65 years and an average of 44 years.

The light scenarios were arranged in four sets of presentation orders, each observed by one group of interviewees. The participants were initially seated at two different places in the room – half of the participants sat in the centre of the room in an audience row (position A); the other half sat in a windowsill on one short side of the room (position B), see Figure 5. The researcher began by explaining the purpose of the study, namely, to study the relationship between light scenarios and spatial perception. Each session started with an adaption time using the first scenario with curtains drawn to block out daylight. The participants silently filled in the questionnaire for one scenario before the light shifted to that of the next scenario.

#### Questionnaire

The participants filled in a questionnaire with answer possibilities on a seven-step rating scale. The Swedish words they used to assess the room were divided into two categories: (1) spatial shape *(high, low, wide, narrow, deep, shallow, round, square, large* and *small),* and (2) spatiality *(delimited, open, enclosed/embraced, excluding, airy, confined alienating* and *close*). The study participants were also asked to select adjectives describing the atmosphere out of 45. Of these, the most frequently-used words were *subdued, calm, warm, public, legible, soft, embracing, welcoming, inviting* and *diffuse*.

The selection of words was based on Küllers' SDE-method (Küller, 1972, 1975), but some words were changed to better fit the purpose of this study. Only two categories from the SDE seemed relevant to the scope of this study – *enclosedness* and *complexity.* The categories *pleasantness, social status, originality, affection, unity* and *potency* were not relevant to the study, with its focus being on descriptions rather than preferences. Words from the *enclosedness* category such as *masculine, fragile, powerful* and *feminine* seemed relevant neither to the room nor to the scope of the study.

Also, other words not included in the SDE were needed to grasp the spatial atmosphere, for example, *embracing, enclosing, inclusive, excluding* and *inviting.* It was decided to not use the SDE's factor analysis for the questionnaire answers, since the focus of this study is more on revealing personal interpretations behind the concepts, rather than on quantifying them.

Following this, the questionnaires were primarily used qualitatively, as manuscripts for the interviews.

#### Interview

After all the light scenarios were shown and assessed, the interview phase began. The participant and researcher moved to the podium to see the room from another angle. During the conversation, which lasted 1 to 2.5 hours, each scenario was shown again as they were being discussed. The individual questionnaire answers were used to compile the script for the interviews. With this script the interviews had a medium level of standardisation and were semi-structured, the focus on follow-up questions to their written answers (Alvesson, 2011).

The interview complemented the questionnaire with such questions as, "Can you describe why you think this room looks higher now?"; "What differences do you experience regarding this and the previous scenario?"; "What is it that makes it high?"; "Is there another word that would describe it better?" One scenario at a time was discussed in the interviews, and the illumination was changed so that the scenario that was the topic of discussion and the one being viewed were the same. Reflective notes were taken by the researcher throughout the session (Kelly, 2017).

The participants could speak rather freely, but the interviewer helped them maintain a focus on the participant at hand and asked follow-up questions. The open-ended interview style followed Kvale's interview method (Kvale, 1996). During the interview the participants were also given the task of drawing the spatial boundaries and directions of the experienced rooms (Branzell, 1976, 1995; Lynch, 1960).

#### Sketching session

During the sketching session at the end of the interview, the participants were encouraged to walk around the space. The sketching task required that the participants draw the limits of the experienced light zone as well as the limits of the experienced physical space (see Figure 5). This was inspired by the methodology of Branzell (Branzell, 1995). These drawings were used to guide discussion during the interview session.

### 3.3 Analysing empirics

The interview process resulted in 27 hours of recorded material. The interviews, lasting from 54-108 minutes, were transcribed into


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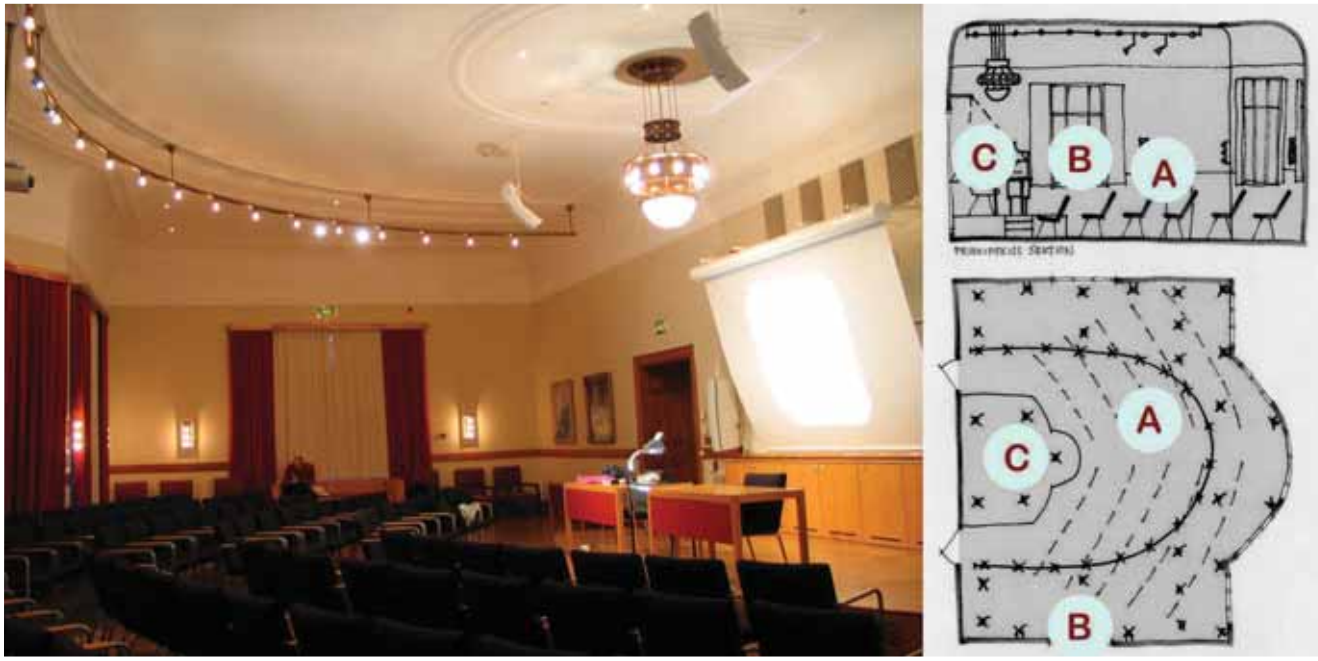


**Figure 5 – This participant is sitting at position B in the windowsill in the Lecture Scenario. Position A is in a chair in the centre of row 3. To the right, a floor plan with assessment positions A and B and interview position C.**

written text. The longest interview was transcribed into 11,380 words. After transcribing the interviews, the selection of quotations was made by searching first for statements that related to the research questions and that explained the questionnaire answers. In the material, 357 quotations were found to be characteristic and specific enough to be selected for the following analysis. Next, the selection was organised into themes. Statements that occur with several participants were chosen. Finally, the most frequent, expressive, and the best explanatory quotations were selected for this article. When several participants spontaneously explained their experiences in a similar manner, this strengthened the results, despite their being just a few participants who did so. Similarly, if some participants expressed an opinion (e.g., that the room is large) and others expressed an idea with the same meaning but in a sort of reverse manner (e.g., in this case, that the room is not small), the hypothesis is strengthened.

A reflective log was kept during the entire procedure to also reveal the researcher's own questioning and interpretation of the interviews. The selection of the most interesting concept was based also on word clouds from the frequent atmosphere encircled words, generated through NVivo (Zamawe, 2015). The questionnaire's scale answers were mainly used as the basis of a script for the interviews.

The drawings were analysed in two ways. First, they were used as visual comparison material when reading the interview and questionnaire material. Later, they were analysed using a sorting and mapping process. All drawings were sorted by scenario in order to compare whether the room directions were drawn similarly.

Additionally, they were sorted by whether the experienced light spaces followed the built room boundaries, whether these were extended or were smaller, and in which way. Comparisons were made both for each participant separately and for each group of participants. The room experiences were also analysed in relation to the different presentation orders.

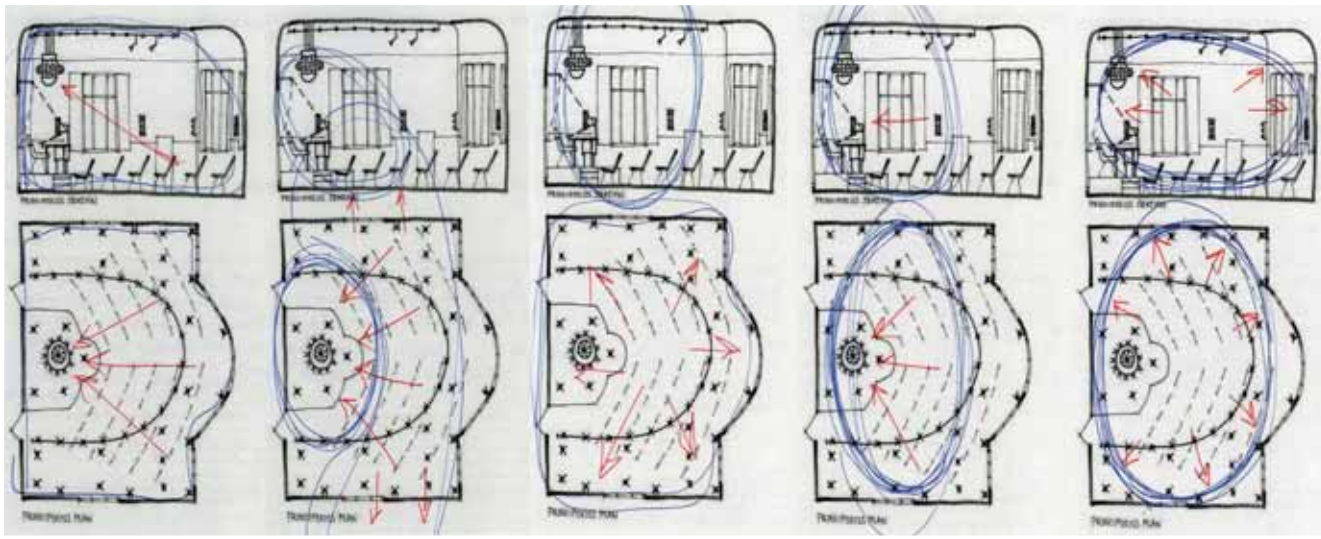

**Figure 6 – Sketches by participant No: 2 (Note that they are not to scale).**

An important component of the study consists of the triangulations and pattern-matching between the multiple cases and their units of analysis (Stake, 2006; Yin, 2003). Therefore, the results of the questionnaire, interview and drawings were combined. Looking at the example in Figure 6, the middle sketch was made during the *Auditory Light Scenario*. The image shows that the experienced light space stretches above the ceiling. This scenario was regarded as high. This finding was compared with the questionnaire and the interview answers that said that the *Auditory Scenario* was high.

## 4. Results

### 4.1 Spaciousness and perceived dimensions

The auditorium is by itself built rather high, with its 4.6m up to the inner vault. Even so, the lighting changed the impression of height, some scenarios were experienced as higher than others. The *Auditory Scenario* was assessed by most participants as high (20 people). It was followed by the *Display Scenario* (17) and the *Mood Scenario* (16), while the other two scenarios fell close behind (15 for both). This was mirrored in the interviews. Most of the interviewees (20 people) considered the room in the *Auditory Scenario* as having the highest wall luminance and the highest degree of indirect light up into the ceiling, as the most open, and also the airiest scenario.

Different reasons for a raised impression were given, including a light emphasis on the furniture – just chairs and a podium – uplighting in the ceiling and the movement of the gaze, attracted by the brightness of the ceiling. This high impression seemed clearly affected by the spotlights being switched on or off.

According to some interviewees (Nos: 11 and 17), the room seemed low and heavy without spotlights. One interviewee (No: 3) was clearly affected by the bright ceiling in the *Auditory Scenario*: "Maybe this was the reason that I wrote uplifting. It is almost hard to focus at eye height, because it is so obvious that the gaze is attracted upwards". Another interviewee (No: 2) adds more information: "If I just direct my gaze in front of me, it falls on the white surface, and then it is like everything above disappears, and I then regard it (the room) as low. But, if I raise my gaze a bit higher, it (the room) becomes high again. So, it depends on which position I had on my eyes if I assessed it as high or low".

No scenario was considered especially deep. Yet, most scenarios were assessed as more deep than shallow. The *Mood Scenario*, which had a low light level with a separated and rather uniform distribution of light, was the one assessed as the deepest. Surprisingly, the scenario with most wall emphasis in relation to other rooms' surfaces was assessed as the least deep one (the *Display Scenario*) – 76% assessed it as shallow, and 67% answered that it was not deep at all.

Some interviewees (Nos: 6 and 14) explained that a raised impression made the room seem narrower. The *Display Scenario* was primarily regarded as low and wide. It had less indirect light up into the ceiling and more wall-light emphasis.

Two interviewees (Nos: 9 and 15) stated that unclear spatial boundaries gave an appearance of openness. One of them (No:15) said this about the *Mood Scenario*: "The light from the wall luminaires were like openings in the wall". In the *Picture Showing Scenario*, an interviewee (No: 9) described how the light zone shrank as the darkness made the space more difficult to define. In that case, the dark room could be perceived as being larger and infinite.

Several interviewees said the darkest scenarios, the *Mood Scenario* (Nos: 14, 18 and 11), shrunk and that the *Picture Showing Scenario* felt delimited and close (No: 19): "In a way, you do not see over there anymore since there is no light there that shows the position of the walls. Actually, the room feels smaller". According to one interviewee (No: 11), the inwardly directed "energy" in the *Mood Scenario*, created by the prominent ceiling crown and dimmed wall lighting, contributed to an impression of smallness. Two interviewees (Nos: 5, 11) assessed the *Mood Scenario* as narrow, since focus was concentrated inwards and upwards towards the ceiling crown.

One interviewee (No: 7) reported that there was a relationship between the clarity created in the brighter scenarios with the spotlight, and a larger and spacious impression.

### 4.2 Shape – angularity and roundness

The darkest scenario, the *Picture Showing Scenario*, with a dominant directed and cold metal halide light from the overhead projector towards the podium, constituted the greatest change in observed room shape. The room in this light was clearly judged to be *angular*, while the room in all other scenarios was judged as being more round than *angular*.

Four participants (Nos: 1, 4, 7 and 12) explained in the interviews that the angular impression was primarily caused by the strong spotlights, a sharp contrasting light that emphasised the room's angularity. Some interviewees (Nos: 1 and 16) described this sharp spotlight as a flat light.

However, several of the interviewees addressed the angularity or roundness among the scenarios differently and used quite different explanations to support their observations. One (No: 10) said the *Auditory Scenario*, which lacked a strong focus from the spotlights or overhead projector, emphasised the roundness of the chair rows, while three others (Nos: 11, 12 and 21) described the same scenario as more angular due to the whole illuminated room where the bay-window area was seen as flatter in this light.

One interviewee (No: 12) described how the wall-emphasised light in the *Display Scenario* widened the room and simultaneously made it rounder and softer. Contrastingly, another interviewee (No: 13), who saw the *Display Scenario* with the lit overhead projector, described how the wall lighting made the room rounder, since his focus on the sides was reduced, but also that the contrasting weak wall lighting diminished the room.

More interviewees (Nos: 1, 3 and 8) described the *Mood Scenario* as round because the corners were less visible. The strong contrast with the overall subdued light compared to the brighter ceiling crown created an inner central focus, with a round spread light that also emphasised the circular-shaped ceiling ornament. One participant (No: 9) described how the separated, dotted light all over the space drew attention to other shapes in this room that was made to appear very angular due to the light scenario. Still, there was one participant (No: 12) who considered the *Mood Scenario* to be angular because of the prominent wall light.


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Five interviewees (Nos: 9, 10, 13, 15 and 16) spontaneously reported that they had seen a vaulted ceiling, a round shape above the ceiling crown. One of the interviewees (No: 16) was so certain of her observation that she did not really believe that the only edges that were rounded were those closest to the joints of the ceiling and walls. The interviewees made these observations in both the *Auditory,* the *Display* and the *Mood Scenarios*.

### 4.3 The experienced spatial boundaries

One of the tasks of the participants was to draw the limits of the light zone, as well as the limits of the experienced space. Most of them simultaneously also talked about how they interpreted these spaces. Hence, the following sections are based on both the drawings and the interviews.

One interviewee (No: 9) explained how the light zone she drew in the *Lecture Scenario* expanded out in the corners. Another interviewee (No: 11) described how the light zone in the *Lecture Scenario* became more important than the physical built space. He explained further that he experienced two different light zones, in conflict with each other, one brighter in the centre and with a duller zone around it.

In the *Picture Showing Scenario*, the physical room was experienced as disappearing by several interviewees (nos. 12, 15, 18). Others (Nos: 1, 4, 5, 12, 13, 14 and 17) judged this room as having the least spatiality. The light did not reach the walls and the space appeared to shrink, according to one interviewee (No: 13). In the sketches, the light zone and the physical room seemed to coincide most within the *Auditory Scenario*, where the light filled the space.

In the *Display Scenario*, several interviewees (Nos: 1, 7, 11 and 17) reported that they were more conscious of the room's surfaces, walls, ceiling and floor. Two persons (Nos: 1 and 4) said this was t he most spatial room. The light zone was as wide as the room but lower in height.

According to three interviewees (Nos: 7, 15 and 20), the light zone in the *Mood Scenario* did not reach the walls and the edges were experienced as diffuse. Yet, others (nos. 6 and 16) described a feeling that they were in the whole physical space. One interviewee (No: 9) described that this diffuse limitation impacted the feeling that the space continued outside the building. The corners were less emphasised in this scenario. Some (Nos: 11 and 21) experienced this light zone as being located above eye height, around the ceiling crown.

Even if the participants were asked about *delimitation* referring to spatial boundaries, 12 interviewees (Nos: 5, 6, 7, 9, 10, 11, 13, 14, 17, 18, 20 and 21) also answered as if the question dealt with how the space *limited* them personally.

#### 4.3.1 Spatial enclosedness

In the interviews, the bright *Lecture Scenario*, with the overhead projector and with spotlights directed towards the podium, was not mentioned as *enclosing (embracing)* – no interviewee mentioned this scenario in relation to enclosedness. Yet, they (Nos: 6, 11, 12 and 17) talked about this scenario as closed, *limited* and *delimited*. Also, the *Display Scenario*, with its great wall emphasis, was not mentioned in relation to the enclosing concept. This contrasts with the three other scenarios that were all regarded to some extent as enclosed (Picture – Nos: 8 and 14; *Auditory* – Nos: 13 and 15; *Mood* – Nos: 5, 8 and 9). Yet, enclosing was most associated with the dark *Mood Scenario*, with a soft, warm glowing and separated, distributed light emanating both from the ceiling and the walls.

#### 4.3.2 Light zones as including or excluding

Community is experienced rather similarly within the *Display* and *Lecture Scenarios*, with the effect of the spotlights as excluding conversation and encouraging one-way communication being the same. The room was said to be anonymous, and the light was thought to create a feeling of being safe as a part of a crowd, a mass of people in full control of the space.

This could simultaneously be regarded as an excluded light for those who might enter the room. Seven interviewees said this light directed attention towards the lecturer. However, they thought it could only be useful for one-way communication, such as in a public panel. In this lighting, the lecturer is not able to see much of the audience due to the glare from the spotlights.

The difference between being in the light zone or outside of it becomes more obvious in the *Mood Scenario*. Six interviewees (Nos: 10, 11, 17, 18, 20 and 21), who initially sat on the edge of the room, described the light as excluding, that they did not belong or even exist within the space. This feeling was, according to some interviewees (Nos: 17 and 21), related to the more diffuse wall lighting. Contrastingly, the fully illuminated *Auditory Scenario* was described by five interviewees (Nos: 5, 6, 8, 9 and 21) as contributing to a democratic atmosphere, where everybody holds the potential to contribute. A community is created that includes both the audience and people on the stage.

Two interviewees (Nos: 20 and 21) commented that they were alone with the interviewer in a space made for a large audience and that this had significant impact on the experience of the space. One of them (No: 20) said that the lack of other people in the space was especially strong in the *Lecture* and *Mood Scenarios.*

## 5. Discussion

Most of the existing research on this topic generally addresses brightness as a factor that increases perceived size and spaciousness (Acking & Küller, 1966; Flynn, 1977; Houser et al., 2002; Matusiak, 2004). In this study it was found, through both the questionnaire and interviews, that darkness can increase the experience of spaciousness. This was shown when the darkness makes the spatial boundaries less defined, and it becomes unclear where the room ends. According to Matusiak, distinct borders between room surfaces are needed to perceive a room's accurate size (Matusiak, 2004).

A possible explanation to the opposite – that brightness can also decrease size – is when brighter light makes walls more prominent. This might be related to the figure-ground relationship, as the walls are perceived as being closer in relation to the other surfaces (Wagemans et al., 2012). In Hesselgren's study, the light seemed to reach a level when it made the walls too bright for an enclosed experience (Hesselgren, 1969, pp. 364-365). A similar threshold might also be relevant for a spacious experience.

The *Lecture* and the *Display Scenarios* were assessed as the widest ones. They had more wall light emphasis. But the interviews provide evidence of rather different explanations for both rooms. With respect to the *Display Scenario*, an interviewee (No: 12) referred to

the wall luminaires showing how big the room really was, as the light emphasised the spatial boundaries. Regarding the *Lecture Scenario*, an interviewee described it as wide because it felt open at the sides (No:. 9).

On the other hand, the darkest scenarios in the auditorium were described as smaller by some interviewees (Nos: 11, 14, 18 and 19) since it was hard to detect the walls, while another interviewee (No: 9) experienced the room as being larger in the darkness, since it could continue into infinity. This relates to another study by the author, in which illuminated tree trunks created spatial boundaries in a park (Wänström Lindh, 2011, 2012, 2013). Interviewees, in both studies, either said the lit semi-open boundaries made the space smaller or larger, but they gave the same cause for their experience. The ones who said it became larger explained: "Now with the lit spatial boundaries, I can really see how big it is"; while the other ones said: "Now with the lit spatial boundaries, I can really see where it ends, so I think it is small".

The interviewees said that bright areas on the sides of the room attracted their gaze, giving a wider impression of the space. This connects to a previous study, in which side wall lightness increased perceived width (Acking & Küller, 1966). Brighter lit areas on the auditory ceiling that attracted the gaze gave the impression of a higher ceiling, which also follows from earlier studies (Houser et al., 2002; Oberfeld et al., 2010).

However, another study by Oberfeld & Hecht, (2011) found no relationship between perceived height and width size. Still, in the auditorium, a wider impression created by wall lighting might have contributed to reducing the high impression created by indirect ceiling light. This is in line with the findings of Oberfeld and Hecht (2011) concerning the additive effect between ceiling and wall lightness.

Shadows can both reinforce a shape, by following it, or flatten and transform it (Häggström, 2009, 2010; Tantcheva & Häggström, 2011). In the auditorium, visible walls and clear spatial boundaries either emphasised angularity or roundness, depending on the level of light and the shadow contrasts in the transitions between room surfaces. Yet, a sharp light also contributed to an angular impression, according to the interviewees.

The character of the overhead projector light, with its clear contrasts and distinct borders between light and shadow, together with an angular light image falling on room surfaces, influenced the room's shape as a whole. In addition to the pattern, light that falls on spatial surfaces constitutes patterns. Luminaire openings also form patterns. In the auditorium, the bent luminaire track and the wall luminaire placements both contributed to creating a round impression of the room, especially in the brighter scenarios. In the darker scenarios, the light was seen as being more separated from the fixtures.

In some scenarios, the indirect light directed upwards from the crown in the ceiling created, according to five interviewees (in spontaneous narratives), an experience of being in a high space with a vaulted inner ceiling. Hypothetically, when an overly-bright light is directed towards the ceiling it may appear to be approaching and can be perceived as slightly more convex, rather than concave (Gregory, 1998). This can be the effect of the brightness contrasts surrounding the ceiling.

Another cause for the vaulted impression can be that the boundaries between walls and ceiling are not clearly visible, and the surfaces seem to merge into each other. A brighter centred spot created by the ceiling crown may have increased the raised effect even more.

### 5.1 Methodological discussion

On one hand, comparing the answers between the in-depth interviews and the questionnaire clearly shows the limitations of the quantitative questionnaire method – people interpret concepts and spaces very differently according to their pre-understanding and, moreover, people answer questionnaires in unique ways. On the other hand, the questionnaire was very helpful as support for the interviews and for providing a structure for analysing qualitative data that was collected for the study. The relatively small number of participants decreases the validity of the study from a quantitative research perspective.

However, the participants' experiences are collected in various ways and in greater depth, which strengthens the study in terms of adequacy. Kelly argues adequacy replaces reliability in qualitative research (2017). This study shall primarily be regarded as a qualitative study that provides examples of how people can experience spaces, and creates pieces for a larger puzzle by generating hypotheses for further and more controlled studies.

It is important to mention that these findings are context-dependent and not directly applicable to illuminated rooms in general. There are many factors that relate to each other in every spatial context, and the aim of this study was to reveal a small number of them to enhance our understanding of this variety. Some words in the questionnaire were especially tricky because the participants interpreted them quite differently, as shown in the interviews.

In the questionnaire, the Swedish word *"avgränsad"* was used. This concept corresponds best to the English word *delimited*. *Delimitation* and *limitation* generated interpretations related either to a distinctly defined light zone, to drawn curtains or to feeling excluding from the activity within a light zone. Several concepts in this study were shown to contain a similar ambiguity.

Previous research shows that this problem is not unique to this study. People sometimes confuse or conflate open spaces and large spaces (Gärling, 1969a, 1969b). Even researchers may refer to essential concepts differently, with some speaking of spaciousness while referring to the floor/ground area (Stamps, 2009) and others referring to volume. Bokharei and Nasar present contradictory results in previous research with the concepts used for representing spaciousness either as narrow-wide or as large-small (Bokharaei & Nasar, 2016). In this study, large can imply either the height or the width of the space, or both. Here, angularity was interpreted either as a sharp contrasting light or as distinct spatial boundaries.

It seemed clear that some participants changed their attitudes between scenarios, not only with respect to the concepts – for example, their interpretation of "limitation/delimitation" – but also in the way they answered the semantic scales. In the first scenario, several of the observers judged the physical space by its furniture, materials and colours, while for each scenario that followed, they progressively placed more emphasis on the light zone. As one of the


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interviewees (No: 4) articulated: "After a while you became blind to the room". This connects to what Boyce refers to in the studies by Flynn et al. and Hawkes et al, that even if participants in one study are asked to assess the room in terms of different lighting, but in another to assess the lighting of the room, the results between them were consistent (Peter Robert Boyce, 1981).

Another interviewee (No: 20) described how the light zone received more emphasis so that eventually she saw the light zone as the space. Since the scenario order shifted for the participants, this difference was at least balanced to some extent in the questionnaire conclusion. There was a clear difference between the scenarios — in the darker scenarios, it was easier to assess the light separately from the physical room. Additionally, there was a general transformation of the discourse from starting out as a discussion of the lighting scenarios as scenarios and rooms to a discussion of the scenarios only as different rooms. Because the room had an unusual shape, short and wide from back wall to front wall (and the podium), participants judging the room from two different directions sometimes addressed the depth and the width in contrast to each other.

## 6. Conclusion

This explorative qualitative study has generated several new hypotheses. These are built on relationships which need to be further studied in different contexts, to secure their validity. Most findings follow previous research. Simultaneously, contradictory participant experiences are also found. The context, including spatial complexity together with the participants' pre-understanding, generate several possible explanations.

This study supports previous research in that uplight, together with wall lighting, reinforces height and openness (the Auditory Scenario). Additionally, a moderate wall lighting and less ceiling light, was associated with a wide and a low impression (the *Display Scenario*).

Surprisingly, darkness was associated with an impression of spaciousness (the *Picture Showing Scenario*). According to most previous research, brightness was predicted to give an enlargement effect. Furthermore, a scenario with prominent lit walls in relation to other dimmed room surfaces (the *Display Scenario*) was assessed as shallow and small. Another unexpected finding is that the room with most wall lighting emphasis was shown to be the least enclosing (the *Lecture Scenario*).

As indicated by several participants, the movement of the gaze when attracted to brightness may be possible to relate to size impressions. If so, this can be important for future studies' methodological approaches.

Interesting quotations concerned how the light zones within the room may affect social interactions. The experience of democracy and participation changed with the light scenarios.

This study can be summarised with the conclusion that the experience of a space is not equal to the boundaries of the physical built room. Spatial empathy, supported by research, is needed to encircle possible interpretations. This knowledge will support lighting design which intends to visually enlarge and diminish rooms. By this, the feeling of being safe can increase, since the feeling of being safe can be associated with *enclosedness* and *spaciousness*.

Based on the main hypotheses developed here we suggest for future studies:

- To further study the effect of brightness and darkness on perception of spatial size and distance, to surfaces and objects in complex environments;
- To study peoples' experiences of room size with different light scenarios in various contexts;
- To study the gaze movement attracted by light in relation to spatial size impression;
- To study peoples' interaction in relation to light zones.

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