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Lighting design at hospitals - An investigation of the interaction between light and materials in waiting areas

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Abstract:
This thesis provides a conceptual design proposal for the hospital waiting areas, focusing on the interplay between light and material. Based on scientific research it is found that hospitals waiting areas can pose anxious, impatient or insecure feeling and the spatial environment do not support a comfortable stay. Based on this, the problem statement is developed:

"How can a comfortable environment be created for hospitals waiting areas through a lighting design, focusing on the interplay between light, space and materials?"

Results from research in the fields of *Hospital Lighting*, *Atmosphere and Perception theory* and the *use of art and colour in healthcare,* form the theoretical base of this lighting design. Furthermore field studies at the hospitals in the Copenhagen area were conducted in order to attain a comprehensive understanding of the spatial characteristics, the atmosphere, and to assess the necessity of a new spatial design. The lighting design process was inspired by Donald A. Schöns *Explorative experiment, Reflection in-action* method that offered a way to approach the physical elements of the design. The final design with a combined slat structure with a moving light interpretation was developed through *Explorative experiments.* The design is inspired by nature, which is commonly considered to have a positive effect when establishing a comfortable environment. Furthermore the design aims towards presenting an aesthetically pleasing visual stimulation, where the light, materials and the structural design interweave. This is achieved through the *abstract representation of nature*, a *balanced combination of materials* and *programmed movement of light*.

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Results from research in the fields of *Hospital Lighting*, *Atmosphere* and *Perception theory* and the *use of art and colour in healthcare*, form the theoretical base of this lighting design. Furthermore field studies at the hospitals in the Copenhagen area were conducted in order to attain a comprehensive understanding of the spatial characteristics, the atmosphere, and to assess the necessity of a new spatial design. The lighting design process was inspired by Donald A. Schöns *Explorative experiment, Reflection in-action* method that offered a way to approach the physical elements of the design. The final design with a combined slat structure with a moving light interpretation was developed through *Explorative experiments*. The design is inspired by nature which is commonly considered to have a positive effect when establishing a comfortable environment. Furthermore the design aims towards presenting an aesthetically pleasing visual stimulation, where the light, materials and the structural design interweave. This is achieved through the *abstract representation of nature*, a *balanced combination of materials* and *programmed movement of light.*

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Introduction

Topic Description

Visible light has a spectrum of 390-700 nanometers, and the human eye can distinguish between some hundreds of different hues. But light is also chromaticity, dispersion, reflection and amplitude, and the simple fact that we need light to observe and define a space is seemingly often forgotten when designing indoor environments. The light in the final design of interiors will often be added very late in the process, when the physical surroundings are more or less settled, and with less consideration as to how the light will interact with the surfaces of the surrounding materials. On such occasions it is hard to modify the final outcome with only the lighting design, and eventually this could result in a compromised spatial design, where the light may seem disconnected from the context in which it should play a vital part.

The initial interest for combining the light and materials into a conceptual lighting design originated from a general fascination about playing with materials and surfaces in a space. About being capable of creating a calming atmosphere in the beholder's visual field, by the surfaces' interplay with the ambient light. But not only designed to be pleasing from an aesthetic point of view, but complemented with a functional approach. This should be paired with a profound understanding of the material characteristics, their benefits, challenges and the context that they are being presented in.

It is not hard to find indoor public spaces, where the aesthetic possibilities are being neglected, and where a new lighting design could be the catalyst with which to optimize the experience for the users. The search for such places was narrowed down to hospital waiting rooms, where people usually have to stay for a certain amount of time. This could also have been classrooms, offices, supermarkets and similar venues, where it is usually seen that the aesthetics have been neglected and the lighting designs are only focusing on achieving the right luminance level for the given context.

Waiting areas were an obvious choice. The purpose of a waiting area is clearly to be staying in the same place, until some unspecified future moment, and the health care system is one of the big contenders in this category. Before a visit to the dentist, a doctor, etcetera, you may feel more exalted, anxious or uneasy than usual, which is somewhat normal, considering that examinations or medical treatments usually are not considered pleasant. Compared to most other public spaces, waiting areas ought to be entities of peace and tranquility, somewhat restful places, where you should feel comfortable and safe, in order to successfully compensate the negative psychological duress of uncertainty and fearful anticipation.

Taking a look at today's waiting areas at hospitals in Denmark, these spaces are generally being ignored when it comes to creating a relaxing and pleasant environment, especially considering the amount of people passing through each day, and the many hours of their lives that they are obliged to spend in there.

Classic Danish waiting area (1)

The decôr is often less than inviting and with a cold, antiseptic expression, where grey linoleum floors, white walls and uncomfortable chairs are the dominant features. In some places vivid colours are implemented in the waiting areas in an attempt to make the space look more joyful or pleasant. Bringing in elements from nature such as living plants, a painting of a landscape or green leaves painted on the wall has also been observed in places.
Most guests will not experience any interaction with such a space, since these elements are not tailored to the space, and at its worst will stand out like a forced attempt to make it a pleasant place to stay. If you add the possible emotional trauma guests and patients suffer during their stay, it is difficult to understand why this is not a tall priority to the interior designers of the hospitals, when you contemplate how much effort the hospitals exercise into caring about their patient's well being in other areas.
The artificial light in hospitals is also often not present to contribute with anything beside lighting up the space with the proper intensity for the visitors to navigate (eg: where to go and sit) and be informed (ref. LED boards telling the waiting time).
One of the interesting qualities of light is, that it is possible to interact with the space as a whole, compared to an art piece on the wall or some vegetation in the corner. Light is a flowing medium, with plenty of possibilities to interact with other materials, and to give reflections and visual perceptions.

Placebo Pharmacy by KLab Architecture (2)

There is already someone who became aware of this problem, not only in the waiting areas, but all through the health care system.
Planetree is an international organization founded in the US in 1978 by a former patient named *Angelica Thieriot.* During a hospital stay she experienced the health care system as impersonal with its white walls, unfamiliar noises and disturbances. She wanted a hospital culture where the quality of the care, kindness and involvement with patients was equal to the clinical treatment. Where the health care was more patient-centered, with one of *Planetree's* basic themes being *"The physical environment can help to improve the patient's health, wellbeing and opportunity to recover".*

By putting this forward, *Planetree* convinced others about how much different strategies needed to be implemented into the health care system.
With one of Planetree's ten model components[1] being *Architecture and Interior Design* focusing inter *alia about light, sound, temperature* and *privacy*, there was a foundation for adding the consideration towards attributing a lighting design concept into the interior design. In that way, it seemed more convenient to add an improvement in an already existing conceptual design approach in the public healthcare system, by having some general guidelines to feed from.

Planetree five components in Architecture and Interior design (3)

By 2012 *Finsencenteret* at *Rigshospitalet in Copenhagen* partnered up with *Planetree*. In cooperation with architect *Linda Korndal*, *Planetree* developed five values that exemplifies a good physical environment for Finsenscenteret[*]. Theses guidelines along within *Planetree's* model component, *Architecture and Interior Design*, are not primarily focusing on the lighting design, but on the interior of the space, and this is mostly what is communicated through the pictures. But it is still possible to add the lighting design to theses values, which in the end could result in an even more coherent environment. *The National Survey of Patient Experience (LUP)* [2.] in Denmark shows, that the patients of today are happy with the treatment they get at *Finsencenteret*, but it also shows that there are still conditions which could be improved, such as better information about expected waiting time and a more cozy decor in the waiting areas[3]. This creates a good foundation for developing a lighting design that does not have to argue for its need.

To get back to the above mentioned research in public spaces, it was continuously discovered that the hospital waiting areas had several possible layers that could be added to the design, according to psychological needs and visual stimulation, when compared to other public spaces. In such a way it is possible to play with probably more abstract and artistic lighting concepts than would have been possible in for example a classroom, where the lighting effects should not be too obvious and thus distract students from their schoolwork.

** Photo 3: Planetree five components in Architecture and Interior design*

Purpose and goal

Based on on-site observations and surveys carried out by *Planetree*, it is acknowledged that hospitals waiting areas often carry an antiseptic, reserved and tense atmosphere[4]. This is among other things caused by the characteristics of the interior design and a light setting that neither alleviate any anxiety nor discomfort, being suffered by their users[5]. The aim of this thesis is to investigate *hospital waiting areas* in respect to certain chosen parameters. This includes the *atmosphere* and *spatial characteristics,* where people's behavior and existing interior will be documented, in order to find the missing links in the lack of a comfortable environment.
Measuring the atmosphere of a space can be quite a challenge, since it is rather individual and idiosyncratic how one is perceiving this. It is not possible to fully know how people will react to environmental factors, or ultimately to know how they will experience the space in the end. This phenomenology of perception has been developed in depth by the french philosopher *Maurice Merleau-Ponty*, who stated (as cited in Poldmaa, 2009) :

"…we are mediators of our perceptions through how we individually perceive color, form, and light. Not only do we "perceive" light and then objects and space, we simultaneously interact with the light and its color effect as we perceive the surrounding environment" [6]

As Merleau-Ponty defines, it is idiosyncratic how we perceive the space, and it is not that we only are affected by one factor - we are manipulated by the environment as a whole. Therefore many aspects of and in the space have to be taken into consideration regarding the development of a coherent lighting design concept. This includes *colours, materials and the reflectance, form* and of course the *light*.

The intention of this thesis is not to present a scientifically proven to-do-list about how to create a lighting design for hospitals waiting areas. Instead it is to analyze certain *spatial characteristics* through *scientific research* and *field studies*, and to explore what *psychological factors* you will experience when you must reside in a hospital waiting area. By this, this thesis' aim is to present a suggestion on how to create a comfortable environment with the use of light, based on field study, scientific research and intuitive design.

Problem Statement

Many studies have shown that there is already a great interest in making the spaces in hospitals a more comfortable, stimulating and pleasing place to stay. This is done among other things, by the implementation of art, colours and decors, seen in both the waiting areas and the wards. But it seems like that the studies are focusing on the effects of the objects and colours, and not necessarily if it fits the context that it is being put in. Through the Planetree international organisation, it was found out though surveys, that there is currently a need for optimization in the hospital waiting areas, with regard to making them more comfortable places to stay[7]. When designing with artificial light, it is often decided that the light should only fulfill the regulations in the context. Being aware of the surrounding materials is rarely prioritized, which can result in a lighting design with a dull and incoherent connection to the space.

This thesis makes a suggestion on how a lighting design could be implemented in waiting areas for hospitals, with an outspoken desire to create a comfortable environment as the end result. A comfortable environment in this context is meant as a space, where you can feel relaxed and pleased by a beautiful and stimulating environment. To create this environment with a lighting design, it has to be in coherence with the space and interior. Therefore, the interaction between light and materials is the main focal point of this thesis, complemented by an investigation of how it can contribute to a comfortable environment:

"How can a comfortable environment be created for hospitals waiting areas, through a lighting design focusing on the interplay between light, space and materials?"

Limitations

The aim of this thesis is not focusing on a design that is going into mass production, and then to be implemented in all hospital waiting areas in Denmark, but merely as one suggestion on how you could approach a wish to make hospital waiting areas into a more comfortable environment for spending some waiting time in. It is as well a reminder of the importance in the awareness of certain factors such as aesthetics, materials and colour uses, to create this environment. This can be done in thousands of ways, and this is just one approach on how to be doing it. Economy has therefore not been taken into consideration, with the exception of the energy efficiency and the projected maintenance of the implemented light sources. It is also not a finalized design, since testing the design on the target group with a real size model is not possible because of financial and temporal constraints. It is most likely that the final design will still need modifications regarding selection of light fixtures, materials, scale etcetera. But this subject is not going to be elaborated on further in this thesis. Since this thesis explore the advantages and possibilities within lighting design, it usually involves the values of not only artificial light, but natural daylight as well. In this regard, the daylight will not be included, since the design is made for all possible hospital waiting areas, disregarding their spatial size or access to natural daylight.
A *comfortable environment* can be created in many ways that are activating our senses, such as sound and smell. But since the aim for this thesis is investigating only the interplay between light and materials, these other factors are excluded.

Methodology

This master thesis is combining *Research based methodology* together with field study observation and using an *Explorative experiment, Reflection In-action*, by philosopher *Donald A.Schön*s as an approach to develop a lighting design concept for hospital waiting areas. This mixed method model allows to gather knowledge from previous researches that are evaluating the same field, and on-site observations offers the possibility to experience the case in an user perspective. The Explorative experiments enables to investigate a specific topic, by studying and discovering some phenomenology without knowing the final outcome. Explorative experiment is (Schön, 1991)

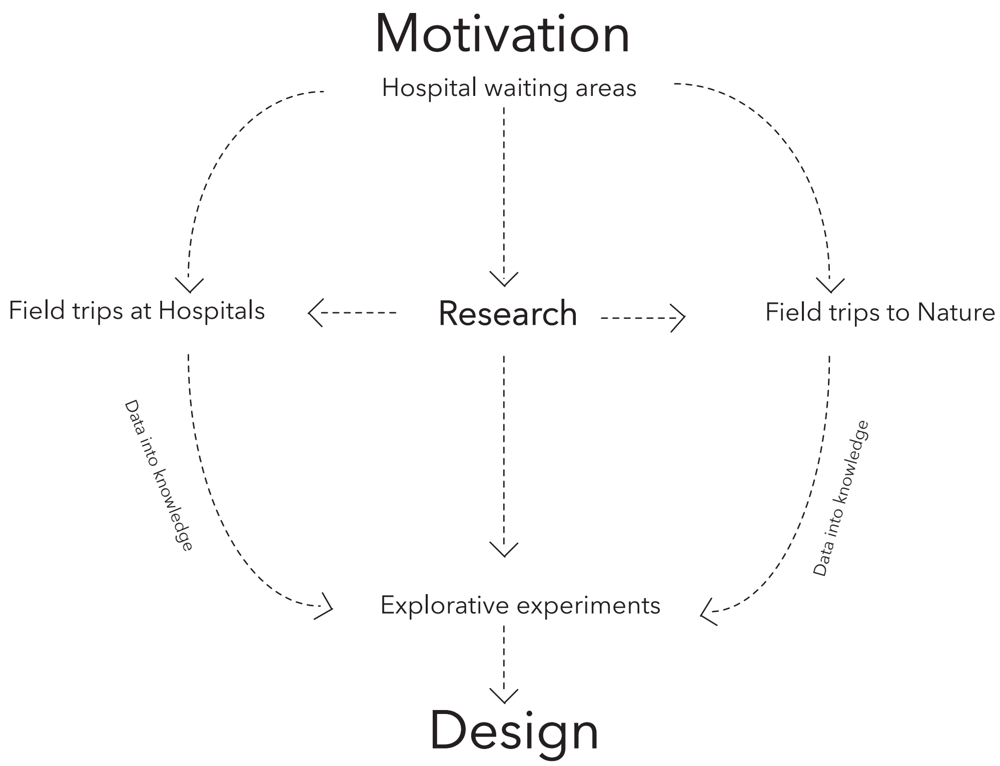
" …act in order to see what the action leads to" [8]

By implementing this method as a tool in the design phase, we believe that by performing exploratory experiments, this will augment a greater understanding of material characteristics and interactions with different light settings. These experiments enables an insight into what kind of materials should be considered in the final design, and what kind of techniques should be implemented in order to achieve a coherent and harmonious lighting design for the waiting areas.

In order to gather the knowledge and information about hospital waiting areas, initial research was made on location, and a sort of psychological assessment was conducted along with field study observations. Both the research and the on-site observations found that often hospitals are designed to meet the needs of technology more that the spiritual and emphatic needs of patients, families, or staff [9]. For instance in the early Greek places of healing, the Aesculapian temples, placed great emphasis on the surroundings, and the temples were built in positions of beauty, so that the patients could recover while enjoying the view. The temples were situated near natural springs, so that the water would be pure, and in raised elevations, so that there would be cooling breezes[10]. During the mid-19th century hospital building began to move away from the concept of being temples of healing, processing aesthetic qualities, and thus gravitated towards being primarily concerned with medical functions[11]. Fortunately, today there is a growing awareness in the scientific community that Nature might in the end be the most universal image of spirituality[12]. Several studies suggest that administrators should pay more attention to the healthcare environment and its connections with nature, as representations of nature might play a significant - but yet not fully understood - role in healing[13].

The intention was to further elaborate the nature phenomenology and to identify which elements have the power to generate certain emotions, and whether it is possible to recreate some of this phenomenology with the light and material interplay. Thereby the field studies in virtual nature were applied as method, in order to find inspiration that could support the intention of creating more aesthetically pleasing and comfortable waiting areas.

Therefore, the aim of this Master thesis is to create a lighting design proposal that should amalgamate with both the healthcare lighting standards and with design considerations. These are supported by the scientific research and based on field study observations, which are developed throughout creative experimentation process.



Method Model (4)

This model presents the overall methodological structure in the analysis, which is combined with research, field study at hospitals and field study in nature. To support the chosen design decisions, the research involves *hospital lighting*, *atmosphere* and *perception theory* together with *material characteristics*. Furthermore, to get an assessment of the current lighting design situation at hospitals, and to investigate if there actually is a need for a new design, field trips to hospital waiting areas are executed and documented. Inspiration will be collected through field trips, albeit the nature theme is already somewhat implemented in the waiting areas, and a different approach to implement this theme is to be desired. In total, the aim is to finally translate and transform all the collected information from scientific research and field studies into a coherent lighting design.

Field Study

Field Study

In order to learn more about the hospital waiting areas, its lighting and spatial design, and how people behave in these spaces, on-site field studies were carried out during March 2016. Waiting areas observations took place in three different hospitals in the area of Copenhagen; in *Rigshospitalet, Frederiksberg* and *Hvidovre*. In total six different waiting areas were observed, one in Rigshospitalet, three at Frederiksberg Hospital and two in Hvidovre Hospital. The choice of the hospitals and these waiting areas were made inadvertently, where the observers did not have any certain expectations nor any experience with the visited areas before. As the goal of the thesis is to design a comfortable atmosphere, it is important to study and explore the existing spaces according to spatial characteristics and general atmosphere. This is to evaluate and understand if spatial design may have influence or relations with patient's emotions and behaviour. Furthermore, the idea was to understand whether the interplay between materials and light could generate any new design approaches for the hospital waiting areas. And if there would be a need for new lighting design concepts, that are focusing on the coherent spatial experience, and not just fulfilling the functional lighting regulations.

The factors that were observed were inspired by architect *Peter Zumthor* and his knowledge about the fundamentals that are important in order to create a successful spatial experience[14]. Followed by his guidelines, the aim was to observe as many possible details related to spatial characteristics, the atmosphere, and how people interact with the space. At each waiting area, the same factors were observed and gathered into one spatial analysis matrix.

	SPATIAL FACTORS						SPATIAL ATMOSPHERE			
WAITING AREA	When	Weather condition	Direction of incoming daylight	Spatial size	Amount of seating spots	Amount of people in space	Daylight and artificial light	Atmosphere	Acoustics	People Behaviour
Rigshospitalet Blood sample Departmnet	17.02.2016 ~13.00 a.m.	Blue sky and few clouds	North/East	~ 60 m^2	40 chairs	~ 15-20	40 round ceiling recessed fixtures with reflectors. Large amount of daylight	Relaxed atmosphere, a bit cold and feel of sitting in a passage	Not bad acoustics, but high ceiling and glass makes the sounds harsh, noise from hallway and the from LED board	A bit of chatting with the companion, seating themselves with space between each other, looking at their phones or in magazines
Frederiksberg Hospital Heart Department Y1	03.03.2016 ~ 10:30 a.m.	Overcast sky	North	~25-30 m^2	~ 20 chairs	~ 7-15	4 round indirect fixtures in the ceiling, some daylight	People were quiet and reserved, tense atmosphere	Bad acoustics, eco, walking noise from other people	Sitting, just in their mind
Frederiksberg Hospital Heart Department Y2	03.03.2016 ~ 11:00 a.m.	Overcast sky	North/West	~25-30 m^2	~ 20 chairs yellow/blue	~ 8-15	4 round indirect fixtures in the ceiling, daylight, 4 Louis Poulsen ceiling lamps in the middle of the room	Extremely quiet atmosphere, people were reserved, tense	Good acoustics	Just sitting, being in their mind, no talking at all
Frederiksberg Hospital Blood sample Department	03.03.2016 ~ 11:20 a.m.	Overcast sky	South	~80 - 90 m^2	~ 50 gray leather chairs	~ 35 - 40	Daylight coming in from south side. 24 indirect ceiling fixtures	Not so tense, people are calm and relaxed, People are changing fast, waiting time not so long, ~10 minutes	Good acoustics, noise from TV and from numbering system	Sitting, talking, watching TV and reading magazines.
Hvidrove Hospital Day Surgery Department	03.03.2016 ~ 14:55 p.m	Overcast sky	South	~40 - 50 m^2	2 black leather couches, a bench, 9 plastic chairs	~ 10	Not much daylight, bit coming in behind reception	Relaxed, people are talking and TV is on with sound	Good acoustics, noise from TV	Sitting, talking, watching TV and reading magazines.
Hvidrove Hospital Blood sample Departmnet	03.03.2016 ~ 15:30 p.m	Overcast sky	South/West	~70 m^2	24 chairs, a bench	~ 5	A big amount of incoming daylight, 8 wall-washers, 8 fluorescent tubes with reflectors.	Relaxed, though people are not really waiting there.	Good acoustics, numbering calling noise	Sitting, talking, watching TV and reading magazines.

Spatial Analysis Matrix (5)

WAITING AREA	SPATIAL FACTORS						SPATIAL ATMOSPHERE			
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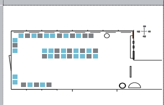
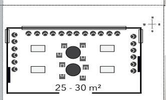
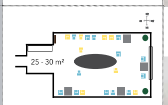
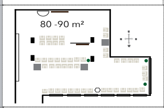
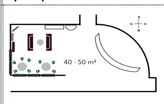
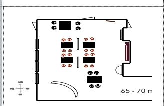
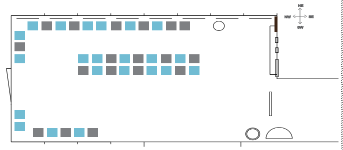
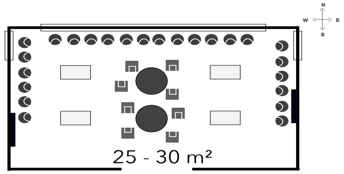
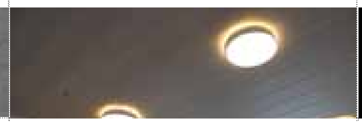
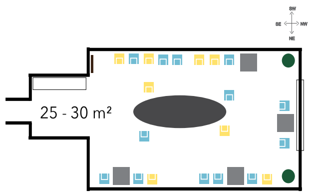
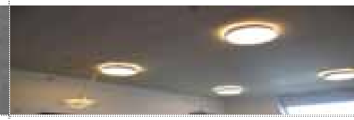
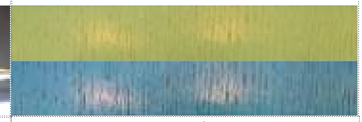
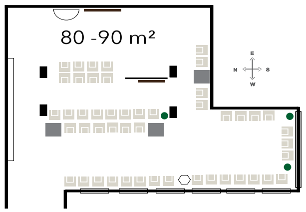
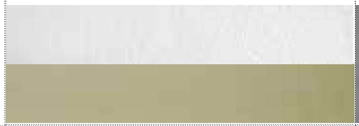
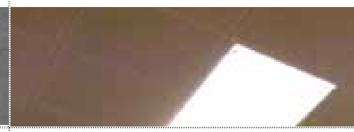
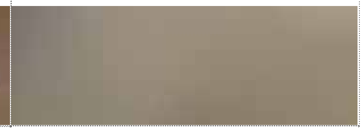
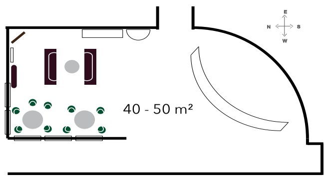
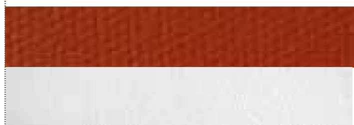
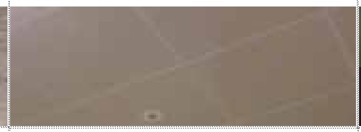
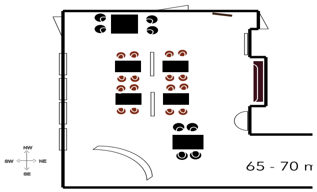
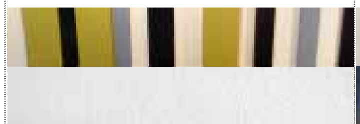
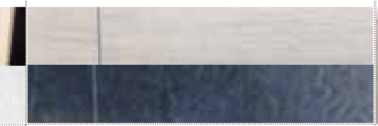
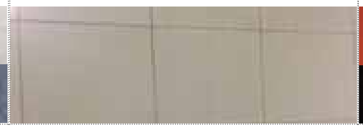
First, the field study was focusing on documenting the overall factors, such as *when the observation took place*, *weather conditions* and *direction of incoming light*. These were observed due to the amount of incoming daylight, since this may have an effect on the artificial lighting and how the space is perceived. *Spatial size*, *amount of seating spots* and *amount of people in the space*, were observed in order to know how the space is used, if it was crowded or not, since these factors may influence how people behave in the waiting area. *Daylight and artificial light, atmosphere, acoustics* and *people's behaviour in the space* were evaluated in order collect more data about the spatial atmosphere and the lighting design. Second, the observation included a closer look into the interior design of the waiting areas, to find the missing links when it comes to a coherent interior and lighting design. The observation included documenting the colors and materials used in the space, such as material use on the walls, ceiling and floors. At each waiting area, all the same factors were observed and later conducted into a material analysis matrix.

WAITING AREA / FACTOR	Architecture of the space	Walls	Floor	Ceiling and Artifical Light	Seating
Rigshospital Blood sample Departmnet		White fiberglass wallpaper	Grey linoleum floor	Blue/green wooden slats, 40 round ceiling recessed fixtures	Chairs: 20 blue and 20 grey, irregular
Frederiksberg Hospital Heart Department Y1		White fiberglass wallpaper	Grey linoleum floor	4 round ceiling recessed fixtures perforated metal panels	24 soft black leather chairs, 8 black wooden chairs
Frederiksberg Hospital Heart Department Y2		White paint	Grey linoleum floor	4 round ceiling recessed fixtures, perforated metal panels	20 wooden blue / yellow chairs, 4 chairs around the oval table
Frederiksberg Hospital Blood sample Department		White paint , columns pastel green	Grey linoleum floor	4 round ceiling recessed fixtures, perforated metal panels	Gray leather soft chairs, with wooden arms and legs
Hvidrove Hospital Day Surgery Department		White paint, orange paint	Grey linoleum floor	Perforated metal panels	9 plastic chairs with dark green pillow, foam texture, 2 black leather couches, a bench
Hvidrove Hospital Blood sample Departmnet		White paint, blue-green-white wall made from wooden slats.	Wooden flooring, brown linoleum.	Perforated metal panels, 8 wall-washers, 8 fluorescent tube fixture	16 brown wooden chairs with red pillow and metal legs, 8 black chairs

Material analysis Matrix (6)

The observation showed that there were many similarities in the different waiting areas regarding the spatial design, such as grey linoleum floors, simple direct ceiling light fixtures and furniture primarily consisting of coloured chairs placed up against the walls. Through the material analysis, it was seen that colours were used in the furniture and on the walls, but with less consideration in respect to the psychological effect of these. The colours on the walls also did not play any significant role, whether it was a small or large room, but it tended to be a more dominant factor in the small rooms than in the larger ones. The primarily used materials in the furniture, laminate and wood had irregular to matte reflectances, and the same reflectance level appeared on walls, flooring and ceiling. In total, the surfaces in the different spaces appeared similar and resulted in a rather dull appearance lack of visual stimulation.

WAITING AREA / FACTOR	Architecture of the space	Walls	Floor	Ceiling and Artifical Light	Seating
Rigshospital Blood sample Departmnet		White fiberglass wallpaper	Grey linoleum floor 	Blue/green wooden slats, 40 round ceiling recessed fixtures 	Chairs: 20 blue and 20 grey, irregular 
Frederiksberg Hospital Heart Department Y1		White fiberglass wallpaper	Grey linoleum floor 	4 round ceiling recessed fixtures perforated metal panels 	24 soft black leather chairs, 8 black wooden chairs 
Frederiksberg Hospital Heart Department Y2		White paint	Grey linoleum floor 	4 round ceiling recessed fixtures, perforated metal panels 	20 wooden blue / yellow chairs, 4 chairs around the oval table 
Frederiksberg Hospital Blood sample Department		White paint , columns pastel green 	Grey linoleum floor 	4 round ceiling recessed fixtures, perforated metal panels 	Gray leather soft chairs, with wooden arms and legs 
Hvidrove Hospital Day Surgery Department		White paint, orange paint 	Grey linoleum floor 	Perforated metal panels 	9 plastic chairs with dark green pillow, foam texture, 2 black leather couches, a bench 
Hvidrove Hospital Blood sample Departmnet		White paint, blue-green-white wall made from wooden slats. 	Wooden flooring, brown linoleum. 	Perforated metal panels, 8 wall-washers, 8 fluorescent tube fixture 	16 brown wooden chairs with red pillow and metal legs, 8 black chairs 

Observations

HOSPITALS OBSERVATIONS

When considering all the spatial dimensions, interior, daylight and artificial light, colours and material use that makes up the atmosphere in the space, it was clear to see that these combined elements had a different function, that was correlated to people's behavior in the room.
In a small room, such as *Frederiksberg Hospital Heart Department Y1*[*] (20-25 m2), chairs were placed close together up against the wall, so more people could fit in, which resulted in a space with no privacy neither direction (nor left, right and front). On top of that, the Heart Department is a high intensity ward, (eg: compared to the Blood Sample Department), which means a greater need for privacy during anxious waiting time. This also meant that people were not talking together, either because they were alone, or that the room tended to be too small to have a private conversation. The acoustics were also lamentable, which was primarily caused by the lack of sound absorbing materials, such as textile surfaces or posters/paintings on the walls.

At the Blood Sample Department[**] (80-90 m2) in the same hospital, the atmosphere was different and less tense. The reason for giving blood derives from a feeling of surplus capacity which also promotes socializing. In the Blood Sample Department people were either chatting, walking around, reading magazines or just relaxing. The seating areas were divided as well, so you could decide whether you wanted to sit in a private corner or in the middle of the room. The spatial materials were somewhat similar, so it was the architecture of the room and the way the furniture was placed that made the difference regarding both acoustics and social behavior. It was observed that it is not only the somewhat dull light setting and interior which has a negative effect on the atmosphere. It also depends on the way the room is exploited, which creates either bad or good acoustics, private and open spaces and social behavior.
A tense atmosphere can also be caused by other factors, such as missing visual stimulation, since it was observed that the atmosphere was more relaxed where this was present at some level (art, magazines, vegetation, fish tank, colours etcetera)

Blood Sample Department at Hvidrove Hospital (7)

* *Photo 5: Spatial Analysis Matrix*
** *Photo 5: Spatial Analysis Matrix*

Hvidrove Hospital's Day Surgery Department (8)

This relaxed atmosphere was observed in one waiting area at *Hvidovre Hospital's Day Surgery Department**, where *Planetree* in 2012 was involved in a general optimization of *Hvidovre Hospital*, in which several departments got new interior and light setting. Here the artificial light were of a particularly high priority when optimizing, since the building has very few windows admitting the natural daylight in. Therefore, the light at the *Day Surgery Department's* waiting area was designed as a beautiful interaction between light and wooden bars at the reception, and a coherent interior in different materials, seating areas and a fish tank to look at. In total, this created a visually stimulating space, with a calm yet quiet atmosphere, that through the observation came along as a pleasing environment to stay in for a limited amount of time.

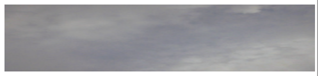
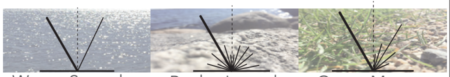
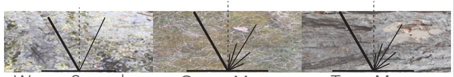
As the initial scientific research was suggesting that nature and its representations may have a positive effect on patient's emotions and healing processes, the on-site observation also presented that *nature theme* is frequently used in hospital spatial decôr, whether it is with a simple colour combination, directly translated plant patterns on the walls, or real plants in the space. Based on field study observations, this way of simplistically mimicking and translating the nature phenomenology comes along as some sadly misconstrued and at most times failed attempts to make the environment more comfortable.

Easily translated nature theme at public space (9)

** Photo 8: Hvidrove Hospital's Day Surgery Department*

NATURE OBSERVATIONS

Therefore, to gather more inspiration and knowledge about the nature phenomenology and its more unconscious calming values, an observational field trip to nature was carried out. The purpose was to evaluate and investigate why nature is often connected with theses positive emotions, and to study how would it be possible to associate the nature theme into a design that enhances it with a more artistic and abstract approach. The *nature field study* was mainly focusing on documenting the ranges of color schemes, the different textures and surfaces and reflections that are presented outdoors. Theses material values could then be translated into understanding which elements are causing and creating the atmosphere of the space and the parallel connection to positive emotions that these elements create.

FACTOR / LOCATION	Valbyparken	Forest near Furesøen
WHEN	11.04.2016 ~ 15:30	12.04.2016 ~ 17:15
WHEATER CONDITION	Sunshine, a bit windy 	Overcast day, a bit windy 
ILLUMINATION	33 000 lux	11 800 lux
SKY COLOR	Blue sky, light blue 	Overcast, gray-blue 
FEATURES NEARBY	Trees, water, rocks, grass 	Trees; small and large pine trees, grass, 
COLOR IN THE SCENE	Light blue, brown green, moss green, sand 	Green, gray, yellow-green, moss-green, dark brown, gray-blue 
ATMOSPHERE	Calming and relaxing atmosphere, can feel warm sun on the face, birds singing, sound from water against rocks, wave sound	Calming atmosphere, birds singing, wind sound, noise from airplanes
REFLECTIONS	 Water: Specular Rocks: Irregular Grass: Matte	 Water: Specular Grass: Matte Tree: Matte

Nature Matrix(10)

Field Study Findings

Two field trips to respectively *Valbyparken in Sydhavnen* Copenhagen and *Furesø* in Holte were observed and photo documented during afternoon March 2016*. Weather conditions and light levels were measured, since different weather conditions could cause a different atmosphere, colours in surroundings and reflections, which were also values to be observed. The registrations of colours on these field trips were important, since there was an interest in finding similarities with the colours already used in hospital waiting areas and what sort of atmosphere they create in the open, compared to how they are used in an indoor environment. Reflections were photo documented for design inspiration, since there was an interest of implementing those effects as a reference from nature into the final lighting design.

Two different weather conditions appeared throughout these field trips, one day with a clear blue sky (*Valbyparken, midday*) and another one overcast (*Furesø, late afternoon*). This changed the surrounding colours as well the atmosphere. When overcast the colours were less vibrant, which created a landscape with a lower contrast. When overcast, the reflections on the surrounding surfaces were also losing their lustre, which made the adjacent material surfaces blend into each other, which created less depth and thereby less visual stimulation**.

Panorama of Vabyparken (11)

Panorama of Furesø (12)

** Photo 10: Nature Matrix*
*** Photo 11, 12: Panorama of Vabyparken, Panorama of Furesø*

By this, it was found that a sunny day created a more stimulating and pleasing atmosphere, since the abundance of light created more reflections, vibrant colours, shadows (and thereby movements as well), and it cast more depth into the scene, compared to any overcast day. These satisfying values would be possible to implement into any indoor environment by playing with *contrasts, shadows, shapes* and *reflections* related to nature, which can be translated into many different expressions. By this it can be designed with a more abstract approach, compared to the existing nature theme at the hospital waiting areas.

The gained spatial knowledge from the two different field studies, combined with the literary research, resulted in four compressed findings according to the hospitals waiting areas, which were divided into four categories focusing on *qualitative parameters*. These findings were turned into a *"problem"*, and they were the stepping stone for formulating the *Success Criterias, Reason's* and *Solutions*[*].

FINDINGS TROUGH FIELD STUDY TO HOSPITALS				
Problem	The decôrs in the waiting areas are outdated and aesthetic lighting is neglected	Patients feeling insecure, anxious, and/or impatient when staying in the waiting area without any pleasant visual stimulation	When not modernized, the light setting is not proper distributed, causes visual glare and is not energy efficient	The nature theme is easily translated and therefore does not create positive distraction and makes patients forgetting waiting time
Success criteria	A comfortable environment achieved by coherent interior and lighting design	A space with a calming lighting design that is creating visual stimulation	A lighting design based on interaction between light and materials and its reflections, should preclude glare and visual irritation	An abstract translated approach to the nature theme, so the users attention and awareness of the space gets activated
Reason	A long time since the decor and light setting has been updated, since other factors in healthcare are considered more important	Waiting areas are missing pleasant and calming elements in the light setting and interior	The non energy effecient light is directly pointed to the perciever and causes visual glare	The nature theme is translated too direct or with motives or elements that is seen before in this specific context
Solution	A design concept that embraces the space as a whole with a gathered interior and lighting design	A lighting design with a pleasant light level that creates an interaction with the surfaces of the surrounding materials	An diffused lighting design that creates an ambient and calm reassurance with the combination of functional and artistic light	A gathered design concept with an abstract design approach to the nature phenomenology

Findings Through Field Study to Hospital(13)

Waiting area at Rigshospitalet (14)

** Photo 13: Findings Through Field Study to Hospital*

The decôrs in the waiting areas are outdated and aesthetic lighting is neglected*

The *reason* is visible, and you can see that it has been a long time since the decor and light setting in the waiting areas has been updated, since other factors in healthcare are considered more important than buying new decôr or light fixtures for these spaces. The interior is stale and the light is not distributed right according to the new light standards for the healthcare system. According to the report made by *The National Survey of Patient Experiences*[15] *LUP*[*] for *Finsenscenteret* at Rigshospitalet, is is acknowledged that the patients found the new waiting area in the Radiotherapy clinic were comfortable with its nice and well decorated decor, with a light and welcoming atmosphere[16]. Still, there was some of the waiting areas at *Finsenscenteret,* where the patients in the survey describes that there was still a need for optimization according to the decor and surrounding noise[17]. The success criteria here was to achieve a comfortable atmosphere in the waiting areas, it is important that the light is coherent with the rest of the interior, with the right luminance level etcetera and in that way behaves like expected to produce a positive emotional response for the visitor[18].

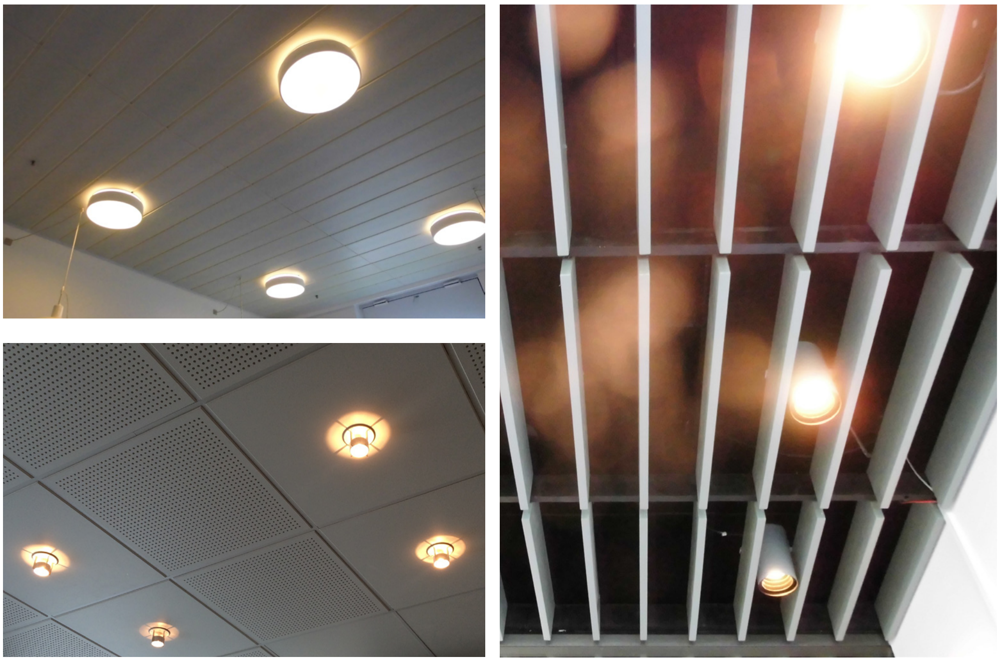
Classic Danish Waiting area(15)

Patients are feeling insecure, anxious, and/or impatient when staying in the waiting area without any pleasant visual stimulation such as art, visuals and proper lighting

Evidence based research has not much to tell about the negative emotions of staying in a hospital waiting area without pleasant visual stimulation. But more about the emotions we are getting when experiencing it. It is shown that; "A lighting solution that is coordinated with the architecture of a waiting room helps counteract undesirable feelings such as insecurity, anxiety and impatience" *(Zumtobel, 2013)*[19] and *"Levels of depression and anxiety tended to be lower in patients undergoing chemotherapy who were exposed to visual art than in patients not exposed to visual art"* (Lanktston et al., 2010)[20]. Similar statements recur in numerous scientific papers which deals with the healing or pleasant effect with the use of of art, materials, architecture and light in the healthcare system. The reason why people still gets in contact with these psychological states of mind, is because of the continual lack of understanding of the

** Photo 14: Waiting area at Rigshospitalet*
*** LUP: Den Landsdaekkende Undersoegelse for Patientoplevelser*

importance of implementing this *healing* or pleasant elements into the waiting area. In order to prevent these unpleasant emotions, the success criteria is to design a space that is not *healing,* but with a *comfortable* lighting design that is also creating a visual stimulation.



Outdated light fixtures from field study observations, causing glare (16)

> When not modernized, the light setting is not properly distributed, which causes visual glare and is not energy efficient*

Due to *Thorn Lighting Company's* catalogue, Applications in *Focus Lighting* for *Healthcare, the performance, efficiency* and *comfort (PEC)* are the core values when making a lighting design for healthcare[21]. To provide an optimal lighting solution, that consume the least possible power and provide a long-life, trouble-free solution, with the ability to give visitors a pleasant and satisfying experience without visual irritation. *"Direct light sources, which typically have a high surface luminance, produce a defensive response on the part of the eye"* and "*The primary consideration is to put the patient and visitors at their ease by providing an ambience of calm reassurance (Lam, 1992)*[22]", are both quotes that underlines the reason why there is a need for an adapted light setting at hospital waiting areas. *"Indirect light is intrinsically interesting to look at. Bright room surfaces satisfy biological needs for structural clarity and for a bright cheerful environment"* (Lam, 1992)[23]. The *success criteria* is to combine these to energy efficient light settings, and at the same time achieve to avoid visual glare to the perceiver. To avoid the direct glare from the light fixtures, these should be hidden from the visual field and/or implemented as an indirect light source, that will have an even distribution of light.

** Photo 16: Outdated light fixtures from field study observations, causing glare*

Nature theme waiting area at Rigshospitalet (17)

> The nature theme is easily translated and therefore does not create positive distraction, and it makes patients forgetting the waiting time

"There is a growing body of evidence that suggests that people are paying attention to the environment of care and that the connection with nature and representations of nature might play a very significant part in healing" (Biely, 1996)[24].

Again, as Biely states the wish is not to create a healing space, but the nature theme does still evoke pleasant emotions and makes you feel comfortable and at ease. From field trip observations, it was discovered that the nature theme in hospital waiting areas is often easily translated. The *reason* for that, is that it is displayed very straightforward and craves no effort from the imagination, such as a green leaf painted on the wall or a framed picture of an animal. In an attempt to change this, the success criteria is to give the perceiver a more abstract and translated approach to the nature theme, so the attention and awareness of the space gets subconsciously activated, and in that way hopefully makes users to forget about the waiting time and makes them more calm and comfortable in the moment.

Nature theme waiting area at Frederiksberg Hospital(18)

Sub conclusion

The field study observations at hospitals in the area of Copenhagen discovered many different types of waiting areas. Some were just outdated, and some had been freshened up with new and vibrant colours, a new interior and light setting. But common to all, except the *Day Surgery Department at Hvidovre Hospital*, it seemed that the colours, interiors and light settings were not 'in tune' with the spaces.

In the outdated waiting areas any aesthetic light setting was not prioritized, but was merely focused on the functional light. These light fixtures were mainly placed in the ceiling as recessed lights, but they still caused direct glare and visual irritation to the people in the space. In the optimized waiting areas, such as *Hvidovre Hospitals Day Surgery Department*, it was seen that an interplay with light and materials came along as a pleasing light setting, though it did not work as a functional light setting*. It was observed that an aesthetic and yet functional ceiling light setting was not present in any of the visited waiting areas, which could be one approach area for the lighting design of this thesis.

Each of the observed waiting areas offered seating areas, where the difference from the outdated versus the optimized ones, did not differ much. Though, it was experienced that vibrant colours, fish tanks and artwork was more prevalent in the optimized waiting areas, and did create a more stimulating space. However, these interior objects were not implemented and correlated with the space, with regard to spatial size and choice of material surfaces. This sometimes made the light and materials create reflections in the room that came along a disturbing or unpleasant, caused by too high light levels or visual glare.

The nature representation in the decor was observed in almost every waiting area, with vegetation or simple paintings or illustrations on the walls being the most common. This translation of the nature phenomenology left a somewhat dull impression, a travesty of forestal mimicry and automated care. But the positive values from nature have to be implemented both more convincingly and subliminally than this.

The *Success Criterias* in the previously presented diagram**, will be the guidelines at the end of the process, and those criterias will tell if the final design has succeeded or not. The *Reasons* are to underline what lies behind the claimed *Problems*, and to determine what is missing in the existing waiting areas in order to create a comfortable environment. The *Solution* is how this possibly can be solved through a well executed analysis and an experimental and judicious design phase.

** Photo 8: Hvidrove Hospital's Day Surgery Department*
*** Photo 13: Findings Through Field Study to Hospital*

Analysis

Hospital Lighting

The decision to do a lighting design for a hospital waiting area arose from curiosity about how the light and space is affecting our emotional response, and about what could add another level of awareness to the final design. Through the two different field studies and complemented with online research, it was found that the basics of *hospital lighting specifications, atmosphere* and *perception theory*, and *material characteristics* needed to be analysed in order to get a broader knowledge foundation, and that would be the starting point for the design phase. The hospital lighting specifications were needed to get the technical knowledge for implementation and selecting appropriate light fixtures. Atmosphere and perception theory was needed in order to know how the visitor will perceive the room with the right selection of materials and light setting. The art and colour use in healthcare, combined with knowledge about pleasant elements from nature, could be merged into the final spatial design.

WAITING AREA

Hospitals are characterized by having a variety of functions covering everything from operating rooms, wards, offices, kitchens and much more. For a part of these tasks, it is crucial to have optimal lighting, while other areas, for example equipment rooms and such, has a less requirements for light standards. Lighting in hospitals is a very comprehensive topic, and is described in detail by the *Danish Standards in DS 703: 1983, Guidelines for artificial lighting in hospitals.* Though, the light specifications for waiting areas goes under the grouping of less important spaces, compared to operating rooms or the wards, considering the need for proper light for performing a task.

The waiting area is a non-clinical area and constitutes a transition border into the medical environment. "*The objective is to create a welcoming atmosphere, populated by reception staff with well lit reassuring faces.*" (Thorn, 2010)[25] *Thorn Lighting Company (UK)* has stated three important values to be aware of when making a lighting design for the healthcare system; and as for the rest of the hospital, the waiting area is a space where the *performance, efficiency* and *comfort* needs to be taken into consideration when implementing a new lighting design. Based on these values, it was easier to be aware of the existing healthcare requirements, and helped to make sure that every aspect was covered to make an adequate lighting design in this context.

The performance of the light is to provide an optimal lighting solution with the correct level of luminance, where medical staff can treat patients correctly with fewer mistakes and quicker reactions. In a waiting room, the need for the correct level of luminance to treat patients is less important when compared to for example an operating theatre, where the luminance should be five times higher[26]. The stated purpose in a hospital waiting room is to make people feel comfortable and at ease, but still with a luminance level that allow visitors to move around easily, be aware of their surroundings and other people's facial expression or skin tone (eg: if someone is feeling sick, going blue or grey).

Efficiency is the concern centered about the energy consumption, practicality and the maintenance aspects of any light installation, and the luminaries should be easy to access and exchange. The operating theatre needs a high luminance level, probably a greater amount in light fixtures and longer "opening hours", depending on the ward. Waiting areas usually have different opening hours and do not need a high level of luminance - still the amount of light fixtures differs, depending on the spatial lighting design. Having a lighting design in the waiting area that is energy efficient is crucial, since it has become a standard value when designing with light in architecture. At the same time, it should be a lighting design that is easy to maintain; *"Poorly maintained lighting gives the impression of neglect, and could instill concern and lack of confidence in the medical facilities." (Thorn, 2010)* [27].

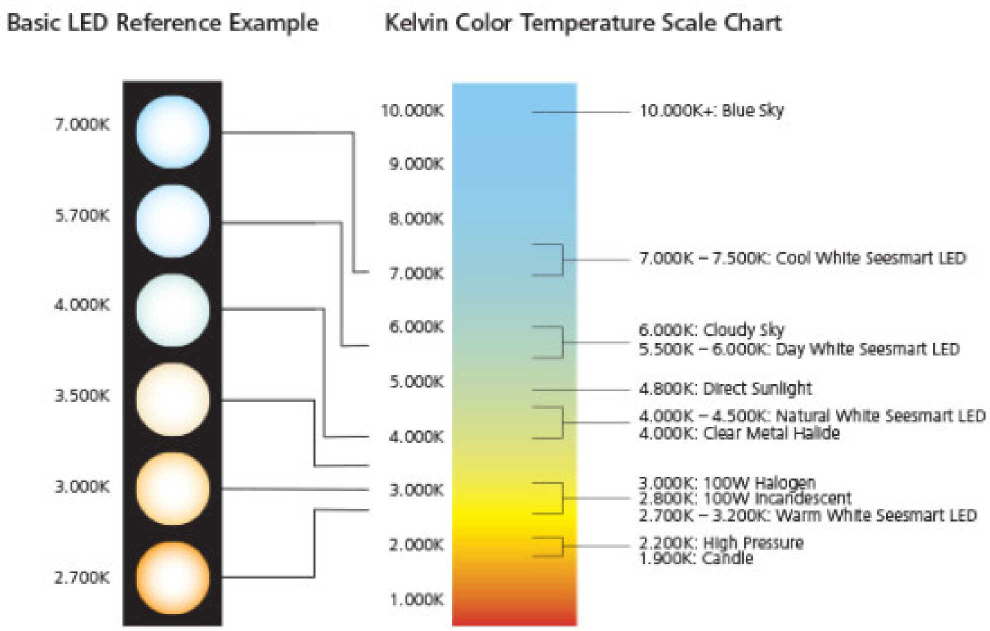
Comfort stands for the ability to give people the right amount of satisfaction and stimulation through the light, and it is concerned with the atmosphere and the general health care environment. According to the design, comfort is one of the most important factors since it is a waiting area where the atmosphere may be the most tense at times. The light should provide for an ambience that evokes calm reassurance, in order to put the patients and visitors at ease before moving further into the medical environment. By this, it is not stated that it has a higher priority, compared to other departments in a hospital, just that it is a factor that especially in this context can not be disregarded or neglected. Here it is especially important to avoid the *visual glare* and use the right materials to interact with the light, in order to achieve a comfortable lighting design.

ATTRACTIVENESS AND WELLBEING

As mentioned, a hospital should be a place that is well lit, in order to recognize people, avoid medical mistakes and feel safe. Since it was not possible to get the exact recommended illuminance levels for hospital waiting areas trough *DS 703: 1983, Guidelines for artificial lighting in hospitals* legal requirements and recommendations, European light standards will be followed throughout this thesis.
According to *Zumtobel Light Handbook**, that follows European standards, lighting levels up to 1000 lux is usually recommended in an operating theatre, where it is *200 lux* for the waiting areas[28]. This light level is similar to the average illumination in private residences (50-500 lux), which can be translated into the value of a comfortable light intensity, that a normal person is comfortable residing in for a larger amount of time, if necessary. A well-balanced luminance level is easiest achieved by using several light components, and this luminance also helps to improve the human spatial perception[29], and it contributes towards making the patients feel secure and at ease, despite the unfamiliar environment[30].

The *correlated colour temperature (CCT)* of the light fixtures is also to be considered, in order to gain a certain amount of well being. Due to biological needs, the natural daylight makes human beings feel safer and more at ease[31], where the intensity and and CCT falls and rises during a 24 hour cycle. A *warm light* in the morning and evening is comfortable and relaxing (sunset and sundown), correlated with waking up or going to bed, and a *bluish light* in the late morning and by midday gives us a stimulating effect (overcast or clear sky), since we need to be awake and alert[32]. Since the perceiver is most often entering coming from the outside of the hospital, he/she has possibly been exposed to the natural daylight just before, and therefore the eyes are still acclimatized to the intensity of the outdoor light. The vision of human beings is adapted to these quick changes in light, so the intensity and CCT of the indoor light does not necessarily have a harmful effect on our visual conception of the room, but the light can also enhance or aggravate any psychological effect is has on our emotional responses. The aim is not to consciously create a lighting design that is controlling our circadian rhythm, but a lighting design you find calming in the sense that it is somewhat adapted and correlated to the the natural daylight outside. By this, the light could change its CCT according to what time of the day it is, so when the Sun sets, the CCT will be automatically lower than during daytime. The light level at the recommended 200 lux for waiting areas should be set, since the need for this light level is necessary due to previous stated values.

** Appendix 1: Zumbtobel Lighiting HandBook, healthcare light standards, p.35*



CCT for LEDs simulating CCT for Daylight(19)

The average CCT of direct daylight differs from 6,000-27,000 Kelvin, but when simulating this CCT into an indoor environment it decreases, since the indoor space is much more compressed*. Therefore the CCT during daytime will be at a level, that is standard to the light fixtures used for indoor environments, which lies between 3,500K (cool white) - 2,700K (warm white)[33]. When the Sun rises and sets, the CCT increase or decrease to a warmer kelvin degree, which will simulate the outside.

"Glare reduces a person's perception of their environment. A good lighting solution that takes into account surfaces and their reflectiveness precludes the possibility of glare." [34]

Since the light is based on the interaction between light and material and its reflectance, there is a risk for the perceiver to experience glare. There are three different kinds of glare; direct, reflected and *disability glare,* where the *reflected glare* is the one to be especially aware of in this lighting design, since the design among other things focus on the interplay with light and materials. Here the placement of the reflecting materials and the bright light sources should be high priority, and where the *beam angle, direction* and *distance* from the perceiver are important parameters. There will be an even distributed light in the space, and possibly with an indirect distribution to cover up the direct light sources, to avoid direct or disability glare. Glare can also be caused if light sources are placed up against each other to attain a high light level span, since glare is caused if the light fixture is brighter than its surroundings[35].

COST SAVINGS AND SUSTAINABILITY

Artificial light represents 19% of the electrical energy consumed worldwide[36], so the importance in using energy efficient light fixtures for this design is high, since the amount of light fixtures has to be sufficient enough to secure the even distribution of light in the room. At the same time lights are placed in a public spaces where the consumption is considerably higher, compared to a private residence, since the light is on all the time during daytime.

"Lighting is also a matter of cost, especially the annual maintenance and electricity

* *Photo19: CCT for LEDs simulating CCT for Daylight*

costs that are incurred in order to run the lighting system. Energy-efficient planning right from the outset lays the foundation for achieving sustainable success." (Zumtobel, 2010) [37]

This contains the implementation of lighting controls with the functions switch (on/off) and/or dim (raise or lower output)[37], or simply implementing maintenance-free LED light fixtures. There are several other considerations when talking about light efficiency, and possibly not all can be elaborated in this thesis. To solve the energy efficiency issue will be to integrate an energy efficient LED lighting system, that has a long lifespan and very little need for maintenance.
To achieve a more homely and comfortable atmosphere and follow the recommended EU standards, a light level at around 200 lux is wished. However, this will not be possible to measure in real life, since there will not be time to do a 1:1 prototype of the design to try out with the chosen light sources. Though, this can be measured in light measurement programs such as *Dialux*.

The correlated color temperature will be set from 2,400 kelvin *at night time*, and between *2,700-3,500 kelvin during daytime*, depending on what materials and their surfaces which will be implemented in the final design (warm or cold). There should as well be an awareness of the *beam angle*, *direction* and *distance* of the light sources, when interacting with the rest of the space and its materials to avoid the different stages of glare and general visual discomfort. This will be developed with *energy efficient LED light sources*, in order to fulfill the requirements to a sustainable lighting design.

Atmosphere and its relation to spatial experience

As this thesis aims to combine a comfortable spatial experience with calming lighting design, it is important to understand the core values that are influencing the spatial experience. One of the factors that is frequently mentioned, when we describe the spatial experience, is atmosphere. But what is atmosphere? It is both the thin veil of gases that are surrounding the Earth[39], but in architecture and design atmosphere is an indefinable kind of quality, alluded with a certain mood or the "vibe" of a place, a situation or a work of art[40]. It is often used for designating some ambient element or emotions, but measuring these factors can be quite challenging. Both of the descriptions are referring to something that is invisible and unreachable, where philosopher Hermann Schmitz characterizes atmosphere as "*…surfaceless space, we cannot grasp its substance, its purpose, its form, its beginning and ends are indistinct*" (Grant, 2013)[41]. But we may sense it, and we are always affected by the atmosphere, either consciously or unconsciously[42].

Atmosphere is commonly mentioned in our everyday verbal exchanges, especially if we want to describe certain emotions or situations. For instance, if we experience something positive or negative we often use adjectives that are related to the atmosphere. We also often make comparisons to the weather, and so we can be "cold" or "hot", "sunny" or "wintry". If relaxing in the garden on a sunny day, we probably experience the atmosphere as nice and relaxing, but if we experience a traffic accident, we will state that the atmosphere was tense, strained or even frightful.

German philosopher *Gernot Böhme*, has elaborated on the metaphorical meaning of atmosphere as well. He has stated that we often have impression that atmosphere is meant to indicate something *"…indeterminate, difficult to express, it is not object nor subject, but it is always with us"* (Grant, 2013)[43]. He has defined that atmosphere is spatially experienced, but they are "...without borders, without place, but it is presented in a space" (Grant, 2013)[44]. He has described atmosphere as *an aura*, it is something that flows forth spatially almost like breath or haze[45]. In order to perceive this aura we have to absorb it bodily, and then it is perceived as an indeterminate spatially extended quality of feeling[46]. Both Schmitz and Böhme concludes that atmosphere is not something we can touch, but it is sensed bodily and affected by the environment. If atmosphere is the sensation of some kind of feelings and emotions, that are reflected from the environment, it is necessary to evaluate what are the factors or things, that are inductive and important in the creation of the atmosphere.

Architect *Peter Zumthor,* has listed the fundamentals that determine how we experience the space and which of these are the core features affecting atmosphere and its context in architecture. In his book, *Atmospheres (2006)*, he elaborates and points to nine *parameters* that influence spatial experience and that are essential for the creation of atmospheres in relation to spaces and architecture. However, all the factors defined have the uniqueness of affecting and *creating atmospheres.* Four of them are mainly about spatially and materially associated factors, such as *Material Compatibility, Temperature of the Space, Sound of the Space* and *Surrounding objects.* These factors are the ones that will be incorporated in this thesis, since these are found to be most relevant in order to design a comfortable spatial experience with interplay between light and materials.
Zumthor has stated, that we perceive atmosphere through emotional sensibility – *a*

form of perception[47]. Unfortunately, there is not one singular way in which people sense and perceive a space, since our perception of the world is strictly individual, which makes it sort of challenging to propose that any odd design will succeed in creating a comfortable environment in the targeted waiting area. But working with the previously stated factors, these guidelines can help leading the way.
Zumthor has pointed out that every aspect in space moves and affects us. An example, in the creation of atmospheres, people interact with *objects, noises, sounds, colours in material presence, textures and forms.*

The *Material Compatibility* is the awareness of how the materials react with one another. Sometimes the material combinations are too far from each other, so they do not react with each other, and sometimes they are too similar and will neutralize each other. But if the combination of materials is right, it can give rise to something both evanescent and unique, where elusive but positive vibrations become present in the atmosphere[48]. Zumthor describes the materials like the *skin* of the architecture, and in creation of an atmosphere, the body with its skin has to touch us not just with the idea of the body[49]. It is the same with people and clothes, and if people feel good about their body and their clothes, the attractiveness and positive impression is reflected on the outside. Therefore, it is essential to make a design, where the awareness of the material characteristics and their interaction with each other is present and that they do not contradict with the rest of the hospital environment.

When working with the materials it is very important to be mindful of the *Temperature of the Space*[50]. By this Zumthor means, that the materials have the ability to extract the warmth from our bodies, and different materials have diverse ways to react. For example, steel is a cold material, and it has the ability to diminish the perceived temperature of a space, in contrast to wood. Zumthor further says, that the temperature is a physical aspect, but presumably a psychological one too - it is what we see, what we feel and what we touch[51]. Hence, it is important to be aware of the internal material reactions, but as well their physical and psychological effects to users and the rest of the space. Steel can bring coldness into a space, but it is not wrong to use it; the idea is to be mindful of its characteristics, and as it brings coldness into the space, the overall design should be balanced with some warm materials. This knowledge could be translated into design in a way that the warm materials should be used in the places where people have direct contact, and more colder materials should be implemented in the areas where people do not have direct contact. The chosen material types should not be too far from one another, in order not to combine the materials in a contradictory fashion. Yet they should not be completely similar either - balance is the key in the creation of a harmonious spaces.

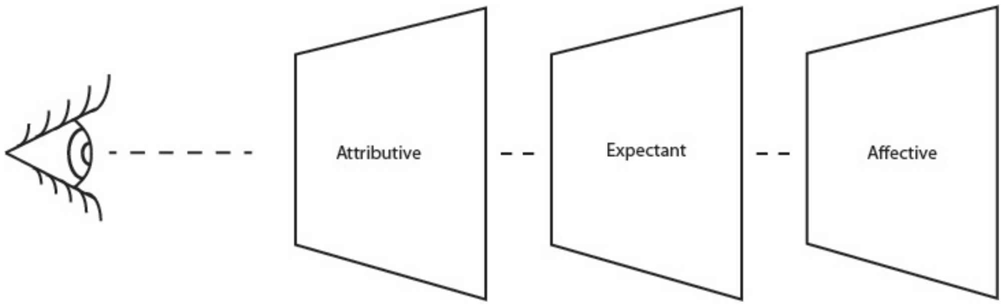
Another parameter, that is also related to materials and vital for influencing the atmosphere, is the *Sound of the Space*, which is associated with the choice of materials used in the environment. This thesis is not focusing on sound *as music,* but the sound of materials reflecting and distorting the sounds[52]. Hospital waiting areas may sometimes be crowded, and the materials used in the interior should not dominate the space with additional sound or noise. However, a completely still and quiet waiting area is not conductive to a comfortable environment. The field study observations found, that waiting areas which did not have sound from appliances or noises from the surroundings had a detrimental effect and actually amplified the tension instead of deflating it. But in spaces where the acoustics were good, the users tended to chat more and the atmosphere was more relaxed.

Moreover, in creation of the right atmosphere, *Surrounding Objects*[53] plays an enormous role in how we feel and interact with the space. It is important to be aware of their connection with the whole space and their *shape, function,* and *aesthetics.* Beautiful objects please us and they can stimulate our sensibility. However, beauty is in the eyes of the beholder, and there is no single way to measure if things are beautiful. Zumthor mentions, that if the form or object surprises us, it also tends to have a beautiful form[54]. Therefore, in order to measure if the design will succeed in creating comfortable atmospheres, it is essential to evaluate whether the final design will generate any pleasing emotions, or if it is bearing some unexpected outcome in a benevolent and surprising way.

When creating a comfortable spatial atmosphere with interplay between light and materials it is important to be aware of their main physical characteristics. But as well their physiological effects on the users. The hospital waiting area is a public space, where the design proposal should create a coherent and welcoming spatial impression. In order to achieve this we need to be aware of how the materials reflect the light, whether they reflect or absorb the heat or sound, and what kind of representations their associations will create. Atmosphere is a difficult matter; it is difficult to create, difficult to measure and difficult to describe. And as both Böhme, Schmitz and Zumthor have stated, the atmosphere *is* a sensation of feelings, reflected from the context and its environment. It is not possible to control it or measure it in any empirical or quantitative way, but the success can be observed and measured the qualitative way. And by observing the four chosen parameters from Peter Zumthor's book *Atmospheres (2006)*; *Material Compatibility, Temperature of the Space, Sound of the Space* and *Surrounding objects*, it is manageable to put the term atmosphere into a box that possibly can be measured somehow.
As Böhme said, atmosphere flows spatially, it is always with us, and the environment we perceive in any specific moment influences it.

Visual Perception

Taking a look at the waiting areas of the hospitals visited during the field trip study, the spaces had some similarities according to interior, use of colour and light setting. Grey linoleum flooring, white walls, simple chair setting and fluorescent ceiling light was the most common observation. When summarizing these characteristics, one can say it does not sound as a particularly pleasing or interesting space to stay in. Still, there is a somewhat pleasant feeling of the recognizable[55], since it does not demand too much of your energy to deal with *"understanding"* the new space that you just entered. *"Seeing is not passive response to patterns of light, but an active information seeking process directed and interpreted by the brain"* (Lam, 1992)[56]. People have an individual perception of a space, but according to William M.C. Lam's book *"Perception and Lighting as Formgivers in Architecture"* (1992), we all perceive it more or less the same way with three different stages of perception; The attributive, the expect*ant and the affective*[57]. In real life, these three components are not experienced separately but are interwoven, and are only divided when used for analysis[*].

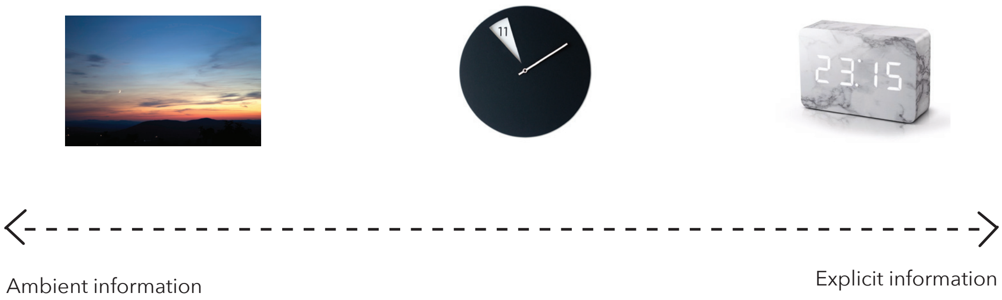


The three levels of Perception (20)

The *attributive* perception involves the simplification of the incoming data by classifying it to the highest recognisable level that you filter according to *past experience* - for instance you know the shape of a circle, and therefore you can perceive and recognize it in almost any visual field that has similarities to that shape[58]. This is the same with the waiting area but on a bigger scale. You see the chairs lined up against the wall, the desk and a numbering machine, and you know that you are in a waiting area because of past experiences in similar environments. The *expectant* perception is what you expect to find when entering a space - this could be the waiting area that is mounted with a classic red LED display, showing who's next in line. When you find all as expected it creates a successful satisfaction (you know when it is your turn), and you are able to relax[59]. The third component, the *affective*, is how the perception is affecting our emotional or evaluative responses to stimuli[60]. This affects the amount of attention which is paid to a certain object - if it is a pleasurable and interesting object, it may be examined in great detail (eg: a beautiful painting), while uninteresting elements may be overlooked and filed in the unconscious visual memory (eg: a simple chair)[61].

** Photo 20: The three levels of Perception*

As mentioned in the developed success criterias, it was discovered in the field study to hospitals, that the nature theme is, as stated in one of the findings from the Field Study to hospitals diagram: *"...easily translated and does not create a positive distraction for the visitors"* *. To make that positive distraction, these levels of perception can be used as a conscious design approach, when developing the lighting design in the waiting area. Since the light should be implemented with some sort of interplay with the surrounding materials, the nature theme will be integrated in both the materials and the light.
To activate the *attributive component*, the light should have some level of *recognisable* elements from nature, which for instance could be a colour (green as the pines, blue as the sky), shape (a leaf or a fish), reflection (water surface or shiny little rocks), or movement (waves in water, wind in trees) that you recognize from nature, but as *ambient* information**. By *ambient* information, it is meant that the colour, material, shape or movement has to be carefully selected, so the four elements are not creating a simulation of nature that is too *explicit* - for instance a blue, wavy shaped material, that is simulating the same reflections and movements that you get from a water surface. Here all three recognizable elements are in the same category (water) and this will most likely present itself as an unsatisfactory and bland design. Yet, in this aspect is hard to measure the proper balance between ambient and explicit, since everybody have their own individual perception. Therefore it will, if necessary, be developed with a somewhat intuitive approach as well.



Example of Ambient versus Explicit information (21)

The *expectant* component will, according to existing interior in waiting areas, expect to find the nature theme in more physical elements, such as a plant in the corner of the room, and not necessarily coming from the light. Therefore, the expected elements in the waiting area should come from something else than the light - for instance a seating area and a counter - since the lighting design most likely would not be something that is seen before in a hospital waiting area by most visitors. As well for colours and materials, these should be carefully selected and not be materials or colours that you associate with something unpleasant or in a marked contrast to the hospital environment. When entering a waiting area, it is always expected that the room is properly lit and has a pleasing or at least neutral atmosphere, which the light should support.
At last, the *affective* component should be balanced in a way, so the light in the waiting area does not create an overflow of emotions due to a lighting design that demands too much attention. This distress can be avoided by designing a design that is simplified, with a simple colour setting, coherent materials, shapes and surfaces that will interact with the light in a pleasing way. Therefore, the light should be created with elements that mimics nature in the simplest way possible, where shapes, colours, materials and movements of the light are combined into an ambient design, but still with recognizable elements.

** Photo 13: Findings Through Field Study to Hospital*
*** Photo 21: Example of Ambient versus Explicit information*

The reflecting surfaces will be carefully selected, and the colours, shapes and materials are taken into consideration. The light will work as a functional and aesthetic light, that will simulate elements from the nature, either in the movement or the colour. Overall, the spatial design will be designed with an *ambient* point of view, in order to avoid a too stimulating and attention grabbing design. The spatial design should incorporate recognisable elements, such as shapes or colours from nature, in order to please the *Attributive* component. The *Expectant* component should be satisfied too, and expected elements from a waiting area should be present (eg: a seating area). The *Affective* component is affecting our emotional or evaluative responses to stimuli, where the lighting design and its interplay with the surrounding materials should be conducive to awakening interest, but should also be carefully balanced, so it would not demand too much attention from the user.

A good hospitals environment

ART IN HOSPITALS

Art has been hung and placed in hospitals since the 14th century[62], and was at the time being implemented to fulfill a specific religious function. Later in the 18th century it developed into a more business minded approach, among others things to attract and impress royal visitors and grantees, and approach them with a wish for a charitable donation. Since the Victorian age the purpose has changed yet again, now with a more holistic approach to to medicine, and ideally to support a more therapeutic and healing environment for the patient.
It is difficult to prove that art has a positive effect on patient's health, since there are too many variables (health, age and personality) to make it a statistically reliable test. But recent research has proved, that an overall good hospital environment has an important impact on the patient's well being[63]. In fact, research shows that patients recover three quarters of a day faster and consume fewer painkillers in a *vibrant environment*, compared to the recovery rate in a dull environment[64]. A vibrant environment could consist of many different things such as colours, shapes, materials and paintings on the walls. Of course a waiting area is not the same as being held as a patient on a ward for several days, but even though the stay is only for a short period of time, a vibrant environment helps keeping your mind occupied and satisfied.

James Scott, a *consultant orthopaedic surgeon* at the *Chelsea & Westminster Hospital,* believes that moving away from the spartan white walls will lessen the feeling of being separated from the outside, and will decrease the feeling of being in a place where you, by definition, must be sick. *The separation from outside contributes to the feeling of being drained and isolated, where the feeling of being connected to the outside makes us feel like a part of everything that is around us*[65], which is one of the reasons for the continuing nature theme seen at the different hospitals. Realistic scenes of landscapes and seascapes should be prioritized over abstract pictures that will confuse the spectator, and might create a feeling of discomfort[66]. As stated in the *perception theory chapter*, it is important to be aware of developing a design, that has some sort of recognition and is not too abstract. Since the wish is to implement the nature theme into the hospital waiting area, the construction of this could consist of materials, shapes, colours or other elements that reminds us of the outdoors.

COLOUR, MATERIALS AND INTERACTION WITH LIGHT

As mentioned before, colours are also a way of implementing a value from nature, where *short wavelength colours as blue* and *green elicits* more pleasure than the *longer wavelengths as red and yellow.* Still, there are some contradictions, where for example yellow is associated with sunny days and nature, and it is defined as inspirational and one of the most positive colours of all[67]. So generally it is hard to know exactly which colours to use (or not to use) in a hospital environment, since it depends on what emotions you want to induce, and also depends on which other visual elements are present in the space. It is known that you should avoid too much red (bloody) and black (deathly), which could adversely disturb the patients[68].
The saturation of the colours are also important, since a high saturation is believed to create arousal, where brightness in the colour should be contributing to pleasure[69]. Since *pleasure* is considered more appropriate than *arousal* in the context of a waiting

area, the use of bright colours would be prioritized higher, than the ones with a high saturation.

The spatial experience is correlated with how light interacts with different materials and surfaces, and how it is reflected from these surfaces into the environment. Light has to hit a surface, in order to be seen, and the quality and quantity of light is reflected from the surface texture[70]. There are various types of materials and surfaces, and each of them have specific characteristics. There are three ways in which to categorize light interaction with different types of surfaces. First is the materials who absorb the incoming light and transforms it into heat *(Absorption)*, second the materials which reflect the light back into the space in a different angle from the incoming ray *(Reflection*), and thirdly the materials that are transmitting incoming light through a medium *(Transmission)*[71].

However, not all light that strikes a surface is reflected back into the environment. Some of the light gets absorbed, and even high-gloss mirrors absorb a small amount of light into the material. Therefore it is essential to be aware of the *material reflectance*, and that the reflectance value does not change if the amount of illumination changes, because the reflectance value depends on the surface characteristics[72]. Another important factor, that is related to the reflectance, is the type of surface texture. There are two types of surface texture, *microscale* and *macroscale*[73]. *Microscale* surfaces are mainly two-dimensional types of material, their characteristics are associated with the quality of reflectance, whether they have *specular, spread* or *diffused* reflectance. Each of the reflectance characteristics depends on the material surfaces, which are often quite smooth. *Macroscale* surfaces are indicated with a more three-dimensional structure and these surface characteristics do not play any important role in how they reflect the light, but rather in how they project shadows[74].

As mentioned previously, it is hard to measure if the final lighting design has a positive effect on the patients staying in the waiting area, since there are many variables to consider such as health, age and personal taste. Therefore the lighting design will, among other things, be developed through findings regarding art and colours used in hospitals. The wish is to diminish the feeling of being separated from the outside, *where elements from the outside* (the Nature) will be implemented in the design, in order to feel connectivity. Regarding the use of colours, *bright colours* appeared to be more pleasant than high saturated colours, so the use of bright colours will be dominant in the use of materials. As the aim is to create coherent spatial design with a calming lighting design, materials and light should be amalgamated in accordance with the statement; *"Do not design with light, design with the effects of light"*[75].

Sub conclusion

Through this analysis, *Hospital Lighting, Atmosphere, Visual Perception*, and a *Good Hospital Environment* have been elaborated. With this, quantitative and qualitative values have been developed, which makes guidelines for the following *Design phase.*

HOSPITAL LIGHTING

Regarding the analysis into *Hospital Lighting*, it was found that a functional light level between 200 lux is recommended for hospital waiting areas. Since it is not possible to measure the final light level in real time, the aim for reaching this light level is not of high priority to elaborate in this thesis. This is not possible, since a 1:1 prototype of the lighting design will not be built due to lack of time and financial restrictions. But light levels can be approximated with light measurements programs such as *Dialux*. Due to the desire of implementing the nature theme into the lighting design, the CCT of the light will be adapted to an average day outside. In the evening the CCT will be set to 2,400 kelvin and between *2,700-3,500 kelvin* during the daytime, depending on the chosen spatial materials.
Thorn Lighting Company has stated four important values to be aware of when making a lighting design for the healthcare system; *Performance, Efficiency* and *Comfort.* These values will also be taken into consideration when developing the lighting design, in order to achieve the formal requirements.

Quantitative values:	Light level: *200 lux* *CCT:* 2,400-3,500 kelvin

ATMOSPHERE

It is difficult to set values for measuring whether the lighting design succeeds in contributing to a comfortable environment. But with the four chosen values; *Material Compatibility, Temperature of the Space, Sound* of the *Space and Surrounding objects,* by Peter Zumthor in mind, some guidelines are drawn for what to be aware of. The choice of materials is essential here, since the materials are deciding whether the environment of the space will come along as balanced or unbalanced, cold or warm, with good or bad acoustics and with a coherent or misfitting interior design.

Qualitative values:	*Material Compatibility:* Material combination in the right context *Temperature of the Space:* Balance between cold and warm *Sound of the Space:* Creating good acoustic in the space *Surrounding objects:* Spatial design should be coherent with the rest of the hospital

VISUAL PERCEPTION

As well for the visual perception, it is hard as well to put up measurable values for the lighting design, since each individual perceives differently. Still, the three layers of perception; the *attributive*, the *expectant* and the *affective*, still needs attention. As for the atmosphere, the materials have to be carefully selected, but with a more overall approach to the unified spatial design. The spatial design will be designed with an *ambient* point of view, where elements from nature will be integrated in the colours, materials, shapes and movement of the light. In order to meet the demands of all three layers of perception, there should be recognisable elements in the interior and lighting design, it should visually not differ too much from other waiting areas, and the lighting design should awaken an interest, but not demand too much attention.

Qualitative values:	*Attributive:* Recognisable elements *Expectant:* Still have the function of a waiting area *Affective:* Spatial design should awake interest, but be balanced

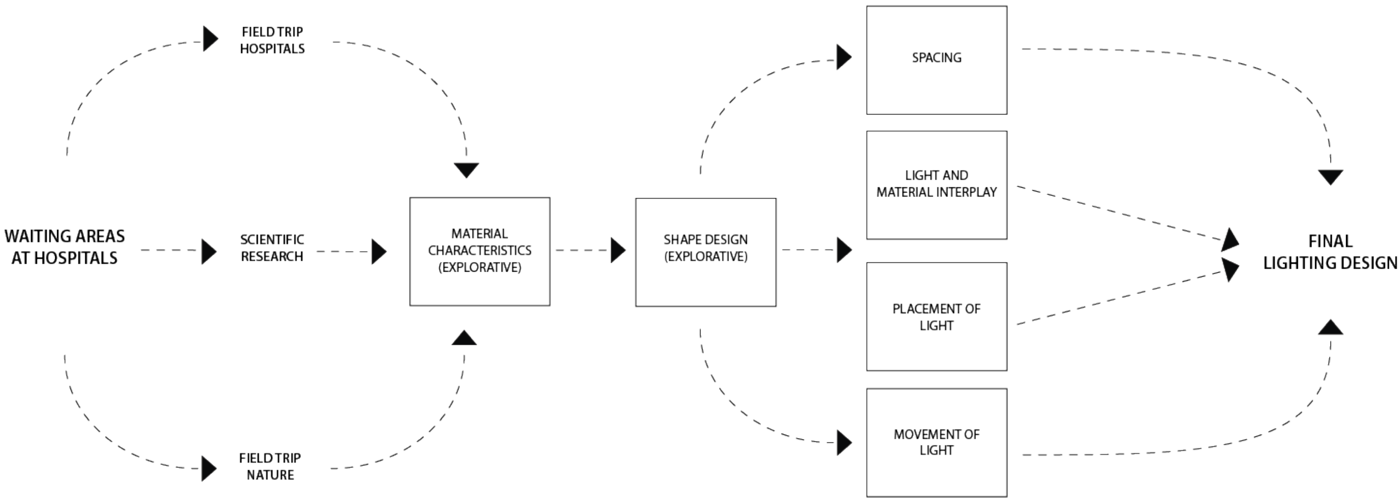
A GOOD HOSPITAL ENVIRONMENT

It was concluded, that values from the outside (Nature) decrease a feeling of being separated from the outside and from each other, so these values will be implemented as much as needed. This will ideally create a feeling of being connected with the space, that can be augmented by the values from the *Atmosphere* and *Visual Perception* as well. Bright colours appears to be more pleasant than high saturated colours, and therefore bright colour will be implemented onto surfaces. Still, the challenge is choosing the right bright surfaces and then select the exactly right amount of these, so the room will not be too bright or fraught with reflected glares, which could create visual discomfort.

Qualitative and Quantitative values:	Nature theme implemented in spatial design Use of bright colours on materials Awareness of material reflectance levels

Design Phase 1:
Idea development

Inspiration and idea development



Flow Chart of Experiment (22)

To give a comprehensive overview of the process in the design phase, a flowchart is conducted, where the different experiments and the following evaluation is shown in the same order as performed.

As stated in the topic description, the initial inspiration came from a general fascination of materials and their interaction with light. Without a surface, the light is only photons, moving in invisible wavelengths, but it is not always that designers are aware of this, which sometimes results in a beautiful design, but where the light does not support or even enhance the qualities of its surfaces. The interaction results in many things, such as creating reflections from specular surfaces, reflect colours and create shadows.

Since it was discovered on the field trips to different hospitals, that elements from the nature were implemented in the waiting areas to support a comfortable environment, an ensuing field trip to nature was conducted. The interactions between surfaces and light were investigated, and reflections, colours, shadows and movements were examined and photo documented. Especially the reflections and movements coming from water surfaces produced an interesting pattern, caused by its specular reflections, differentiating movements and interchanging colours.

Subsequently, this inspirational field trip to nature opened up for a new study into material research, where different moodboards were constructed*, dealing with structures and shapes, colours and their reflections. The interesting values found in the water surface were still topical, so the research was also investigating how this was translated into other places than nature. At this conjecture the artist *Olafur Eliasson* came to mind, since a lot of his artworks are dealing with the interaction between light and materials. Especially one of his installations, *"Notion Motion"* (2005), was interesting - not only because it was playing with the reflections from a water surface, but also because of the movements, shadows and depths of the installation.

Olafur Eliasson light instalation, Notion Motion (23)

Architect *James Carpenter* also has been an inspirational source. He is a lighting designer, but works with light on bigger scale architectural structures. His explorative approach to the interaction with light and materials, especially translucent glass, came along as a great inspirational source. His work with "*Structural Glass Prisms*" (1987) in the CTS Chapel in Indianapolis, USA, worked with natural daylight and shadows, colours and reflectances the translucent glass made. This inspiration was the starting point for the *Explorative experiments,* where different chosen materials and their surfaces were investigated, in order to gather data and knowledge about any possibly useful materials for the lighting design.

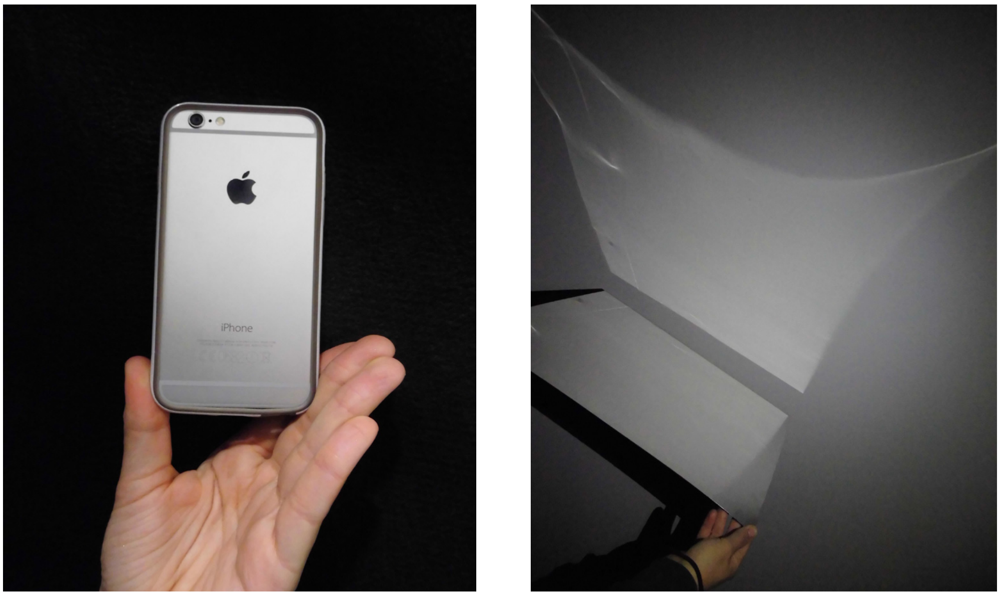
James Carpenter ,Structural Glass Prisms (24)

** Appendix 2: Inspirational Moodboards*

Explorative experiment: Material characteristics

The aimed light source for the material experiment was a cool light with a narrow beam and a high light level. First, an *IKEA 11W 2700K* fluorescent *light bulb* was tried out, but the beam was to too wide for the experiment and did not have a sufficient lux amplitude. Therefore it could not contribute enough light to exaggerate the surface texture and its reflections, which was supposed to be elaborated during this experiment. Subsequently, by trial and error it was found out that the light beam coming from an *iPhone 6S* had the values for the experiment. With a correlated colour temperature (CCT) around 7000 K, high light level and a narrow spread from the small LED beam, this proved to be a suitable light source for the testing of the material attributes.

IKEA 11W 2700 K flourecent light bulb (25)

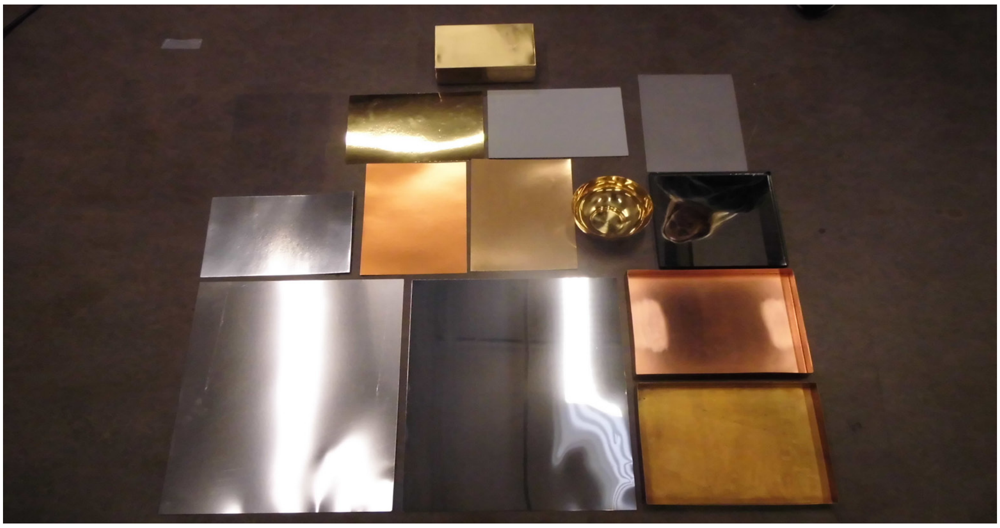


Apple iPhone flashlight beam (26)

The aim of this experiment was to do a randomly *explorative experiment* with no structured or pre-defined results, but merely to test the properties of the different materials.The choice of materials was selected from a mix of naturally occurring and manufactured materials with different reflectance values, surfaces and shapes. In the experiment nine different materials were tested according to their attributes. The reflectance level of the materials was also measured, and each surface reflectance was documented with photos* and video clips for subsequent evaluation.

The goal was to find, explore and evaluate a surface texture that created interesting patterns or movements, and one that could also be related to the nature theme. In previous evaluations of the reflectances in the nature, it was found that the interaction between light and water was particularly interesting, because of its differentiating moving patterns and changing intensities from the reflected light. The colours of the materials in the experiment played a minor role, since there was not an interest in finding a material that reflected too much colour, so the surface texture could come into its own.

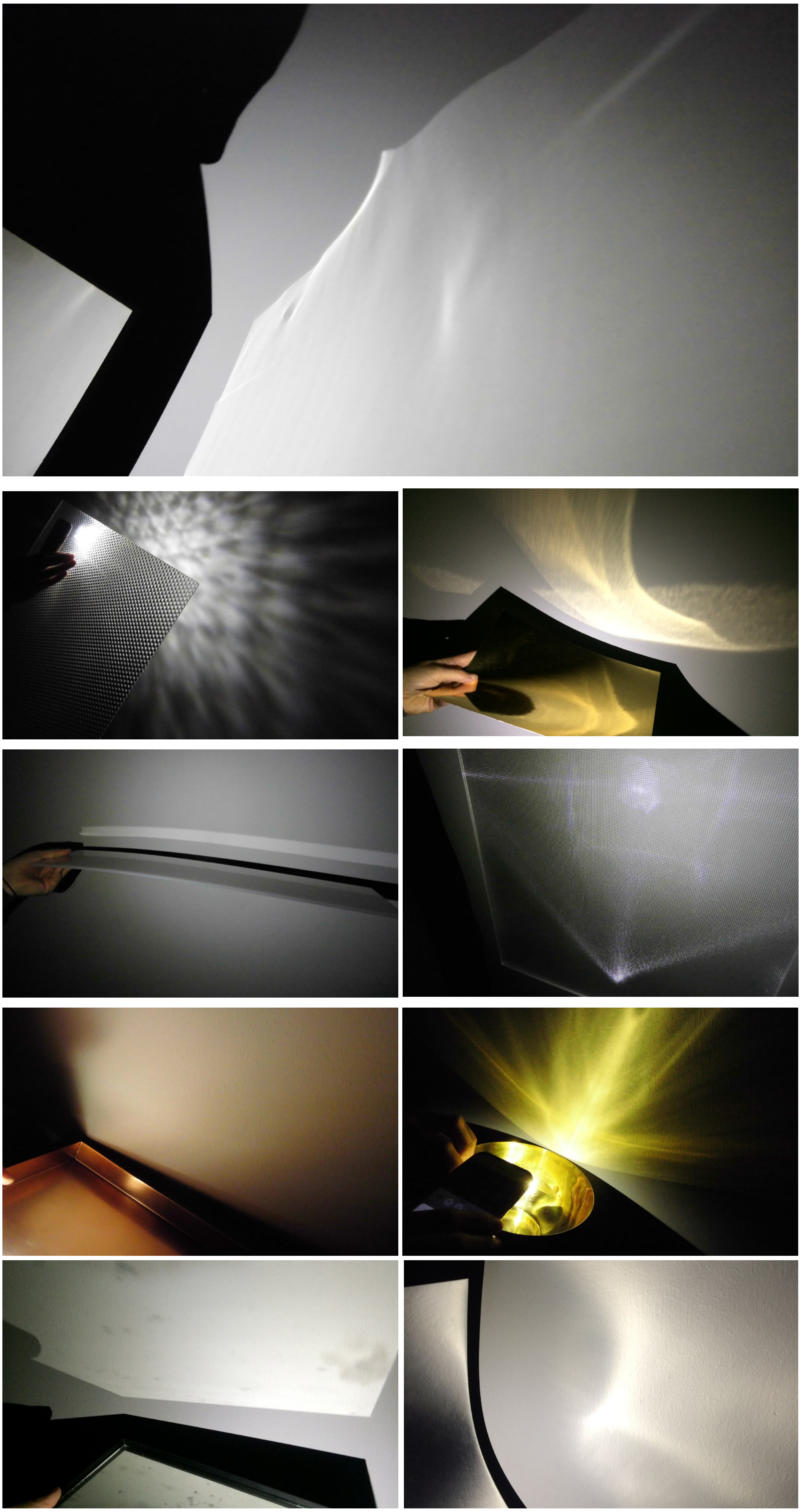
The different materials that were involved in this experiment were *aluminium, brass, copper, mirrored glass* and *acrylic*. All of them in solid materials, and all items had a squared or rectangular shape, aside from a round shaped specular brass bowl, which was the only material included that had a round shape, as the prime purpose was to find the attributes of a material with an even surface, and further on to explore how to work creatively with the shape of the chosen material.



Materials for Explorative Experiment: Material Characteristics (27)

The testing was carried out with each material horizontally placed in front of a white with an even white surface. The light beam from the iPhone6 was placed at different angles against each material, and the surface reflectance was displayed on the adjacent white wall.
It was found, that the closer the beam was to the material, the more detailed the reflected surface became. When angling the beam, the details in the surface were stretched and changed in form. Both *specular, irregular* and *diffused* surfaces were investigated, and it was found that the matte surfaces did not reflect any details from the surface such as dents or scratches. The irregular surfaces did that to some extent, but the specular ones reflected most surface details. The specular mirror was an exception when talking about interesting specular reflectances, since the light was traveling directly to the wall surface and resulted in a mirrored light beam. The *specular aluminium was found interesting*, since the edges and surface created a *water-like wavy* pattern that could generate allusions to water surfaces.

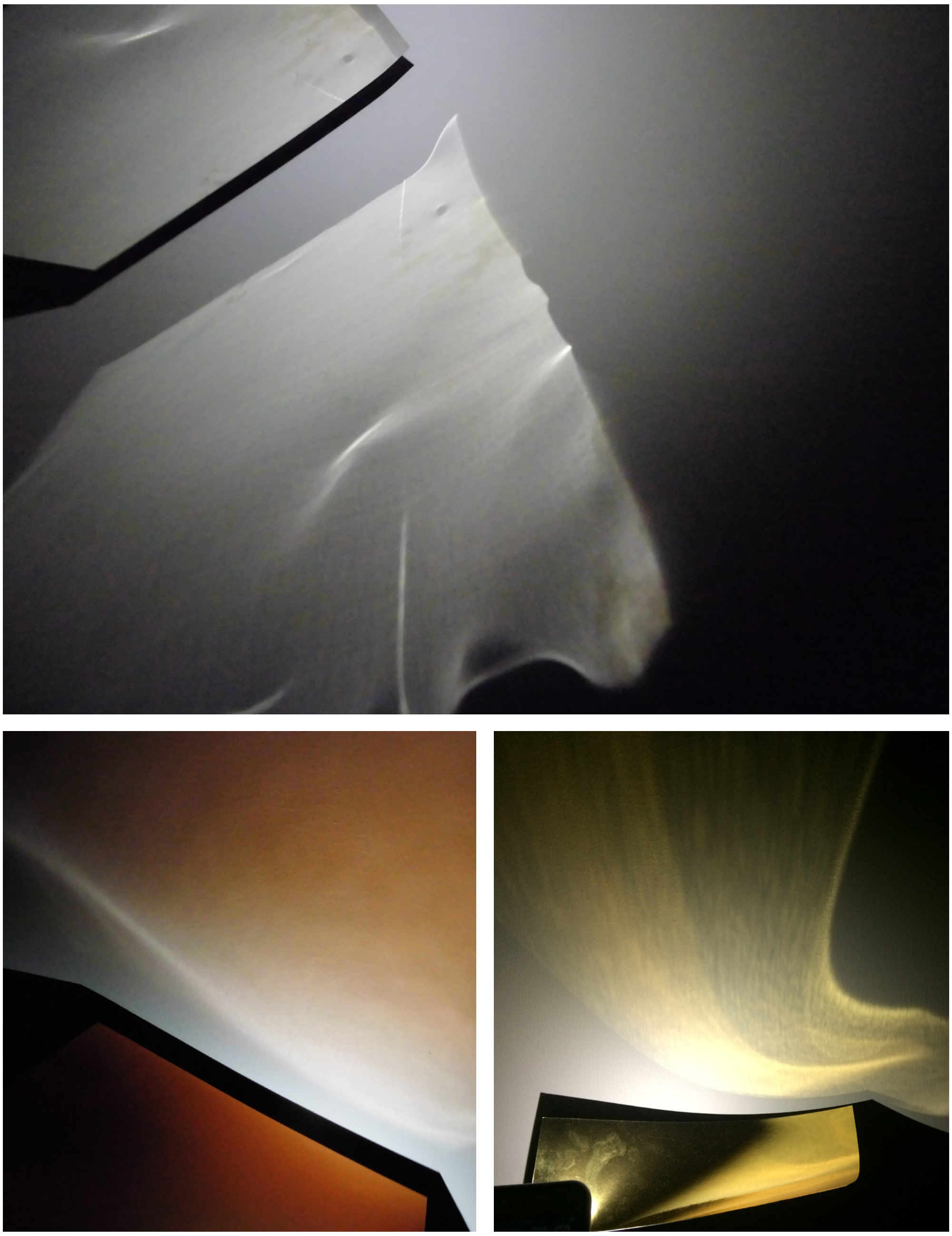
* *Appendix 3: Explorative Experiment: Material Characteristics*



Examples of reflected light from Explorative Experiment: Material Characteristics (28)

Explorative experiment: Shape design

The explorative experiment dealing with material characteristics involved nine different types of materials, and it demonstrated that materials with high specular surfaces such as polished aluminum or brass, possess the properties to create beautiful reflectance patterns. However, it was observed that these patterns are appearing mainly if the light beam hits the edge of the surface, or if the material is bended in any way. If the light beam hits the smooth or plain surface, the material reflects mostly the surface details and the colour.



Examples of reflected light from Explorative Experiment: Material Characteristics (29)

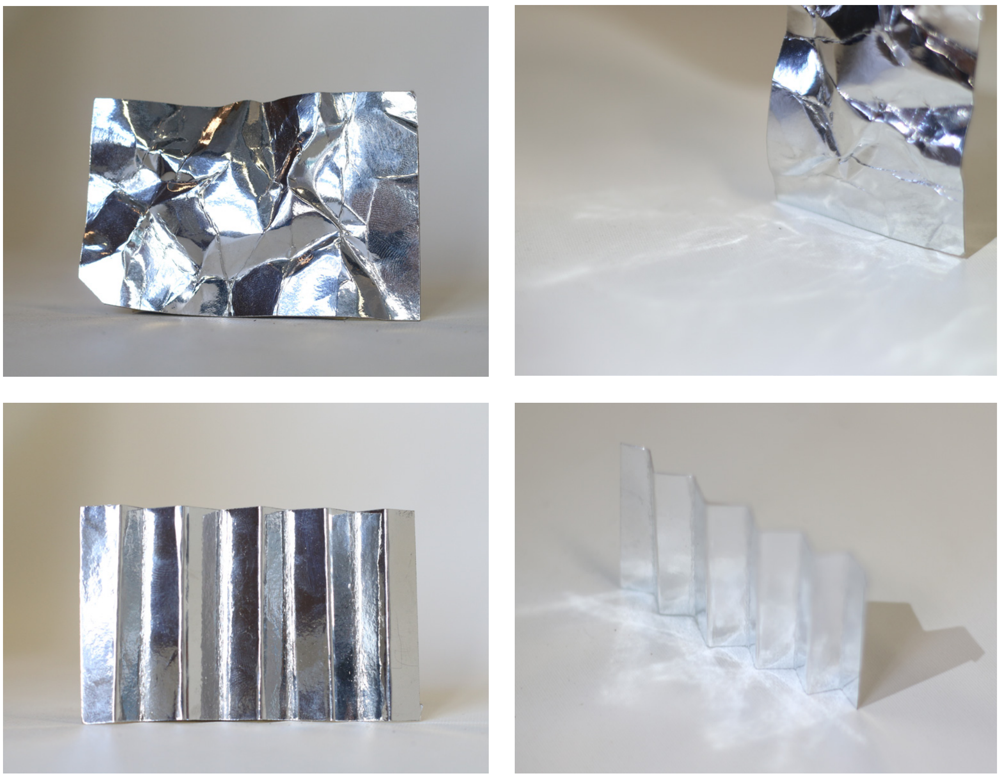
As the idea was to generate the nature theme in the desing along with its reflectance, the field trips made an emulation of water patterns and the mimicking of their reflectance an interesting challenge to take on.

The next step in the design process was to carry out a *second explorative experiment,* which was focusing on how the *high reflective materials could be implemented into the interior and lighting design*, and *how the materials should be formed in order to create the previously observed reflectance patterns.*

Nature theme is frequently implemented in the hospital interior decoration, but this representation is often depicted too literally and without concerns about an aesthetically pleasing spatial experience. Therefore, the s*econd explorative experiment* was focusing on *how to represent the nature theme in a more abstract way along with the interaction between light and materials*. In order to evaluate the process and the different design proposals, Peter Zumthor's guidelines[76] were followed, and he says that in the creation of a comfortable spatial experience, the shape of the objects has to have an essential role. He explains that if the design has to *surprise,* and if the shape should move us, it would tend to have a conceivably *beautiful form*. But if the shape does not create any spectacular effect the redesign considerations should be applied.

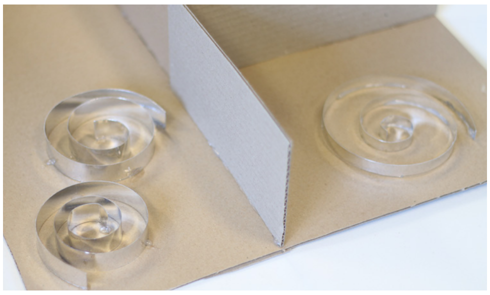
The second explorative experiment started with creating small size figurines, both hand shaped as well as more elaborately laser-cut shapes were tried in the experiment. As the initial idea was to combine the aesthetic lighting with functional lighting, the design considerations were mainly focusing on working with lighting effects from the ceiling.

The first shape designs were inspired by water reflections, and, as the *explorative material experiment* demonstrated, it should be feasible to construct a beautiful reflectance pattern by shaping the material surface. This simple experiment gave a harmonious water-like reflective patterns, and it gave rise to wonderment about how such a simple form can transform light into a delightful appearance, just by arbitrarily modifying the shape of the material surface.



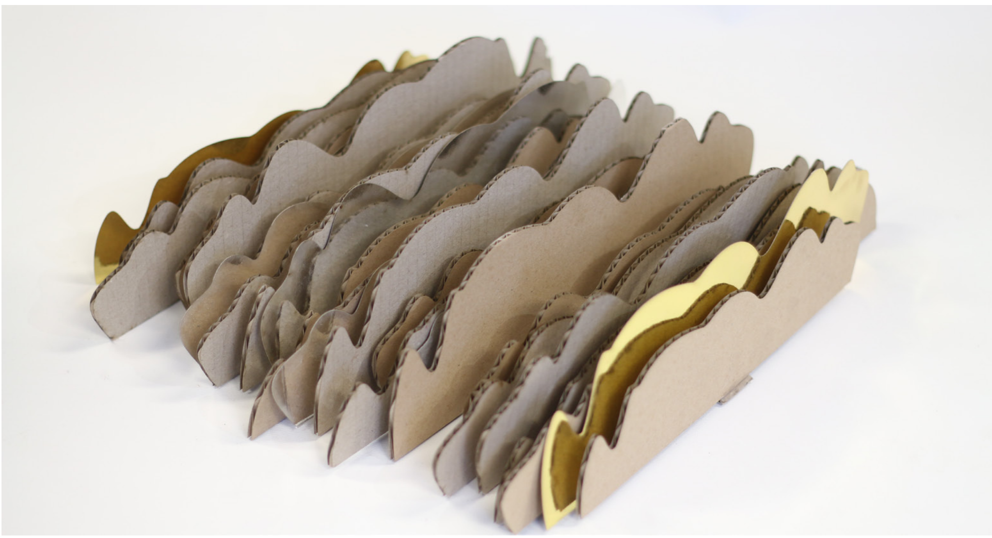
Examples of reflected light from Explorative Experiment: Shape Experiment (30)

As the initial idea was to integrate the design to the ceiling, there was an intention to create some kind of suspended structure, which could reflect the already reflected patterns back to the walls and the floor. During the experiment several different shapes were tried out. The intention with these small models was to mimic reflective similarities with water, and each of the explored shapes did present an attractive appearance and interesting reflections.

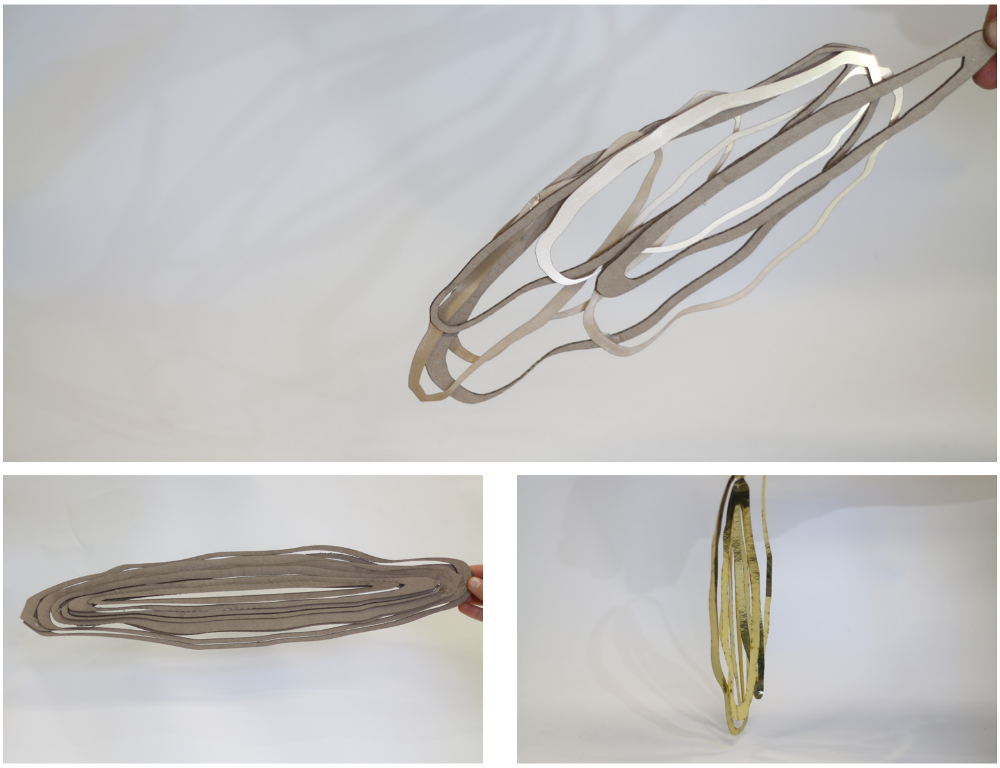

Examples of reflective shapes from Explorative Experiment: Shape Experiment (31)

The shape development process followed, sketching different shapes inspired by the nature phenomena in computer based programs, such as *Adobe Illustrator*. One of the first laser-cut shapes was inspired from a water pattern, but it also resembled clouds. The ensuing wavy cloud idea was using only one organic shaped matrix, which was then scaled to size and cut into three different slat forms. This systematic design was recognized as an improved proposal, but the evaluation process concluded that this representation was bordering on the naïve and was too straightforward in its symbolism, and so it was decided to continue with inventing and exploring different forms.



Example of cloud shape from Explorative Experiment: Shape Experiment (32)

The fascination to bring the nature and water phenomena into the design concept was still lurking as the theme was explored further on and into the realm of the formless abstract. The more abstract among the representations led to experiments with some unevenly layered ring structures, which gave way to exploring how the light would interact with the surfaces and edges, and whether it would reflect similar patterns in the surrounding space.



Example of ring pattern from Explorative Experiment: Shape Experiment (33)

The ring pattern experiment brought forward some unexpected and aesthetically interesting forms, compared to the previously designed cloud shape, however, this symbolism was too abstract. The aim of the design was to represent the nature in an abstract way, yet it should not be too far from the recogniseable, and thus create boredom or confusion for the patients.

A hospital waiting area is subject to a constant people flow, and if people spend an amount of time there, they mainly tend to sit down while waiting for their turn. As it was observed at the field trips to hospitals, the seating areas were frequently organized in a traditional way with chairs or couches. The arrangements were often placed alongside the walls, so visitors are facing the opposite wall. This seating placement may adversely encourage anxious, insecure and impatient emotions, due to the lack of decôr and nothing else to look at but other people occupying the same space. The dominating decor element in most of the spaces was solved with simple artwork on the walls, which often as not do not draw attention, nor help to stimulate or raise the mood. Therefore, the waiting area function is to offer patients a comfortable stay by having possibility to sit, but it should as well provide a stimulating or soothing experience in order to forget the waiting time. The further design considerations were not only focusing on the ceiling designs, but as well on the wall surfaces, since there was a desire to make a coherent and integrated spatial design.

The next step in the shape design process was focusing on how to combine the ceiling and wall surfaces into one structure, and also interacting with the light and materials. And how to implement the nature phenomena, together with functions and aesthetics. Inspired by natural structures and layers, the simple lines and minimalistic style was also an inspiration, since it should not be too drastic a contrast to the rest of the hospital environment.

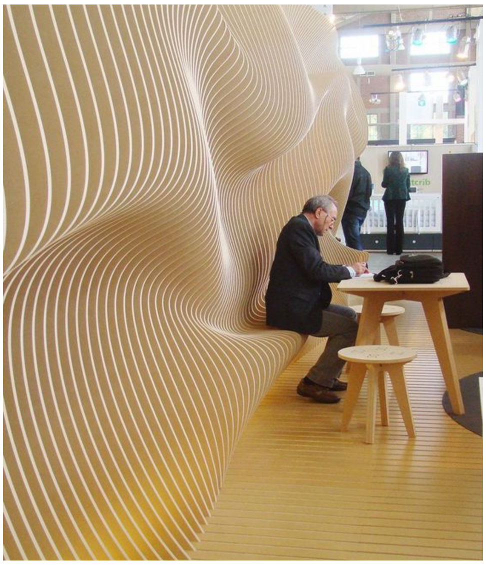
An online research was made on different spatial designs both in architecture, furniture design and retail. Since there was a desire to integrate the interior and light as a whole in the space, large gathered structures were investigated more, compared to smaller interior objects. In this research the private residence *Integral House*[77] (2010) in Toronto, Canada by *Shim-Sutcliffe Architects*, was the starting point of the interest of working with a structured set-up, made of slats. The architects had judiciously integrated the light with the wooden slats that defined the walls of the building, and it was beautifully interacting with the natural daylight, and this created depth and dimension to the room with distinct shadows highlighting the floor.

Integral House by Shim-Sutcliffe Architects (34)

Paulo Merlini Architects, *Bakery Gondodoce* in Portugal[78] (2012) was a second inspirational project that integrated the wall and ceiling surfaces into one structure. This structure design and slat representation in the interior inspired to implement certain elements into our shape design as well.

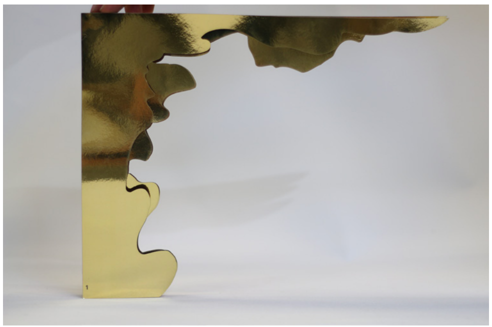
Barrios Escudero design studio made a installation, *Pabellón Ricchezze*[79] (2015), where the slat structure were formed into beautiful organic wall structure, together with the seating function. This work displayed an interesting structure, and it was inspiring to apply similar techniques to the design.

Bakery Gondodoce by Paulo Merlini Architects (35)



Pabellon Ricchezze by Barrios Escudero (36)

All of the accumulated inspiration, the field studies and idiomatic reflections on aesthetics, has lead to a design with a slat structure that engulfs both wall and ceiling. Moreover, it decided to incorporate the seating function with the structure design. The shape of the structure followed the water representation, for example creating a wavy sea surface or similarities of it. The evaluation process revealed that this design representation might have the greatest impact.



Examples of slat structure from Explorative Experiment: Shape Experiment (37)

The evolving design ideas were a significant transformation from the initially explored models. The more elaborate designs, together with the combined seating solution, had achieved the surprise effect, and it was concluded to further work with the light implementation in this model design. Since the simple slat method allows for creating various shape representations, the light interaction brings and creates different layers for the whole structure. This structure enables the designer to work more creatively with lighting design, since light and shadows creates depths and constantly shifting patterns and shapes on the whole structure. By continuing to work on this design it is possible to create an harmonious interplay between light, material and structure interaction.

From all of the designed shapes, the most appealing and the most natural appearance was derived from the wavy structure, but without the highly reflective materials. The simple light experiment had demonstrated that highly reflective materials on this structure would be detrimental to the shape design. The highly reflective materials can produce beautiful water-like reflection patterns in smaller scale models, however, in this layering structure design they did not accomplish much of a difference, apart from linear light reflections. Implementation of a highly reflective design in the hospital waiting areas may create too great contrast between the rest of the environment, and it may not enhance any comfortable spatial experience.

Sub conclusion

As the first two *explorative experiments* revealed, it is possible to recreate the water-like reflectance pattern with light and material interplay. It was found out that polished aluminum mimics this representation in a most realistic way, especially if the light hits the material edges. The small surface experiment confirmed this theory that with polished aluminum and with a more deliberate surface design it is possible to reproduce credible reflections from a water surface. However, this was shown not to work with large scale models.

The *explorative shape experiment* demonstrated that the material and light interaction could be enhanced with the slat structure principle. This method can be used for creating endless variations of structure designs, and the interaction with light could induce an aesthetically pleasing visual stimulation, blending the ceiling and wall surfaces into one naturally organic, yet functional structure. These two explorative experiments were important in order to analyze the physical characteristics of different materials and their reaction with light. This explorative method is a creative tool with which to develop the design idea. It gives the freedom to experiment, observe and evaluate both the process and the outcome. This idea development phase has presented a structure design that should contain the blueprint instructions with which to obtain a comfortable spatial experience, but further design implementations and experiments need to be considered and tested in order to finalize the design. Hence, the following chapter will deal with how this slat structure could be finalized in real life, and what concerns there are about the technical implementation and lighting design.

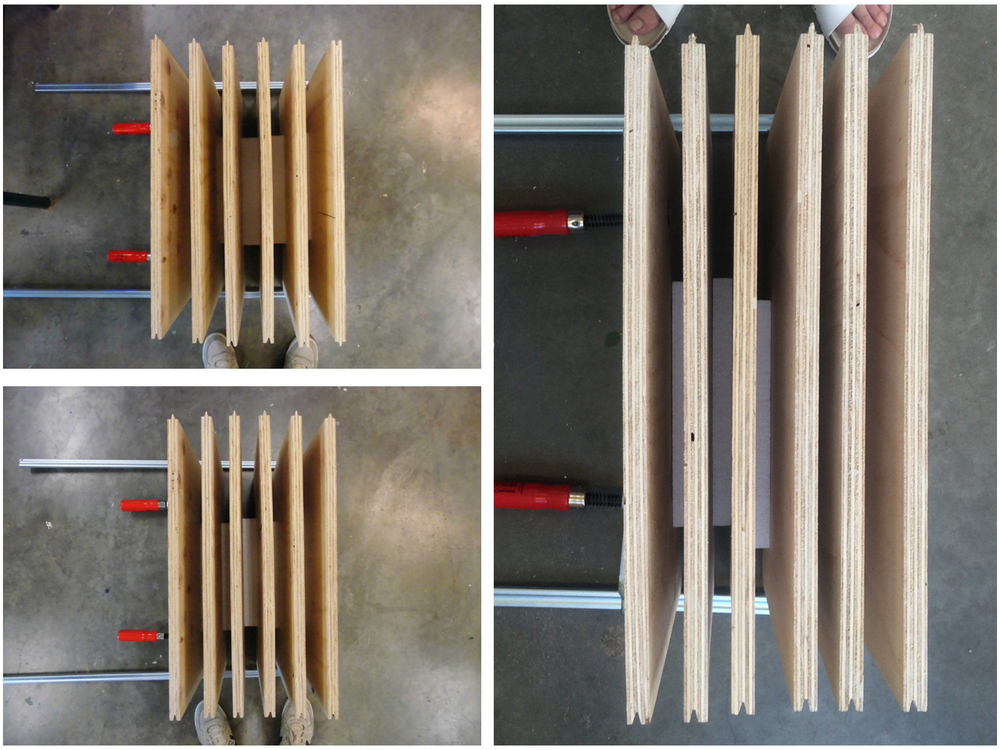
Design Phase 2:

Implementation

Experiment: Spacing

In order to support the idea of a comfortable atmosphere, the ergonomic aspect of the seating area in the structure needs attention as well.
The previously mentioned installations by design studio *Barrios Escudero* and *Paulo Merlini Architects,* were not only applauded for the shape of the design, but also for the materials used for the structure.

Plywood is a much used material when it comes to building large scale structures, since it is a cheap material, compared to other wood types, biodegradable, and easy to work with. Accordingly, this became the chosen material for further experiments.
The idea of a structure consisting of slats also included a seating area, and the spacing between the slats needed to be tested in order to find the ideal spacing, that would allow light to interact with the surfaces and as well be comfortable to sit on.



Spacing between slat (38)

Three different spacings were tried in the experiment, with respectively *3, 4* and *5* centimeters between the slats, inspired by existing similar structures where seating was included. The slats were made out of plywood with a *thickness of 2,5* centimeters which was considered suitable for a 1:1 seating area in this experiment. Squared shapes in polystyrene foam were cut in the different dimensions and placed between the slats and temporarily secured with a set of clamps, which made it possible for people to test the comfortability of the seating.

During the experiment it was decided that the 3 centimeter spacing was the most comfortable to sit on, though maybe only for a short period of time. The 4 and 5 centimeter spacings came along as less comfortable, yet still alright, but with a need for some kind of cushion that would form a barrier between the slats and the seats.

Even though the 3 centimeters spacing was the most comfortable, the possibilities for the light to interact with the surfaces was obviously lesser than with the 4 and 5 centimeter spacings. As the 4 centimeter *spacing was in the middle*, *this was chosen* as a compromise in order for the light to be visible and also to have a seating that was still comfortable (with a possible cushion).

Testing the comfortability in slat structure (39)

As wished, the spatial design should contain some sort of a reflective material, and the previous *material surface experiment* was reviewed. The conclusion was then, that the reflective aluminium was an interesting material to continue with, caused by its simple water-like reflected pattern, related to the nature theme. This led to the *Explorative shape* and *surface experiment*, where it was concluded that aluminium surfaces worked on smaller scales, but grew to be too intense and reflective with bigger structures.

The intensity and surface pattern needed to be subdued in order to make a more calming and less visually disturbing atmosphere. Aborting the use of aluminium, it was considered covering the surface of the plywood, where regular wood paint was cheap and easy to implement. In order for the structure not to be adversely visually disturbing, colours were not included for aesthetic reasons. Since white absorbs way less reflected light than black, *painting the plywood structure in white* was tried. To work with different intensities of reflected light, three *different* types of white paint containing different amounts of lacquer, were included in the following experiment.

A light source was needed for this experiment, where *Philips Hue LightStrip Plus* occurred as a suitable solution. Since the decision to design a structure of slats with a spacing of 4 centimeters in between, there was a need for a light fixture that could be placed in between. With *Philips Hue LightStrip Plus* measuring 170 millimeters, this was a fitting option compared to the other possible light sources that were available for testing from the Aalborg University CPH Light Lab. At the same time, this light source was not only intended to use for the experiment, but as well for the final design, since it is energy efficient and easy to implement as well.

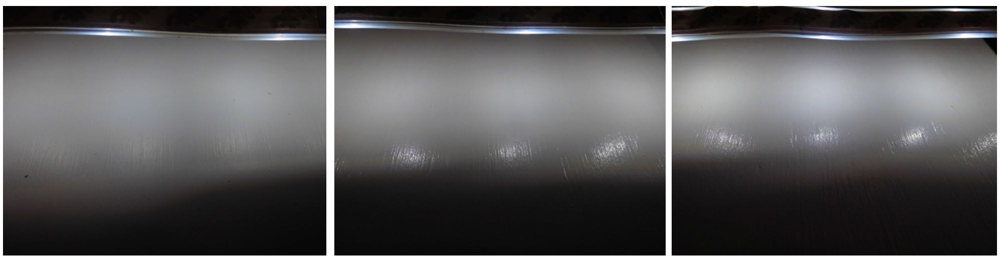
Experiment: Light and Material interplay

Two different small experiments were carried out in order to find the most suitable reflectance level:

- Reflectance level of the different reflective surfaces, to find out how big the difference is between the different lacquer levels in the paint and the raw plywood
- Illuminance level of different reflective surfaces placed against each other in order to find the suitable reflectance and interaction between the surfaces of either plywood and white painted plywood

REFLECTANCE LEVELS

Four different reflective surfaces were included; one raw plywood and three different white painted plywood surfaces with a lacquer intensity of respectively *10, 50* and *90,* with 10 being with the lowest content of lacquer and 90 the highest. A two meter long *Philips Hue LightStrip Plus* was used for the experiment, set with the highest intensity in order to observe and measure reflectance level as well as possible. The test was carried out in an otherwise dark room. It was found that the reflectance level did not differ much from one to another, with a reflectance of 43% (*lacquer 10)*, 39% (*lacquer 50*) and 40% (*lacquer 90*).



(from left) White paint with lacquer level 10, 50 and 90) (40)

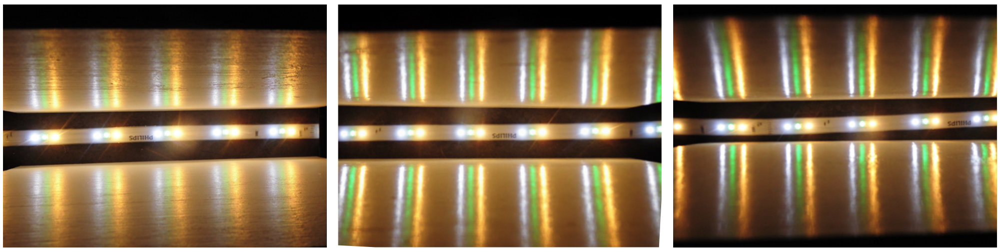
From that it was concluded, that the significant differences in the lacquer levels did not correlate with differences in the light reflectance level. Based on this experiment, there was an interest in finding out how much these reflective materials were interacting with each other and whether this made any difference to the reflectance and intensity level.

White painted plywood in three different reflectances; 10, 50, 90
Philips Hue LightStrip Plus placed directly pointed to material

Reflectance level:
10: 420 / 970 = 0,43 = 43%
50: 370 / 930 = 0,39 = 39%
90: 385 / 960 = 0,40 = 40%

ILLUMINANCE LEVEL OF DIFFERENT REFLECTIVE SURFACES PLACED AGAINST EACH OTHER

The three different white painted plywood surfaces and the raw plywood was placed up against each other with a distance of 4 centimeters. Here the light measurements clearly showed the increased intensity depending on the lacquer level in the paint and the raw plywood, with plywood being with the *lowest light level at 1560 lux* and the white paint with the highest lacquer level being at its *highest light level at 3200 lux.*

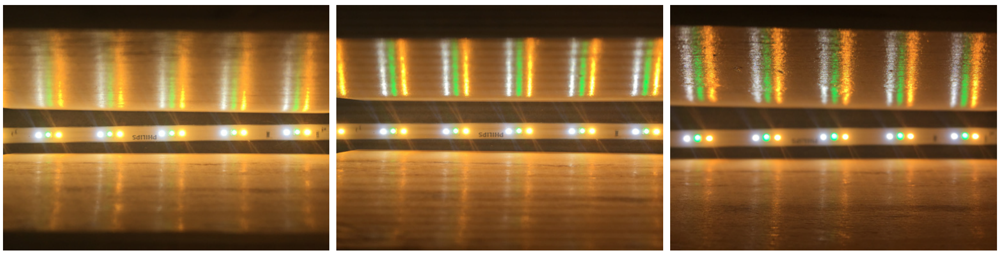


(from left) White painted surfaces facing, with lacquer level 10, 50 and 90) (41)

White painted plywood placed towards each other, distance of 4 cm
Philips Hue LightStrip Plus pointed directly up between materials

Illuminance level:
Wood: 1560 lx
10: 2200 lx
50: 2800 lx
90: 3200 lx

A combination was carried out as well, where the raw plywood was placed against the three different painted surfaces, where the light levels obviously decreased. The surfaces placed against each other gave a much higher light intensity, since the materials were interacting in narrow spacing with the even surfaces of the (painted) plywood. From this it was concluded, that different mix ups of material surfaces produced a large range of different light intensities. This could be an interesting approach to implement in the design and would support the visual stimulation to the perceiver.



(from left) White painted/wood surfaces facing, with lacquer level 10, 50 and 90) (42)

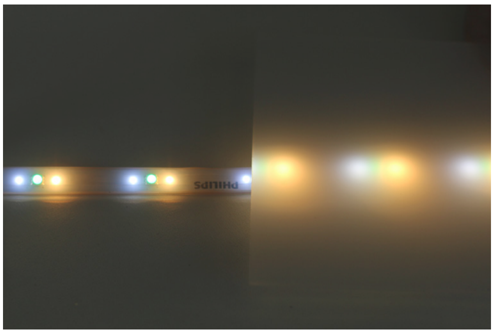
Placing a mix of natural plywood and painted plywood
Philips Hue LightStrip Plus pointed directly up between materials

Illuminance level
Wood / 10: 1880 lx
Wood / 50: 1970 lx
Wood / 90: 2070 lx

Experiment: Placement of light

The success criteria states, that the lighting design should *preclude glare* and *visual irritation*. The fact that the light is already interacting with the surrounding materials, can (depending on the surfaces) already help avoiding *reflected glare* from some of the surfaces. The direct glare though, is something that would be hard to avoid with the intended slats structure, since they are vertical, and therefore not covering up the light source and turning it to *indirect light*.

To avoid the *direct glare*, *a semi-translucent acrylic* plate with a thickness of 4 millimeters was chosen and placed on top of the *Philips Hue LightStrip Plus*. This was the only material tried for this experiment, in order to implement a diffusing material that made an even distribution of the light and was made from a light and easily accessible material.



Acrylic placed on top of LED in two different distance (43)

To make the light setting evenly distributed, smooth and comfortable, it was found that the acrylic plate should have a spacing from the *Philips Hue LightStrip Plus* and not be placed directly on top of it. A *spacing of 5 centimeters* came out as the most suitable for an even distribution. This setup was placed between the two slats, where the *Philips Hue LightStrip Plus* was placed in a parallel direction as in the previously described experiment.

Physical setup of the Experiment: Placement of light (44)

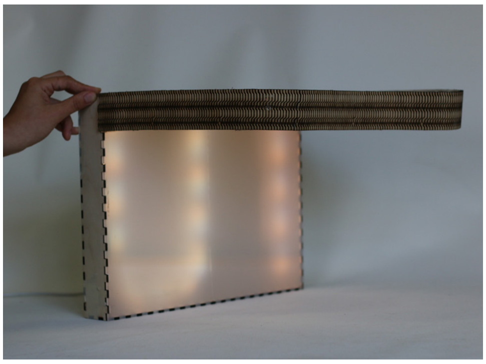
Measuring the light intensity with the acrylic gave a decrease, since the semi translucent acrylic diffused and absorbed the light to some extent. It was measured, that the paint with lacquer 50 had the combination with the *highest light intensity at 720 lx,* where the combination of pure raw plywood had the *lowest light intensity at 460 lx.*
In a previous experiment it was found that the *Philips Hue LightStrip Plus* without the acrylic on top, was creating a high level of reflected glare from the white paint, especially with the lacquer levels 50 and 90. With the acrylic on top of the *Philips Hue LightStrip Plus*, it was then found that the light was still reflecting but it did not cause the same visual irritation as before, as the light was more evenly distributed. At the same time, the direct glare was eliminated by selecting a proper distance between the *Philips Hue LightStrip Plus* and the acrylic plate. The acrylic surface works as a diffuser for the light, and it will eliminate reflected and direct glare to the user as the perceiver, and at the same time make a more evenly distributed light, as is recommended for hospital lighting.

White painted plywood with 4 cm distance in between.
Placing 4 mm semi-translucent acrylic plate on top of Philips Hue LightStrip Plus, distance 5 cm from LED to acrylic material

10: 660 lx
50: 720 lx
90: 650 lx
Wood: 460 lx
Wood / 10: 490 lx
Wood / 50: 430 lx
Wood / 90: 520 lx

Experiment: Movement of light

As the structure was more or less set, the implemented light had to be tested. *The Philips Hue LightStrip Plus* was decided to be placed between the slats in previous experiment, and hidden behind *a semi-translucent acrylic surface*. Although the colours and reflections from nature are not present in the material and its surface, apart from the colour of natural plywood, the final structure design still contains references; the wavy shape in the structure can be translated to the water surface or a hilly landscape, and the changing colour temperature emulates the day, going from cool to warm white. Still, another layer from the nature could be added, where the movements experienced in the nature could evoke a calming effect - this being the moving pattern in the water as previously mentioned. Therefore there was an interest in implementing this into the movement of the light, where direction, movement and the intensity of light would be tested in the following experiment.



Light box for conceptual model, without and with slat structure (45)

STATIC LIGHT IN THE WHOLE STRUCTURE

First a static light setup made of *Philips Hue LightStrip Plus* and a box made out of plywood and the chosen semi-translucent acrylic. The static light was tried out, to first of all find out if a light setting with either only the ceiling or the wall was enough to light up the structure. This was tried out, with the thought of a possible solution to make the design more energy efficient with less use of light.

Static Light in the whole structure (46)

LIGHT FROM CEILING

A setup where the light was turned off on the wall surface and only lit in the ceiling, obviously gave a less intense light level, which made the seating area seem dark and uninviting to some extent. Though the ceiling light worked great as a functional light and was lighting up the rest of the space, it still seemed as a lighting solution that did not make an even distribution in the space, which is considered necessary in order to fulfill hospital requirements for a well-lit and evenly distributed lighting design.

Light from the ceiling (47)

LIGHT FROM WALL

As well for the ceiling light, only lighting up the wall also created a space that was perceived as too dark, and with a light that was not evenly distributed. Lighting up the wall as the only area was an even poorer solution than the singular ceiling light, since it lit up the space even worse. At the same time, as a perceiver to the lighting design and sitting on the seating area in the structure, the light is not possible to experience directly as you would be facing away from it. As none of these two combinations worked, lighting up the whole structure, but with different intensities was explored.

Light from wall (48)

LIGHT IN CIRCLES

The moving element from nature was about to be implemented in the light, where different shapes, movements and intensities were tried out. First, *a circle shaped structure* was placed in between the light, to create *a random distribution* of the light. When moving this structure, the light gave *different intensities* according to what surfaces it hit, and the white painted slats gave an expectedly higher intensity than the wooden ones. This was tried out with *two different levels of speed*, one being *slow* and one *fast*. The slow occurred more calming than the faster moving disc, since the structure's pattern itself created a lot of interaction with the materials, and therefore the faster one appeared too confusing. The slow pattern came along as an interesting, stimulating and calming light flow, that resembled the reflection patterns from water by its random movements and differing intensities of light.

Light in Cilcles (49)

LIGHT IN ONE COLUMN

Though the circle shaped structure from the former paragraph came along as a possible disperser for the light, other shapes were also explored. To lower *the high intensity* of the wall and ceiling light, light in just one *column* was tried out as well. The reason for trying out one column only was to simplify, and to try out a more monotonous movement of the light. The pattern and reflections came out beautiful, but demanded too much attention since the light was only visible in only one place in the structure at a given time.The rest of the structure was too dark as well, and did not fulfill the requirements for an evenly distributed light.

Light one Column (50)

LIGHT IN COLUMNS

Since one column created an interesting movement, but did not contribute enough light to the whole space, a structure with *several lighted columns* was tested, and that lit both the ceiling and the wall up with lines of light in and on the structure. Again inspired by the movement of the water, but this time multiplied. This was an interesting look, but it came *along predictably boring* since the travellings of the light strobes could be anticipated beforehand, compared to the randomly placed circles in the first movement experiment.

Ind the end the *circle* pattern *came* along *as the most interesting movement*, and as a pattern to work with, it was judged the most i*nteresting, stimulating* and *pleasant* one of them all. The columns also contributed to a beautiful movement and pattern, but one of tranquility which gave reference to rolling ocean waves, whereas the highly reflective discs gave reference to the shimmering and jittery movements of a quiet lake in the forest.

Light in colums (51)

Final Design

Through field study observations, scientific research, conducted experiments and an unknown amount of personal sense of the aesthetic, the final design was developed. This is a *conceptual proposal* on how *interior* and *lighting design* can be approached in the hospital waiting areas, in order to create a *comfortable spatial experience*. The final structure can therefore be adjusted to any individual waiting area, according to *size, structure* and even the use of *colours.* By this it is assumed to be understood, that the shape of the structure, choice of materials and reflectance levels should be set as standard.

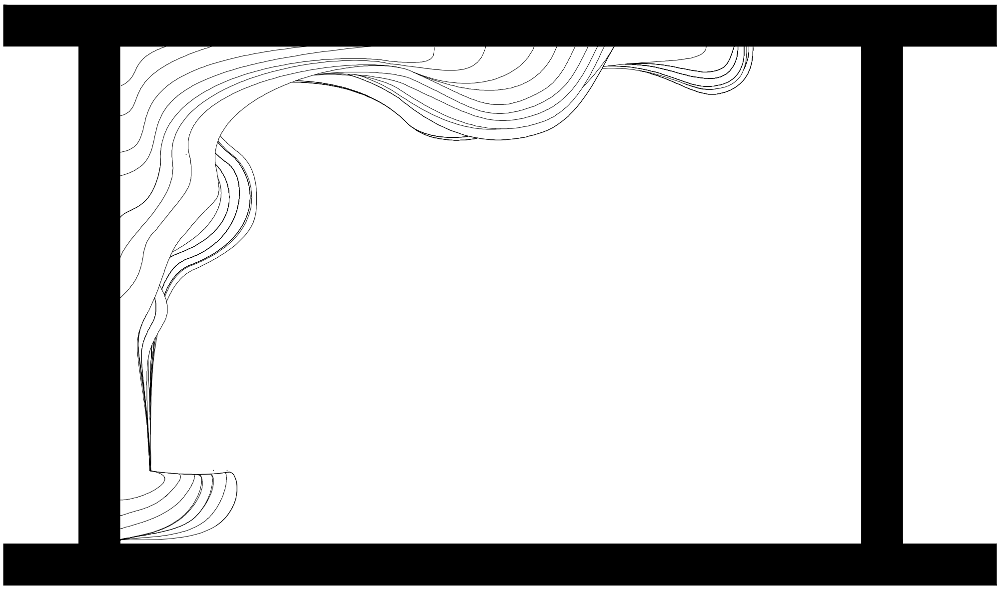
SHAPE DESIGN

The idea of implementing the nature phenomenology with an ambient symbolism, is depicted within the shape design and its structure. Through the field study observation, the hilly landscapes and reflections from water came as along as a great inspirational source, and organic shapes have been implemented in the structure. The shape of the structure is therefore open to free interpretation, whether it comes along as a *water surface* or a *hilly landscape*. The structure is designed with the purpose of making the spectators perceive the space as a whole that they can feel connected with. The dark edges are applied to emphasise the shape of the structure. A seating area is built in, in order to satisfy the expectant perception for the user, since a seating area is to be expected when entering a waiting room. As stated in the analysis, people will feel connected with a space if you take elements from the outside, inside.

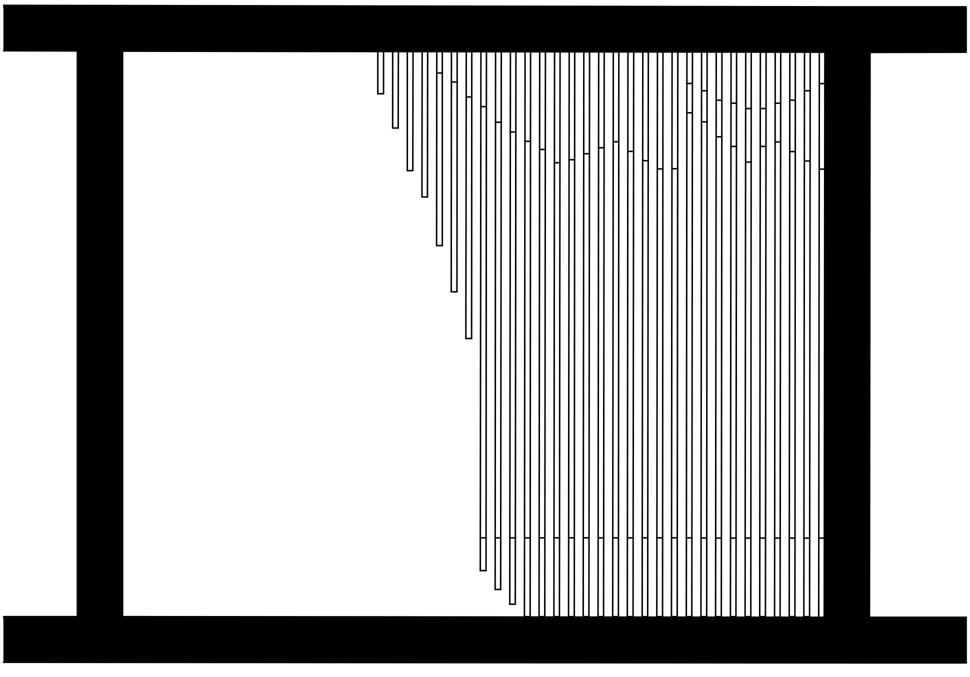
Concept Model (52)

STRUCTURE CONSTRUCTION

As the *Material Characteristics* and the *Shape experiment* presented, high reflective materials should be neglected in the bigger scale structures, due to the great material contrast and the risk of causing reflected glare. Hence, the final design is not focusing on high reflective material implementation in the structure. The material proposal for the final design structure is *plywood with 2,5 cm thickness*, since it easy to handle and thus ideal for design variations of shapes, and the reasonable cost is an additional plus. The spacing experiment revealed that the 2,5 cm plywood with *4 cm spacing* enables a relatively good seating experience. The *concept model* is a presentation of approximately *2,5 metres in length, which includes 39 slats*, but this can be adjusted if wished.



Structure drawing, side view (53)



Structure drawing, front view (54)

MATERIAL AND REFLECTANCE

The experiment *Light* and *Material Interplay* led to the conclusion that the in order to achieve a greater interaction between light, materials and their reflectance, the final design should be made from *natural plywood* and *white painted surfaces*. Plywood is *a warm* material and as it was stated in the analysis, warm materials should be used in the elements where people have physical contact, respective of the material characteristics and their assumed psychological effect[80]. Since this design proposal is integrating the seating placement, the users will have direct contact with the structure. In order to *stimulate comfortability and bring warmness into the space*, plywood was chosen for its material characteristics. Plywood also contributes to good acoustics, since it has the characteristics to distort the sound of the space. The white paint was chosen because bright colours are known to create a pleasant environment, according the colour theory. The white colour does as well support the idea of a simple design, where white gives the feeling of purity and neutrality[81]. The experiment with *Light and material interplay* found that white p*aint with lacquer level 50* was most appealing, since it reflected light evenly and it did not create too high contrast next to the plywood. Based on Zumthor theory and *Material Compatibility*[82], plywood and white paint creates an interesting and balanced combination, since they are different, but not too far apart.

The concept model includes three different variations of surface placements:

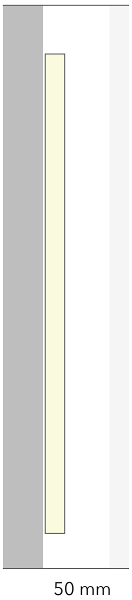
Wood / wood
Wood / White paint
White paint / White paint

The light interplay in this structure presents variations of brightness, since the mixed up *surfaces reflects light in different intensities*. The interaction creates distinctive *depths* and *highlights* for the whole structure, according to what type of surfaces are opposite each other. These depths and highlights creates a *stimulating and differentiating visual experience*, that hopefully can make the user forget about the waiting time and defuse their anxious and impatient state of mind. Even though the final design is only natural plywood and white surfaces, the light in this design creates the illusion of more than two different types of surfaces.

Final structure with light (55)

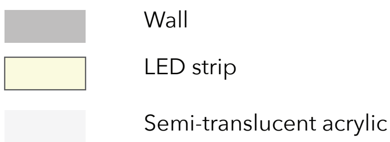
LIGHT PLACEMENT

As the idea is not just to create a beautiful slat structure, the overall goal is to create the light and material interplay within this structure. In order to do this, it is important to be aware of the use and placement of the light fixtures. As the *Spacing experiment* revealed, the recommended spacing between the slats is only *4 cm.* This distance determines the requirements for the light fixtures, since they have to be able to fit in between. Another requirement for the light fixture should be, that it is able to control the light movement and the *correlated colour temperature (CCT)*. The *Philips Hue LightStrip Plus*, which was used in the testing phase, led to the conclusion that this LED strip is the most suitable light fixture for the final implementation of this design. This was because of its suitability for placing it in between the slats, the possibility to control the CCT temperature, and being able to program the movement of light. According to energy efficiency, LED is as well one of the most energy efficient light source, is durable and markets at a reasonable price.



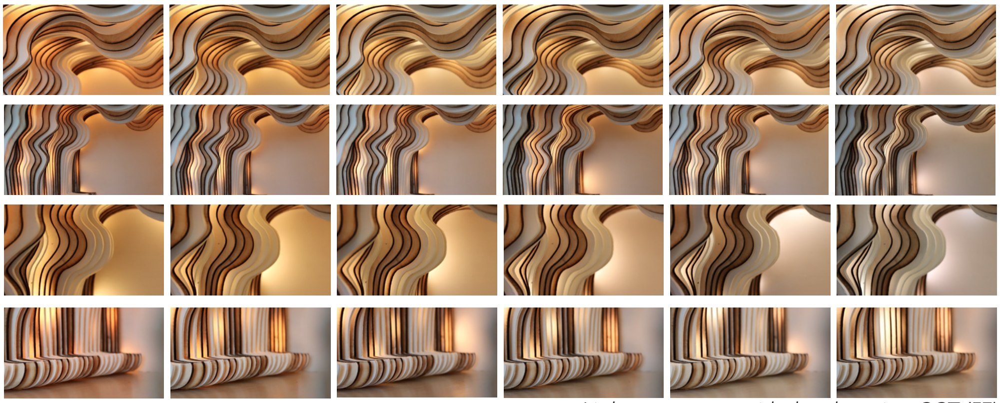
LED strip placement (56)

In the *Placement of Light experiment* it was concluded that the *Philips Hue LightStrip Plus* should be diffused with *semi-translucent acrylic* to achieve a more *evenly distributed light* and *avoid direct glare.* This experiment also revealed that the diffuser should be placed on top of the *Philips Hue LightStrip Plus* with a distance of 5 cm. However, there is no final decision whether the LED strips should be placed in between every slat or every second or third, this could be tested and finalized in a 1:1 scale model.



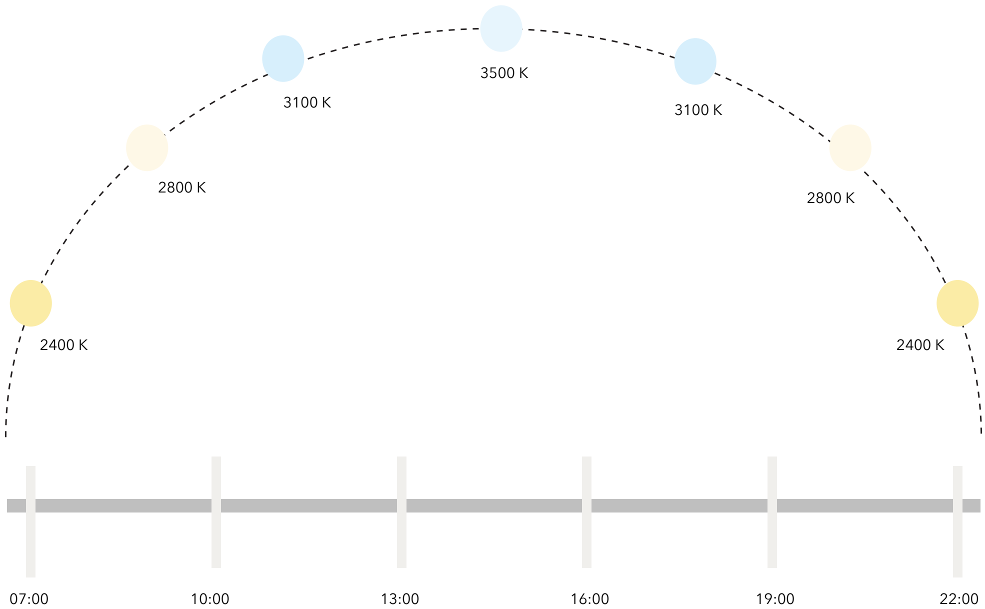
MOVING LIGHT

The goal was to provide visual stimulation with a slowly changing lighting program. When creating *changing movement patterns* with light, it is possible to control the LEDs by not having them all turned on at the same time. The idea was to create a *continuous rhythm of light patterns* that would *mimic the moving water surface* and *its reflections*. This movement should catch the user's attention, that at the same time would establish a harmonious interaction with the surrounding materials and the shapes of the structure. Since there was a wish to make a simple light setup, the movement should be set in a slow tempo in order not to come out as distracting or stressful. The *Movement of Light experiment* concluded, that the circle pattern was the most interesting and pleasing and was mimicking the water surface the best. In order to create this movement pattern, idea is that the *Philips Hue LightStrip Plus* should be programmed in real time, in a sequence and rhythm which mimics the previously displayed circle pattern carried out in the Movement of Light experiment.



Light movement with the changing CCT (57)

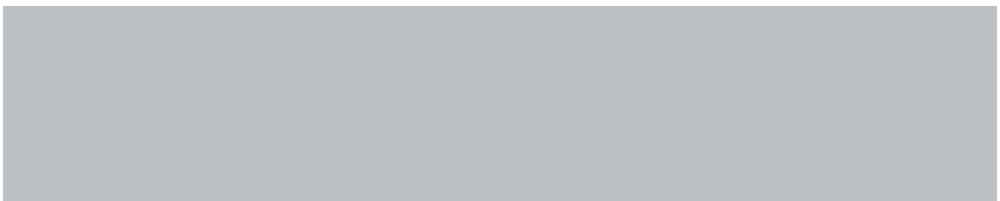
Besides creating the slowly moving light tempo, the idea was to control the light *correlated colour temperature (CCT)* at the same time. In order to create a comfortable spatial experience with lighting design, the contrast between the indoor and outdoor environment should be balanced. The *CCT* will gradually change from *2,400 kelvin - 3,500 kelvin during a day*. The proposal for the lighting scenario would be that, *the CCT slowly increases from 07:00 in the morning* and *continues until noon, where it should reach the coolest values, approximately 3500 K*. In the afternoon, the light CCT temperature starts to gradually goes down again until it has reached the *2400 K around 22:00 in the evening*. This chosen time interval is representing the daylight hours within an average day, but can be adapted to a desired time interval.



Changing CCT day scenario (58)

TECHNICAL IMPLEMENTATION

The circle movement can be realized with for example *Processing library* that controls *Philips Hue API interface*. *Zigbee alliance* is the wireless communication protocol, that sends commands between the *Bridge* and *Philips Hue LightStrip Plus* via a connected lighting platform. The *movement* and the *CCT* change is controlled and created with *Processing code*, that communicates with *Philips Hue API interface*. As this project is a concept proposal, the custom created Processing code about the movement of the light and its *CCT* change is not part of this project phase. However, these lighting movements and the gradually changing light temperature can be realized in real life with the above described setup.



Evaluation

Evaluation

Through reflections from the initial research, along with case studies and the final design, the evaluation is conducted in this chapter.

FIELD STUDY

Hospital waiting areas were decided to be the public space to make a lighting design for existing waiting areas in some of the hospitals of the Copenhagen area were investigated. The reason for visiting hospitals in Copenhagen was based on the interest in seeing hospitals that already had gone through a transformation, assisted by the organization *Planetree*, to see what differences were visible in the architecture and interior design.

The spatial characteristics and general atmosphere was recorded in the visited waiting rooms. The material characteristics were also documented, because the objective was to find out if there had been any aesthetic considerations regarding selection of interior, material surfaces, colours or shapes for the waiting room.
It was not possible to carry out a photo documentation of each waiting area, since this was not allowed due to privacy of the patients waiting. But these photos would have been useful for documenting the atmosphere and spatial characteristics better, as well as for consulting this documentation later in the process of the thesis. This was solved in the best way possible, by writing down all experienced details regarding spatial characteristics and atmosphere.

This made the general outcome of the field study slightly unstructured, and gave some uncertainty to the outcome. This process was a learning process, and if it had been carried out more structured it might have gathered more useful documentation. As well for the photo documentation, it might have been wiser to contact the different departments in advance and make them aware of the forthcoming visit, which also could have opened up opportunities for user surveys on location, which maybe could have helped with stating that the users in the waiting area did in fact feel anxious and impatient*.

HOSPITAL LIGHTING

From the chapter concerning hospital lighting, *Thorn Lighting Company's* health care brochure was used as a guideline for choosing the suitable light standards, and requirements for *efficiency, performance* and *comfort*. The reason for using Thorn Lighting Company as a qualified source for these guidelines was because it is based on the Europeans standards and that they offer an overview of what is needed considering booth quantitative and qualitative aspects.
Other aspects, such as *healing light* could have been taken into consideration. But it would have opened up for a huge field of scientific knowledge that there was simply not enough to dig into, due to the time limit of this thesis.

Regarding the implemented control system, that allows the light to change in colour temperature during a day, specific kelvin degrees were set for all year round. This control system could have been implemented with a more intelligent system that

** Photo 13: Findings Through Field Study to Hospital* would support the users circadian rhythm. With the 1st semester project (*"Lindin Bath"*) at Lighting Design evolving studies about *circadian rhythm*, it was acknowledged that this topic had a lot of biases when implemented in lighting design. Therefore this is not a field that has been considered in this lighting design, as it would risk becoming a design with many pitfalls.

ATMOSPHERE

In the problem statement it is questioned, how a *comfortable environment* could be achieved in hospitals waiting areas through a lighting design. It was therefore needed to investigate the values of a comfortable environment, and the theory of *atmosphere* was studied. Architect *Peter Zumthor* has stated *nine values* in his book *"Atmospheres"* (2006) to be aware of when designing an atmospheric space. Four *of them* were chosen*, since they suited this thesis subject regarding the interplay between light and materials. The reason for choosing Zumthor's values for implementation in the design was among other things caused by the already existing awareness of *"Atmospheres"* from the course in 1st semester, *Light & Context* at Lighting Design. It could have been possible to consider other theories regarding atmosphere and materials in a context, such as architect *Carl Petersen's "Stoflige Virkninger"*** (1919) that deals with the complexity of different materials. But with Zumthor's listed values of how to achieve the right atmosphere for the context, it became more concrete than the other considered theories. By using these stated guidelines instead of using a more undefined theory as inspiration, it made restrictions for the design, which confined and refined it. This might also have left out other aspects of how to achieve a comfortable atmosphere.

VISUAL PERCEPTION

The perception theory was included in this thesis, in order to gain a better knowledge about how humans perceive a space in real life. The intention was to support the atmosphere theory, and to get perhaps an understanding of how visual information is received and translated in our brain. This theory was found in "*Perception and Lighting as Formgivers for Architecture*" (1992) by lighting designer *William C. Lam*. Here the fundamentals of visual psychology are presented, and the three *different layers of perception**** are elaborated in this thesis.
These three layers explain in a simple way, what we perceive through past experience, what we expect to experience when entering a space in a context, and how a good spatial design can awake interest without being too stimulating. This theory is scientifically proven and tested, which makes it a highly credible source that sums up the general knowledge from this field. Accordingly it differentiates from Peter Zumthor's atmosphere theory, which is based on Zumthor's own ideas about how to achieve an atmospheric environment.
It is debatable whether it was necessary to include this theory on top of the atmosphere theory. But since the perception theory is dealing with how nature can be mimicked and incorporated into the interior and the lighting design, it was concluded that this was of importance for this design.

A GOOD HOSPITAL ENVIRONMENT

The chapter involving *a good hospital environment* is based on a combination of various bits of information from the fields of *art in hospitals, colour psychology* and *material reflectance*. These topics were chosen as relevant to the development of the design. Since this design is not directly translated to a piece of art, it still retains some artistic elements, such as the shape of the structure that is open to interpretation and could generate different emotions. The theory about art in hospitals was just one of many, and it was in general a difficult topic to cover, considering how big of an influence it has on people's emotions. In this thesis the topic is covered rather

** Material compatibility, Temperatyre of the space, Sound of the space, and Suurounding objects*
*** From the book; "Faaborg Museum: I Skoen forening", Gertrud Hvidberg-Hansen & Gry Hedin (2015)*
**** The attributive, expectant and affective layers of perception*

superficially, and it could have been considered whether it should have been left out - or elaborated in more details.

In the same chapter it is stated that a *vibrant environment* improves people's healing process, rather than a stay in a dull environment. Bringing in values such as colours or shapes from nature can be one of the ways to create a vibrant environment. And now the vibrant environment is mentioned, it could also have been considered to go more into detail about how this could be created, aside from bringing in values from nature.

Planetree has put up five values to be aware of, regarding interiors and architecture in health care; *privacy, reflections, togetherness, expression of space* and *support.* Since the idea was that the final design should be a part of Planetree's optimization of the interior in health care, these values need to be incorporated. Though these values were dealing with interior design, some of them can be modified to a lighting design. Here the *reflection, expression of space* and *support* is achieved through a visual stimulating and coherent spatial design along with the lighting design, that is offering support through the integrated seating area. If the intention was not to cooperate with Planetree or other organizations, these values could have been modified or left out.

There are other factors in regard to creating a good hospital environment that are not included in this thesis, such as *sound, tactility* and *daylight*. These are not included due to the need for a preliminary analysis, though they would have been relevant to include. *Sound* is a huge topic, and one that comes with many subcategories such as music and the ensuing psychology of it. This thesis is aiming to create a comfortable environment with the i*nterplay between light* and *materials*, and the topic of sound came along as being too far away from the context. The *tactility* of the materials could have been interesting to include, but due to difficulties finding useful and scientifically proven information pertaining to tactility, this subject was not included. The *daylight* is also a major topic, and a lot of useful material certainly could have been investigated on this subject.
But since the design was made for all kinds of waiting areas, often in areas where there is no daylight, considering incoming daylight was not included. This could be an important topic to leave out since this thesis is dealing with light. But due to our own point of view, a lighting design does not necessarily have to include all types of light, and daylight in this respect has been deemed an unimportant part of the design.

EXPERIMENTS

Six experiments were carried out, in order to find the most suitable materials, shapes and light settings for the final design.
In the very first experiment the characteristics of different materials were investigated. The light source that was used in this experiment ended up being the flashlight from an Apple iPhone 6, which was the most suitable in order to see the details in the reflected surface. The test was carried out in a dark room, which made it easier to see the reflected light. Though, since the design also at that time was expected to be implemented in a room with daylight, the test could have been carried out in a room with a similar intensity of daylight.

Due to the theory about art in hospitals, it was stated that elements from nature (eg; such as an organic shape) was found pleasant when integrated with an indoor environment. Because of this the *Shape Design experiment* was subsequently focused on shapes and surfaces that were inspired by nature. Here it could also have been explored, if going away from the organic shapes could have created another beautiful visual experience or surface reflection.

Regarding the *Spacing experiment* and the choice of material (ref: plywood), it would have been possible to explore other materials and different thicknesses of the slat structure. But since plywood is a cheap material, easy to work with and commonly used in inspirational structures* , this material came along as suitable for the experiment.

In the final structure, the plywood was painted with white paint or kept with its raw surface. These surfaces were put together randomly, but record was kept on on how each surface reflected to the surface it was leaning up against. In the *Light* and *Material Interplay experiment* , only white paint and the raw plywood surfaces was explored. Other colours than white were not tried, since the colour theory was only stating that *bright colours came along as the most pleasant*. Also, the wish to design a simple and not too stimulating design carried the decision of only experimenting with white paint and raw plywood.

Due to financial and temporal limitations, it was not possible to make a prototype of the structure with integrated light. With a 1:1 scale model the *Placement of Light experiment* and *Movement of Light experiment* could have been carried out with a more reliable outcome than with the 1:15 conceptual model. The LED strips could as well have been implemented in between the slats in the 1:1 prototype, which was also the intention for the final design. With this, it would have been possible to see exactly how the light would react with the surrounding materials. Furthermore, the LED's could have been programmed to move in the same way as carried out in the Movement of Light experiment, which would have contributed to the reliable outcome of making it in a 1:1 scale.
The technical aspects of implementation of the light have not been described in detail, since this thesis is considered as a proposal for a *conceptual design*. Therefore, the technical details are considered to be of lesser interest, and also a task that a light technician could quickly help with.

Reflecting back on these experiments, others could have been conducted in order to visualize the final design better and to measure whether the final lighting design served as a functional light as well. To visualize this, renderings in computer programs such as *3DS Max* could have been created. In order to measure whether the lighting design achieved the recommended functional light level for a waiting area, light measurements could have been made with the computer program *Dialux*. But due to lack of time this was not prioritized.

When considering other factors, that were not dealt with in the experiments, there could as well have been deliberations made about what kind of waiting area this design was suitable for. It has not been concluded which functions are working specifically for a spatial design, whether it is for a Cancer Department, a Blood Sample Department or yet another department. It was experienced, that there is a huge difference in how the patients' state of mind is perceived, according to what department they were staying in, which again puts more demands on the lighting design. In this thesis, that issue has not been further discussed, which might have caused that the final design is more suitable for some waiting areas than others.

** Inspirational photos on p.56, 57*

Conclusion

Improving hospital environment has been the subject for many scientific articles, but most have only dealt with either the interior decor or a functional light setting. Articles about designs that are about creating a comfortable environment, achieved through a coherent spatial design with the light used as an aesthetic medium, have been few. The point of view in this thesis has been the lighting designers, and this proposal for a new lighting design is to be implemented in waiting areas for hospitals. The problem statement was developed, and read as follows:

"How can a comfortable environment be created for hospitals waiting areas, through a lighting design focusing on the interplay between light, space and materials?"

Research was conducted in order to investigate how to create a comfortable environment with light and material interplay. This involved field trips to hospitals and nature, theoretical analysis into hospital lighting, atmosphere and perception, and the use of art and colour in healthcare. Several experiments were performed in order to reach the final design. The hospital field trips were made in order to find out whether a new spatial design was actually needed, whereas field trips to nature had the purpose of being inspirational studies. Theoretical analysis was conducted for gathering knowledge regarding a comfortable hospital environment and the human perception of a pleasant and comfortable atmosphere. The different experiments were performed in order to find the appropriate level of interplay with light and materials, shape of design and suitable light fixtures.

Through the field studies *four finding*s were conducted that became guidelines throughout the structure of the thesis. It was found, that considerations about decor and aesthetic lighting were neglected in the hospitals, where the light sources often caused visual glare. Furthermore, the too explicit representations of nature, together with the light and decor were not conductive to positive visual stimulation, and so did nothing to alleviate the patient's anxiety or impatience.
To find out how the negative emotions could be decreased through spatial design and material characteristics, a theoretical analysis involving *atmosphere theory* and *perception theory* was performed. *Hospital lighting* was studied as well, in order to gain knowledge about how visual discomfort could be avoided by the right use of materials and light fixtures. *Art and colour used in healthcare* has been elaborated in the analysis as well, to find out how to represent nature in the design and how it interacts with materials and artificial light. The experiments were concluded before implementing all the gathered knowledge into a final design. These experiments helped form the base, from which the development of the final structure was created together with the integrated moving lighting design. This phase was where the interplay between light and materials were investigated most closely, and certain materials and light sources were also selected at this point.

To decide whether the final design succeeded or not, the developed *success criterias* are used as guidelines for the evaluation. The primary success criteria are stating that *a comfortable environment is achieved by a coherent interior and lighting design.* According to the atmosphere theory, a comfortable environment is achieved through an awareness of the *Material Compatibility, Temperature of the Space, Sound of the Space* and *Surrounding objects* . The natural plywood and bright reflective painted structure is combined in a balanced design that brings warmth into the space. The curved slats structure, inspired by the nature's physical attributes, adheres to the theory concerning the pleasing effect of bringing the outside, inside . The slats structure is as well contributing to bettering the acoustics of the space, with its sound absorbing plywood integrated structure going from the floor up the wall, and continuing all the way into the ceiling.

The second success criterion establishes that to *create visual stimulation, a calming lighting design is needed.* This criteria could sound like it is contradictory, but here the calming lighting design is creating the visual stimulation by implementing a moving pattern. This pattern was inspired by nature, with the light pattern mimicking the movement and reflectance seen on a water surface. The moving light is creating the visual stimulation, where the pattern is considered to provide the calming assurance.

The third success criteria states, that *a lighting design based on interaction between light and materials and their interaction, should prevent glare and visual irritation.* Throughout the experiment regarding *Light and Material Interplay* it was found that a combination of the raw plywood surface and the white paint with a medium reflectance level was the most suitable in order to prevent glare and visual irritation. The white paint with a lacquer level of 50 still had an intense specular reflectance level, but placed between the matte plywood it came along as less reflective. This was further improved by implementing a semi-translucent acrylic plate in front of the *Philips Hue LightStrip Plus*, which diffused and decreased the reflected glare and eliminated the direct glare. The intensity and *CCT* of the *Philips Hue LightStrip Plus* were measured to be suitable according to hospital light recommendations and thus fitted to the setup of the slat structure. On top if this, the combination of plywood and the white painted surfaces created an aesthetically pleasing interplay with changing intensities of light and an impression of depth that made the structure seem almost alive.

The *fourth* and last success criteria: *to activate the user's attention and awareness, an abstract translated approach to the nature theme should be implemented.* To achieve a subliminal yet recognizable implementation of the nature theme, the *Attributive* and *Affective levels of perception* were stimulated by implementing an organic element (plywood), but balanced so it would not demand too much attention. This approach was implemented in both the light and the slats structure. The nature theme is seen in the movement and pattern of the light that is mimicking the reflective water surface. The changing in correlated colour temperature (CCT), going from *2,400 kelvin - 3,500 kelvin* during the day, is simulating a day with a sunrise in the morning, followed by the sunset in the evening. The structure can be translated to a hilly landscape or the wavy surface of moving water, where the light creates the depths that is also seen in Nature. All this together is designed as "*ambient information*", where for example colours and reflective patterns, taken directly from nature, could have come along as a design that would be too explicit.

A hospital is somewhere you go to get healed, treated and cared about. It should be a place where your body and mind can rest and rejuvenate, and where negative emotions can be forgotten for a while. For ages the hospitals have been sterile, cold and loud places, where the light is set mostly for counting the pills and changing the bedpans. But helped along by the organization *Planetree*, a more holistic approach to the healing process in hospitals has been developed. Suddenly beautiful artworks, calming colours and live plants and flowers were brought inside, which was seen to have a positive impact on the patient's healing process. Still, the light is an underappreciated medium, and one which can contribute to the already existing and growing awareness about creating a more comfortable environment.

With this thesis, a lighting design focusing on the interplay between light and materials has been developed for the hospital waiting area. When simultaneously implementing both light and structure into a space, an effect of synergy can be achieved, where we can re-discover the many capabilities of light. From there on it is hoped to see aesthetic lighting design being adopted and implemented in the healthcare sector.

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Appendix 1

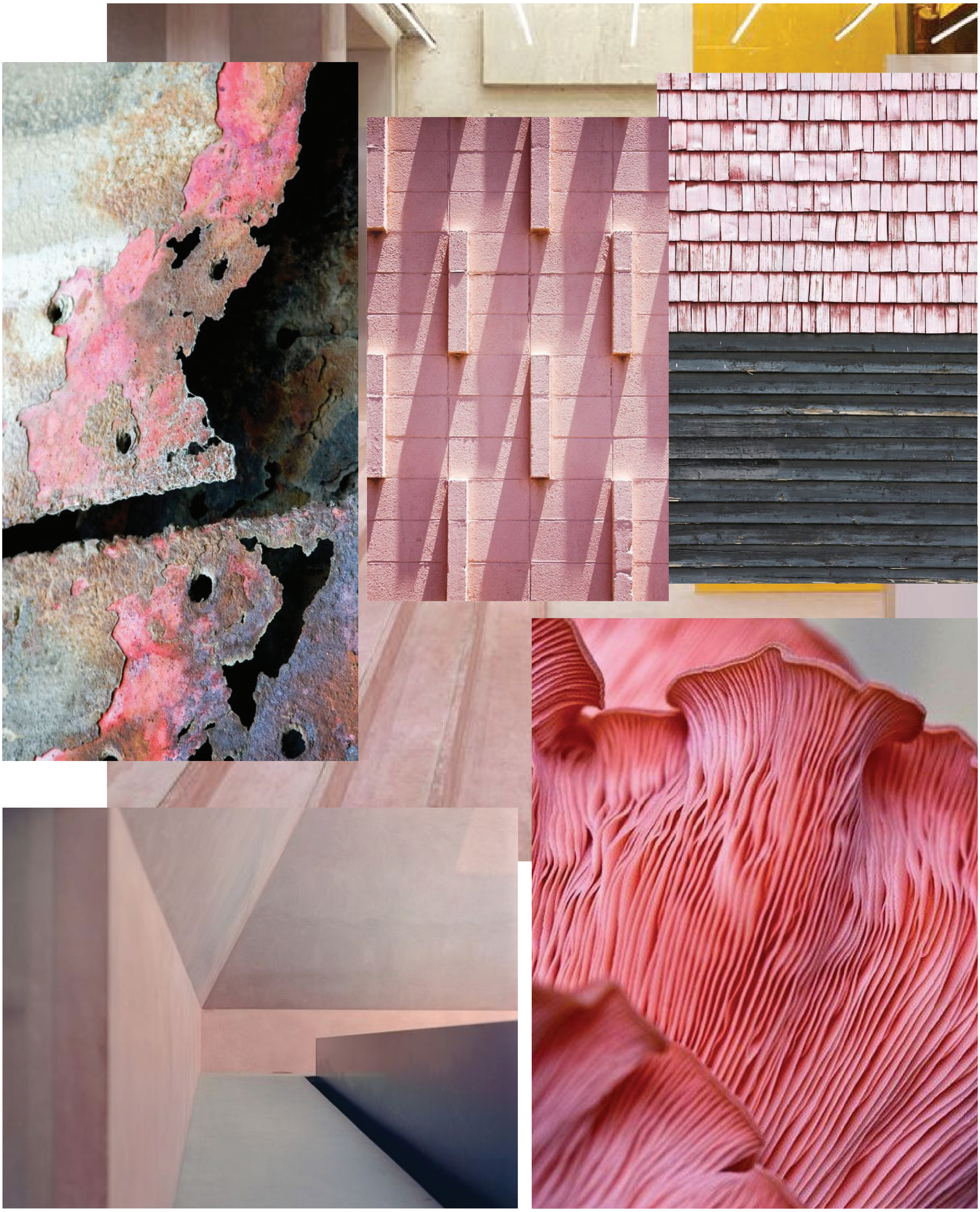
Type of interior, task or activity

Educational premises		$\bar{E}_m$	UGR_L	U_o	R_a
Nursery school, play school	Play rooms	300	22	0.40	80
	Nurseries	300	22	0.40	80
	Handicraft rooms	300	19	0.60	80
Educational buildings	Classrooms, tutorial rooms	300	19	0.60	80
	Classrooms for evening classes and adults education	500	19	0.60	80
	Lecture halls	500	19	0.60	80
	Black, green wallboards and whiteboards	500	19	0.70	80
	Demonstration tables	500	19	0.70	80
	Art rooms	500	19	0.60	80
	Art rooms in art schools	750	19	0.70	90
	Technical drawing rooms	750	16	0.70	80
	Practical rooms and laboratories	500	19	0.60	80
	Handicraft rooms	500	19	0.60	80
	Teaching workshops	500	19	0.60	80
	Music practice rooms	300	19	0.60	80
	Computer practice rooms (menu driven)	300	19	0.60	80
	Language laboratories	300	19	0.60	80
	Preparation rooms and workshops	500	22	0.60	80
	Entrance halls	200	22	0.40	80
	Circulation areas, corridors	100	25	0.40	80
	Stairs	150	25	0.40	80
	Student common rooms and assembly halls	200	22	0.40	80
	Teachers rooms	300	19	0.60	80
	Library: bookshelves	200	19	0.60	80
	Library: reading areas	500	19	0.60	80
	Stock rooms for teaching materials	100	25	0.40	80
	Sports halls, gymnasiums, swimming pools (general use)	300	22	0.60	80
	School canteens	200	22	0.40	80
	Kitchens	500	22	0.60	80
Health care premises					
Rooms for general use	Waiting rooms	200	22	0.40	80
	Corridors: during the day	100	22	0.40	80
	Corridors: cleaning	100	22	0.40	80
	Corridors: during the night	50	22	0.40	80
	Multiple-use corridors	200	22	0.60	80
	Day rooms	200	22	0.60	80

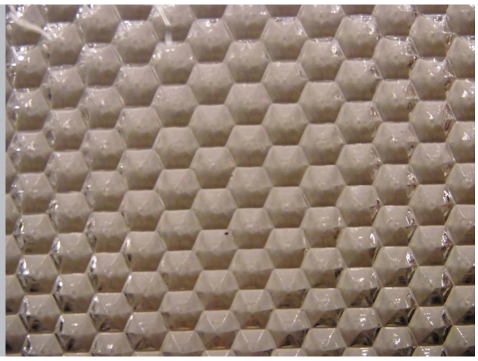
Type of interior, task or activity

		$\bar{E}_m$	UGR_L	U_o	R_a
Rooms for general use	Elevators, lifts for passengers and visitors	100	22	0.60	80
	Service lifts	200	22	0.60	80
Staff rooms	Staff offices	500	19	0.60	80
	Staff rooms	300	19	0.60	80
Wards, maternity wards	General lighting	100	19	0.40	80
	Reading lighting	300	19	0.70	80
	Simple examinations	300	19	0.60	80
	Examination and treatment	1000	19	0.70	90
	Night lighting, observation lighting	5	–	–	80
	Bathrooms and toilets for patients	200	22	0.40	80
Examination rooms (general)	General lighting	500	19	0.60	90
	Examination and treatment	1000	19	0.70	90
Eye examination rooms	General lighting	500	19	0.60	90
	Examination of the outer eye	1000	–	–	90
	Reading and colour vision tests with vision charts	500	16	0.70	90
Ear examination rooms	General lighting	500	19	0.60	90
	Ear examination	1000	–	–	90
Scanner rooms	General lighting	300	19	0.60	80
	Scanners with image enhancers and television systems	50	19	–	80
Delivery rooms	General lighting	300	19	0.60	80
	Examination and treatment	1000	19	0.70	80
Treatment rooms (general)	Dialysis	500	19	0.60	80
	Dermatology	500	19	0.60	90
	Endoscopy rooms	300	19	0.60	80
	Plaster rooms	500	19	0.60	80
	Medical baths	300	19	0.60	80
	Massage and radiotherapy	300	19	0.60	80
Operating areas	Pre-op and recovery rooms	500	19	0.60	90
	Operating theatres	1000	19	0.60	90
	Operating cavity			–	
Intensive care units	General lighting	100	19	0.60	90
	Simple examinations	300	19	0.60	90
	Examination and treatment	1000	19	0.70	90
	Night watch	20	19	–	90
Dentists	General lighting	500	19	0.60	90
	At the patient	1000	–	0.70	90
	Operating cavity	–	–	–	–
	White teeth matching	–	–	–	–

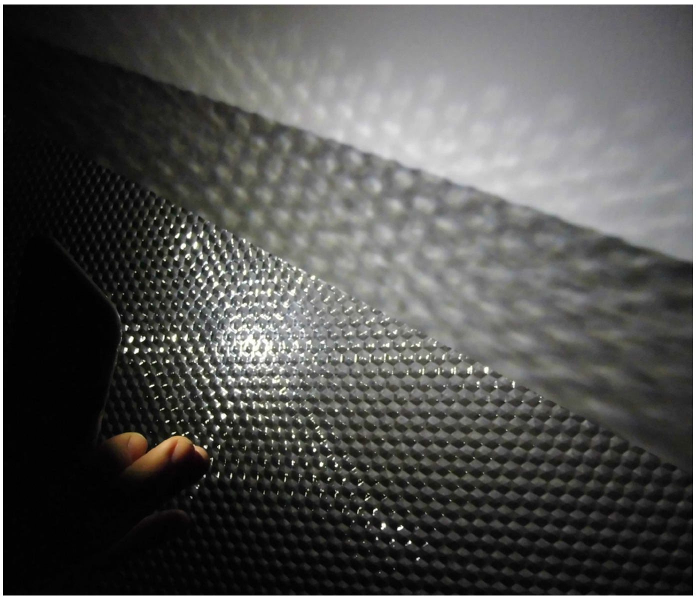
Appendix 2: Inspirational Moodboard

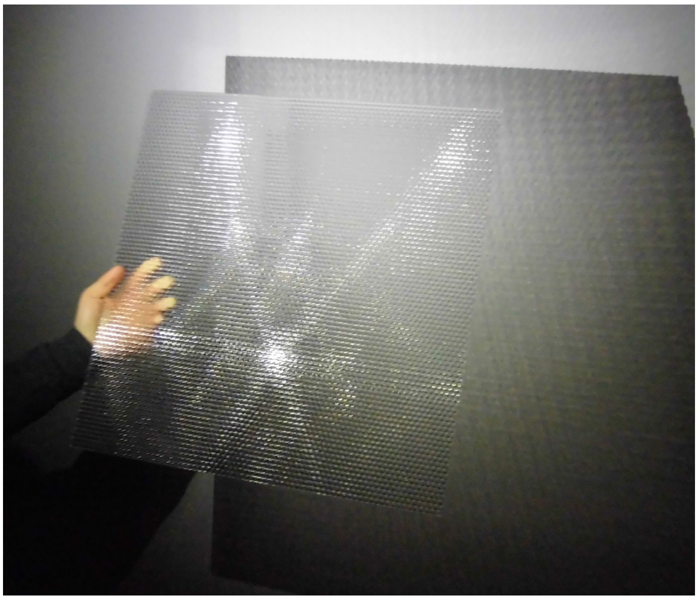


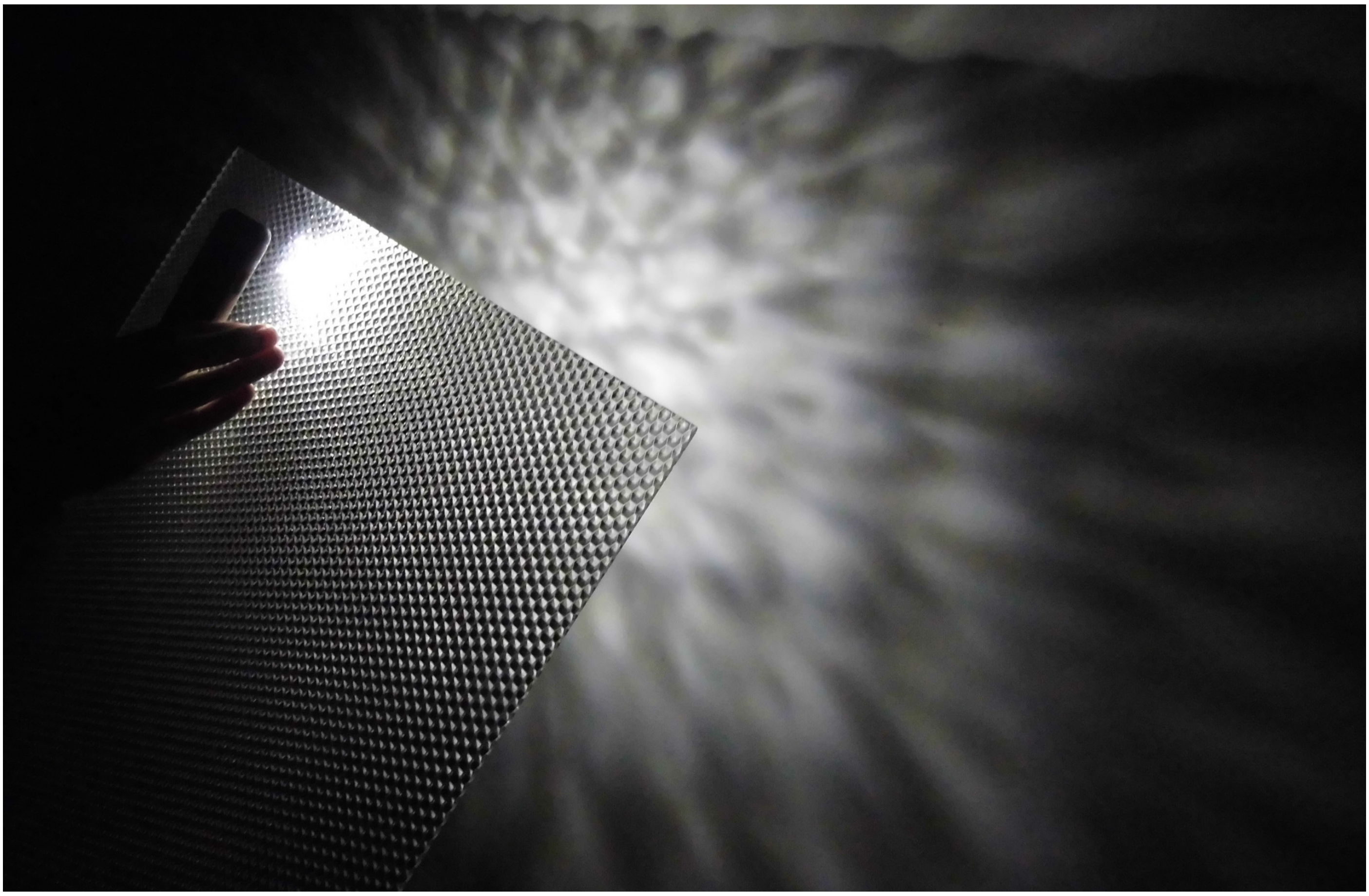
Acrylic prism big



Material Discription:
Thickness 4 mm
Hexagone pattern, clear, translucent
Reflectance: 25 %
Reflected light: Pleasing, sparkling, water look alike, layered

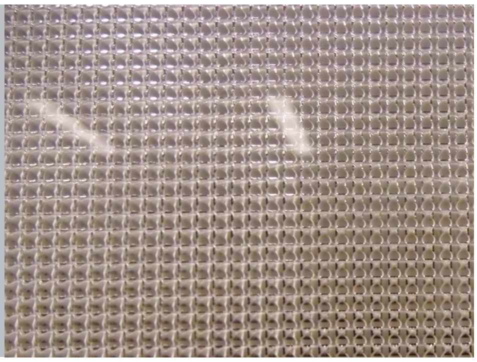


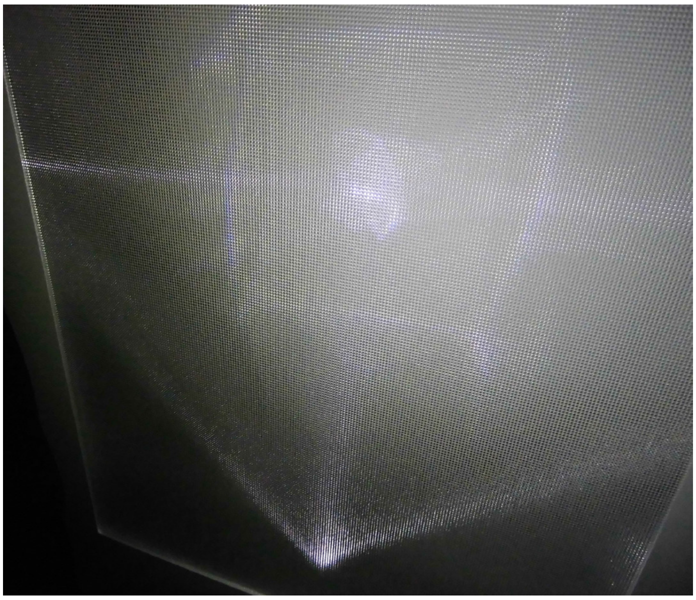


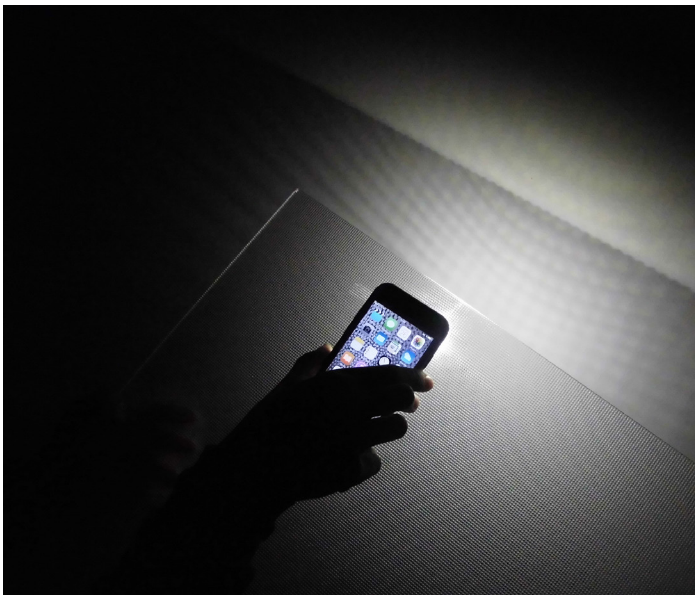


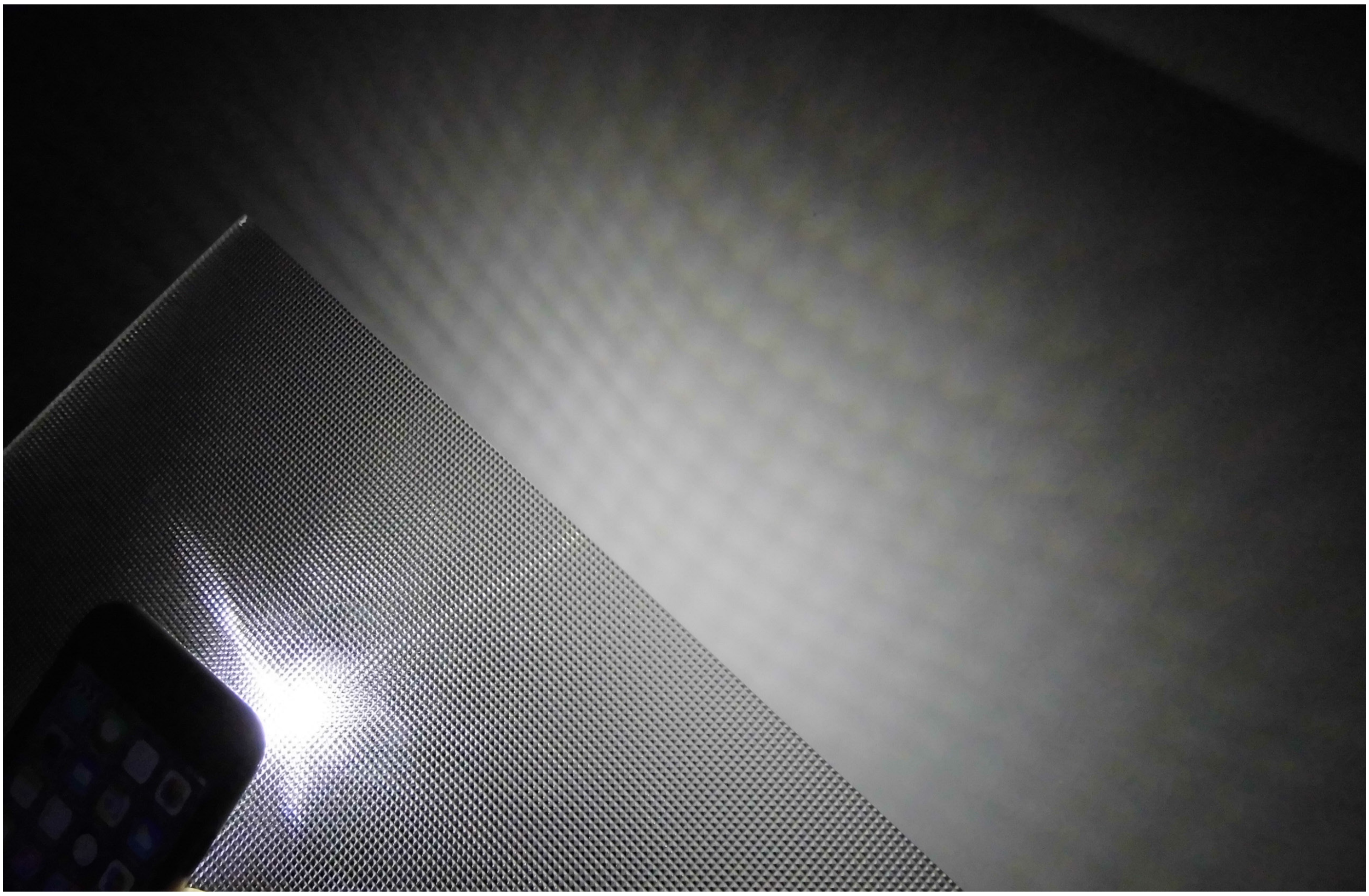
Acrylic prism small

Material Discription:
Thickness 3 mm
Squares pattern, clear, translucent
Reflectance: 30 %
Reflected light: Squared, lines, less sparkling





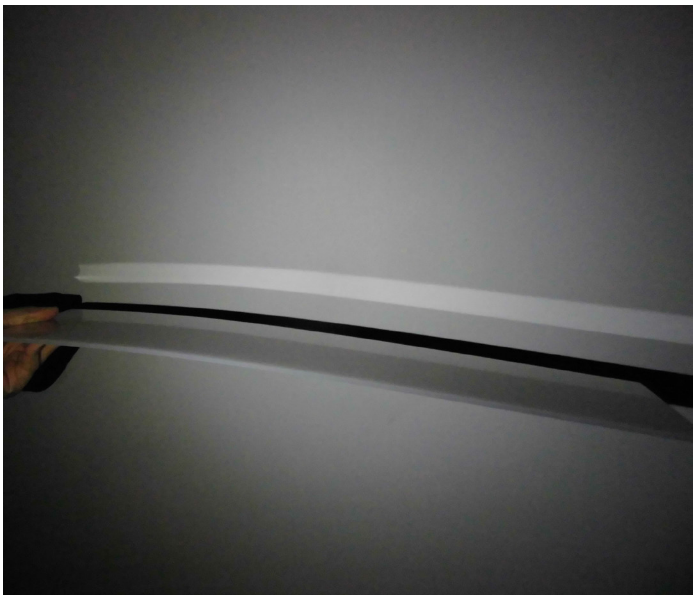


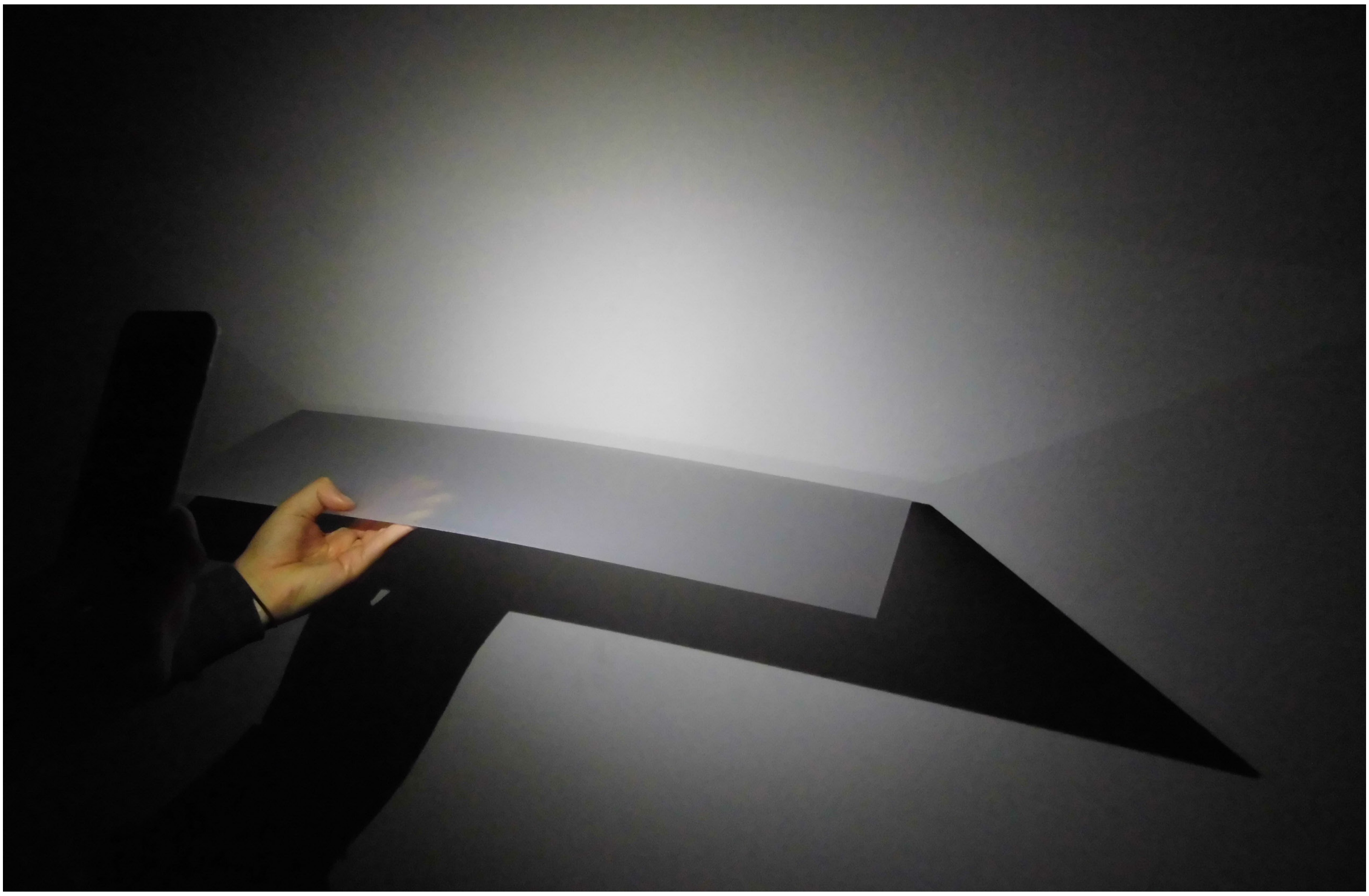


Acrylic milky white

Material Discription:

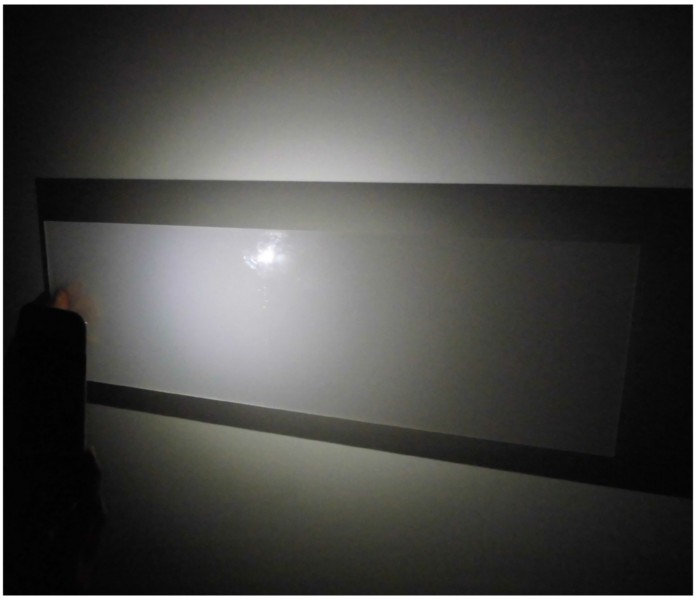
Thickness 3 mm
Matte reflectance on side/specular on other side, bit translucent, smooth surface
Reflectance: 26 % (specular side)
Reflected light: Reflects the shape of the material and surface

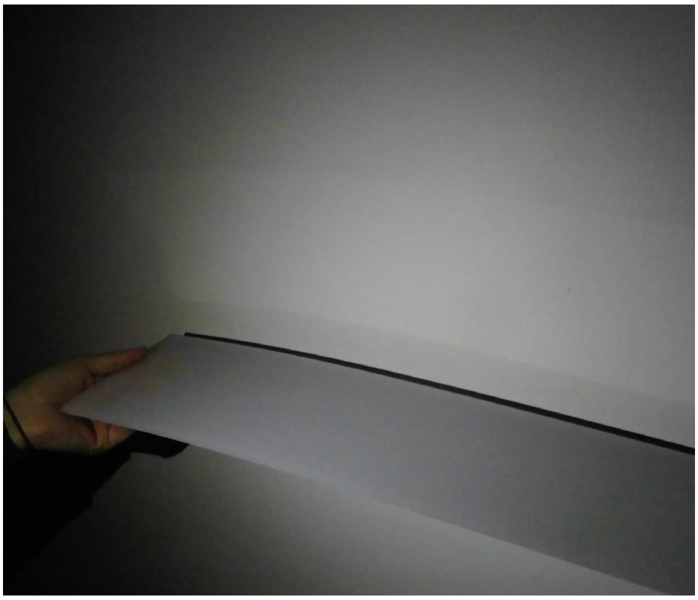




Acrylic white

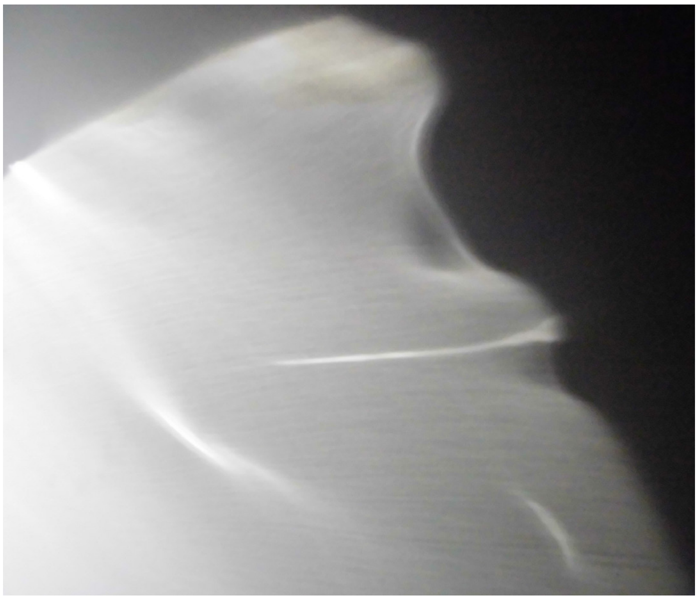
Material Discription:
Thickness 3 mm
Specular on both sides, not that translucent, smooth surface
Reflectance: 26 %
Reflected light: Reflects the shape of the material and surface





Aluminium specular

Material Discription:
Thickness 1 mm
Specular reflectance, bendable, smooth surface, silver color
Reflectance: 50 %
Reflected light: Different angles, shapes and edges creates
wavy pattern with different intensities



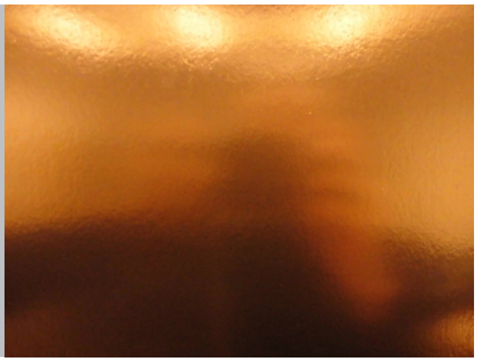
Aluminium matte

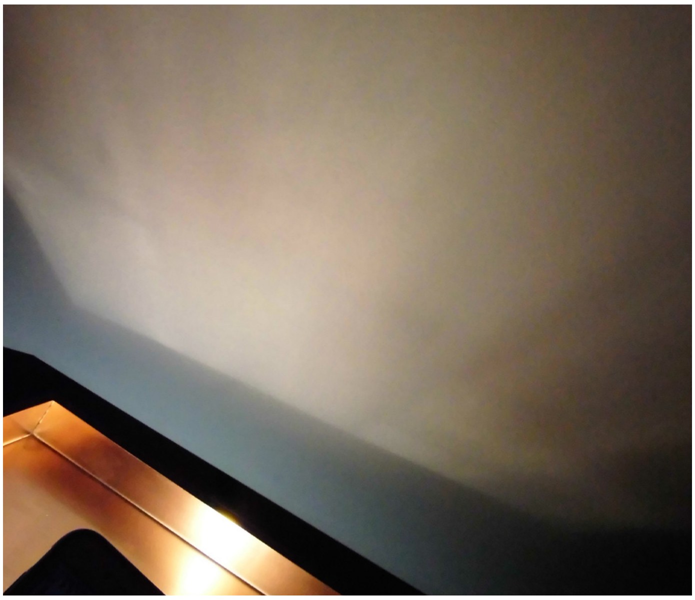
Material Discription:
Thickness 1 mm
Irregular reflectance, bendable, smooth surface, silver color
Reflectance: 28 %
Reflected light: No surface details, edges creates patterns

Copper matte

Material Discription:

Thickness 2 mm
Irregular reflectance, smooth reddish-orange color
Reflectance: 12 %
Reflected light: Reflects the material color, no surface detail, edges creates patterns

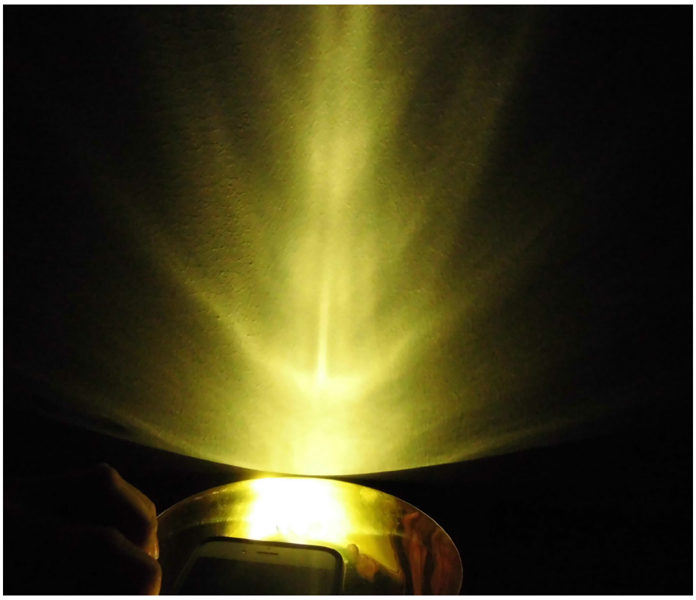


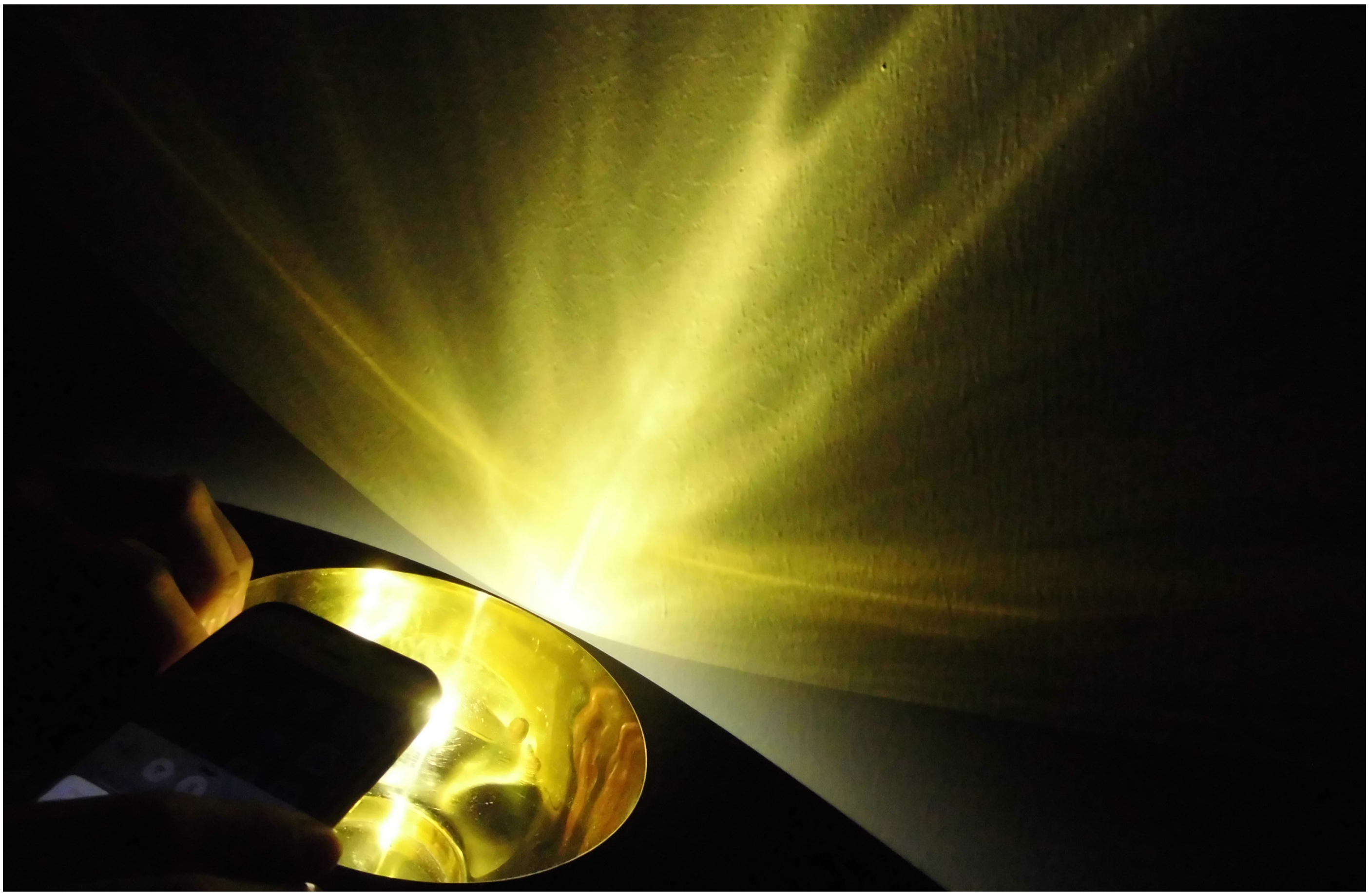


Brass specular

Material Discription:

Thickness 2 mm
Specular reflectance, round shape, smooth surface, gold color
Reflectance: 20 %
Reflected light: Shape creates surface patterns and reflects the material color





Mirror with patina

Material Discription:

Thickness 6 mm
Specular reflectance
Reflectance: 60 %
Reflected light: Reflects small details on mirror as shadows