The Impact of Scale when Using Models for Daylight Analysis.

**MAIN FIELD:** Produktutveckling med inriktning Ljusdesign

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This thesis is carried out at the Jönköping Technical University in the field of Product Development with focus on Light Design. The authors answer themselves for opinions, conclusions and results.

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Abstract

The study examines the issue of scale regarding models when analyzing daylight, which scale is the most representative of a real space. There have been previous studies done regarding scale model and daylight, however, they do not look at how the scale itself can affect the experience of daylight. The use of the architects’ already built scale model can be seen as valuable for light designers when evaluations and visualizing daylight in a real space. However, the use of the architect's scale model depends on its scale, hence why this study is being conducted. The aim of this study is to evaluate the effects the scale has on daylight visualization with scale models.

This study began with conducting a small literature study regarding daylight, scale models, visual perception and practical consideration when using scale models. The method was designed thereafter. By choosing a real room to base the scale models on, three scales were chosen, 1:50, 1:20 and 1:10. Thereafter the questionnaire was designed by using the analyzing method PERCIFAL as a base.

The result of the study showed the subject's answers regarding; light level, shadows, light distribution and specular reflections. As well as a question regarding which scale model the found most representative of the real room and why. The compiled data showed which scale model was the most representative of the real room. The results show a difference between the different scale models and a correlation to the real room is seen. In conclusion, the scale model can be used to estimate and visualize the daylight within a space. However, the scale must be regarded and looked at so the chosen scale can represent the real space, which allows for an easy view of the model.

Keywords: Daylight, scale models, scale, visualization,
Glossary

Foam board – Consist of three layers, two outer layers of thin cardboard and an inner layer consisting of foam (Otte 2014).

Illuminance - The light flux that hits a surface per square meter (Starby, 2006).

Luminance - The density of light in one direction, a type of measurement of how light a surface is (Starby, 2006).

Light distribution - How dark and light areas are experienced in relation to each other (Klarén, 2011).

Light level - Is aimed at describing whether a space is perceived as light or dark (Klarén, 2011).

Lux - Illuminance is measured in lux (Starby, 2006).

SAD - ‘Seasonal affective disorder’ (Aries, Aarts and van Hoof, 2013).

Shadows - Appear in areas not completely reach by light. Refer to the overall experience of shadows impact of a space (Klarén, 2011).

Specular reflection - Light hitting or touching on a smooth, glossy and mirror like surfaces can make reflections appear (Klarén, 2011).
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1 Introduction

This thesis is written on the subject of lighting design as part of a bachelor’s degree in Product Development Lighting Design at Jönköping University. This thesis project will investigate the issue of visualization of daylight in a scale model.

1.1 Background

Today scale models are used more within the architectural sector than it is in the lighting design sector to visualize space and form. Visualizing space and structure with both artificial light and daylight is vital when designing a space. The scale model is used in various stages in architecture. In an early stage when it is used to show suggestions of the composition of different rooms in a building, and these models tend to be less accurate. Scale models are also used at a later stage as an aid to see context and cohesion between rooms in a building and its shape and form. The two different phases have in common that they both aim to describe form and meaning in a building (Gibson, Kvan and Wai Ming, 2002).

1.2 Problem description

There have been studies done concerning scale models and daylight, however, they did not make a comparison between the actual scale of the model and how the scale can affect how the daylight is perceived and experienced in the scale model.

There are digital methods of visualize daylight within a space today. But these digital programs are often very complicated and do not have sufficient program documentation (Liang Wong, 2017). These visualization programs available today are often time consuming and if there is already a finished scale model by the architect it would be much quicker to use than creating a new virtual model (Baker and Steemers, 2002).

A need for visualizing daylight in a scale model can be seen, as it would be a quick and easy way for a lighting designer to use the architect’s work of building a scale model to analyze and visualize daylight within a space. However, the use of the architects already built model depends on its scale, hence why this study will investigate the impact scale has on visualizing daylight.

Daylight design is based on a diffuse sky, meaning a cloudy overcast sky. A white surface becomes 5 to 10 times brighter when it is hit with a patch of sunlight than when it is illuminated from a diffuse sky. Scale models, which are mostly made of cardboard, plastic or plywood, can be used to check the daylight design in a room or building. The most typical scales used range from 1:10 to 1:50. These are usually
viewed in an artificial sky which is defined as a room that provides the same characteristics in illumination as a real sky. However, scale models can also be illuminated under a real sky, this is usually when it is direct sunlight as it is hard to model in an artificial sky (Baker and Steemers, 2002).

1.3 Aim and research questions

The aim was to evaluate whether the scale of a model affects the perceived daylight in the model and which scale is the most ideal when it comes to visualizing and analyzing daylight in a scale model. The research questions are;

1. Which scale 1:50, 1:20 and 1:10 is the most representative when analyzing daylight?
2. What influence does the scale have on how daylight is experienced in a scale model?

1.4 Scope and limitations

This thesis will include a literature review which is the base for the building of the three scale models. The three scale models were built of white foam boards in the scales 1:50, 1:20 and 1:10. Different texture and colors of the room, as well as other scales, other than the scales mentioned before are considered in this research. Neither were glass windows built into the model so no reflection of transmission from the glass will be taken into consideration. In the study, no artificial lighting will be used as it is only the daylight that is being considered. The experiment will be done under a real sky with no artificial daylight. The evaluation of the collected results was not taking gender or age into consideration.

1.5 Disposition

This thesis begins with an abstract followed by a glossary and a table of content which then leads into the report which starts with an introduction chapter containing; background, problem description, aim and research questions followed by scope and delimitations. The next chapter regarding theoretical framework contains theory on daylight, visual perception, scale models and practical considerations when using scale models. The third chapter is about the method and how it has been implemented. The next chapter presents the results of the study and analysis of the compiled data. The last chapter is the discussion as well as conclusion, recommendations and further research. Ending with a reference list and appendix.
2 Theoretical frameworks

2.1 Daylight

Daylight consists of electromagnetic wavelengths ranging from 200-4000 nanometer (nm). The light humans can see is only in spectral 380-780 nm. This does not mean that the other parts of the spectrum do not affect us. In buildings, it affects by contributing to the heating of the house and it also releases some radioactive radiation. However, daylight is widely believed to influence human health and some of them are; “reduced fatigue, relief of SAD, decreased depressive symptoms, improved skin conditions, better vision, positive impact on the behavioral disturbances seen in Alzheimer’s disease and multiple other health advantages” (Aries, Aarts and van Hoof, 2013).

The definition of daylight is the combination of direct and indirect radiation on the earth’s surface during daytime. Daylight is also affected by different types of sky, where the daylight has diffused out of different molecules in the atmosphere. The International Lighting Committee (CIE) has worked out 15 different types of skies that fall into three categories:

1. CIE Clear sky
2. CIE Intermediate sky
3. CIE Overcast sky (Szybinska Matusiak, 2014)

The sky is very rarely the same and is continually changing. Important factors that are recorded in the sky are the position of the sun, the cloud cover, the cloud formation and the air’s composition. The position of the sun determines the main direction of the light, the position and nature of the cloud determine the direction and intensity of diffuse sky. The composition of the air is essential to the extent that solar radiation is spread in the atmosphere. There is thus an infinite variation of luminance distribution (Szybinska Matusiak, 2014).

2.1.1 Window configuration

Leslie (2003) claimed in her article that in the early 1970’s electricity prices began to rise, and at the start of 2001 there were major power outages. This made people think more about daylight as a new way to save energy. One also began to rediscover the benefits the daylight has for people, and how to create interesting environments using daylight.
Window design is something that has changed during the development of technology and history. They are also affected by maintenance requirements, material and technology development. It can also be seen that it has been influenced by fashion trends. It was not until 1945 that Sweden made a standardization of the window design called the Swedish Standard for Window Profile (SS 818103). In the early 2000 the window design changes to larger windows that followed the buildings’ façade, to dominate the space and give a bigger outlook (Larsson and Wasberg, 2009).

2.2 Visual perception

The eye's visual field is approximately 140° in both vertical and horizontal directions and it consists of three parts that have very different characteristics. In the middle of an area of 1°, this area is the one that gives the absolute best view. The second surface run area of central vision has a range of about 60° and is used to get information about items needed when performing different tasks. The third fields’ limitation is around the forehead, nose, and cheek and is called the peripheral vision. This part of vision does not perceive objects clearly if they do not move (Baker and Steemers, 2002). Visual performance is defined in terms of the speed and accuracy of processing visual information (Rea, 1991) and three factors play an important role in this process:

1. “The apparent size of the details to be perceived on the task and the luminance contrast between details and background
2. The illuminance of the task
3. The visual fatigue state “(Baker and Steemers, 2002).

The bigger things are and the closer you get, the easier it is to see details. A visual display unit (VDU) makes it very easy to change the size of what you are working with. When working with a book, for example, the scale is the same all the time. However, you can enlarge the text by moving the eye closer to the object. In this way, the surface projected on the eye’s retina increases (Baker and Steemers, 2002).

2.3 Scale models

Scale models are made by architects to conceptualize ideas in three dimensions (3D). There are several advantages of working with physical 3D models. The models communicate information and ideas of material, shape, size and color in a very feasible way. The scale of the model is often decided by the scale that is required by the various stages in the design process. This is because 3D scale models can be used to illustrate both separate buildings and rooms as well as cities- and
landscapes. The 3D model also allows for experiencing the space rather than having to imagine it (Dunn, 2014). Scale models have the same shape and dimensions as a proposed design for a room or building. The reason why smaller scale models may be used when analyzing daylight within a space and how it may be experienced in a larger structure is that lights interaction with an object is independent of the size of the object. Scale models vary in size, from 1:500 for urban environments to 1:10 for interior daylight studies (Reinhart, 2014). Scale models can be used in all stages of the design process. Architects and light designers use scale models in a variety of aspects:

- “The draft scale model while carrying out research.
- The design model while carrying out research.
- The presentation model to communicate and present your design.” (Reinhart, 2014).

By using a scale model something abstract can become concrete by building it. It can be used as a design tool to convince the client to invest. With the help of a 3D model one can consider and feel the space and see different aspects and contexts that could not be seen if any other kind of visualization technique was used. For architects, a scale model can provide clarity and experience in building the actual building. You may see problems that may arise during the upgrade. Scale models are a way to draw attention to their project and it makes it easier for the client to ask eventual questions (Otte, 2014).

2.3.1 Advantages and disadvantages concerning scale models

Advantages of using a scale model are:

- “accurate, quantitative results, even when crude models are used;
- Ease of making comparisons by changing a single design component;
- Familiarity of most designer with construction and using scale models;
- Opportunity for qualitative evaluation (such as identification of potential glare problems) Thro visual observations or photography (Moore 1985).

There are limitations with scale models in architecture, even though scale models can be built to a high accuracy, these very accurate models can be very expensive to build and in most cases does not meet the requirements for daylight analysis. Another limitation is when materials are used in the models which cannot be properly scaled down, such as fabrics. Regarding electrical lighting, it cannot properly be integrated in the scale model for quantitative analysis such as the light distribution and how the luminaires would look in the space, however, the intensity of the light can be visualized (Baker, Fanchitti, Steemers, 1993).
2.4 Practical considerations when using scale models

Boccia and Zazzini (2014) stated in their article that the scale model is a very effective approach to study daylight performance in buildings. But that it also requires accuracy in the construction of the model. This is because both photometric and geometric features can affect the results of how the daylight is perceived. The authors also stated that the scale model approach to visualizing daylight performance often overestimates the daylight performance. Reasons for this are the positioning and alignments of the actual building. However, research also states that daylight performance often is overestimated when analyzed in scale models.

Bodart and Causwert (2017) experienced the real full scale mock-up room and the scale model to be very similar when visually comparing them. However, a difference between the baseboard and the walls and ceiling was observed. It was evident that the walls and ceiling appeared brighter. Despite the care taken with building the scale models, there was a significant difference in luminance levels. The level of difference varied depending on if there was no shading, the white or the black shading. However, in conclusion, the authors could see value in considering using scale models when evaluation design choices if absolute values of luminance levels are not required.

Li, Cheung and Cheung (2006) stated that the accurate estimation of the daylight entering the building is key when evaluating daylight design in buildings. The study looks at the daylight coefficient under various sky conditions with the means of scale models. In an interior space, the daylight illuminance is a key element when evaluating visual performance. The data from the study was taken from measurement done in the scale model. The authors claimed that the use of a scale model provides a simple way to change the variables of the space such as orientation, window geometry, and internal reflection. It has also been shown that models are one of the most understood presentation techniques, comparing them to technical drawings and renderings. The model in the study was built in the scale 1:10 and the experiment was conducted on the rooftop of the City University of Hong Kong from morning till about noon. The model was internally coated with black paper and then with white paper to cause a change of reflection. The scale model in the study represented a rectangular cellar office, built in the scale 1:10. The Illuminance was systematically measured and analyzed in four different measuring points inside the scale model.
3 Method and implementation

3.1 Experimental procedure

The experiment was based on two different analyzing methods, PERCIFAL: Perceptual spatial analysis of color and light (Klarén, 2011) which is part of the SYNTES project report series. It consists of eight different visual concepts that explain the spatial experience of color and light. The eight visual concepts are: Light level, Light distribution, Shadows, Light patches, Specular reflections, Glare, Color of light and Surface color. Out of the eight visual concepts four were taken that could be applied to daylight and the experiment, these visual concepts were; Light level, Light distribution, Shadows and Specular reflection. The four visual concepts were used as a base for the questionnaire answered by each of the subjects for the real room and each of the three scale models. The questionnaire which was written in Swedish had a 6-point scale with antonyms. The study was conducted at a Swedish university, hence why the questionnaire was conducted in Swedish.

The second analyzing method was Branzells’, (1995) method which he describes in his book "Något om ...”. The structure of this method means that an environment such as a room is experienced, Branzell means that these collected feelings will create a wholeness which will then be sketched and interpreted as bubbles (see Figure 1). The room was then evaluated through observation and feelings on how the room was experienced. Branzell also talks about where there are openings in a space, it feels airier and contributes to more freedom than in a space where there are no openings.

![Figure 1 Example of Branzell's sketching method as shown in his book 'Något om…' (Branzell, 1995)](image)

The experiment began with the subjects answering questions about age, gender, if they are studying or not, what they are studying or what their profession is. Then each subject answered the questionnaire and executed a Branzell sketch for the real room and each scale model. The order the experiment was conducted was random. Lastly, each subject was to answer a question regarding which scale model they
found to be most representative of the real room (see Appendix 1) and explain why they answered the way they did.

3.2 Experimental design

To ensure that the scale models were properly and successfully built previous studies regarding scale models were researched. These studies regarded the assessment of scale models and problems the authors had encountered during the build-up of the scale models. Thanachareonkit, Scartezzini, and Andersen, (2005) wrote in their article about the level of accuracy in scale models, that if the accuracy of the construction is too low it can cause unwanted light to come into the model from the slits and slips in the construction.

To ensure that the questionnaire would be understood by the subjects, 6 people with no expert knowledge in the field of lighting design evaluated the questionnaire. Thereafter the questionnaire could be altered to be better suited for the purpose and be more easily understood.

3.2.1 Documentation

Documentation of the real room was made to ensure the three scale models were correctly scaled down from the real room. The documentation of the room was made with a measuring tape and a laser meter (Leica DISTO™ D210) (see Appendix 2). In addition, pictures were taken of the actual room as a basis for the building of the three scale models.

![Figure 2 Image of the real room of which the scale models were based on (Photo Erik Adolfsson, 2018).](image)
Drawings from six different views were made; plan view, ceiling view and one view for each of the four walls. As well as drawings of the furniture and other detail in the room, such as the whiteboard and the projector screen (see Appendix 3).

3.2.2 Building the scale models

The three models in scale 1:50, 1:20 and 1:10 were identical to each other, which meant that the same level of detail and number of objects were in each scale models. The building method for how the scale models were constructed was attempted to follow the identical order to the different scales. As a result, the only thing that distinguished the models from each other was their scale (see Figure 4).
The three different scale models were built out of the same materials (see Appendix 4). The main part of the construction was done with foam board which has a glossy finish. Otte, (2014), as well as Bodart, Deneyer, De Herde, and Wouters, (2011) studies, recommended not to use glossy finishing’s and therefore the surfaces were covered with a white diffuse paper to prevent unnecessary reflection and gloss. The surfaces that were not covered with the diffuse white paper were the whiteboard, furniture, ventilation drums, computer and cable drawer. The reason for them not being covered was that they had a glossier surface in the real room. The tools used to build the model was based on Dunn’s (2014) book ‘Architectural model making’ with the addition of tweezers and scissors to ensure that the building of the scale models was done correctly and to a high standard (see Appendix 4).

To ensure that the scale models were properly built, recommendations in the study of Bodart et.al (2011) were followed regarding the building of scale models and the technique of overlapping the edges in the scale model to minimize the risk of daylight seeping through. Bodart et.al (2011) used small nails to secure the different building elements to each other, also by using black tape, covering all edges to even further minimize the risk of undesirable daylight.

Figure 5 Shows how edges should be put together to ensure no light sips trough in the construction according to Bodart et.al (2011).
On each wall, ceiling and floor element a 0.5mm space was cut out for joining the edges (see Figure 6). When securing the different elements together, instead of using nails, a glue stick was used. This due to the fact that nails of appropriate size for the smallest scale model (1:50) could not be found, therefore nails were not used for any of the scale models. Thereafter the outsides of all the edges were covered with black tape. In the places where the black tape could not stick to the surface of the scale models, black hot adhesive glue was used, applied with a glue gun. Lastly, the scale models were covered in diffuse black paper to ensure that no unwanted light could enter and that no external reflections could affect the participants who would be partaking in the experiment (see figure 7).
3.3 Implementation

The experiment was conducted from the 12th to the 14th of March 2018 at Jönköping University Library on the first floor in the group activity rooms C2022 and C2023. Preparations and setting up the experiment started at 09.00 and was done by the authors. The experiment started at 10:00 and lasted until 16:00. In the room C2022 the three scale models were placed in the window by tapping those against the windows (see Figure 8). Room C2023 was the actual room the scale models were based on.

![Figure 8 The models were secured on the windows using duct tape to hold them in place, thus securing the same placement over the course of the three days (Photo Erik)](image8)

After each day, the scale models had to be taken down and the furniture placed back to its original setting. To ensure that it was set up again in the right place, the location was documented with pictures and by marking the places where the scale models should be fitted with black tape (see Figure 9).

![Figure 9 Black tape was used to document the placement of the scale models, ensuring the same placement over the course of the three days (Photo Erik Adolfsson, 2018)](image9)
As the experiment was carried out in two rooms and lasted for three days, the illuminance levels were measured in the real room (2023c) and in the room with the scale models (c2022). The illuminance levels were continuously measured as well as the temperature in the room with the scale models. This was to ensure that all the subjects had the same conditions in both rooms so that the illuminance values did not vary in the two different rooms.

This was done using 3 illuminance loggers (YOYOlog) where two were only logging the illuminance (2YL-M61-4M Lux Logger) and the other logging both illuminance and temperature (2YL-M62-4M Lux Logger) (Se Appendix 5). The sensor’s that measured lux levels were placed in the window in the real room and the other two were placed in the window of the room with the scale models. This placement caused the measuring of temperature to become incorrect as it was placed right next to a window and therefore did not measure the actual temperature of the room, this data has therefore been discounted. The sensor that measured the temperature was placed in the room with scale models because it was this room the test subjects were in the longest during the experiment.
3.3.1 Real room

In this part of the experiment, each subject analyzed the behavior of daylight in the real room. Each of the subjects then answered the questionnaire that is based on PERCIFAL and perform sketches based on Branzells’ method.

![Figure 11 The real room which the scale models were built from (Photo Lisa Yngvesson, 2018).](image)

3.3.2 Scale model room

In the room with the three different scale models the subjects would evaluate the scale models in a random order.

![Figure 12 The room with the scale models showing the placement of the scale models (Photo Lisa Yngvesson, 2018).](image)
3.4 Participants

The experiment was conducted by 25 different subjects, 20 people were considered having expert lighting design knowledge. The remaining 5 subjects had no formal education or working experience in the field of lighting design. The youngest participant was 20 years of age and the oldest was 52 years of age. The majority of the participants were in the age group 20-25 (see Table 1). There were 11 men and 14 women participating in the study. Lan and Lian (2010) discuss in their article regarding the number of subjects participating in the study and the effect it has on the statistics. The bigger the subject group the more statistical power the study will have and the standard deviation will become smaller.

<table>
<thead>
<tr>
<th>Age</th>
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<tbody>
<tr>
<td>20-25</td>
<td>15</td>
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<tr>
<td>26-30</td>
<td>3</td>
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<td>31-35</td>
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<tr>
<td>46-50</td>
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<tr>
<td>51-55</td>
<td>1</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>27.08</td>
</tr>
</tbody>
</table>

3.5 Data analysis

A quantitative method was used to compile the data. To easier be able to find patterns and make connections (Bjereld, Demker and Hinnfors 2009) between the different scale models and the real room. When it comes to compiling the analyzed data Pallants’ (2010) chapter on Bar Graphs and Histograms was used to compile the data, as well as do’s and don’ts when it came to compiling the data.

Due to that, the questionnaire was paper-based and the authors used a Google Docs questionnaire to transfer the answer from paper to a digital document. This simplified compiling the data into an Excel document which was then compiled and presented in diagrams which showed how the subjects answered each question in the questionnaire. The diagrams were divided into questions, the answers compiled from the three days. The different diagrams were done to be able to see if there was a greater difference the scale models in relation to the real room. Diagrams were also made by dividing the answers by day, making three further diagrams for each question. Making it so that the days could be compared to each other. As well an independent ANOVA and T-test was conducted to confirm if there were a non-hypothesis or a deviation between the different questions in regards to the real room.
The sketches done according to the Branzell method and later compiled and analyzed. The real room was used as the reference from which the sketches of the three scale models were compared to. It was then analyzed to find out how the subjects drew the light and if any correlation could be seen between any of the scale models and the real room.

To document and analyze the data from the illuminance loggers, Excel was used. The data was compiled in tables, showing the highest, lowest and the average value of each day. In addition, data was compiled to show the highest, lowest and the average value for each of the different subjects. Thus, comparing the different subjects and different rooms.
4. Result and analysis

4.1 Conditions

The compiled data from the real room was used as reference when analyzing the results from the three different scale models. This meant that all collected data was compared to the data from the real room.

4.2 Compiled data

4.2.1 Light distribution

4.2.1.1 Results

The majority of answers regarding the real room were on alternative 3, 4 and 5 with none of the subjects answering a 1 and only one answer a 6. For the large model, most answers were alternative 5, showing that the majority of people found the light distribution in the large-scale model. The answers regarding the medium scale model were mostly on alternative 3, 4 and 5, with no answers in alternative 1 and only one answer on alternative 6. Regarding the small model, the majority of answers were on alternative 5, showing that the subjects found the light distribution to be even.

![Diagram of the answers regarding Light distribution compiled from the three days, showing answers for the real room and each of the scale models.](image)
4.2.1.2 Analysis
The majority of people found that the large- and small models had a significantly more even light distribution than the real room and the medium scale model. By viewing the diagram, a trend was detected in how the subjects have perceived the real room and the medium scale model. A similar trend can also be seen between the small and the large model, making it appear as if the experience of them were quite similar even with the difference in size.

4.2.2 Shadows

4.2.2.1 Results
The majority of answer regarding the real room was alternative 2, with no subjects answering alternative 6. When it comes to the large model the majority of answerers were for alternative 3, with five people answering 2 or 4 and only two and one people answering alternative 1 or 5 respectively and no subjects answering alternative 6. Regarding the medium scale model, the answer is relatively evenly spaced between alternative 2 to 4, with answers of ten, six and seven respectively and with no answers on alternative 6. The small model had answers evenly from alternative 2 to 5, seven, eight and seven answers respectively, with none of the subjects answering alternative 6.

Figure 14 Diagram of the answers regarding Shadows compiled from the three days, showing answers for the real room and each of the scale models.
4.2.2.2 Analysis
The subject’s answers regarding shadows in the real room and scale models varies and no clear pattern can be seen. However, a small trend can be seen between the real room and the medium scale model, where they have their high point and low points.

4.2.3 Light level

4.2.3.1 Results

No subjects answered alternative 1 on the scale dark to light regarding light level for the real room or any of the three scale models. The answers regarding the real room were on alternative 2 to 5, with no answers on either alternative 1 or 6. Most subjects answered alternative 5 with ten answers, second came alternative 4 with eight subjects. With the large model, the majority of subjects answered alternative 5, that the rooms were very light. The answers on the medium scale model were centered on alternative 4, the second most answers were on alternative 5, and then alternative 3 and 2. With no answers on alternative 1 or 6. The most answers for the small scale models were on alternative 5 with nine subjects. With six subjects each answering alternative 3 and 4. The remaining four subjects, two answered alternatives 2 and two alternatives 6.
4.2.3.2 Analysis

The answers that corresponded the most with the real room were those of the medium scale model. However, differences in where they peak, with real room peaking at alternative 5 and the medium scale model peaking at alternative 4. The answers for the small- and large models varied between 2 and 6, differentiating them from the two other which had no subjects answering alternative 6. Making the trend between the real room and the medium scale model clearer.

4.2.4 Specular reflections

4.2.4.1 Results

Regarding specular reflection, no subjects answered alternative 6 on neither the real room or for any of the tree scale models. Answers on the real room were on alternative 2 to 5, with the least answers on alternative 2. On the remaining alternatives, the answers were relatively evenly distributed. With the large model, nine subjects each answered alternative 2 and 3. With only one answering alternative 1, four alternative 4 and two answers on alternative 5. When it came to the medium model ten subjects answered alternative 2, which was the alternative that had the most answers. The least answers were on alternative 5, with only two subjects answering that. Regarding the small model, alternative 1 and 6 had no answers. Alternative 3 and 4 had nine subjects respectively and alternative 2 and 5 had six and one subjects respectively.

![Specular reflections](image.png)

*Figure 16 Diagram of the answers regarding Specular reflection compiled from the three days, showing answers for the real room and each of the scale models.*
4.2.4.2 Analysis
There can be no clear pattern seen between the real room and the three scale models. However, a trend can be seen between the medium and large scale models regarding specular reflections in the space.

4.3 Day 1, 2 and 3

4.3.1 Light distribution day

4.3.1.1 Results
The three diagrams show the variation of answers regarding light distribution over the three days the experiment was conducted.

There can be seen a relation between the three different days regarding how similarly the different test subjects answered. The answers vary from 2 - 5 on the 6-point scale. While for the scale models, especially for the large and small models', the majority of answered alternative 5 on the 6 point scale. The medium scale model was the closest to the real room in how the test subjects answered.

![Light distribution Day 1](image)

*Figure 17 Diagram of the compiled data for the answers regarding Light distribution day 1 for the real room and the three scale models.*
4.3.1.2 Analysis

As shown in the diagrams from the three different days regarding light distribution the subject’s answers varied. During day one no close correlation could be seen between the real room and any of the three scale models. The closest would be the
medium scale models as it follows the same answering pattern as the real room over the 6 different alternatives.

For day two the correlation appears to be much the same as day one, where the scale models follow the pattern of the real room the closest. The two other scale models differing and peaking on completely different answer alternatives. Whereas, the medium scale models peaked at the same alternative as the real room. On the third day a correlation could be seen between the medium scale model and the real room.

Thus, according to the three diagrams over the three days, the medium scale model correlated the closest to the real room in how the subjects experienced the light distribution. The medium scale model, in this case, matched the closest to the real room.

4.3.2 Shadows

4.3.2.1 Results
The three diagrams show the variation of answers regarding shadows over the three days. Looking at a real room, you can see a majority of the answer on day 1 is in options 2. In the scale models, the subjects respond that the shadows were harder. During the other two days, the answers from the real room and the scale models are very similar.
4.3.2.2 Analysis

During day one there is no clear pattern in the answers as the answers for the real room were centered on alternative 1 and 2, whereas the answers regarding the three scale models varied over the other alternatives. Making it hard to see a clear trend between the real room and any of the scale models on day one.
Neither can a clear relationship be seen over the course of the other two days, day two and three. However, some trend can be seen in the medium scale model and the real room when looking over the course of all three days.

4.3.3 Light level

4.3.3.1 Results

The three diagrams show the variation of answers regarding light level over the three days the experiment was conducted.

The most answers on day one were on alternative 5, regarding the real room, small and large-scale models. Whereas the answered for the medium scale model peaked at alternative 4. On day two the answers regarding the real room and the medium scale model varied from alternative 2 to alternative 5. Whereas the answers regarding the small and medium scale models varied from alternative 2 to 6. Whereas on day three the answer for the real room and each of the three models all varied between alternative 3 to 5.

Figure 23 Diagram of the compiled data for the answers regarding Light level day 1 for the real room and the three scale models.
4.3.3.2 Analysis

Both on day two and day three, correlation can be seen between the real room and the medium scale model. However, on day one the answers regarding light level are mostly congregated on the higher part of the scale whereas the answers on day two are more spread out over the entire scale. Apart from alternative 1. A similar trend can be seen in day three where the answers are mostly congregated on the higher end and none of the subjects answering alternative 1 or 2. Day tow is however
different from the other two days where the answers are more evenly spread out over the alternatives, except for alternative 1 which, as similar to the other days had no answers.

4.3.4 Specular reflection

4.3.4.1 Results

The three diagrams show the variation of answers regarding specular reflections over the three days the experiment was conducted.

The majority of answer from the three days congregate between alternatives 2 to 5. The answers regarding the real room were rather evenly distributed between alternative 2-5. Whereas the different scale models peaked at different alternatives, apart from day three were all answers are quite level with each other.

Figure 26 Diagram of the compiled data for the answers regarding Specular reflection day 1 for the real room and the three scale models.
4.3.4.2 Analysis

No clear correlation can be seen between the real room and either of the three scale models when looking at the answers separately over the course of three different days. Each day had instances where either the real room or one of the scale models would stand out and be the only column on the specific alternative on the scale. Such as on day one where the medium model is the only one having an answer on alternative 1. Also on day two only the large scale model had an answer on alternative 2.
on alternative 1. The same can be seen on day three where only the real room had answers on alternative 5. Making it hard to distinguish a pattern, making a comparison with the real room hard to accomplish.

4.4 Average

4.4.1 Results

The diagrams show the average value of each question in the questionnaire, show the correlation of each of the scale models and the real room with each other. The real room which is the blue column is used as the reference of which the three scale models are compared against.

The light distribution shows that the average value varies from 3.84 to 4.6, which shows a small variation in answers from the subjects. The real room had an average value of 3.92, with the large scale model being the furthest away with an average of 4.6 and the medium scale model is the closest to the real room with an average of 3.84. Showing that the model furthest away had a difference of 0.68 and the model closest had a difference of 0.08.

The shadows show in a similar way to the result of a light distribution that the variation of answers is small, varying from 2.64 to 3.2. The real room had an average of 2.64, with the smallest scale model being furthest away with an average of 3.2 and the medium scale model being the closest with an average of 2.76. This showing that the model furthest away had a difference of 0.56 and the model closest had a difference of 0.12.

When it comes to the light level within the space, the average value varies from 3.96 to 4.64. Here the medium scale model showed the same average value as the real room at 3.96. The large scale model was the furthest away with an average of 4.64 with a difference of 0.7.

The specular reflection within the space varied from an average value from 2.88 to 3.8. The real room had an average of 3.8, where small scale model was the closest to it with an average of 3.2, making that a difference of 0.6. The large and medium scale model which both had an average value of 2.88.
4.4.2 Analysis

The average value of the real room and scale models correspond with the values shown in diagrams regarding, light distribution, shadows, light level and specular reflection (see 4.2.1, 4.2.2, 4.2.3, 4.2.4). How the different scale models correspond to each other and to the real room. It is only regarding specular reflection where the pattern differs from the medium scale models being to most similar to the real room, whereas with specular reflection the small scale model is the most similar. However no clear correlation can be seen regarding light levels when looking at separately at the three different days.

4.5 Anova

4.5.1 Light distribution

An independent-samples t-test was conducted to compare the light distribution assessment for the real room and one of the three models as well as for each of the models with each other. There was a significant difference in assessment score between the Small Model (M = 4.6, SD= 0.18) compared to the Real Room (M = 3.96 SD= 0.18), t (48) = -2.39, p <0.05.
Figure 30 The mean assessment of Light distribution, a comparison and evaluation between the real room and the three scale models. Real=The real room, S=Small model, M=Medium model, L=Large model.

4.5.2 Shadow

An independent-samples t-test was conducted to compare the light level assessment for the real room and one of the three models as well as for each of the models with each other. There was not a significant difference in assessment score between the models.

Figure 31 The mean assessment of Shadows, a comparison and evaluation between the real room and the three scale models. Real=The real room, S=Small model, M=Medium model, L=Large model.
4.5.3 Light Level

An independent-samples t-test was conducted to compare the light level assessment for the real room and one of the three models as well as for each of the models with each other. There was a significant difference in assessment score between the Small Model (M = 4.64, SD= 0.18) compared to the Real Room (M = 3.96 SD= 0.18), t (48) = -2.39, p <0.05 (two-tailed) as well as between the Small Model (3,96) and the Medium Model), t(48) = -1.79, p <0.05 (two-tailed).

![Mean Assessment Light Level](image)

*Figure 32 The mean assessment of Light level, a comparison and evaluation between the real room and the three scale models. Real=The real room, S=Small model, M=Medium model, L=Large model.*
4.5.4 Specular reflection

An independent-samples t-test was conducted to compare the shadows assessment for the real room and one of the three models as well as for each of the models with each other. There was a minor difference in assessment score between the Small Model (M = 2.88, SD= 0.18) compared to the Real Room (M = 3.88 SD= 0.18), t (48) = 3.16, p <0.05.

4.6 Open ended questions

4.6.1 Results

After viewing the real room and the scale models the subjects answered an open question regarding which scale model the found to be the most representative of the real room (see appendix 1). 11 subjects found the large model the most representative when they answered the open ended questions. 9 found the medium model most representative and 5 subjects found the small model the most representative. Alongside answering which the found most representative each subjects had to answer why they had answered as they did (see Appendix 8).
4.7 Luminance values

The highest luminance value differed during the three days in the both of the rooms. The biggest difference being in the real room between the first and second day with a difference of 2778 lux. The room with the scale models the biggest difference in luminance was also between the first and second day with a difference of 2943 lux.

When it comes to the lowest luminance value in the real room the biggest difference was between the second and third day with a difference of 1326 lux. In the room with the scale models the biggest difference was experienced between the first and third day with a difference of 1219 lux (See Appendix 6).

Regarding the average value of the real room the biggest difference was seen between day one and day two with 2007,876 lux. The room with the scale models there was a difference of 1641,382 lux between the second and third day.

Looking at the luminance values (see table 2) there is a clear difference between day 2 and the other two days. The weather differed between the days (see Appendix 7) resulting in varying luminance values. Therefore, it can strengthen the reason for the difference in answers between the different days.
Table 2: Show the average, highest and lowest value of each day the experiment was conducted in each of the rooms.

<table>
<thead>
<tr>
<th>Day</th>
<th>Highest value Real room</th>
<th>Room with scale models</th>
<th>Lowest value Real room</th>
<th>Room with scale models</th>
<th>Average value Real room</th>
<th>Room with scale models</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/3</td>
<td>7883 lux (12:18)</td>
<td>5529 lux (12:18)</td>
<td>1139 lux (15:20)</td>
<td>773 lux (15:22)</td>
<td>3835 lux</td>
<td>2653 lux</td>
</tr>
<tr>
<td>13/3</td>
<td>2619 lux (11:36)</td>
<td>2586 lux (11:36)</td>
<td>969 lux (15:20)</td>
<td>943 lux (15:20)</td>
<td>1827 lux</td>
<td>1794 lux</td>
</tr>
</tbody>
</table>

The illuminance values over the course of the three days varied, however values on the two different rooms followed very similar curves even though the values of the scale model room were lower than those in the real room. For day one the variation between the two days were larger than for day two where the difference was lower. The third day placing in between the first and second day when it came the variation of illuminance levels between the two rooms.

Figure 35: How the illuminance values in the real room and the room with the scale model corresponded with each other during day 1 of the experiment.
Figure 36 How the illuminance values in the real room and the room with the scale model corresponded with each other during day 2 of the experiment.

Figure 37 How the illuminance values in the real room and the room with the scale model corresponded with each other during day 3 of the experiment.
5 Discussion and conclusion

5.1 Result discussion

The illuminance levels on day one and three were very similar and the levels for day two differed and showed up as much lower (see Appendix 6). This could be seen in the table showing the average luminance level for each day, how they compared with between the two rooms and between the different days (see table 2). A difference can be seen in the answers during day 2 compared with the other two days. When looking at the average of each of the four questions (see 4.2) it was easy to see that there was a difference in how the different subjects answered. And the relation between the three different scale models and the real room, if there was a correlation or not.

The weather conditions during the three days varied very slightly (see figure 34,35 and 36), all days being overcast except for on the afternoon of the last day (14/3 2018) the study was being conducted (see 2.1). One of the subjects conducted the experiment during this time, however, there was no clear deviation seen in this subject’s answers compared to the other 24 subjects.

As the room with the three scale models had its blinds down to cover the windows as much as possible to prevent unwanted daylight to come in. Small parts of daylight would still come through to the room. This could have had an effect on how the models were experienced as light would not only come through to windows of the models but the door which the subjects looked through. However, in the real room there was also a window at the side of the door which the subjects stood next to when viewing the room which also caused unwanted light in the room. As both the real room and the scale models had light coming in from behind, it is hard to see if it was a cause for a difference in result.

In the image (see figure 4) of the three models, it is clear to see the difference in size and that the background is clear in the large model and blurry in the small model. Baker and Stemmers (2002) stated in their article that the bigger objects are and the closer you get to them, the easier it is to see details. Corresponding with the experience of the small model being blurrier than the large and medium model when viewing it.

The three different scale models were also experienced to have the different light level. Bodart and Causwert (2017) stated that it was evident that the walls and ceiling appeared brighter in the scale model compared to the real room. Which could be seen clearly in the large scale model, that it was much brighter than the
other two models and brighter than the real room. Boccia and Zazzini (2014) stated in their article that the scale model is a good way to visualize space and daylight, however, that the daylight is often overestimated. This could be seen in the results regarding the large-scale model which appeared brighter than the other two scale models and to the real room. The smaller model was experienced as darker than the other two scale models and the real room. It was the middle scale models that appeared to be the closest to the real room regarding brightness.

The materials also affect the experience of the scale model, in this study materials were not taken into consideration when building the scale model, more than diffuse white paper were used on the surfaces that were not glossy such as the whiteboard. Thus, the reflections in the scale models were not the same as in the real room and the experience was therefore different. Reinhart (2014) stated in his article that visualizing daylight in scale models is often independent of the size and a smaller model can be used as daylights interaction with objects is independent of size. However, this study can state that this depends on the size of the real room which is the most representative when it comes to visualizing daylight.

5.2 Method discussion

To answers the reports research questions, a questionnaire based on Klaréns’ (2011) eighth visual concepts that explain the spatial experience of color and light were formulated. The authors could see that the subjects had answered and understood the questions correctly and thus contributed the answer of the reports research questions. The second part of the study was based on Branzells (1995) method regarding sketching a spatial experience of a space on a plan view (see 3.1). Even though the authors explained the process of this part of the study to each of the subjects before they began the experiment, the explanation was not significantly understood. Due to that the different subjects all interpreted Branzell differently the result gained from this is now void and cannot be used to compare the different scale models to the real room. Therefore, the result cannot be seen to answer the report research questions.

There were instances or details that could have negatively impacted the reliability in the experiment. The fact that the number of participants was not the same in the three different days the experiment was performed and thus it could have affected the result. Another thing that could be done to increase the reliability of the experiment is to document the time the test subjects ended the experiment and not just document a start time as it was done this time. Lan and Lian (2010) described in their article the effect that the number of participants have on the study an later on the results gathered from the collected data.
As Thanachareonkit et.al (2005) explains the accuracy of the scale model and thus careful documentation of the room was made to ensure the three scale models upheld a high standard (see 3.3.1 and Appendix3). By example, adding diffuse paper inside and out minimizes the risk of unwanted daylight coming into the model as described both by Otte (2014), as well as Bodart et.al (2011). By using materials and tools recommended by research when it comes to building models (Dunn 2014).

When it comes to the selection of the room, there could be of consequence that there were nearby buildings that obscured the natural flow of sunlight into the rooms where the study was executed. Even though the rooms were next to each other the building opposite was at an angle and also had different roof heights.

The difference in material between the real room and the three scale models was one of the delimitation of this study. It could have had an effect when it came to light level and also specular reflections as the surfaces of the real room and the models differed from each other. The scale models which only had white diffuse surfaces, except for whiteboard, furniture, ventilation drums, computer and cable drawer that was more glossy than the other surfaces of the models. The real room had colored surfaces, such as the table which was red and the floor which was grey which who'd have had different reflektiv karakteristik than i the scale model.

5.3 Conclusion

In conclusion the medium scale model (1:20) and the large model (1:10) was the most representative of the real room. This may be due to that the medium model and large model was most similar to the real room and had the most representative lighting situation to the real room. The large scale model (1:10) was at first perceived as being too bright in the relation to the real room. However, after conducting an ANOVA and T-test it was concluded that it was not the case, that they were similar to each other (see 4.5). It’s also what the compiled data of the open questions showed. The large model (1:10) was the preferred by most of the subjects, followed closely by the medium model (1:20). The small model (1:50) was considered too small to be able to perceive the shape and detail of the room, making it difficult to see a wholeness and for the eye to find a focus in the room.

5.4 Recommendations

It should also have been noted down if the subjects had impaired eyesight and if they wore eyeglasses or not. This could have affected the results due to the fact that some of those wearing eyeglasses had to remove them in order to properly see into
the model, especially the small-scale model (1:50). Thus, making the experience of the scale model become blurry and less representative of the real room as the conditions changed.

5.5 Further research

Research on whether the weather conditions had any impact on the results as the condition were very similar over the course of the three days the experiment was conducted. Similarly, the experiment could be performed during the different season to further investigate the impact of weather conditions. As well as performing the experiment in other countries as the sun’s’ movement across the sky differs depending on where in the world you are. Further research regarding the level of detail in the scale model would beneficial to garner an understanding of space and its impact on the visualization of daylight. The scale could be further looked at and a larger variety of scales investigated.
Reference list


Reinhart. C (2014) *Daylight Handbook 1 Fundamentals Designing with the Sun* USA


## Appendix

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Appendix 1 Questionnaire

Kön
Man [ ]
Kvinna [ ]

Ålder:
[ ]

Läser du på universitet eller högskola?
Ja [ ]
Nej [ ]

Om ja Utbildning

Vilken termin?
1 [ ]
2 [ ]
3 [ ]
4 [ ]
5 [ ]
6 [ ]
7 [ ]
8 [ ]
9 [ ]
10 [ ]

OM nej :Vad har du för yrke?

Fylls i av författarna
Dag [ ]
Tid [ ]

Ordning

Fylls i av den som gjort experimentet.

Vilken av de tre olika skalmodellerna tycker du är mest representativ för det riktiga rummet?
Liten [ ]
Mellan [ ]
Stor [ ]

Varför kände du så ?

[ ]
Ljusfördelning
Fråga: Hur upplever du ljusfördelningen i rummet?
Förklaring: Med ljusfördelning menas upplevelsen av hur mörka och ljusa områden ligger i förhållande till varandra i rummet som helhet, hur mörker och ljus fördelar sig över rummet.

![Rating Scale]

Skuggor
Fråga: Hur upplever du skuggorna i rummet?
Förklaring: Med skuggor menas den övergripande upplevelsen av skuggornas verkan i rummet som helhet. Skuggor kan artikulera och betona ytstrukturer, föremålens och rummets form. De kan också indirekt beskriva ljusets karaktär,

![Rating Scale]

Ljusnivå
Fråga: Hur upplever du ljusnivån i rummet?
Förklaring: Med ljusnivå menas upplevelsen av om rummet som helhet är ljust eller mörkt. Den övergripande ljusnivån anger ett rum's karakter och påverkar våra möjligheter att orientera oss i rummet.

![Rating Scale]

Reflektioner och blänk
Fråga: Upplever du några reflektioner i rummet?

![Rating Scale]
Titta in i rummet och med hjälp av bubblor rita upp hur och var du upplever att rummet faktiskt är. Det menas att de samlade känslorna kommer att skapa en helhet som sedan ska skissas och tolkas som bubblor på planvyn.
Appendix 2 Laser meter

Leica DISTO™ D210
Original laseravståndsmätare

*Swiss Technology by Leica Geosystems*

**Helt enkelt funktionellt!**


Leica DISTO™ D210 – och du använder aldrig mer ett måttband.

**Utrustad med:**
- Power Range Technology™
- IPS4 damm- och stänkavtfyllningskydd
- Belyst display med 3 rader
- Automatiskt, multifunktionellt baktycke

*when it has to be right*
Precision per knapptryck
För alla som vill vara exakta, Leica DISTO™ D210 mäter med en noggrannhet på ± 1,0 mm.

Liten och hanterbar
Tack vare sin ergonomiska och kompakte design med ett mjuka grepp, ligger Leica DISTO™ D210 sålret i handen och passar i alla fickor.

Multifunktionellt bakstycke
Mätning i höjd, spår eller från kant, detta bakstycke kan allt. Den automatiserade positionssäkringen hjälper dig att undvika dyra mätel.

Översiktlig display
Resultaten visas i 3 rader. Display-belysningen underlättar avläsning även i mörker.

Leica DISTO™ D210
Art. No. 705045
- Leica DISTO™ D210 laseravståndsmätare
- Bakstycke
- Hanterbar
- Batterier

Tekniska data

<table>
<thead>
<tr>
<th>Funktion</th>
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<tr>
<td>Måttillåtelse</td>
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<tr>
<td>Måttillåtelse</td>
<td>0,001 m, 0,0001 m, 0,0001 m</td>
</tr>
<tr>
<td>Power Range Technology™</td>
<td>0,001 m, 0,0001 m, 0,0001, 0,0001 m</td>
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<tr>
<td>Avstånd</td>
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<td>Siktuppsättning</td>
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<tr>
<td>Duketsklass</td>
<td>IP54, IP54, IP54</td>
</tr>
<tr>
<td>Mätning per batteri</td>
<td>Upp till 6 000 mätningar</td>
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<td>Typ AAA 3 x 1,5 V</td>
</tr>
<tr>
<td>Längd</td>
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<tr>
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<td>Mätfunktions</td>
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3 Years Warranty

Leica Geosystems AG
Heerbrugg, Switzerland
www.leica-geosystems.com

- when it has to be right
Appendix 3 Drawings
### Appendix 4 Materials and tools

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foamboard</td>
<td>A 5mm thick white board. Two pices of thicker paper with a layer of foam between them.</td>
</tr>
<tr>
<td>Cardboard</td>
<td>1mm thick white board.</td>
</tr>
<tr>
<td>Diffuse black paper</td>
<td>A black paper with a small amount of reflection</td>
</tr>
<tr>
<td>Diffuse white paper</td>
<td>A white paper with a small amount of reflection</td>
</tr>
<tr>
<td>Glue stick</td>
<td>Suitable to as a cutting guide</td>
</tr>
<tr>
<td>Hot adhesive black glue</td>
<td>Glue stick used with glue gun</td>
</tr>
<tr>
<td>Hot adhesive</td>
<td></td>
</tr>
<tr>
<td>Transperant glue</td>
<td>Glue stick used with glue gun</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide snap knife</td>
<td>The blade can be snaped of in sections to keep the blade sharp</td>
</tr>
<tr>
<td>Scalpel</td>
<td>For the more intrecate paperwork</td>
</tr>
<tr>
<td>Cutting mat</td>
<td>To prevent damage to table and keep the knife sharper</td>
</tr>
<tr>
<td>Scale ruler</td>
<td>Ruler with scale markings</td>
</tr>
<tr>
<td>Aluminium ruler/cutting</td>
<td>Suitable to as a cutting guide</td>
</tr>
<tr>
<td>ruler</td>
<td></td>
</tr>
<tr>
<td>Glue gun</td>
<td>Produces a hot adhesive glue which dries and bind quickly</td>
</tr>
<tr>
<td>Tweezers</td>
<td>For more detailed and intricate work</td>
</tr>
<tr>
<td>Scissor</td>
<td>Used for cutting</td>
</tr>
</tbody>
</table>
Appendix 5 Illuminance logger

2YL-M Series Lux Loggers
Technical Specifications

<table>
<thead>
<tr>
<th>2YL-M Series Lux Loggers - Technical Specifications</th>
<th>2YMLE1-4M</th>
<th>2YMLE2-4M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td><strong>Dimensions (d x h)</strong> mm</td>
<td>50 x 30</td>
<td>50 x 30</td>
</tr>
<tr>
<td><strong>Ambient temperature range</strong> °C</td>
<td>0 to 40°C</td>
<td>0 to 40°C</td>
</tr>
<tr>
<td><strong>Measuring range</strong> °C</td>
<td>0 to 4000 Lux</td>
<td>0 to 4000 Lux</td>
</tr>
<tr>
<td><strong>Accuracy</strong> °C</td>
<td>± 20%</td>
<td>± 20%</td>
</tr>
<tr>
<td><strong>Internal sensor resolution</strong></td>
<td>1 Lux</td>
<td>1 Lux</td>
</tr>
<tr>
<td><strong>Memory capacity (readings)</strong></td>
<td>4 million</td>
<td>4 million</td>
</tr>
<tr>
<td><strong>Active start</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Sensor type</strong></td>
<td>Single Channel Luminance</td>
<td>Single Channel Luminance</td>
</tr>
<tr>
<td><strong>Humidity Sensor</strong> (Internal and External)</td>
<td>0 to 100% RH ±0.1% RH</td>
<td>0 to 100% RH ±0.1% RH</td>
</tr>
<tr>
<td><strong>Intervals</strong></td>
<td>1 second to 24 hours</td>
<td>1 second to 24 hours</td>
</tr>
<tr>
<td><strong>IP rating</strong></td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td><strong>Battery type</strong></td>
<td>LITHIUM-12</td>
<td>LITHIUM-12</td>
</tr>
<tr>
<td><strong>Battery life (Logging Speed)</strong></td>
<td>4 years</td>
<td>4 years</td>
</tr>
<tr>
<td>1 minute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 seconds</td>
<td>230 days</td>
<td>230 days</td>
</tr>
<tr>
<td>1 second</td>
<td>33 days</td>
<td>33 days</td>
</tr>
<tr>
<td><strong>Robust, shock proof</strong></td>
<td>*</td>
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</tbody>
</table>

2YL-M Series Lux Loggers - Accessories

<table>
<thead>
<tr>
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<th>2YMLE1-4M</th>
<th>2YMLE2-4M</th>
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</thead>
<tbody>
<tr>
<td><strong>YoyoView Software</strong></td>
<td>*</td>
<td>*</td>
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<tr>
<td><strong>Wall Holder</strong></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><strong>Lead Seal Kit</strong></td>
<td>*</td>
<td>*</td>
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Note: Optional Extras include - YoyoView Software, Calibration Certificate, Wall holder, Lead Seal Kit, Probes and Accessories.
# Appendix 6 Illuminance values

<table>
<thead>
<tr>
<th>Subject</th>
<th>Day and time</th>
<th>Order</th>
<th>Real room</th>
<th>Room with scale models</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12/3 10:00 – 11:00</td>
<td>R – M</td>
<td>5234 lux (10:46)</td>
<td>3612 lux (10:46)</td>
</tr>
<tr>
<td>2</td>
<td>12/3 10:00 – 11:00</td>
<td>R – M</td>
<td>5234 lux (10:46)</td>
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<tr>
<td>4</td>
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<td>M – R</td>
<td>6357 lux (11:58)</td>
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<td>7882 lux (12:18)</td>
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<tr>
<td>7</td>
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<td>M – R</td>
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<td>1189 lux (14:48)</td>
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<td>R – M</td>
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<tr>
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<td>2619 lux (11:36)</td>
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<tr>
<td>14</td>
<td>13/3 10:45 – 11:45</td>
<td>M – R</td>
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<td>2526 lux (13:04)</td>
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<td>M – R</td>
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<td>3474 lux (15:02)</td>
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<td>Subject</td>
<td>Day and time</td>
<td>Order</td>
<td>Lowest value Real room</td>
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<td>-------------------------</td>
<td>------------------------</td>
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<td>12/3 10:00 – 11:00</td>
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<td>2321 lux (13:58)</td>
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<td>12/3 14:45 – 15:45</td>
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<td>1139 lux (15:20)</td>
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<td>1315 lux (10:00)</td>
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<td>---------------</td>
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<td>3048 lux</td>
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<td>4924 lux</td>
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<td>1789,011</td>
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<td>2038 lux</td>
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<td>1936 lux</td>
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<td>1973 lux</td>
<td>1936 lux</td>
</tr>
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<td>R – M</td>
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<td>1280 lux</td>
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<td>3509 lux</td>
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<td>3509 lux</td>
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<td>4389 lux</td>
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<td>R – M</td>
<td>4751 lux</td>
<td>4389 lux</td>
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<td>M – R</td>
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<td>2503 lux</td>
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### Appendix 7 Weather conditions

<table>
<thead>
<tr>
<th>Day</th>
<th>Observations</th>
<th>SMHI - Swedish Meteorological and Hydrological Institute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Cloudy with a bit of rain with sludge and small portions of snow on the ground</td>
<td>Cloudy</td>
</tr>
<tr>
<td>Day 2</td>
<td>Cloudy with sludge and portions of snow on the ground</td>
<td>10–11 Foggy 11-16 cloudy</td>
</tr>
<tr>
<td>Day 3</td>
<td>Cloudy, with very small amount of snow. 14.30 the clouds are clearing and sun start peering through</td>
<td>10-12 Cloudy to half cloudy 13-16 Half cloudy</td>
</tr>
</tbody>
</table>
Appendix 8 Subjects comments from open ended question

Comments from test subject regarding what scale model they found the most representative of the real room and why.

**Started in real room**

1 Mellan
Den minsta var alde för svår att se i var för ansträngande. Mellan var tillräckligt tydlig och man kände igen rummet och dess utformning bra. Den Stora fungerade också bra men kändes inte som att skulle vara nödvändigt att ha en sådan stor.

2 Stor
Man känner att man kunde relatera mer till det stora och få en bättre uppfattning av rummet

3 Mellan
Den lilla vart realistisk och den stora var för lätt översiktlig och detaljerad

5 Stor
Tyckte rumsligheten var det svåraste att uppleva i modellerna också blänk och reflektioner och skuggor något svårare att uppleva i modellerna. Den stora modellen förde med sig de egenskaper bäst.

6 Stor
För att man fick ett mer rumsligt perspektiv, då det kändes mer som att man var inne i rummet när man tittade i den stora modellen. Enklare att se detaljer tyckte jag.

9 Stor
Fick en tydlig överblicks vy av höger och vänster vägg som jag tyckte stämde överens med rummet i fullskala. Naturlig bedömning med den stora skalmodellen

10 Mellan
Det kändes som att ljusfördelningen, men sämst ljusnivåer stämde bäst överens. Skuggorna skalmodell 1 och 2 upplevdes mindre representativa för det verkliga rummet.

11 Liten
för att jag uppfattade de andra två som för ljusa jämfört med det riktiga rummet nosskuggorna tidigare hos den lilla.

13 Mellan
Jag upplevde det proportionerna kändes mer levande levande, storleksmässigt. De övriga kändes för små, för stora.

16 Stor
I den verkliga rummet upplevdes ljusfördelningar av bubblorna blev som stunt i det riktiga rummet. Ju mindre modellerna var desto närmre verkade bubblorna vara.

17 Mellan
Skuggorna var på samma ställe, liknade blänk, kändes som det var lika ljusa.

18 Mellan
The “light” area under the table was less precise than were in the larger modell. The small model felt too small to be “mad”

21 Mellan
Ljusförhållanden och för vad jag faktiskt kunde se.

20 Stor
Mer detaljer kom fram och ljuset gick att studera mer noggrant. Även om alla rum var små var detta närmsta storleken så därför tyckte jag den var bäst.

Started in scale model room

1 Mellan
Skuggor var för diffusa och skarpa i dom andra.

2 Liten
Det verkliga rummet hade fler skuggor och jag upplevde det mörkare. Kan bero på materialen.

4 Stor
Gav ett bättre helhetsperspektiv, enklare att analysera. Lättare att se ljuset.

7 Stor
För det var lättare att se in i hela rummet. Att “känna in” dagsljuset, att se skuggor ordentligt.

8 Stor
Lättast att blicka in i. Upplevde dock det verkliga rummet bredare. men kan bero på att jag stod i rummet och inte blickade in i rummet.

13 Liten
Ganska mörkt, men inte med reflektioner som i mellan. Hade helst satt ihop båda och för att få “det riktiga”. Det lilla var också lite kargt och dunkelt, vilket mer kan liknas vid “det riktiga”.

14 Mellan
15 Liten
Mellan och stor var för ljusa. De 2 känns luftigare än det riktiga rummet.

19 Stor
the material properties effect a lot on light reflections & shadows. The perception of store room was closer to the reality but the shadows & reflections was different. I also think that the light coming from the windows can not perceived with model.

24 Stor
Upplevde alla rummen väldigt lika men det var svårare att se desto mindre modellen blev.

25 Liten
Den “lilla” modellen reflekterade skuggbildningen mer likt den verkliga rumsupplevelsen. Även reflektioner upplevdes tydligare och mer överensstämmande.