LIVING WITH THE SUN

AN INVESTIGATION IN NATURAL LIGHT AND MULTI-SENSORY DESIGN | SAMUEL GRANDIN KARLSSON

LIVING WITH THE SUN

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ABSTRACT

The aim of this thesis is to explore the relationship between natural light and the built environment, by designing a mountain cabin without the use of any artificial lighting. How is it possible to make a house livable and functional without the use of any light sources besides the sun?

The thesis digs into the fundamentals of natural light. Why to use it and how to use it in architecture, with the help of lighting typologies and daylight simulations. To make the cabin livable even in the darkest hours of the day and year, multi-sensory design and design for low-vision are also investigated and implemented into the proposal.

To further explore how light and shade can be simulated and represented, the thesis applies a perception based evaluation method in the form of real-time rendering. This also brings an interactivity to the proposal where it is possible to move around freely and experience the building through different hours of the day and season.

The result is an interactive simulation of the proposal.

CONTENTS

INTRODUCTION

The starting point of this thesis was a competition I learned about called "The Home of Shadows". The brief was quite simple, design a home without any artificial light inside of it. What sparked my interest was the absurdity of it. How would it be possible to live in a building without any controllable lighting whatsoever, not even candles?

I started thinking about how and when I use artificial light and came to the conclusion that it was almost all the time, except for when I am asleep. However, even then there is a green LED-light glowing on the thermostat opposite the bed. I realized that I would have to change the way of living completely to adapt, or could my home adapt instead? Could my everyday activities be arranged and placed in such a way that I could always rely on the sun and sky to deliver adequate light?

I began researching natural light and how it is used in buildings to provide optimal lighting. However in a Swedish climate, when the sun sets at 14:00 in the winter, not even a house covered in glass would give sufficient light. There would have to be another way to navigate the home and do the daily activities.

This got me thinking of people with visual impairment. They often live ordinary lives in complete darkness. What kind of design principles are used to make their lives functional and livable? This led me into the field of multi-sensory design. Designing for more senses other than visual.

The last piece was in how to represent it all? How can the light inside the building be experienced without actually constructing it? There are many ways of analyzing light using two-dimensional simulations but I wanted to create a feedback loop where the design could be evaluated and altered based on the spacial experience of it. This is where real-time rendering came into play. By using a three-dimensional model and a simulated sun, the space and light in the building could be visualized without any delay in processing time.

All of these thoughts resulted in a submission to the competition and this thesis to dig into the subject even deeper. Where the first part is about my investigation of living without artificial lighting and the second about the final proposal. The result of which is an interactive simulation of the building where every day and hour of the year, in different seasons and weathers can be experienced in real-time.

Figure 1

My notes and sketches.

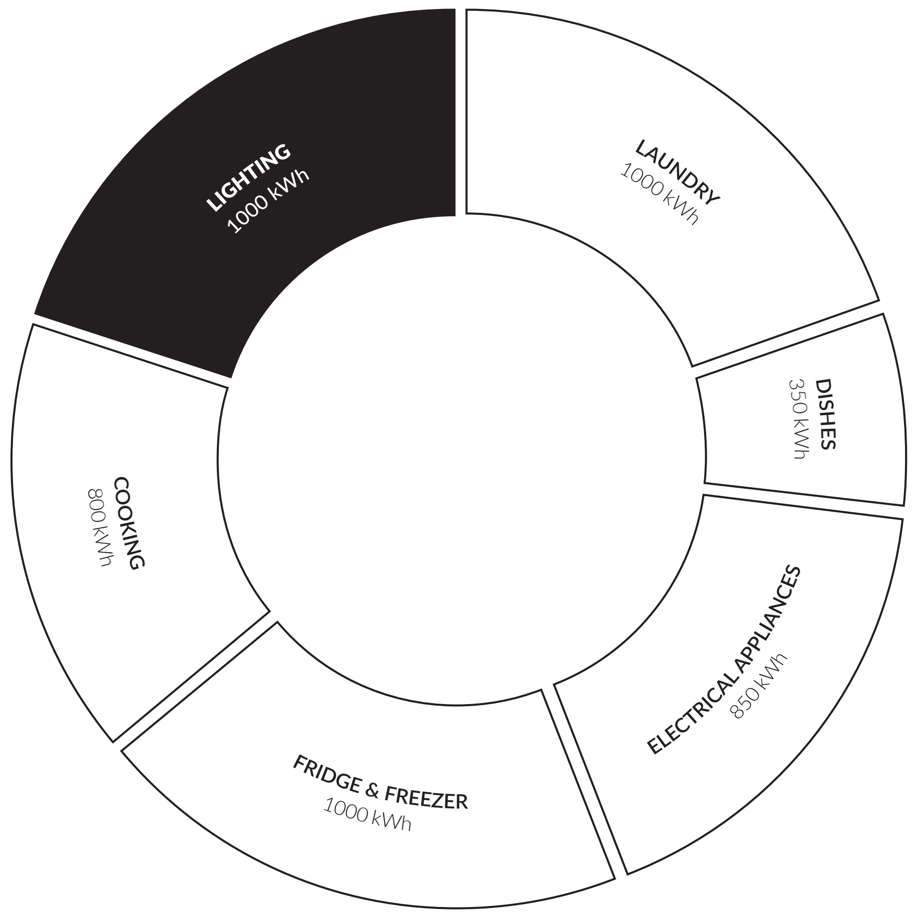
FRAMEWORK

ENERGY & ENVIRONMENT

In a world where energy demand keeps increasing as well as the price of it, resourcefulness has become even more important. The average energy consumption of artificial lighting in houses in Sweden accounts for about 20% of the household electricity (not including heating) (Bergmark, 2022). By designing for the use of natural light instead of artificial light this number can be reduced.

Artificial lighting also accounts for the increase in light pollution from cities. *Light pollution* is a phenomenon where the electrical light from mostly urban areas brighten the sky during night. This affects both people and animals, as the day and night cycle of our brains become disrupted. This cycle is also referred to as the *circadian rhythm* and a disruption of it can in worst cases make humans more fatigued, stressed and sleep deprived. Whilst animals have their migration patterns disrupted as well as their *circadian rhythm*. This leads to problems within the eco-system since animals and insects can end up in other eco-systems or cities. (National Geographic, 2022)

Figure 2



Average electricity consumption for a residential household in Sweden.

THE GLASS BOX

To create a house with enough light during the daytime is not a challenge when the framework is undefined. The house could be glazed all over and all would be well. The maximum amount of daylight would be received. During night, a glass box would also maximize the light received from the stars, moon and light pollution. It is perfect for the aim of not using any artificial lighting. However...
The living conditions in such a box would most likely be miserable. With poor insulation during the winter and with a greenhouse effect during the summer. Offering no privacy, the visitors become completely visible to watchers passing by.

Figure 3

Glass House/Johnson House (1949), New Canaan, Connecticut - Philip Johnson

FRAMEWORK

A DARK HOME

Before electrical light was invented humans were reliant on fire to be able to see in the dark. With the invention of the light bulb came the freedom to choose whenever we wanted to have adequate lighting. It could be daytime all the time if we so wished. With this freedom came both possibilities and challenges. To explore these possibilities and challenges no other source of light will be used in the thesis investigation besides the natural light from the sky. This, with the aim to find out more about how the relationship between artificial light sources and the built environment affect our daily lives. How is the lifestyle of the inhabitants affected by having a completely dark home during the morning, evening and night? Is it possible to make a home both livable and functional?

The benefits of living with the natural cycle of the sun are many, humans are still biologically mostly the same as we were 100,000 years ago. We have evolved to live with the natural cycle of the sun and is since the most natural state for our bodies and brain to be in. Studies have shown that we are less tired and less sick when we are not using artificial light sources as much (Fridell Antler & Klarén, 2017). The geographical location has an impact on this study however. As living with the natural cycle of the sun in Sweden for example, has certain downsides. The long nights in the winter and long days in the summer are a disruption to the way we evolved to live around the equator. The challenge of designing a livable house without the use of artificial lighting in Sweden is to make the benefits of the daylight that is received outweigh the drawbacks, and to minimize the negative impact of the darkness on function.

Historically fires and candles have been used in Swedish homes to combat the darkness. For the sake of investigating the relationship between artificial lighting, with the freedom of choosing when and where to have light, and natural lighting where humans have to conform to what the sun offers. I have not allowed myself to use any artificial light source including fire. An extreme way of life according to both historical and modern standards.

What ordinary tasks become difficult when you can't see? How can spaces and furniture adapt to the darkness to accommodate all the basic functions we take for granted?

Figure 4

Sunset in the north of Sweden.

REAL-TIME RENDERING

Recent technological leaps within computer rendering of images have led to the possibility of doing photorealistic simulations in real time. Before, it could take several hours for just one image to be produced in high resolution and now it is possible to produce over 100 images in just one second. This brings the possibility of visualizing as well as experiencing space and light in real time referred to as *real-time rendering*.

Visualizing the effects of design on lighting is now much easier than before, having access to the result of the design almost instantly and being able to walk around in it and see how the light reacts to the space, what type of shadows are created. This is something traditional daylight simulations have trouble showing, where light is analyzed in a two-dimensional plane. Traditional daylight simulation is good for estimating daylight conditions but can not provide a result based on the individual experience of the lighting condition, which brings a problem and risk of designing spaces that are well lit but with a dull atmosphere. This is something that real-time rendering analysis and simulation can help with and work as a complement to the two-dimensional analysis.

Using *single frame renderings* (render as a single image) as a means of visualizing space can often be misleading. Still views are much easier to fake to sell a project since the geometry only has to look correct from one angle. It could be adding fake lights to the scene, or shifting walls or windows to better the lighting or views. Often times the temporal aspect gets overlooked and the turn of seasons, time and activities ignored. By not framing a single point in time and angle of the building, but instead showing it as it is reacting to seasons, weather and time, a more honest presentation of it can hopefully be achieved.

FRAMEWORK


Figure 5

Single frame render to the left. Real photograph to the right.

AIM

There are several layers to this thesis that aim to explore and combine into the result, a design proposal for a mountain cabin in northern Sweden.

Layer 1 - Natural Light

To use natural light in order to create a comfortable environment indoors during daytime, nighttime and with the turn of seasons. No artificial lighting is to be used.

Layer 2 - Sensory Design

To use multi-sensory design to make the home functional to navigate through in the dark.

Layer 3 - Design for Darkness

To reinforce functionality for everyday activities in darkness without making them more difficult.

Layer 4 - Representation

How to accurately represent the lighting and temporal aspects of the building without constructing it in reality.

All of these layers are weaved into two overarching questions:

What needs to be considered in designing a livable and functional house without the use of any artificial light? And how could it be implemented into a proposal?

METHOD

The method is divided into four main steps. The first being the research of natural light, how it is used in buildings and the physical aspects of it compared to artificial light. This will be complemented with daylight simulations and typologies of daylighting design.

Sensory design focuses on how the five human senses can be implemented practically to a building to heighten the experience of it and to increase the understanding of the space without the use of the visual sense.

Design for darkness focuses on the use of design for blindness to also improve the functionality and navigation of the building. This is done by looking at how low-vision accessibility is implemented in urban contexts and scaling it down, using haptic design principles.

The last step is the representation and application of the previous ones. By creating a real-time simulation of the proposal using Unreal Engine, the temporal and spacial characteristics of the building can be experienced without building it in reality.

LIMITATIONS

To have some limitations within the design of the building, I will use the guidelines of the competition "THE HOME OF SHADOWS" held by Buildner as a base. The guidelines state that the building should be a house for a couple but with one rule; that there can be no artificial light within the home. At the end of May the final design will be submitted to the competition.

The proposal will use the findings from the theory part of the thesis in it's design. However, not all of the findings will be used in the proposal. The theory part should be viewed as a general framework for the design and not as a part of the process.

DEFINITION

Natural light is within the framework of this thesis defined as the light that comes directly from the sky, in the shape of sunlight, moonlight, starlight and Aurora Borealis. It can be argued that other sources of light also can be considered natural and that unnatural light is restricted to the artificial light produced by human interaction. For the sake of this thesis to focus on the relationship between the everyday life of humans and artificial light, I have chosen to not include other natural sources such as fires and bio-luminescence. With the purpose of not making this thesis into a task of finding alternative light sources to electrical light.

The use of natural light has always exceeded its necessity for humans, at least in practical terms. It has become something more than just a tool for sight. It has a spiritual function in our lives, at it's extreme, it is the essence of mysticism and sacredness. In the daily life it is the comfort and source of energy. Natural light has shaped our bodies through evolution and become a necessity for our wellbeing. To understand our close connection to natural light we first need to understand what it is.


Figure 6

Sunlight

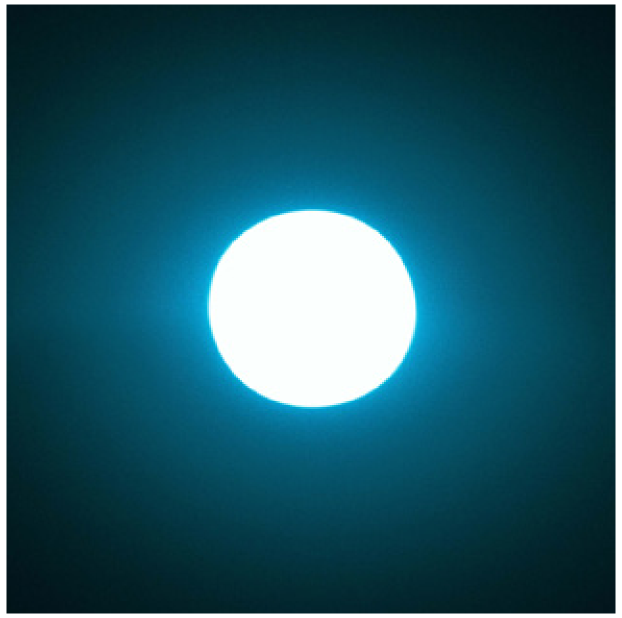


Figure 7

Moonlight


Figure 8

Starlight

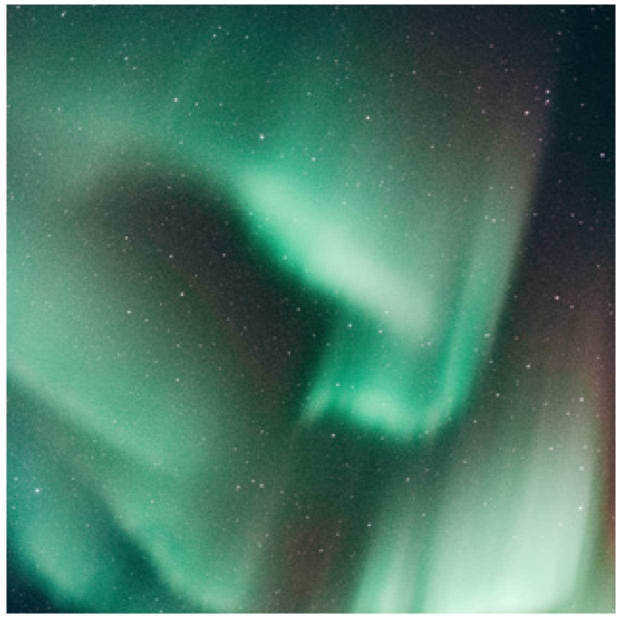


Figure 9

Aurora Borealis

DAYLIGHT & MATERIALS

Light & Color

Light is understood as having the properties of a wave and particle simultaneously, referred to as a photon. It exists in different wavelengths which radiate energy in varying sizes. Daylight is what has evolved the human eye to see the world. It is therefore in daylight that we can find all the colors that humans are able to perceive. The color of an object is determined by the energy and frequency of the light wave that hits the object. The brain then processes the light that is reflected from the object and then determines it's color. It is therefore differently interpreted between individuals and species. (Dubois et.al, 2019)

Reflectance

Another aspect that determines how we perceive light is a material's reflectivity. When light hits the surface of a material it is reflected into our eyes, thus making us see it. Every material has its own reflective properties where it reacts differently to distinct wavelengths. This property is often defined by the micro-surface of the material and the angle in which the light enters. A metal surface is smoother than a wooden one and will therefore be more reflective, since there are less protruding molecules that block the light. This can be divided into types of reflectance, *diffuse* and *specular*. Diffuse surfaces reflect light in many directions due to the irregularity of the surface, while specular surfaces reflect light in one direction only, like a mirror. (Zajac & Hecht, 2003)

Refractivity

When light hits a surface it can not only be reflected back but also pass through it. When the light goes through the material it's direction gets shifted. How much it gets shifted is determined by the materials *refractive index*. This index is measured using light with a wavelength of 589 nanometers, this is because the refractivity varies depending on the wavelength but also on the material's temperature, pressure and purity if it is a composite. The refractivity is mostly relevant for translucent materials such as glass and polycarbonate. If the material absorbs light it appears black. (Zajac & Hecht, 2003)

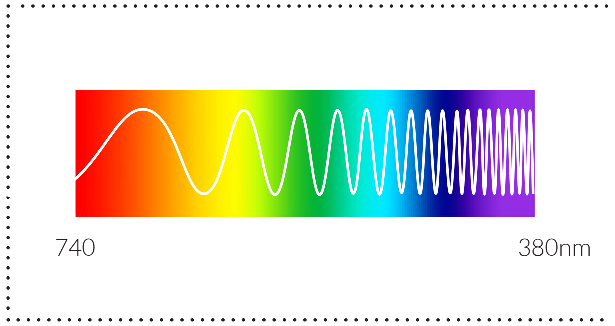


Figure 10

The visible spectrum of light, ranging from 740nm to 380nm.

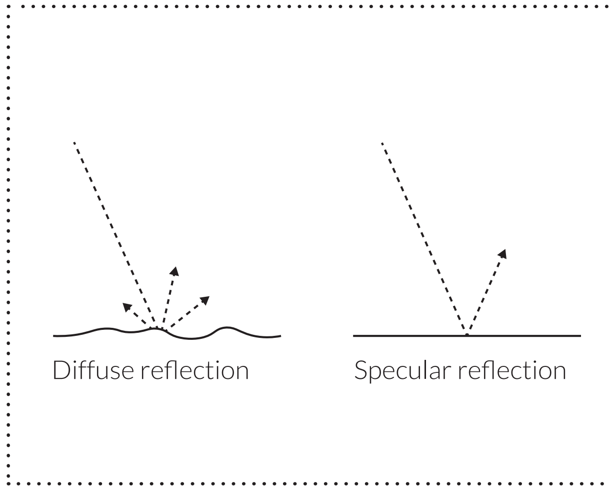


Figure 11

Irregular surfaces create a diffuse reflection. Flat surfaces create a specular reflection.

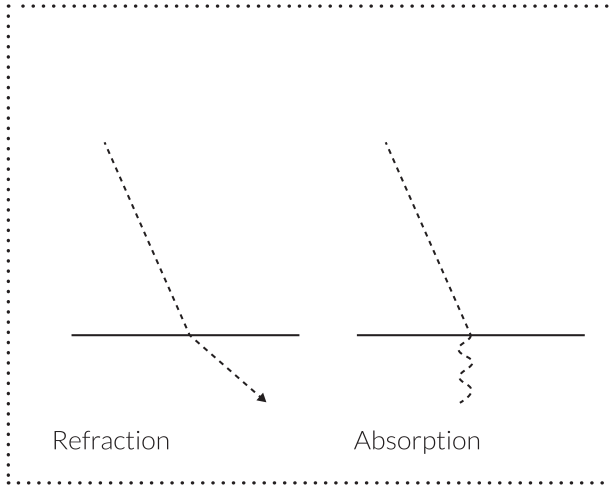


Figure 12

Refracted light changes it's course. Absorbed light does not reflect back or go through the material.

IMPORTANCE FOR HUMANS

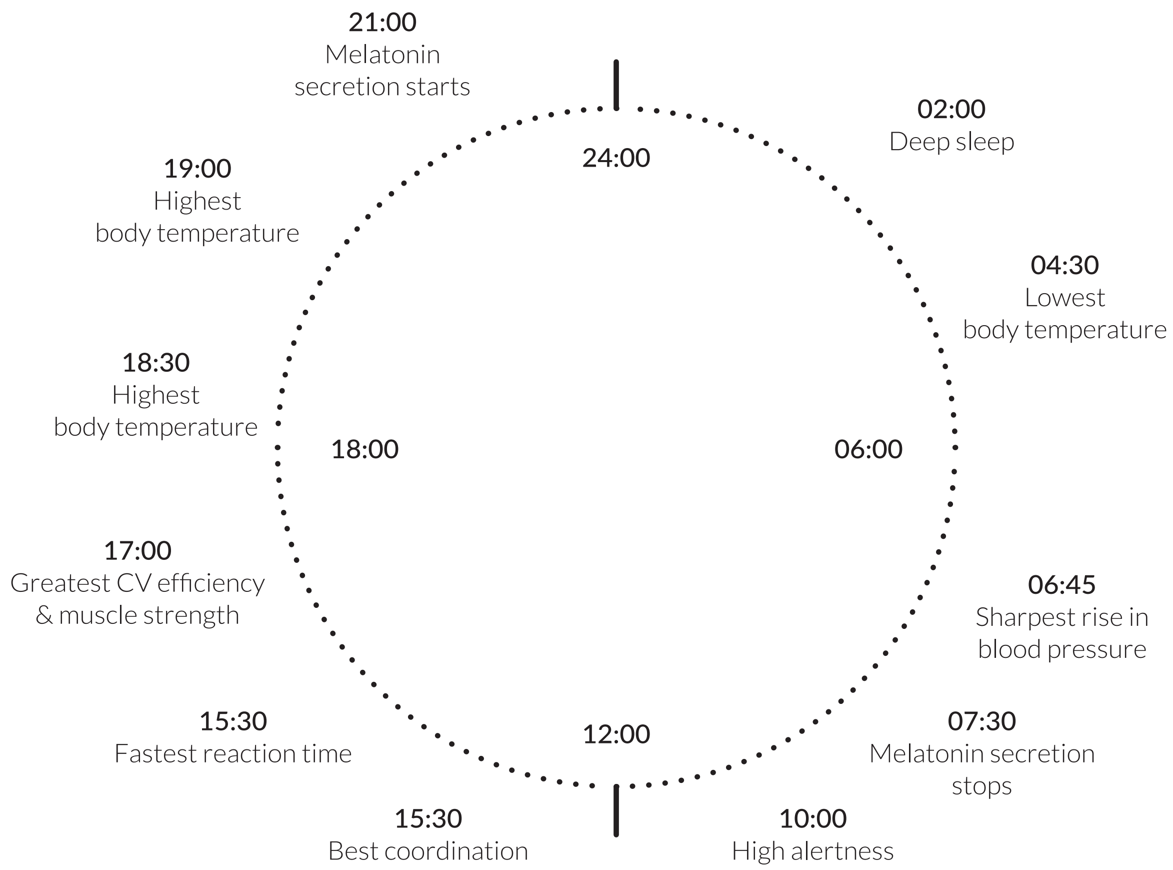
Despite the fact that we have evolved to live our life outdoors, in the modern world we spend 90% of our time indoors (Dubois et.al, 2019). This means that we do not get exposed to as much daylight as we need to for our health and well-being, and our risk for illness is much higher. Living with the natural cycle of the sun means that you are following your *circadian rhythm*, which means that you sleep when it is dark and are awake when there is light. This has shown to produce less stress and less tiredness. When we are looking at screens that produce a very bright blue light during the night, the brain gets tricked thinking it should be awake. The circadian rhythm gets disrupted. Having natural light when it's possible makes it much easier for the brain to adapt to the circadian rhythm. (Dubois et.al, 2019)

Natural light also produces a much better performance visually than electric lighting, this is due to the fact that it is much more intense in energy. If there is a good natural light intake in a room you should not notice if a lamp is turned on or off, because the sunlight is enough. This makes it possible to save energy turning off electrical lights while keeping the light performance in the room.

Experiencing the dynamics of natural light during the day is not only good for our circadian rhythm but also our visual interest. Having a dynamic light and shade environment around you have shown to increase productivity and happiness (Dubois et.al, 2019). It also helps with navigation and the understanding of spaces when lit from varying angles during the day, as you are observing the shadows when they move through the space. Daylight not only benefits our visual sense and mental health but just like plants live of the energy radiated from sunlight, humans also have non-visual ways of benefiting from it biologically. The production of hormones for example is dependent on natural light. (Dubois et.al, 2019)

NATURAL LIGHT

Figure 13



The circadian rhythm in humans.

PERCEPTION OF LIGHT

Glare

When the contrast in brightness is too high within the visual field it becomes discomforting or even disabling. This is referred to as *glare*. An example is when you are looking at a computer screen with a large window behind it (Dubois et.al, 2019). It can also be when materials with high reflectivity receive light and reflects it back giving off a blinding light. Glare can be reduced by lowering the contrast in various ways, such as making the surface around the glare brighter or shaping it with a gradual transition instead of an abrupt end.

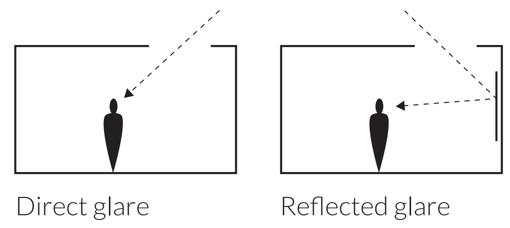
Adaptation

The human eye can adapt to light in different ways. These are called *photopic*, *mesopic* and *scotopic* adaptation. Where in a photopic state the eye is adapted for daylight and interior lighting. The mesopic state is where the light level drops, for example outdoor lighting after dark. The last state, scotopic, is when the light is very faint. Such as with moonlight. In this state the eye loses it's function to see any color. (Dubois et.al, 2019)

The time period it takes for the eye to adapt is referred to as transient adaptation. In this state, the eye has trouble adapting to the light or dark and you have an impaired vision. Going from a bright space to a dark one takes about 30 minutes to adapt to. Whereas going from dark to light is almost instantaneous. There is no visual blindness. This is a problem when entering buildings during sunny days, where you get temporarily blinded. It could be partly prevented by having covered walkways before the entrance so that the eye has time to adapt slowly. (Dubois et.al, 2019)

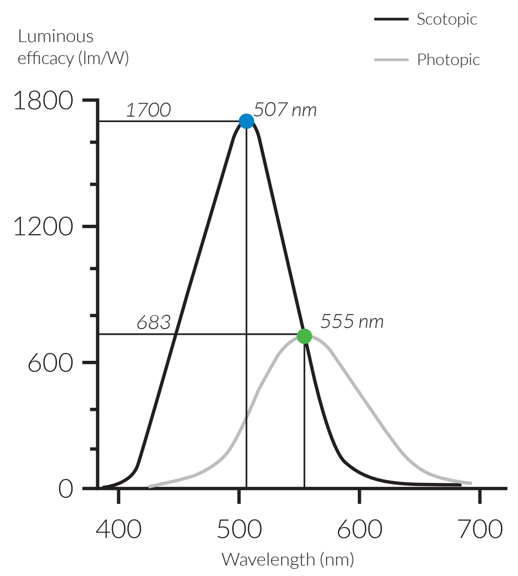
In this thesis the adaptation is an important element when designing with no artificial lighting. Details that aren't noticed in daylight could be the only things noticed in the dark and vital to be able to navigate a room.

Figure 14



Direct and reflected glare. The direct glare comes from looking out a window while the indirect one might be reflected light on a metal surface or mirror.

Figure 15



Adaption states sensitivity. In the scotopic state,the peak sensitivity is blue color which explains why it's easier to see in the dark. In the photopic state the eyes are most sensitive to green color, like plants.

LIGHT SOURCES

Definition

As mentioned before artificial light can be defined in various ways but in this thesis it is defined as all light that is not coming from the sky. Light from fires and bio-luminescence will not be discussed but instead limit artificial light to electrical light.

Incandescent and halogen lamps

Modern electrical light sources function in a wide variety of ways. There are for example *incandescent lamps*, *halogen lamps*, *LED-lights* and *fluorescent lamps*. Incandescent and halogen lamps work by running electricity through a tungsten filament wire which then radiates light. 90% of the of the energy emitted is in the infrared spectrum or with other words, heat. This is highly inefficient which is why most incandescent and halogen light sources have been replaced by LED-lamps today. (Dubois et.al, 2019)

LED-lights

LED stands for *Light-Emitting Diode* and works by having two semi-conductors, one with an excess in electrons and one with an excess in holes. The electrons move from one to another when a current is applied to the conductor's diode and energy is released in the form of photons. This phenomenon is referred to as electro-luminescence. Using LED-lights instead of incandescent light bulbs can increase efficiency from 9 lm/W to 150/ lm/W in *luminous efficacy*. This is a drastic improvement that makes it possible to use electrical lights without a significant energy loss. (Dubois et.al, 2019)

Fluorescent Lights

Fluorescent lights are made up of a gas and discharge technology. Mercury vapors and electrons are passing through a glass tube where the electrons excite the vapor which emit radiation. Fluorescent light radiate in singular wavelengths that causes flicker, which will be discussed on the following page. Compared to the other light sources fluorescent lights have an luminous efficacy of 70-90 lm/W which lands it somewhere in the middle. (Dubois et.al, 2019)

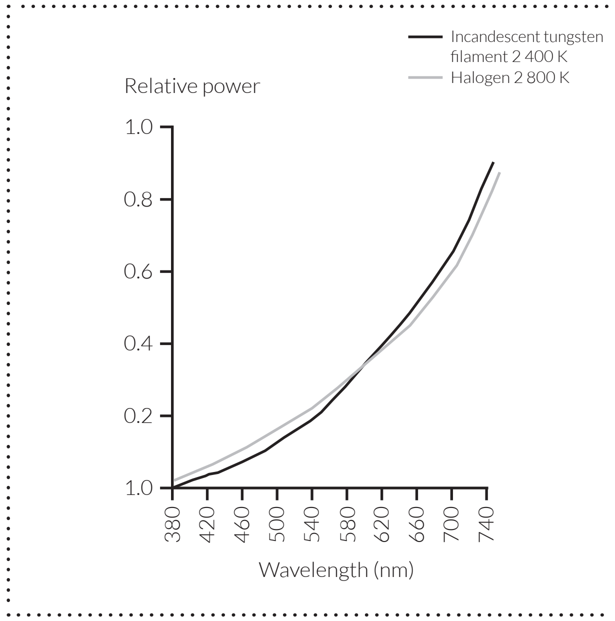


Figure 16

Spectral Power Distribution (SPD) of Incandescent and halogen lamps. High relative power in the low spectrum makes it glow yellow.

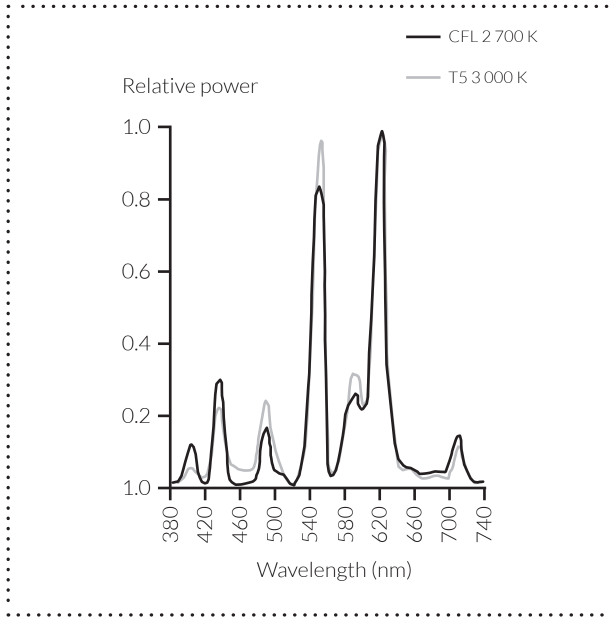


Figure 17

Spectral Power Distribution (SPD) of fluorescent lamps.

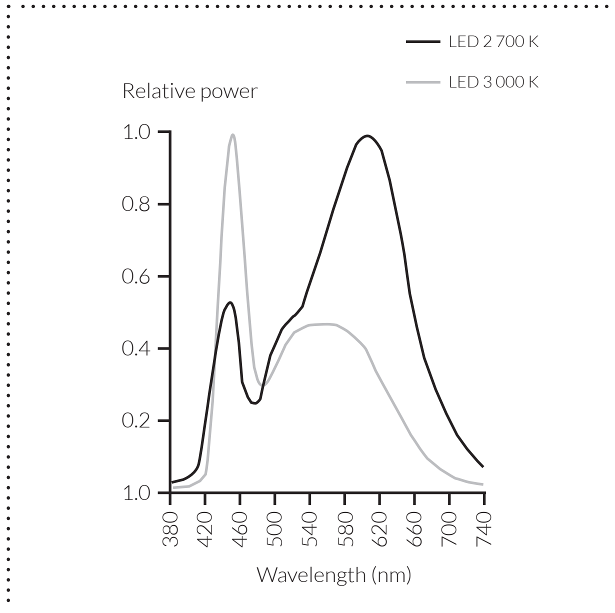


Figure 18

Spectral Power Distribution (SPD) of LED lamps.

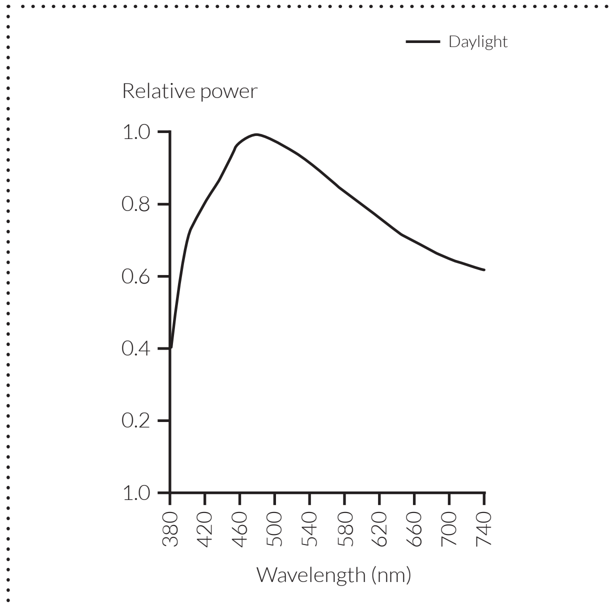


Figure 19

Spectral Power Distribution (SPD) of daylight. Daylight shows the most colors for the human eye.

ELECTRICAL LIGHT

DRAWBACKS OF ELECTRICAL LIGHT

Flicker

Flickering light can develop when a light source is powered by a fluctuating signal. This means that the light switches between on and off rapidly, often not visible to humans. However it has been shown that flickering has very negative effects on our brain, causing stress, headaches and tiredness. The most common light source to cause flicker is fluorescent light, there are ways of controlling this flicker, however indications have shown that LED-lights may also flicker. Which is a reason not to use them as much even though they are energy effective. (Fridell Antler & Klarén, 2017)

Constant light

As previously mentioned, being exposed to the dynamic changes of natural light has a great significance for our health and well-being. Although electrical light sources have the possibility of being placed anywhere, turned on/off at anytime and also the ability to change color and intensity dynamically. They are still far from being able to replicate the dynamic variability that natural light produces, in *luminous power*, positioning and change of season.

Light pollution

When there are many artificial light sources the combined luminous power becomes so strong that it causes light pollution, which can disrupt the biological functions of humans and animals. It also hides the sky during night because our eyes adapt to the light from the artificial light sources instead. We are in the mesopic adaption state instead of the scotopic.

Turning off the light

Removing all artificial light sources from the building will make living in it a much more dynamic and temporal experience. You will not be able to use light when you need it but instead have to rely on the changes in natural light to plan your daily activities. A downside to the removal of artificial light is that potentially more windows are needed to let in light from different angles, thus creating a higher risk for *glare*. The possibility to pull down blinds to shade from harsh sunlight while keeping a lamp on to do regular activities is also removed.

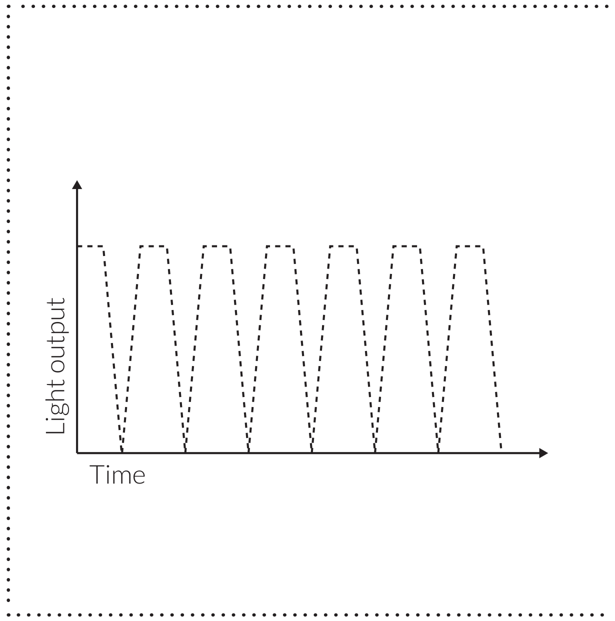


Figure 20

The light output is fluctuating in a constant pattern over time causing flicker.

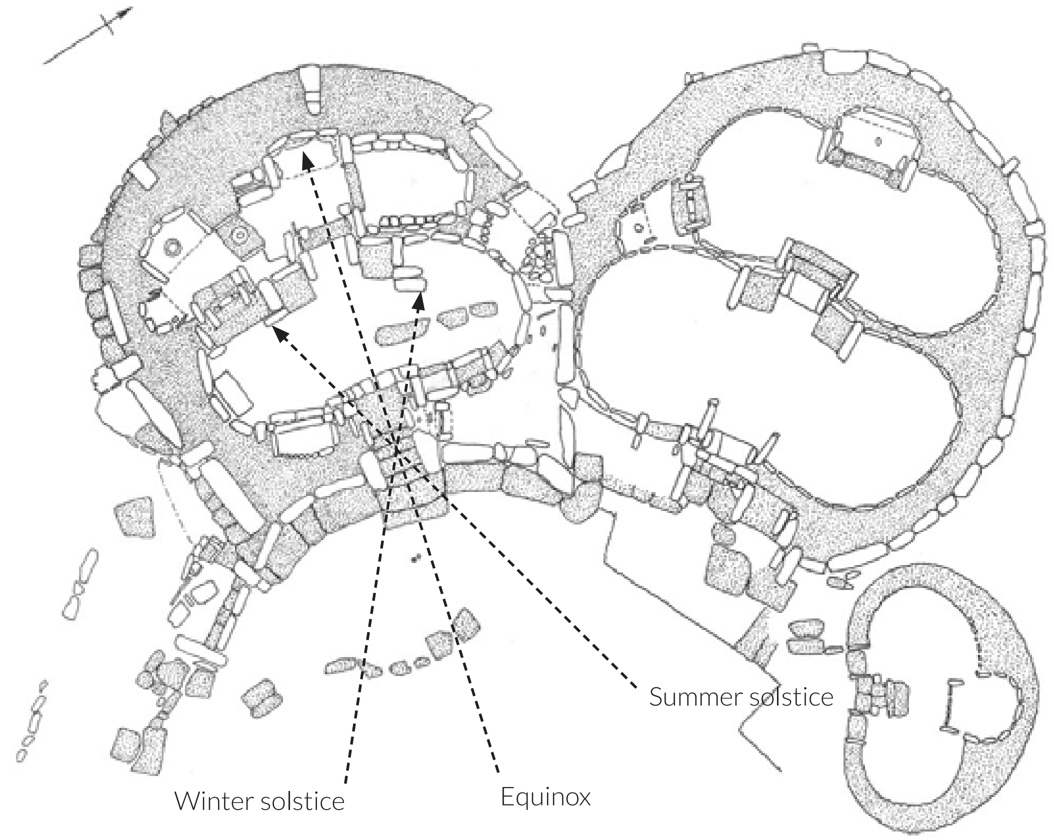
HISTORY

Designing with natural light has historically been of higher importance in more significant places such as palaces and religious buildings. As far back as the antique the pantheon utilized an oculus in the ceiling to let in natural light with a spiritual purpose, that also served as a calendar (Dubois et.al, 2019).

For as long as homo-sapiens have walked the earth we have lived with the changing of the light and dark. It has been of great importance and always been one of the key foundations for religion. For thousands of years buildings have been affected by how they receive daylight in the way that they are designed. It can be strategically placed openings to let in light in a way that is considered spiritual or it could be to mark important dates with precise direction of the light, such as in the temple Mnajdra (c.3600 BC–c.3200 BC) on Malta which is using astronomical alignment to the solstices as a way of orientating the temple. Important dates for the users of the temple. Even the stars have been argued to make out the alignment of temples such as on Malta (Lomsdalen, 2015).

For regular people and their homes, daylight conditions has been in a conflict with comfort. Looking at vernacular architecture the window serves as an opening for ventilation as much as an opening for light. The days were spent outside when the sun was up so the need for light inside was less necessary than it is today. A window also brought in cold and was best not to being too large.

Figure 21



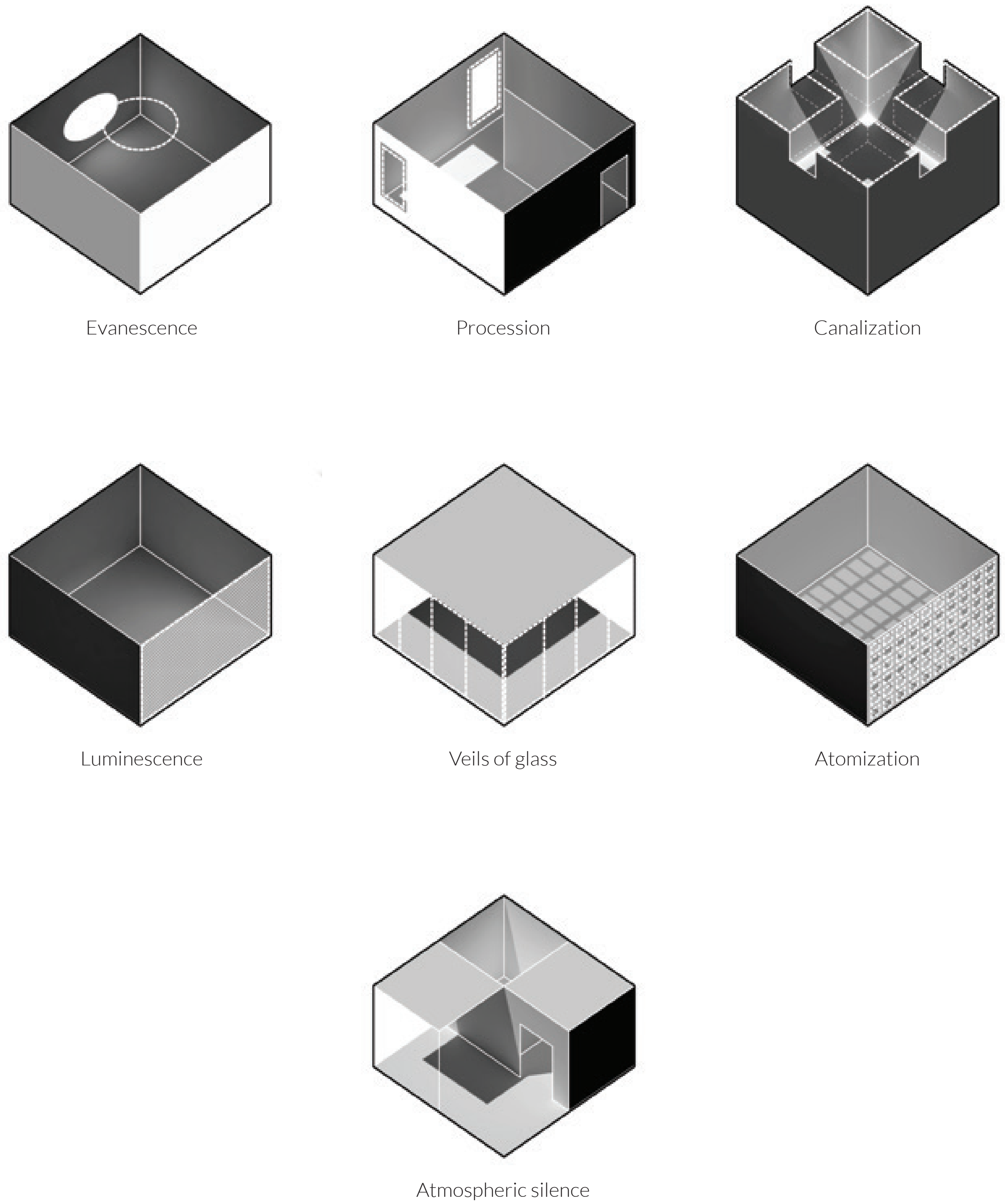
The Mnajdra using astronomical alignment. During the equinox the sun lights up the temple through the main hallway.

DESIGN FOR LIGHT

LIGHTING TYPOLOGIES

There are many ways of designing with daylight in mind. Henry Plummer writes in his book “The Architecture of Natural Light” (Plummer, 2009) about seven typologies in designing for natural light. There are possibilities to create more typologies but I found these to cover the foundation and the essence of design for natural light. The typologies will be explained more in detail in on the following pages. They consist of seven different ways of placing, shaping and materializing openings, referred to as *evanescence, procession, canalization, luminescence, veils of glass, atomization and atmospheric silence.* These typologies are supposed to be a foundation for an aware design process when dealing with natural light. There are however other aspects, such as view that are not the main focus of these typologies but can be highly influential in the decision of opening placement.

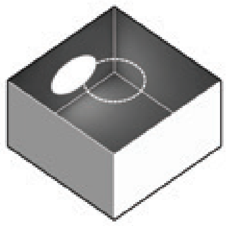
Figure 22



My interpretation of the lightning typologies described by Henry Plummer.

Figure 23

Koshino House (1984), Ashiya-Shi ,Japan - Tadao Ando



Evanescence

Evanescence is described as the orchestration of light to mutate through time. It is to design with a temporal mindset, where time and seasons come into focus. This could be to open slits in the building to create specific shadows or light streaks that change over time and season. Or it could be to highlight certain elements in the building.

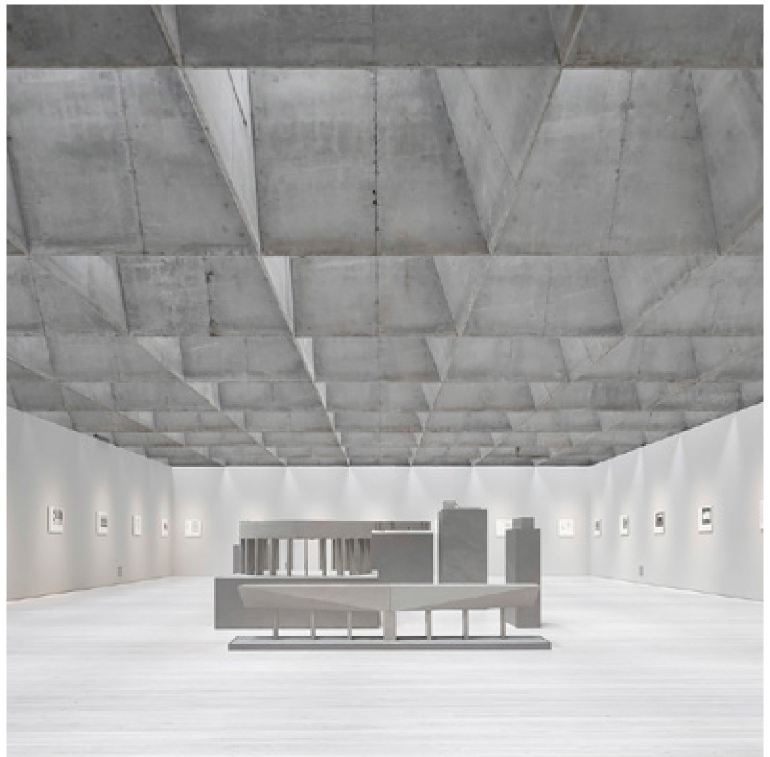
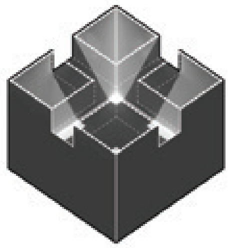


Figure 25

Liljevalchs + (2021), Stockholm, Sweden - Wingårdhs



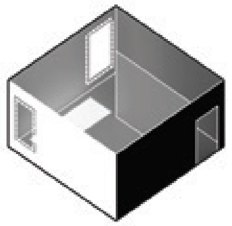
Canalization

Canalization is the channeling of light through a hollow mass. This is when light is controlled and directed by bouncing it on the surface of the hollow mass to create a more diffuse light or to direct it into areas where it is impossible to create openings. The principle of light tunnels.

DESIGN FOR LIGHT

Figure 24

Dutch embassy (2004), Berlin, Germany - Rem Koolhaas/OMA



Procession

Procession is the "choreography of light for the moving eye" or the guiding light. It is when a light source serves as a guide or attraction point, leading the user through a building or marking important sight lines in the building.

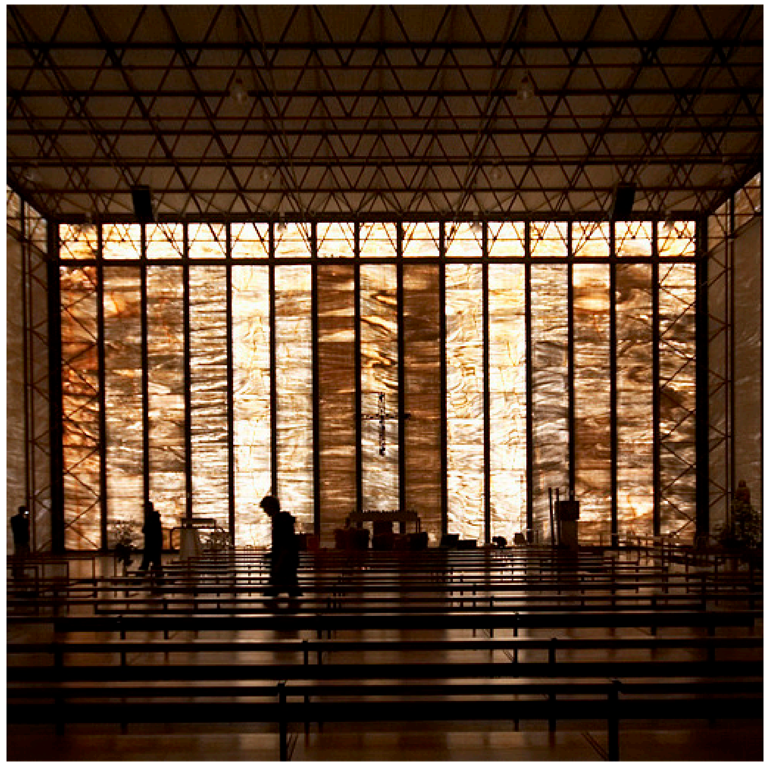
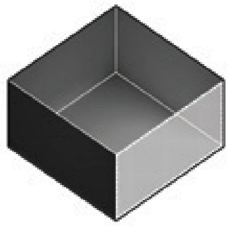


Figure 26

Pius Church (1966) , Meggen, Switzerland - Franz Fueg

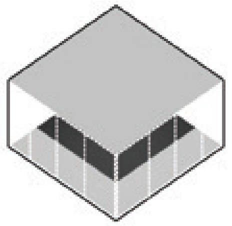


Luminescence

Luminescence or the materialization of light in physical matter, is when light is visibly reflected on or transmitted through a material with a solid mass. Examples of this is when light shine through marble, the diffuse reflection of wood or specular reflection of metal. This is often just a byproduct of material selection but could be used with more awareness as guidance or to create visual interest.

Figure 27

Glass Pavilion (2006), Toledo Museum of Art, Ohio, USA - Kazuyo Sejima + Ryue Nishizawa/SANAA

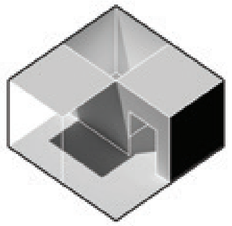


Veils of glass

Veils of glass or just veils are the refraction of light through a translucent film. In other words a filtering light without obscuring the vision through it too much. This can be used to easily manipulate diffusion and color of natural light.

Figure 29

Gasper House (1992), Los Viñedos Ica, Spain - Alberto Campo Baeza



Atmospheric silence

Atmospheric silence is a more abstract typology than the rest. Plummer describes it as the “suffusion of light with a unified mood”. It is the perceived atmosphere of a space, often bringing feelings of spirituality to the user. It can not be quantified or simulated but only experienced physically and subjectively. It is when all aspects of a building unify in harmony, materiality, color, reflectivity, light and shadow.

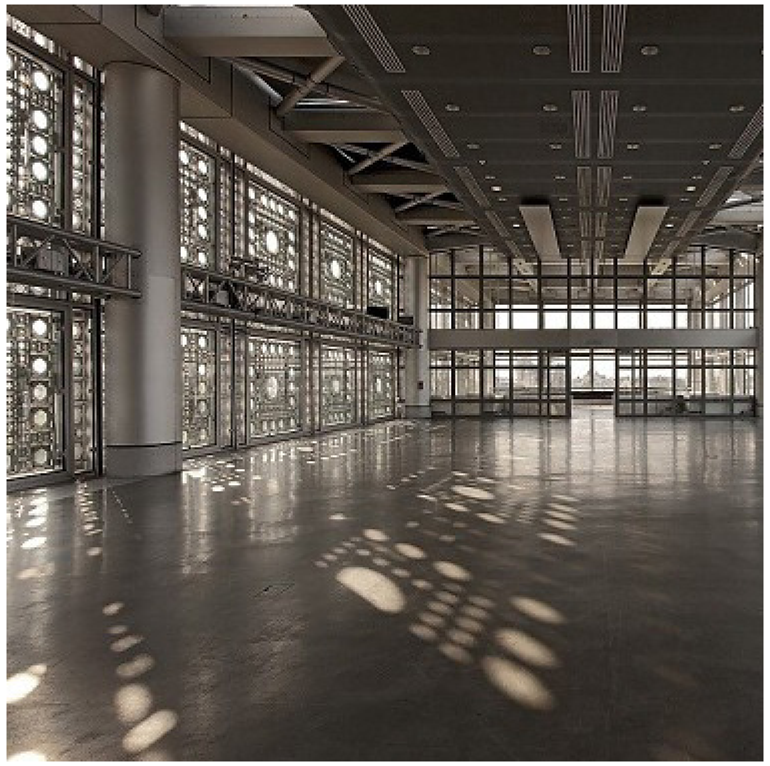
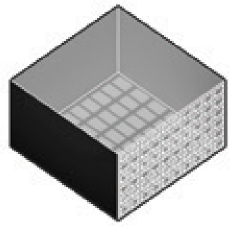


Figure 28

Institut du Monde Arabe (1987), Paris, France - Jean Nouvel



Atomization

Plummer refers to *atomization* as the sifting of light through a porous screen. It is also a way of filtering light but in a larger scale. It can be used to create shadow play or diffuse light. In warmer climates this has historically been the main way of letting in light into buildings without getting direct sunlight, one such element is the mashrabiya.

QUANTITATIVE SIMULATION

For the last couple of decades tools have been developed to simulate daylight using computers. We have become more aware of the effects daylight has on our health and well-being and formulated building regulations according to this. For this thesis I have chosen two measurements as the most relevant, *daylight factor* and *glare*.

Most daylight simulations use four geometrical elements as input data:

- *Building of interest*. The building that is used as the envelope for the simulation based on the point of view of the user.
- *Surrounding area*. Buildings, landscape and vegetation in the most immediate area of the area of interest.
- *Ground*. The landscape on which the building stands. This is used to accurately block off light coming from below from the sky model and to reflect light from above.
- *Sky model*. A quantified amount of luminance distribution coming from the sky dome. Using date, time, latitude, longitude, sky condition (overcast, clear...) and weather data.

All of the geometrical elements are applied with material reflectance data to accurately bounce the light. A glazed building in the surroundings has a higher risk to cause glare than a brick building for example. (Dubois et.al, 2019)

Daylight factor

The *daylight factor* (DF) is the factor that determines the *luminescence flux* measured from a specific point of view or on a subdivided surface. By using DF it is possible to predict and evaluate how much light that enter a space. The simulation is run for a specific point in time and can therefore be used to predict a worst and best case scenario for daylight. (Dubois et.al, 2019)

Glare

Glare is measured in simulation by using a point of view in a rendered space and then applying a *luminance map* to it. The luminance map shows the contrast between the darkest and brightest areas of a 180 degree view with a color spectrum. (Dubois et.al, 2019)

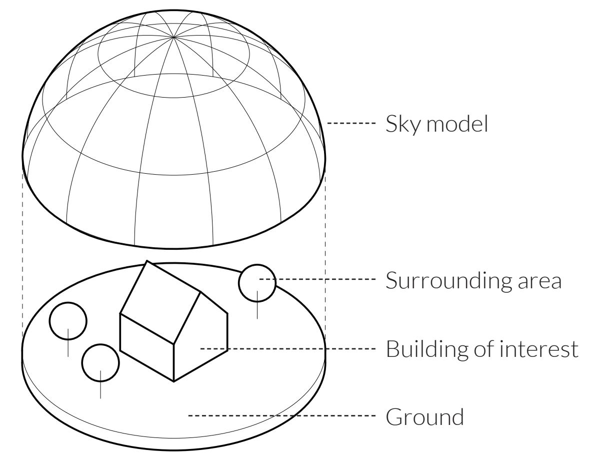


Figure 30

The four geometrical elements used as input data for daylight simulations.

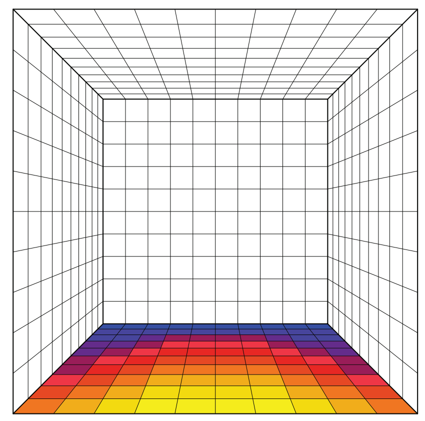


Figure 31

Daylight Factor or DF measured on a subdivided surface. Red means a high DF while blue means a low DF.

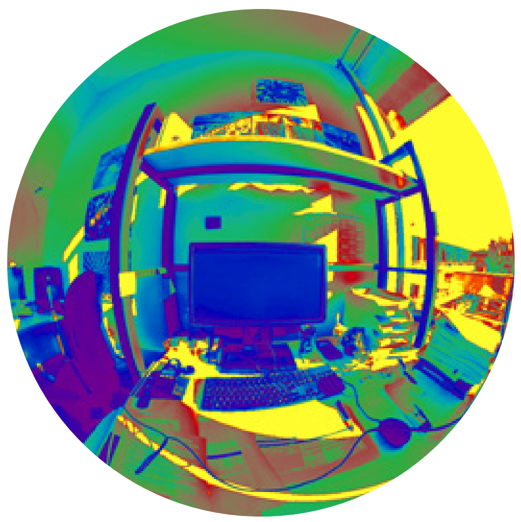


Figure 32

Glare measured by a luminescence map. The yellow areas have a high risk of causing glare.

PERCEPTION-BASED SIMULATION

Using quantitative simulation models to assess daylight is a good way to predict the lighting quality of a space, but it is not adequate to predict the visual experience of it. To evaluate this we have to use human subjects to tell of their individual experience. Then compile the answers to an average or median. A semantic formula called *Perceived Indoor Lighting Quality Tool* (PILQ) can be used for this which consist of 16 bipolar scales and one question about how well you can see in the environment. (Dubois et.al, 2019)

Recent studies have been exploring working with perception based evaluation of daylight in a virtual environment. The study *Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments* (2019), investigates how adequate the method of using virtual reality is. This is done in a similar way as the PILQ study using questions about the experience of a space. By evaluating five aspects in both reality and virtual reality, these being the perceived pleasantness, interest, excitement, complexity and satisfaction with the amount of view in the space. The results indicated a high level of perceptual accuracy, showing no significant differences between the real and virtual environments on the studied evaluations. (Chamilothori et.al, 2019)

The PILQ formula is not suggested to be used in a digital environment because of the difficulty to accurately simulate lighting. However, the study done by Chamilothori et.al (2019) suggests that it could be used as a surrogate to real world environments. The study is made using *Radiance*, a physics based render software which means that the lighting will react the same way as in real life using the same units. The study was made by rendering seven scenes of varying daylight without the use of materials. Radiance uses the technique *ray-tracing* as a means of reproducing accurate lighting. This technique has seen a major leap in recent years and it has become possible to accurately simulate lighting in real-time. This in combination with the use of *Physically Based Rendered (PBR) materials* has made digital simulation almost indistinguishable from real life. As the study proves that the participants did not change their perception of the space in the digital environment, the topic could be further explored using materials and real-time changes to lighting to enhance the perception based simulation even more.

Figure 33

	Hedonic tone	Brightness	Variation	Colour	Flicker
LIGHT		☐			
UNPLEASANT	8- ☐				
COLOURED					
WEAK		8- ☐		☐	
CONCENTRATED			8- ☐		
COOL	8- ☐				
EVEN DISTRIB.			☐		
SOFT					
FOCUSED			8- ☐		
UNNATURAL	8- ☐				
NO FLICKER					8- ☐
DRAB		8- ☐			
MONOTONOUS	8- ☐				
SHARP	8- ☐				
SHADED	☐				
BRILLIANT	☐				
GOOD					
SUM	:8	:4	:3	:1	:1
MEAN					

The Perceived Indoor Lighting Quality Tool (PILQ) formula.

Figure 34

Table 3. Overview: Variables and questionnaire items.

Independent variables	
S.1	Environment: real or virtual environment
S.2	Presentation order: real space first or virtual environment first
Dependent variables	
Perceptual impressions	
PI.1	How pleasant is this space?[a]
PI.2	How interesting is this space?[a]
PI.3	How complex is this space?[a]
PI.4	How exciting is this space?[a]
PI.5	How satisfied are you with the amount of view in this space?[a]
Physical symptoms	
PS.1	How sore do your eyes feel?[a]
PS.2	How fresh does your head feel?[a]
PS.3	How clear is your vision?[a]
PS.4	How fatigued do you feel?[a]
PS.5	Do you have any other symptoms? (open question)
Reported presence	
RP.1	How much did your experience in the virtual space seem consistent with your experience in the real space?[a]
RP.2	How much did you feel like "being there" in the virtual space?[a]
RP.3	How much did the virtual space become the reality for you?[a]

[a]A scale from 1 to 5, 1 corresponding to *not at all* and 5 corresponding to *very much*, was used for the marked questions.

Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments questionnaire.

Figure 36

Virtual reality simulation from *Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments.*

Figure 35

Real life photo from *Adequacy of Immersive Virtual Reality for the Perception of Daylit Spaces: Comparison of Real and Virtual Environments.*

DESIGN FOR SENSES

In a study made by Morton Heilig in 1992, he ranked the order in which he believed our attention to be captured by the various senses. According to Heilig's rankings: vision, 70%; audition (sound), 20%; olfaction (scent), 5%; touch, 4%; and taste, 1%. When the vision is impaired other senses become more important. Hearing, touching and smelling can be used in the design to make the building more interesting. (Spence, 2020)

Charles Spence writes in the article "*Senses of place: architectural design for the multisensory mind*" from (2020) about a multi-sensory approach to architecture. He describes how multi-sensory design usually has been done by using a sense-by-sense approach where each of the senses are designed for separately. This approach however often neglects the connection between the senses which is decisive. For example the sound of a songbird can be described as lovely when heard in a forest with rustling leaves and the smell of pines. But in a parking garage the sound becomes discomforting, reverberating on concrete walls in the damp and dusty air.

The difficulty in designing for darkness with other senses is that the darkness is often ominous in itself, and it's discomfort can if not careful become worse when the other senses are activated. Think for example a horror scene in a movie. It often has auditory senses activated when a door opens, the leaking of a pipe, echoes with large reverberation and whistling winds.

On the following pages I will dive deeper into how the non-visual senses can be activated with a sense-by-sense approach using examples and then connect them to see how the senses influence each other.

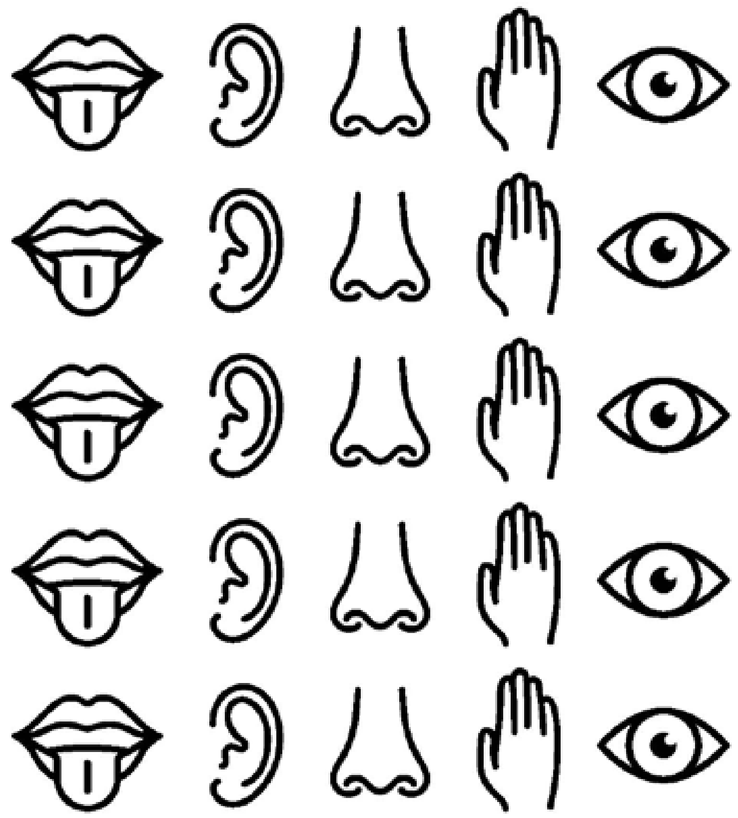


Figure 37

The five senses

VISION

Colors

The use of colors changes our perception of a building and can even influence our psychological mood. For instance a bright tone can make a space seem larger while a darker tone makes it seem smaller. The use of monotonous contrasts and weak intensities can create an under-stimulated environment while the opposite, creates an over-stimulated environment. When other senses are activated as well, the risk of over-stimulation increases with the use of colors. Keeping the colors to natural tones decreases the risk.

Light

Light provides the shape to the environment. A rounded corner is perceived as rounded because of the shade that appears on it once light hits it. Rounded edges makes the light blend together and the shape more diffuse and harder to identify. While sharp edges create sharp shadows that makes the environment easier to read and understand, with the possible drawback of becoming less interesting.

Material

We understand the materials around us. Just by having a visual connection to a material can let us understand it's physical properties, if they are hard, soft, smooth, rough, warm or cold. By directing light to highlight or shade materials their properties become more apparent as their micro structure is revealed. Shining light directly onto a stone surface will make it seem flat, but when rotating the light to the side the cracks become more apparent and the tactility easier to understand.

Patterns

The use of patterns can as well stimulate the visual sense. A two dimensional pattern is perceived differently from three dimensional patterns. Three dimensional patterns has a closer connection to material and tactility than two dimensional patterns, which makes it more multi-sensory. Different scales of the pattern can affect how stimulating the surface is. Using a scale that is too small can make the surface over-stimulating, while a scale that is too large makes it not be perceived as a pattern.

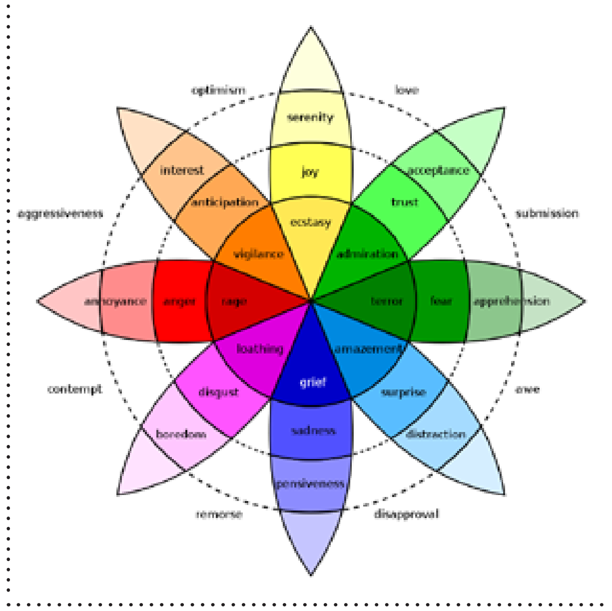


Figure 38

Different colors give different mood illustrated by Robert Plutchik's Wheel of Emotions.

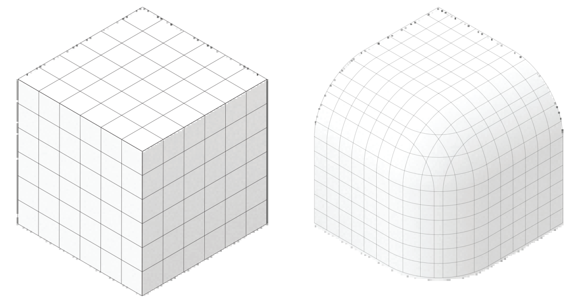


Figure 39

Rounded edges creates a gradient of light that makes the shape harder to read, while sharp edges does the opposite.

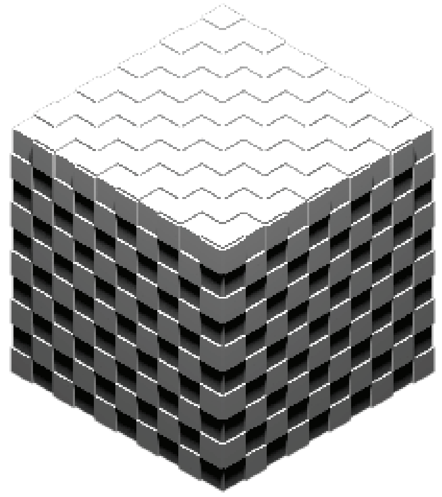


Figure 40

The structure on the sides of the cube casts shadows when hit by light from the top while the top seems rather flat.

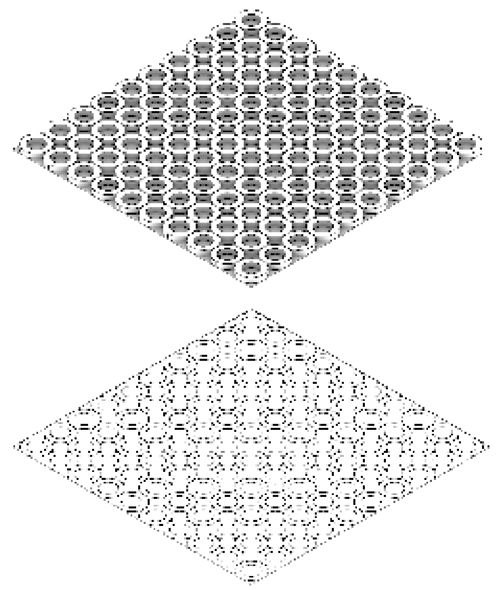


Figure 41

A three dimensional pattern gives more depth to the surface.

DESIGN FOR SENSES

TOUCH

Body movement

Movement can be used as a way to interact with the architecture with your body. Such an example can be seen in the memorial of the blind activist Helen Keller Arakawa and Madeline Gins created a unique building in the suburbs of Tokyo called "Reversible Destiny Lofts—Mitaka". The apartment building is made up of spheres and cubes to create a space that encourages movement and interaction with our body.

Moving parts

Moving parts can increase the enthusiasm to touch a surface or object. Where active interaction with them can be used to change the space. Such as curtains, folding walls or even running water. The use of moving parts can create another dimension of interactivity with the building but has a risk of making it tedious to live in if it is dependent on these interactions. For instance placing out doors for the sake of interactivity.

Tactility & Haptics

The simplest way of activating the sense of touch is by having materials with different structures that are allowed to be touched. A wall that is painted in a clear white color with no structure, if touched, will immediately be left with a fingerprint and make the wall seem dirty. Materials that do not look dirty even when they are, are more likely to be touched and appreciated. Closely related to tactility is haptics. The information that is carried over from a surface to the body and how the body reacts by movement of joints. This is important when dimensioning furniture and stairs for example.

Temperature

Having materials of different temperatures also activates the sense of touch. At 20 degrees indoors metals are perceived as much colder than wood at the same temperature. This is because metal has a higher thermal conductivity than wood. Designing with a variety of materials with different thermal conductivities can help with navigation and indoor comfort.

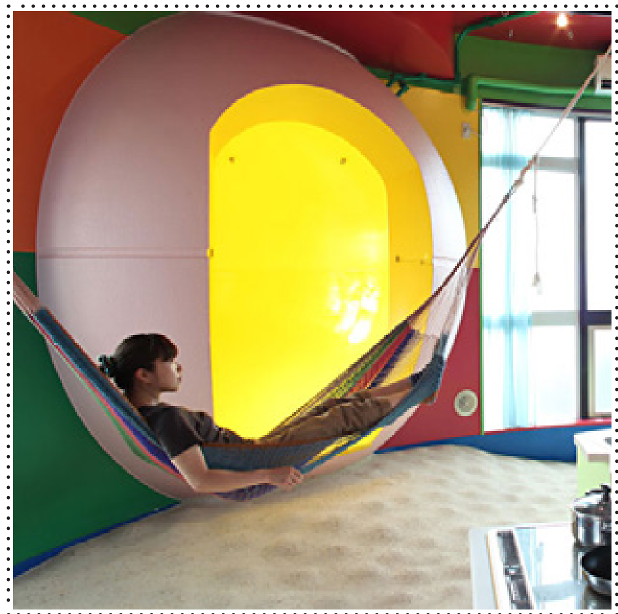


Figure 42

Reversible Destiny Lofts—Mitaka (2005), Tokyo, Japan - Arakawa and Madeline Gins

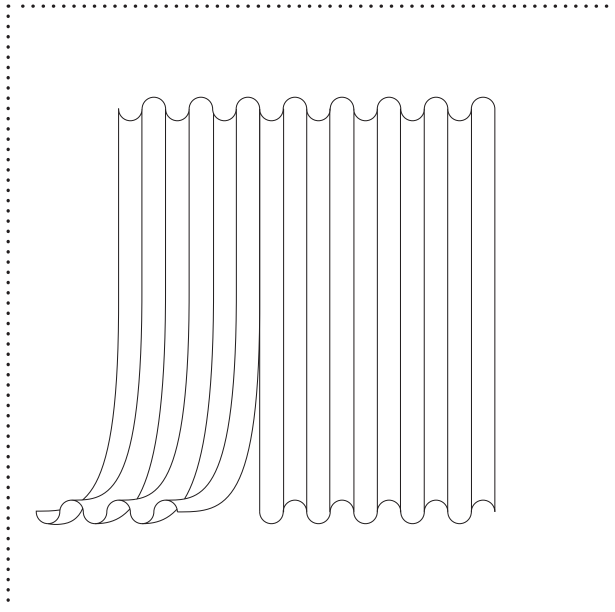


Figure 43

Moving parts such as curtains help create more interactivity within the building.

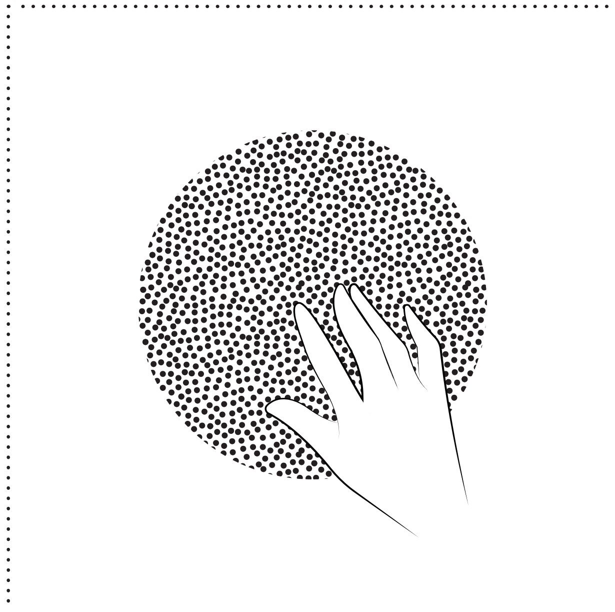


Figure 44

Tactile materials activates the haptics in the sense of touch.

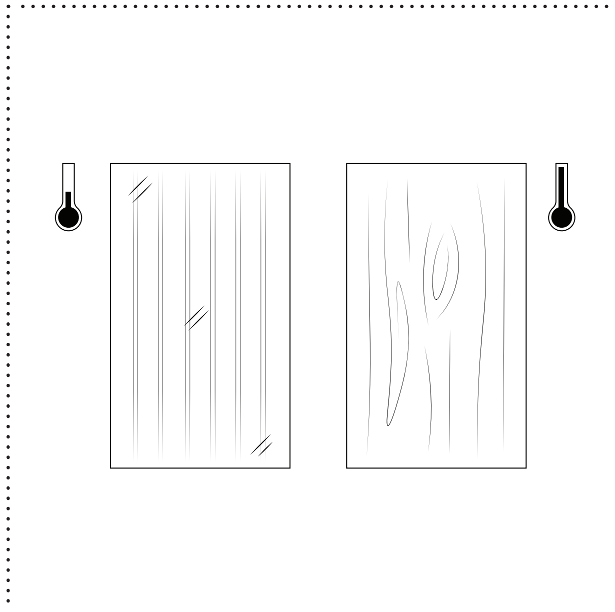


Figure 45

Thermal differences in materials create a more dynamic atmosphere.

DESIGN FOR SENSES

SOUND

Acoustics

It is very difficult to imagine beforehand how a space will sound. What materials are used affect the acoustics as well as the shape of the room. A circular room for example do not interrupt the sound waves like a rectangular room do, where the sound is gathered in the corners. By having different ceiling heights, angles and edges the acoustics of a room can help with navigation and distinguish distinct spaces.

Generating sound

Sound can also be generated using things like wind chimes, flutes or running water. One such example is the Zadar sea organ in Zadar, Croatia, where the waves of the water enter a cavernous system beneath the stairs and resonate with the wind and water. Wind chimes are traditionally used as a landmark to ward off evil spirits by having them turn away from the building. They could alternatively be used as a landmark to help locate the building. Other means of generating sound include running water, crackling of a fire, the ticking of a clock or speakers.

Augmenting sound

The sounds of the surrounding environment could become augmented. Such as amplifying or reducing the sound of raindrops hitting the roof, or gusts of wind sweeping along the walls. By using different materials depending on the desired effect. A metal roof or glazed skylight will amplify the sound of rain hitting more than a ceramic roof for instance.

Infra-sound

Ventilation placement and system should also be taken into account when designing for the sense of sound. A constantly running ventilation unit can cause a lot of discomfort, difficulties with focus and headaches.

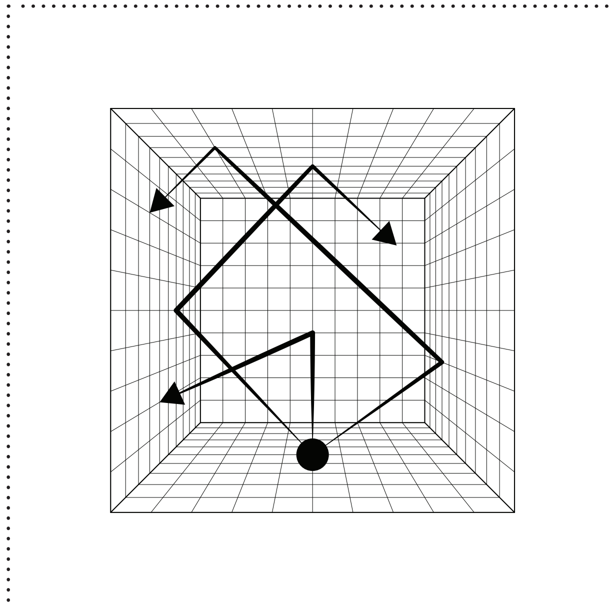


Figure 46

Differences in spacial height and character can create a variation of acoustic environments.

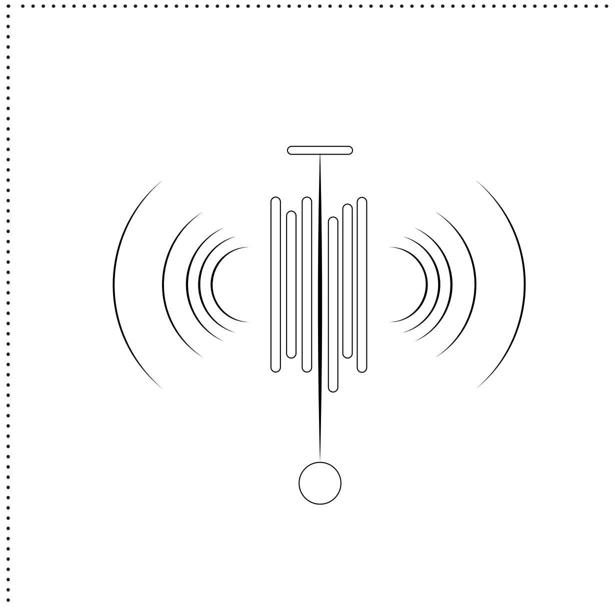


Figure 47

Generating sound can be done by using wind chimes and other objects that react to the climate.

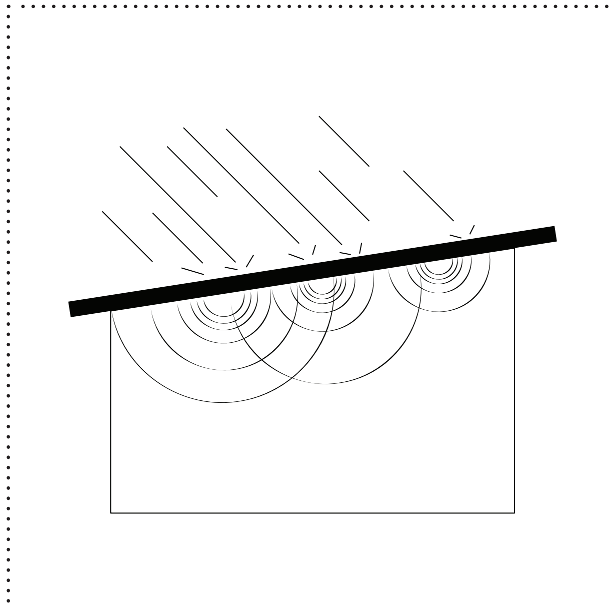


Figure 48

Augmenting sound can be done with the choice of materials, a metal roof makes the rain sound louder for instance.

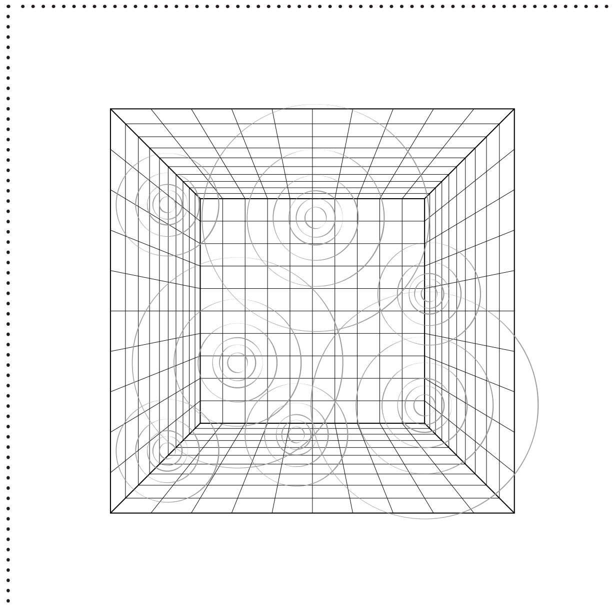


Figure 49

Infra-sound comes from ventilation etc. It can cause a lot of discomfort.

DESIGN FOR SENSES

SCENT

Scented objects

Using plants and flowers indoors can help with the indoor comfort. Growing herbs or vegetables in the kitchen creates a direct connection to food and cooking. While having flowers and plants with a scent in for example a living room, bedroom or bathroom can increase the will to stay in these places. Another option is to use different scents as landmarks. Some flowers are more intense than others, and some are changing with the seasons. Different rooms could have their distinct smell by using differently scented flowers materials and objects.

Activities

The placement of the kitchen and bathroom as the most fragrant places in a house, should be placed separately to not conflict with each other. The kitchen should be able give a hint of what is cooking to attract the users, but should be contained and not spread to far in the building. It is possible to use some type of scent to cover the bathroom smell. A natural way of making the bathroom smell nice is to place the shower or bath in the same open space as the toilet, because of the use of soap and perfume after showering. Almost all activities from humans produce smell, even just sitting down a long time can produce sweat and body odor. It is therefore important to separate the activities to different rooms, so that the smells are controllable.

Fragrant environment

Using materials that have a natural fragrance such as resin rich wood can activate the sense of smell. How well insulated, air tight or ventilated the building is also affects the smell significantly. A concrete building with a thick climate shell will most likely produce a damp and confined atmosphere if not ventilated properly. The ability to open windows to let in the scent of the outdoors is also desired.

Figure 50

Scented objects such as herbs and flowers can give a pleasant atmosphere.

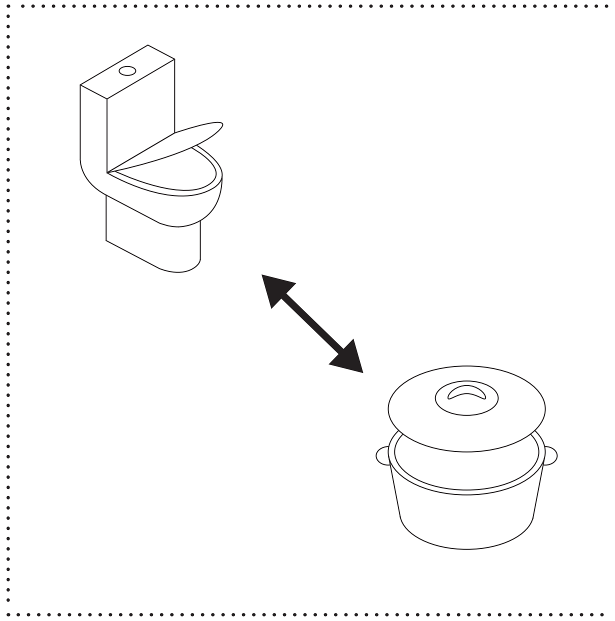


Figure 51

Placing activities such as cooking and toilet separate from each other so the scent and smell do not conflict.

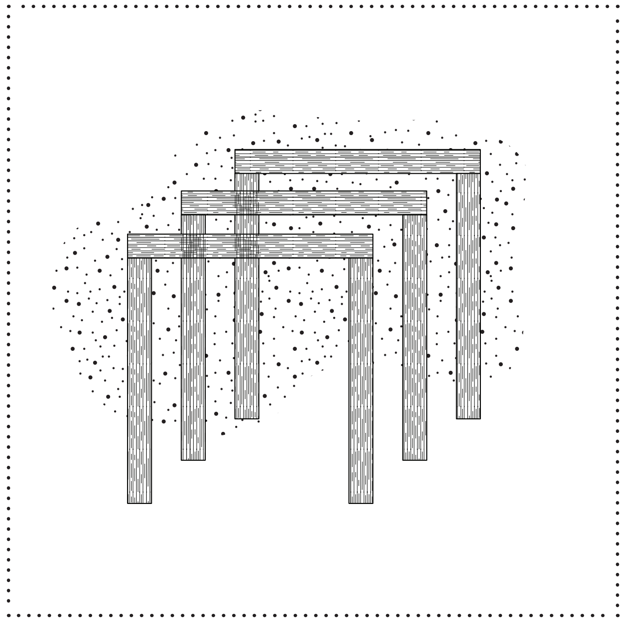


Figure 52

A fragrant environment can be created by using materials with strong scents.

TASTE

Colors

The sense of taste is less applicable in architecture, but Juhani Pallasmaa suggests that colors have a connection to taste, he writes "The suggestions that the sense of taste would have a role in the appreciation of architecture may sound preposterous. However, polished and coloured stone as well as colours in general, and finely crafted wood details, for instance, often evoke an awareness of mouth and taste." (Spence, 2020). The suggestion that colors are related to taste could instead be a crossmodal correspondance, that is to say interaction with more senses, where fragrance could play a more significant role. The connection between colors and taste could be even more literal where the actual color of a specific food translates directly to the color of the material. This could be used to add to the sense of scent and visual use of colors to produce varying moods.

Particles & materials

The actual taste of the air in a building is also to be considered. Since taste and fragrance are closely connected the air quality of a building can not only be smelled but also tasted. If the air is damp inside a building it might taste like mold, or if there is a fireplace the air can taste of burnt coal.

DESIGN FOR SENSES

Figure 53

Facade reminiscent of Fizzy-pop candy. A literal translation of color to taste.

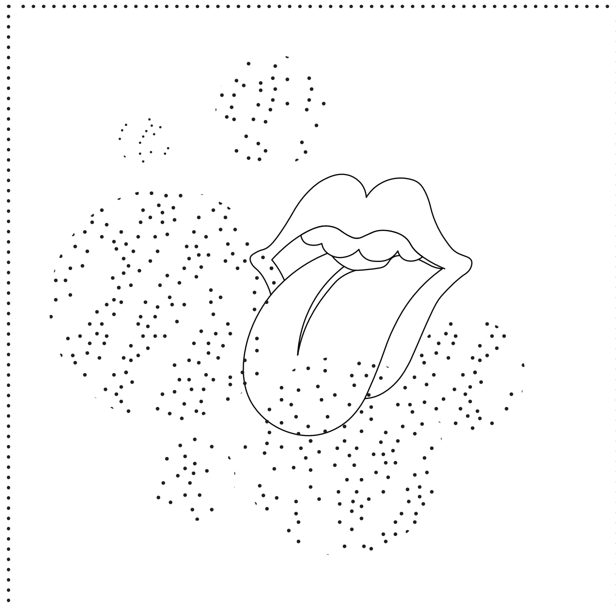


Figure 54

Particles and materials in the air can give foul taste.

A COMPLETE EXPERIENCE

Most of the effects of our senses are subconscious. We don't usually react to them unless presented with a different environment. Our consciousness adapt to the changes quickly and after a while we do not pay any thought to our surroundings, it becomes the ordinary. By having dynamic changes in the building our minds can become more stimulated and conscious about the lived environment. I am not suggesting that the building should be present in our minds at all times, that would be disturbing for our daily activities. However, all of the spaces in a building should have it's own identity and place that support the daily life in mood and function.

By using the sense-by-sense approach to multi-sensory design we can see that the approaches overlap and create synergies. Color, material and space (placement of things). These overlaps and connections can be seen in figure 55.

DESIGN FOR SENSES

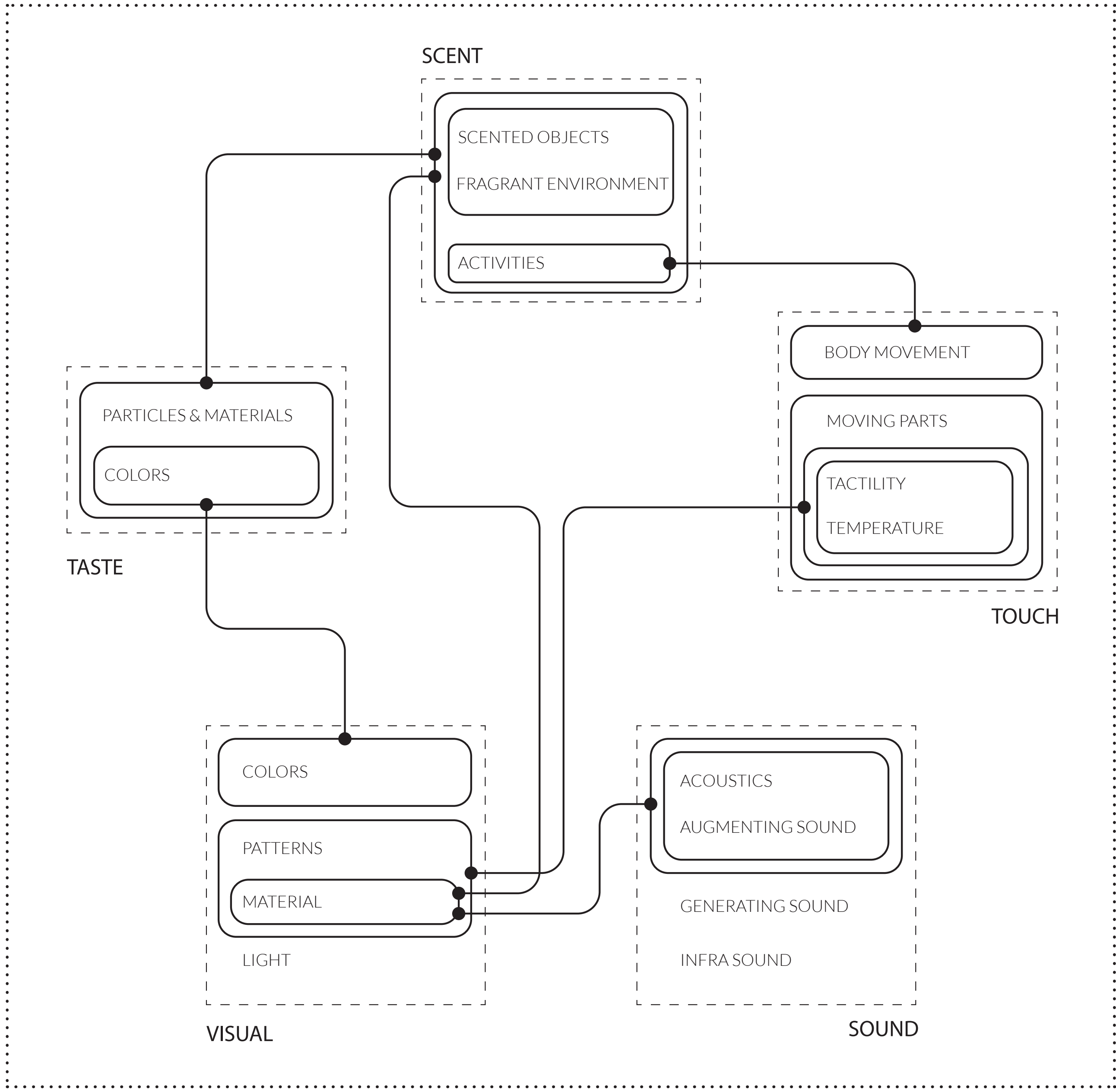


Figure 55

Diagram of overlapping synergies. Elements within the specific sense can both overlap or be separate from each other. Connections are made between the elements that overlap across the senses. For example the choice of *material* affects the *acoustics* of a space.

LIVING IN DARKNESS

While you can get many benefits from sunlight. A lack of it creates health issues. One such issue that is very common in Scandinavia is SAD or seasonal affective disorder, which is a type of depression related to seasons, most commonly winter and autumn when it is dark. It is therefore crucial to take full usage of the light that is available during the day and for the architecture to support it. Both in shape and integration of lifestyle.

In a cold and dark environment a lot of comfort can be gained from turning on a warm light or candle. But when no artificial light sources are available other means have to be used to achieve comforting qualities. One way of doing this is through accepting the darkness to a degree. Such acceptance is described in the novel "*In Praise of Shadows*" by the Japanese author Jun'ichiro Tanizaki (2001). He describes the differences in Western culture compared to Eastern, where western culture has developed to praise cleanliness and brightness. Tanizaki brings up an example of how the Shinto temple differs from a Christian church. The church is often spacious and well lit by large windows in an effort to bring heaven and God closer. Whereas the temple is completely devoid of natural light, to support the users inner spirituality. The church is more extroverted and the temple introverted. Even in the smallest details such as tableware these distinctions can be seen. Western tableware is often made of white, shiny porcelain that is easy to wash and get clean. While eastern tableware can be made from black, lacquered wood, that Tanizaki describes as garish when lit under electrical light or the sun. He suggests that the darkness wraps it with a mythical sheen that is broken under high intensity light. This mythical sheen can also be seen in the dark temples where gilded details work as a form of navigation, where even in the dimmest light they glow brightly.

These accounts are based on Tanizaki's observations and are not meant to be taken as scientific facts but rather phenomena.

"But what produces such differences in taste? In my opinion it is this: we Orientals tend to seek our satisfactions in whatever surroundings we happen to find ourselves, to content ourselves with things as they are; and so darkness causes us no discontent, we resign ourselves to it as inevitable. If light is scarce then light is scarce; we will immerse ourselves in the darkness and there discover its own particular beauty. But the progressive Westerner is determined always to better his lot. From candle to oil lamp, oil lamp to gaslight, gaslight to electric light—his quest for a brighter light never ceases, he spares no pains to eradicate even the minutest shadow." (Tanizaki, 2001)

DESIGN FOR LOW VISION

In urban design, universal design is nowadays often mandatory. This includes designing for the blind. In the cityscape this design is most noticeable in the use of tactile paving as a form of haptic language. Where modular 400mm x 400mm tiles are put together as a guide with pathways and landmarks. The tiles are differently textured to indicate edges, paths, nodes and landmarks. In public buildings and spaces reverberation and echo can be used to indicate landmarks and spaces as well. By having varying heights and angles in the architecture navigation becomes much easier.

The use of haptics as navigation is studied in *Haptic design research: A blind sense of place* by Jasmien Herssens and Ann Heylighen (2011). The study investigates haptic qualities and constraints in the built environment with the help of people who are congenitally blind. The data that was collected showed that haptics relate to surfaces. They bring up as an example, "when we walk over a bridge we feel the upper surface of the floor while placing our foot on the bridge, the surface of the handrail while passing our hand over the handrail. Not the volume of the floor is felt, nor the points or dots that compose this surface as their scale is too small, but its material and spatial characteristics." It also became clear that furniture is as important as architecture in haptic perception. It also matters which body part is used to touch. For example our hands are more sensitive than our feet. The surfaces that support our hands should therefore be different to the ones that guide our feet and are proposed to be divided into varying surfaces relative to the body. They also propose a division of surfaces into three categories *movement plane*, *guiding plane* and *rest plane*. Functional oriented design asks for surfaces that could be named as movement plane. For example, a ground floor, the steps of a staircase or a door. While the guiding plane are the guiding surfaces such as a handrail. Lastly, the rest plane is a surface where people can sit, sleep, relax or lean. There are also different types of haptics that relate to these classifications, dynamic touch, static touch and active touch which lets them intersect with each other. A handrail, for example, can be actively touched but gives information about the wall or construction on which it is fixed as well. This lets the guiding plane become a part of the movement plane as well. A handrail that is designed to also enable leaning transforms it into a rest plane.

Furthermore Herssens and Heylighen explain that the haptic design parameters are described by both spatial characteristics (the positioning of planes) and material characteristics. Materials give an identity to the surfaces through their temperature, texture, density, permeability, light reflection and elasticity. The texture of a material gives direction, reflects light and defines the way a material is felt. They suggests that to support active touch, movement will be encouraged by a rough texture for the feet, while the hands and other body parts ask for smooth surfaces. When relaxing, on the other hand, the body prefers smooth textures for hands as well as feet. For example, rough stones are excellent for staircases but should be avoided for walls that are regularly touched like movement planes.

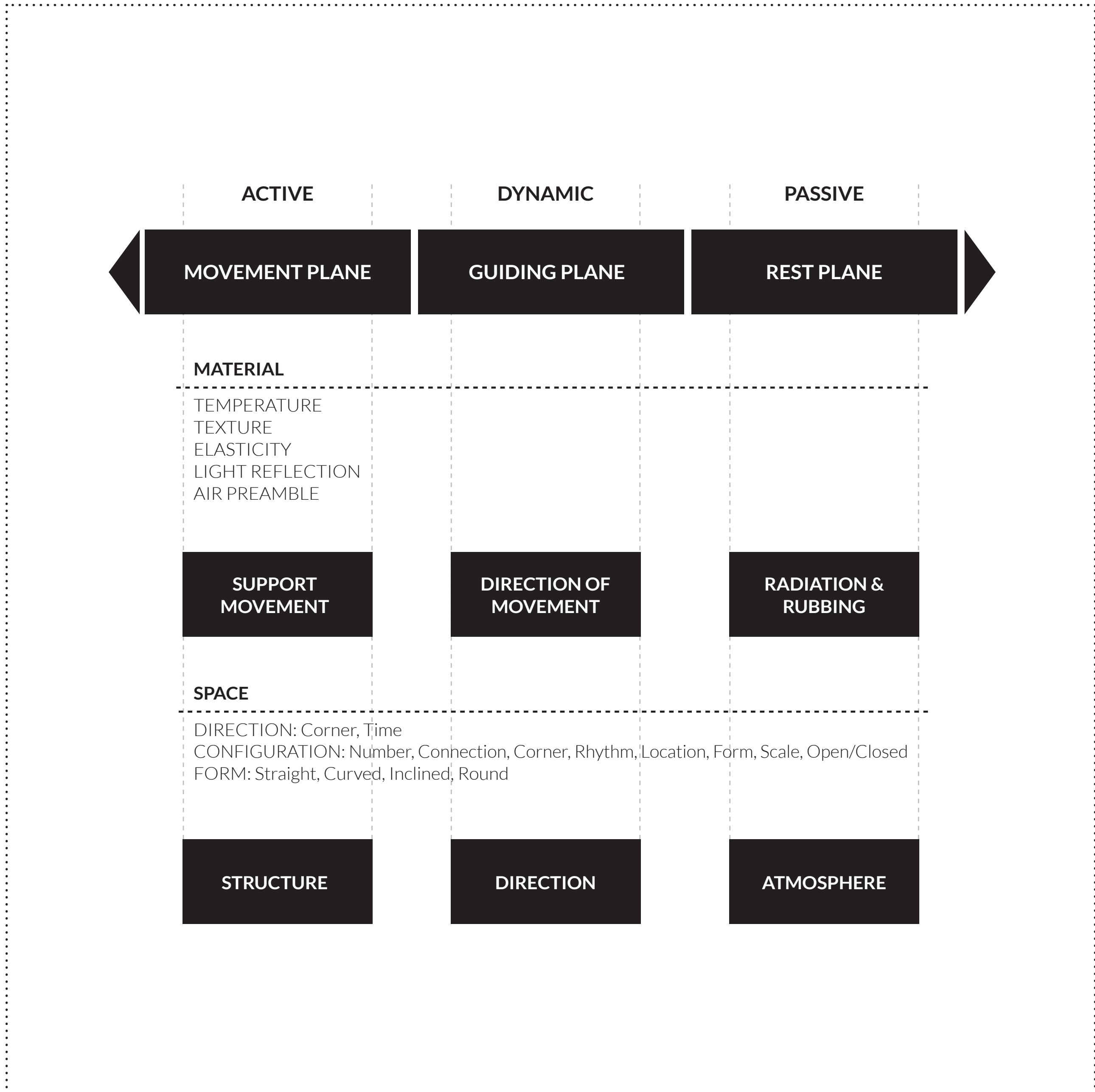


Figure 56

Haptic Language. The different planes separated by *active*, *dynamic* and *passive* characters. The planes are divided into categories of *material* and *space*, where the *movement plane* for instance is categorized to *support movement* with it's *material* and to create *structure* with it's space.

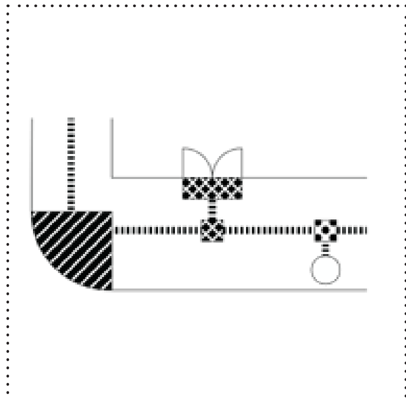


Figure 57

Haptic language in an urban environment.

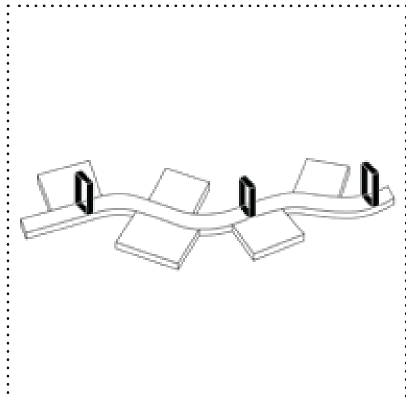


Figure 58

Haptic and visual landmarks.

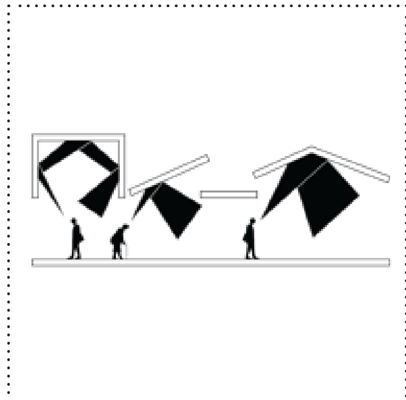


Figure 59

Acoustic landmarks.

INTRODUCTION

The proposal is located in the northern parts of Sweden where the mountains, lakes and forest laps each other. This makes a good landscape for skiing during the winter and hiking during the summer. The low urban density makes for a good place without much light pollution and disturbances. In accordance with the limitations the competition brief lays out, the proposal functions as a single family home for at least two persons. The layout is spacious to allow for more opportunities of integrating the findings from the thesis theoretical part. Furthermore, the result of the implementation of materials and sensory design makes the building able to fit in with it's surroundings and to use local materials for production.

Figure 60

The cabin grows from the rocky ground into distinct, rotated volumes.

SITE

The site is located in Ottsjö, Åre municipality in Sweden. It is a small town with some tourist operations for skiing and hiking. The town is situated by a lake up in the mountains.

The site was chosen as because of the following reasons:

- Low light pollution to influence the design. The street lamps of a city lights up the interior during night as well. This could have given some interesting design rules if it was the selected approach.
- Snow during the winters. The snow brightens the night so that is not completely dark. The snow also allow day time activities such as skiing. Even though Ottsjö is a small town the proximity to Åre as a skiing resort also brings tourists here for skiing during the winters and hiking during the summer.
- The scale of the project as a cabin in a low density area allows it to explore the relationship between artificial lighting and buildings without being as restricted to plot size and building regulations.

Figure 61

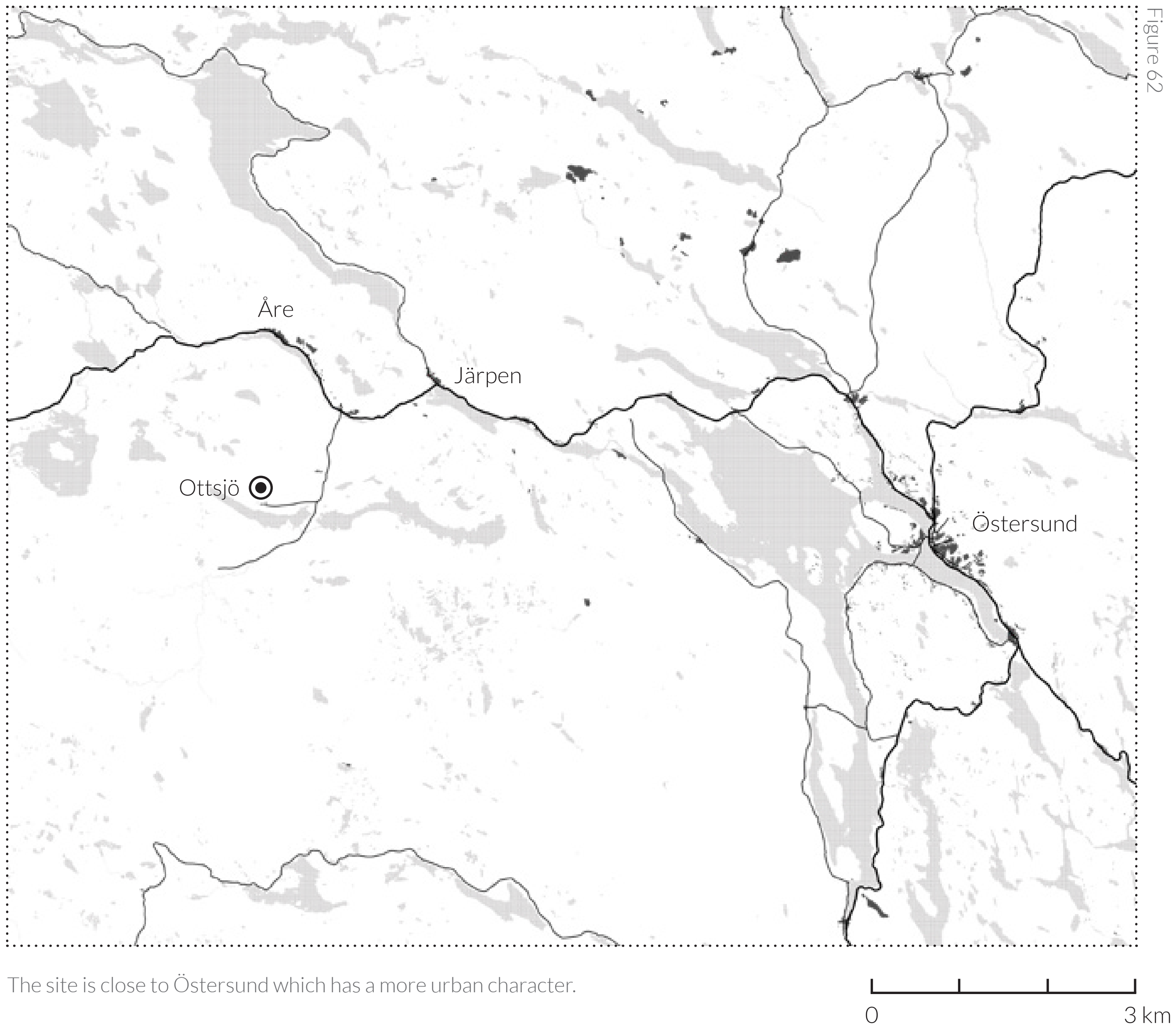


Figure 62

The site is close to Östersund which has a more urban character.

PROPOSAL

CONCEPT

Life follows the sun & season

The placement of rooms and openings are made to promote the everyday life inside the cabin. The bedroom is placed so that the users are not woken by sun, kitchen to be able to utilize last hours of sun to cook dinner for example. The roof is adapted to let in sun during winter and block out harsh direct sun in summer.

Lighting typologies

Different lighting typologies are used to enhance the movement and atmosphere inside the cabin. These are based on the typologies interpreted from Henry Plummer.

Sensory design

The cabin uses multi sensory design to help each space become distinct. The sensory design also works as landmarks inside the building to improve navigation.

Design for navigation

The cabin uses a system of materiality and textures for navigation during the dark hours. The surfaces of the building are divided into the planes (guiding, movement and relaxation) that were suggested by Herssens and Heylighen. The surface textures are adapted to the body part touching the planes and the use of the space. The bedroom walls are more smooth and warm to encourage relaxation compared to the hallway for instance. The furniture is placed along the walls, clearly marked out using different materials on the walls and floor or integrated into the walls. This follows the principle of experiencing the building in planes, making the furniture an integrated part of the architecture.

Figure 63

The hallway between the living room, kitchen and bedrooms.

DESIGN PROCESS

1 - Choice of approach
The process started by selecting between two different approaches to design without artificial lighting.

- Urban context, with street light as main design focus.
- Snow as reflector, putting the building in the north with a lot of snow that reflect light during evening.

The second approach was selected to allow more freedom in the design of the building and not be influenced by other light sources.

2 - Form finding

Sketching different programs and forms of the building. Adapting the volumes to daylight conditions and everyday activity. As can be seen in figure 64 the chosen form principle allows for rotation of rooms to give freedom in placement for optimal daylight conditions. The form finding resulted in two forms that was worked on simultaneously.

3 - Iteration

The two chosen forms where then iterated upon to find a form that would have proper access to daylight as well as optimized for the users daily activities. The iterations where done using real-time rendering to evaluate the direct daylight's effect on the spatial experience of each room. This was done without the use of materials inside the software *Enscape* by altering the time and season. In tandem with the real-time rendering a model of daylight factor was also used to control that adequate lighting was given to all spaces.

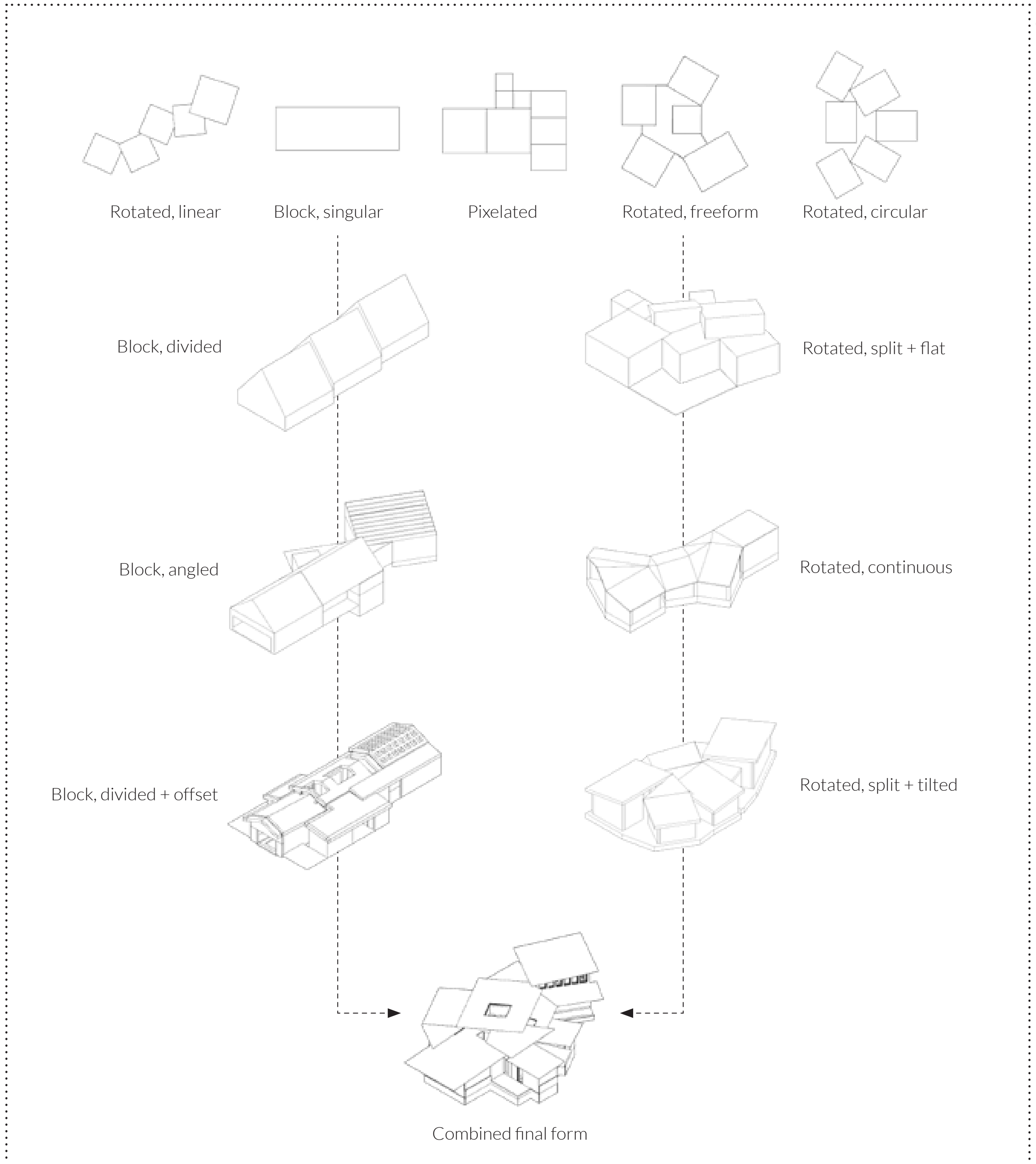


Figure 64

The design process. Iterations of design choices leading to the final form.

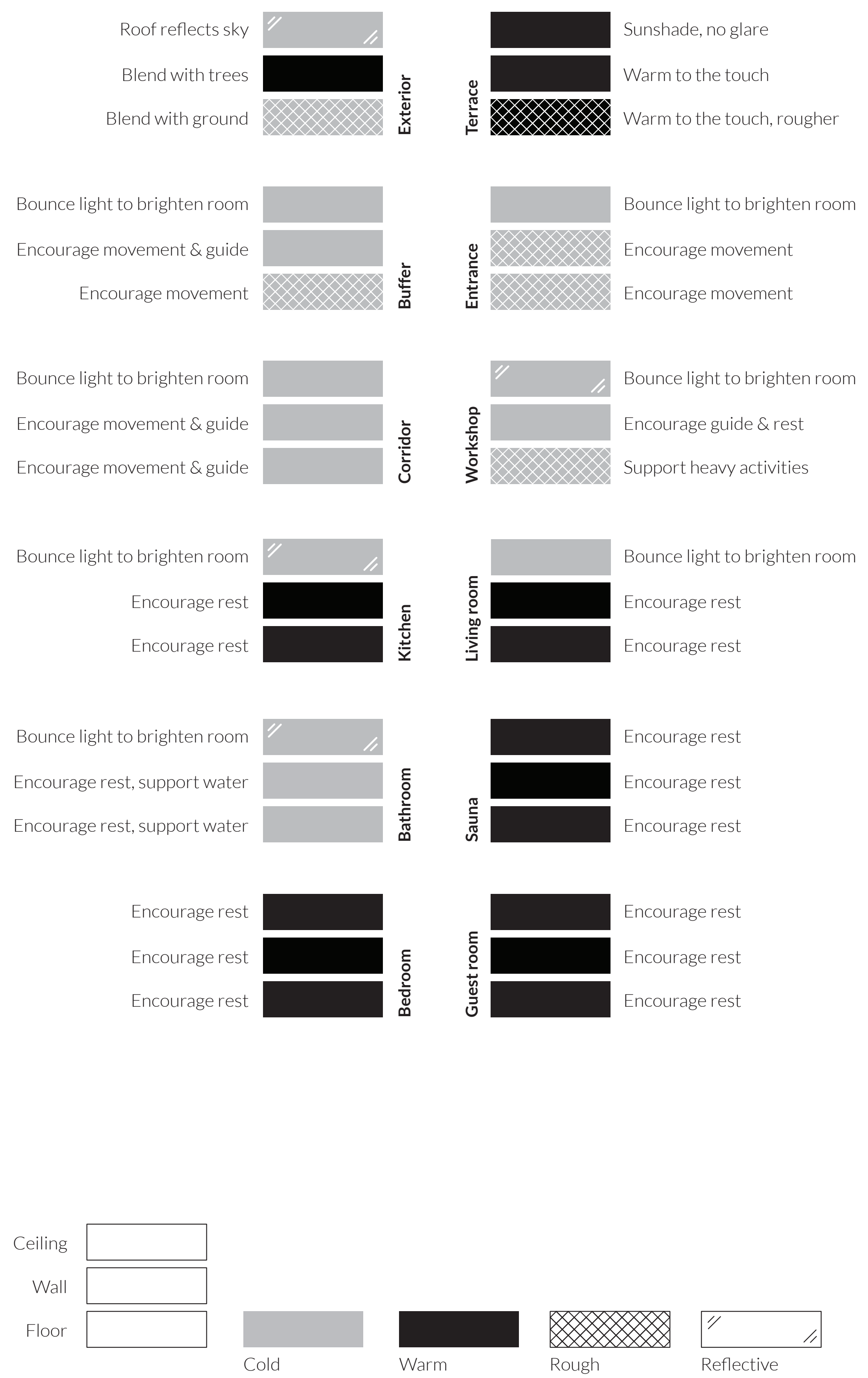


Figure 66

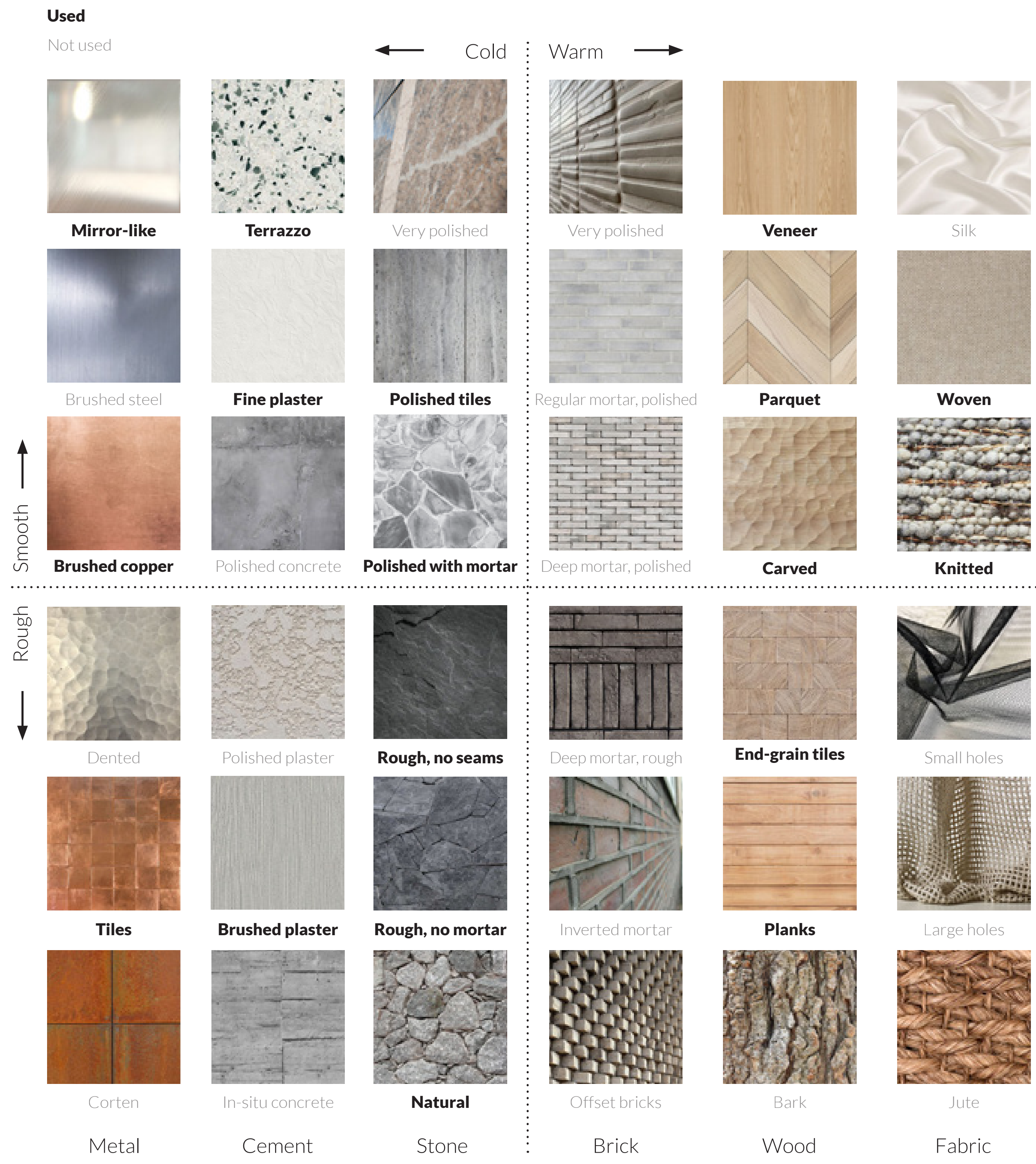


Figure 67

MATERIAL CONCEPT

The surfaces of the cabin (floor, walls and roof) are divided into sections along the edges to blend them together in a gradient. The different sections have varying characteristics, both in material selection and texture. The floor could for example be of the material stone and the edge section is a rougher texture of the stone. This division helps with the navigation, as you can feel with your feet when you are close to the edge. The system of landmarks and guiding planes are in this way integrated into the architecture and materials.

MATERIAL TRANSLATION

FLOOR - Wood, smooth, warm

FLOOR - Wood, rough, warm

FLOOR - Wooden terrazzo, smooth, moderate

FLOOR - Copper, smooth, cold

FLOOR + WALLS - Stone, rough, cold

WALLS - Stone tile, smooth, cold

WALLS - Wood, smooth, warm

WALLS - Wooden strip, carved, warm

WALLS - Stone tile, bright, smooth, cold

WALLS - Plaster, rough, moderate

WALLS + ROOF - Plaster, smooth, moderate

1 EXTERIOR
2 ENTRANCE
3 CORRIDOR
4 BUFFER
5 TERRACE
6 BEDROOM
7 BATHROOM
8 SAUNA
9 KITCHEN
10 LIVING ROOM
11 WORKSHOP
12 ATRIUM

Figure 68

Material Translation. Application of materials according to material concept of surface division.

Figure 69

Entrance - Skylight shines light on the integrated wardrobe

PROPOSAL

Figure 70

Workshop - Diffuse light enables the users to work undisturbed by harsh direct sun

Figure 71

Living room - (Left Summer) Direct light is blocked from entering (Right Winter) Direct light can enter

Figure 72

Guest bedroom - Diffuse light when sleeping

Figure 74

Bedroom - The sun enters the bedroom no earlier than 8:00, casting a light on the closet

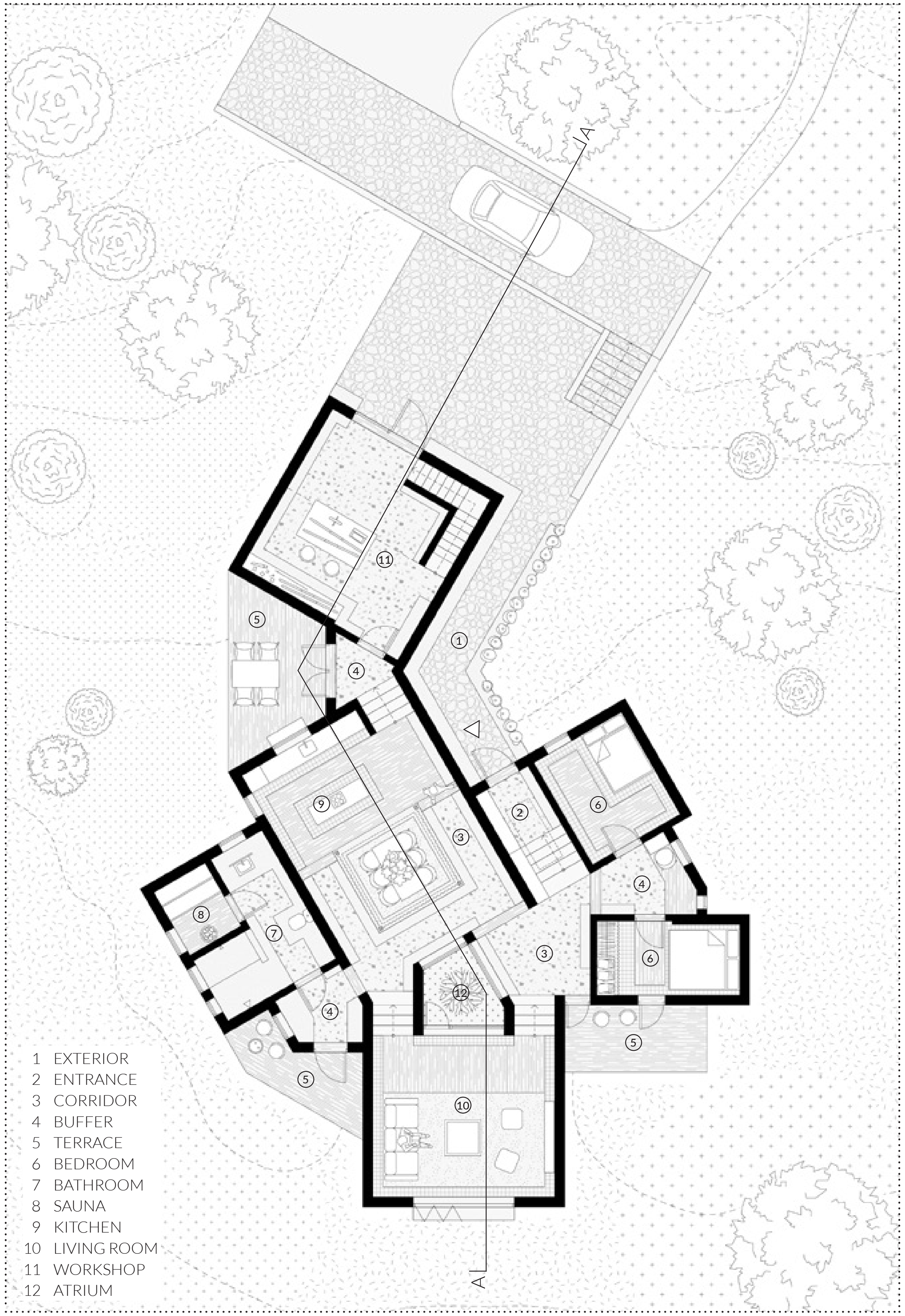
Figure 73

Kitchen - Facing the west enables the users to cook dinner by using the evening sun

Figure 75

Bathroom - Evening light lets the users take evening showers and sauna

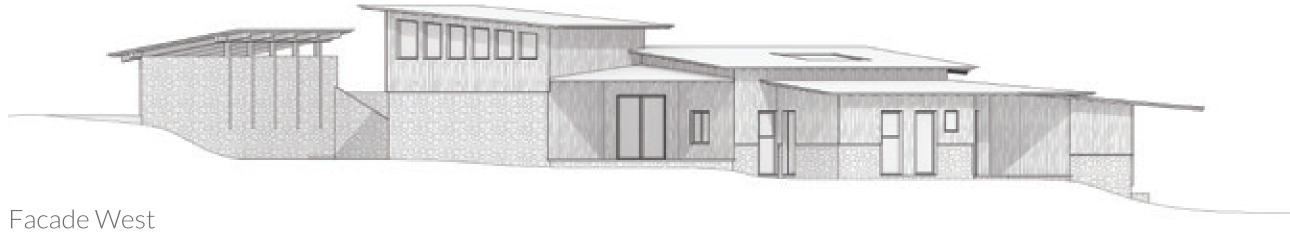
Figure 76



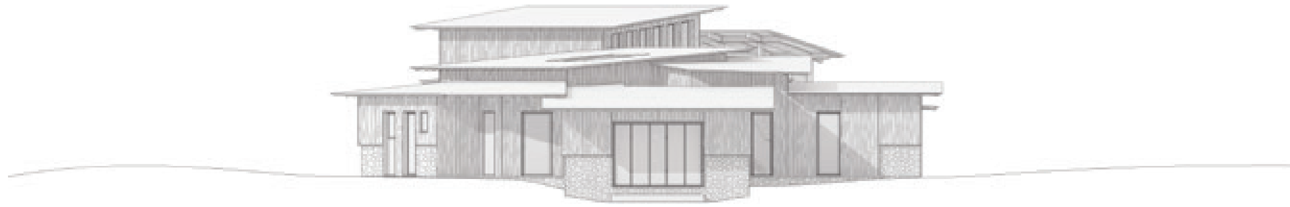
Plan

0 1 5 10 m

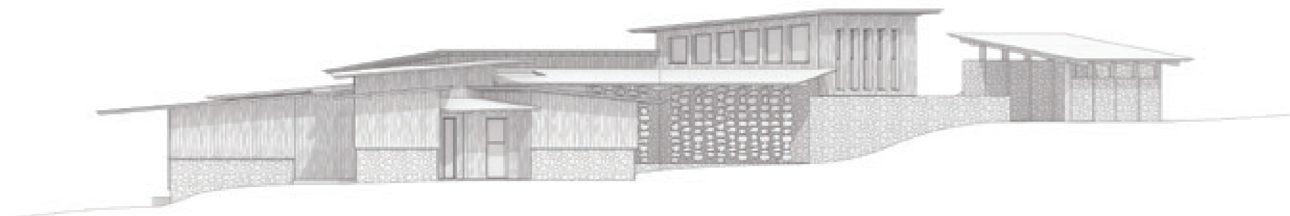
Figure 77



Facade West



Facade South



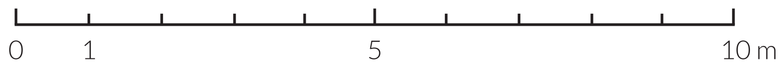
Facade East

Facade North

0 1 5 10 m

Figure 78

Section A:A



CONSTRUCTION

The supporting structure of the building is made out of wooden joists and studs. These are stuffed with insulation and cladded with wooden panels and stone tiles on the exterior, while using a variation of stone, wood and cement on the interior. This structure is fastened into the foundation made up of cast concrete and insulation. On top of the foundation is a layer of flooring, also in different variations of the same materials like the interior walls. This blends the walls and floor together into a system of different surface materials and textures. The roof is constructed of wooden beams, insulation and metal sheets. Wooden lamellas are protruding into overhangs that prevents rainwater from hitting the facade and terraces, as well as providing shelter from the direct sunlight. The upper most layer of the roof is made out of metal sheets, reflecting the sky and amplifying the sound of rain hitting it.

PROPOSAL

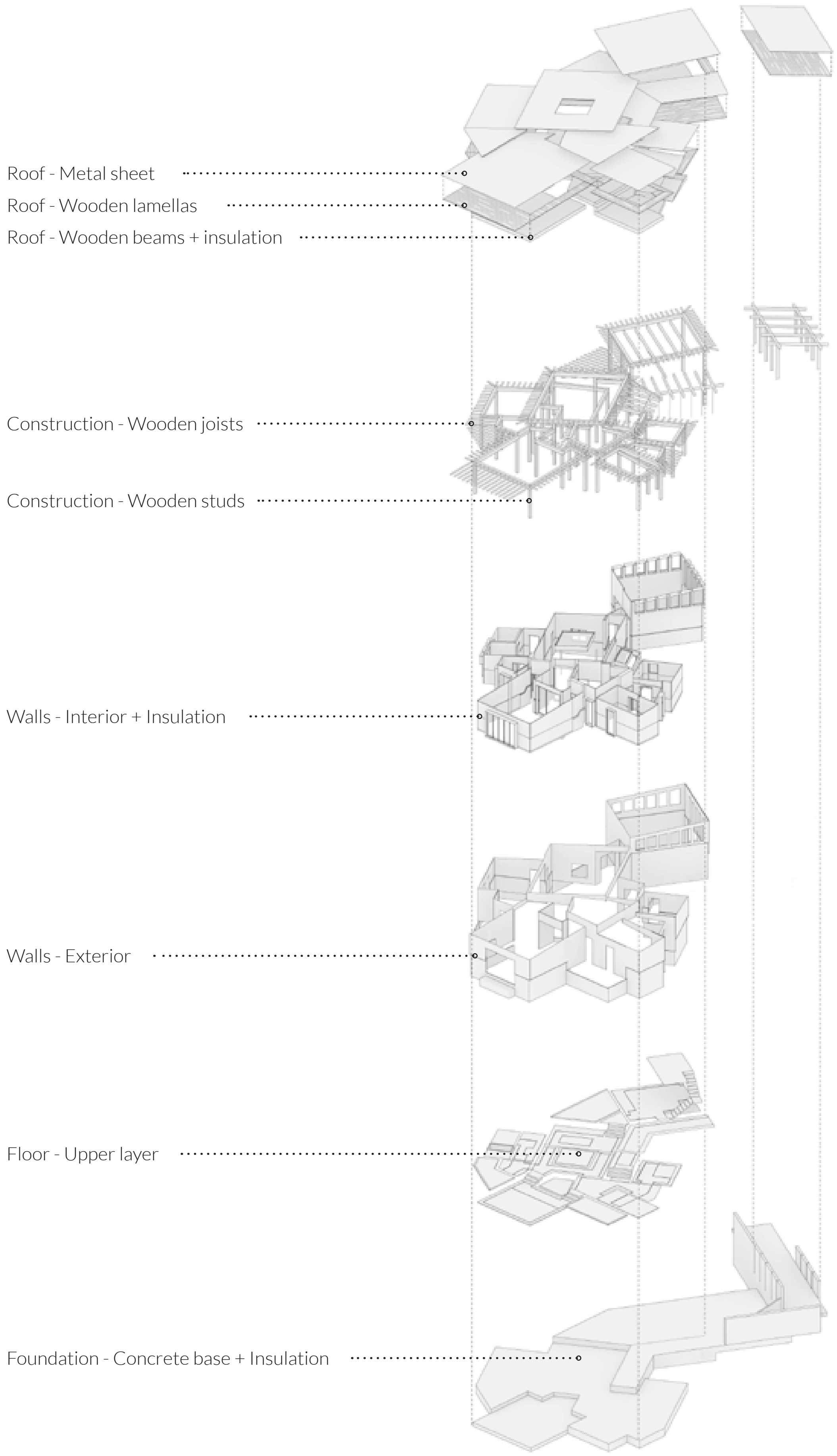


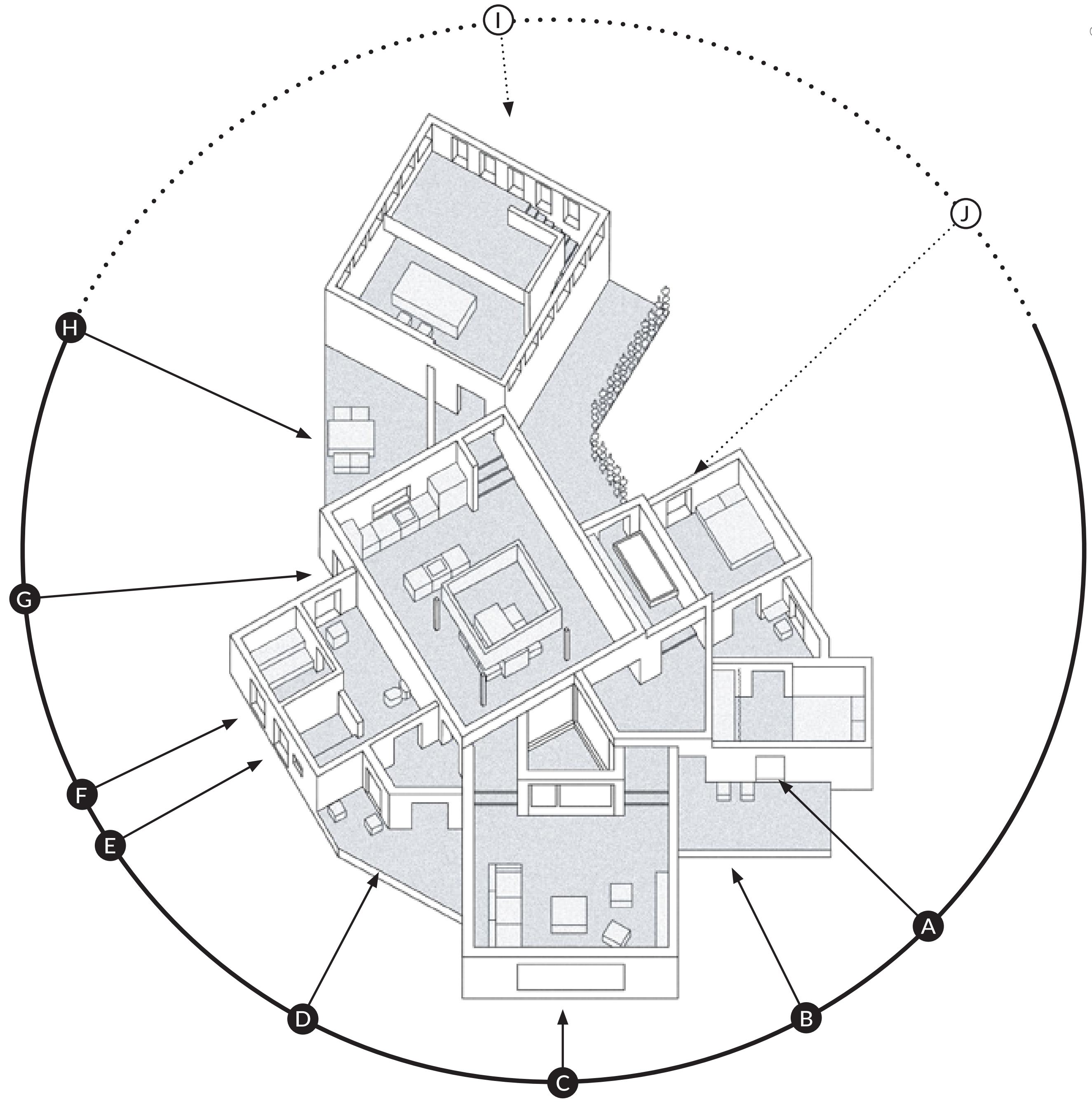
Figure 79

PROPOSAL

USING THE NATURAL LIGHT

- **A** Morning light enters no earlier than 8:00. Casting direct light on the wardrobe.
- **B** Morning sun on terrace
- **C** Sunshade does not let in direct sunlight in the summer but does in the winter.
- **D** Midday sun terrace
- **E** Evening sun to provide vision when showering
- **F** Evening sun in sauna
- **G** Evening sun to use last rays of sun to cook dinner
- **H** Evening sun terrace
- **I** Diffuse light avoids glare when using the workshop
- **J** Diffuse light for sleeping

Figure 80



Enhancing everyday life activities by positioning the rooms so the activities can utilize the direct sunlight.

LIGHTING TYPOLOGIES

A **PROCESSION -** The turning nodes in the building have a view towards openings, guiding the user through the building.

B **CANALIZATION -** The skylight canalizes the light down to the eating area.

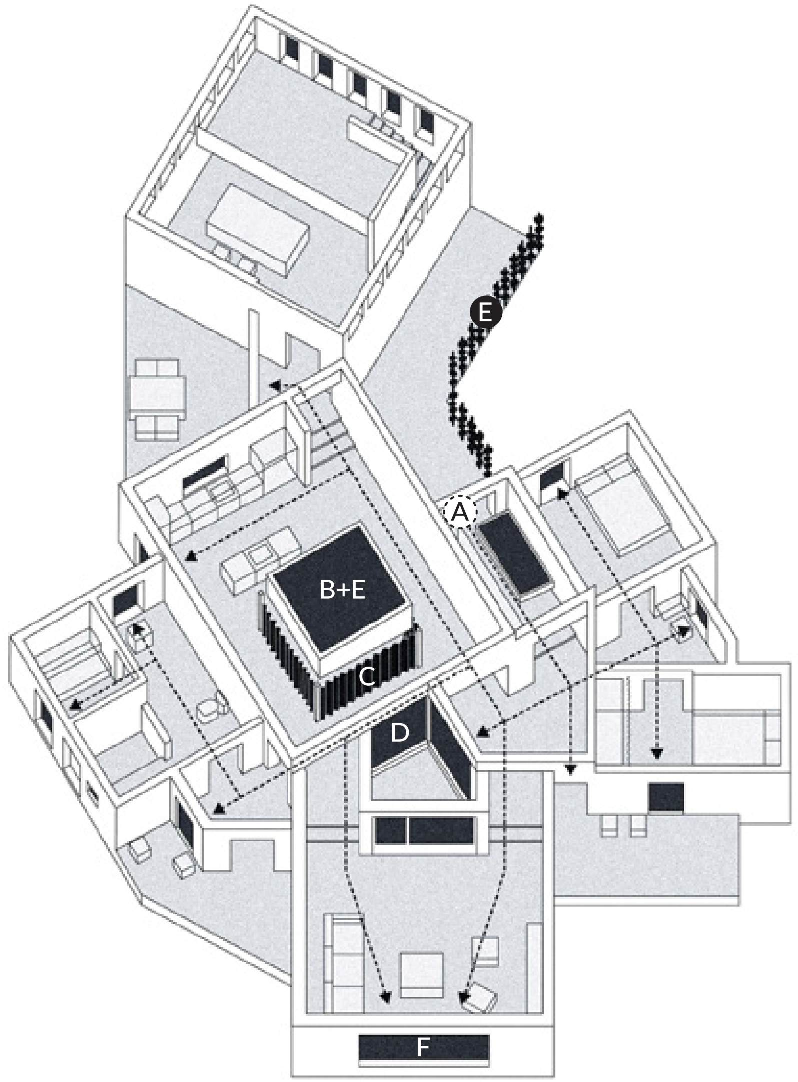
C **LUMINESCENCE -** The fabric materializes the light coming down from the skylight, making the fabric glow.

D **VEILS OF GLASS -** Large windows towards the atrium brings the exterior closer to interior.

E **ATOMIZATION -** A floating rock wall filters the light to create shadows and diffuse the light when entering and exiting the building. Allowing the eyes to adapt. The herbal crown and fabric filters the light.

F **EVANESCENCE -** The sunshade outside the large living room opening blocks the harsh summer sun but allows the winter sun to enter. The lighting changes over time and season.

Figure 81



The lighting typologies by Plummer implemented into the building.

SENSORY DESIGN

SOUND - Large ceiling height, separating spaces from each other. Acoustic landmark

SOUND - Wind chimes as auditory landmarks, guiding towards the entrance

SOUND - Rain amplified by metal roof brings nature closer.

SCENT, TASTE - Herbal garden, fragrant landmark.

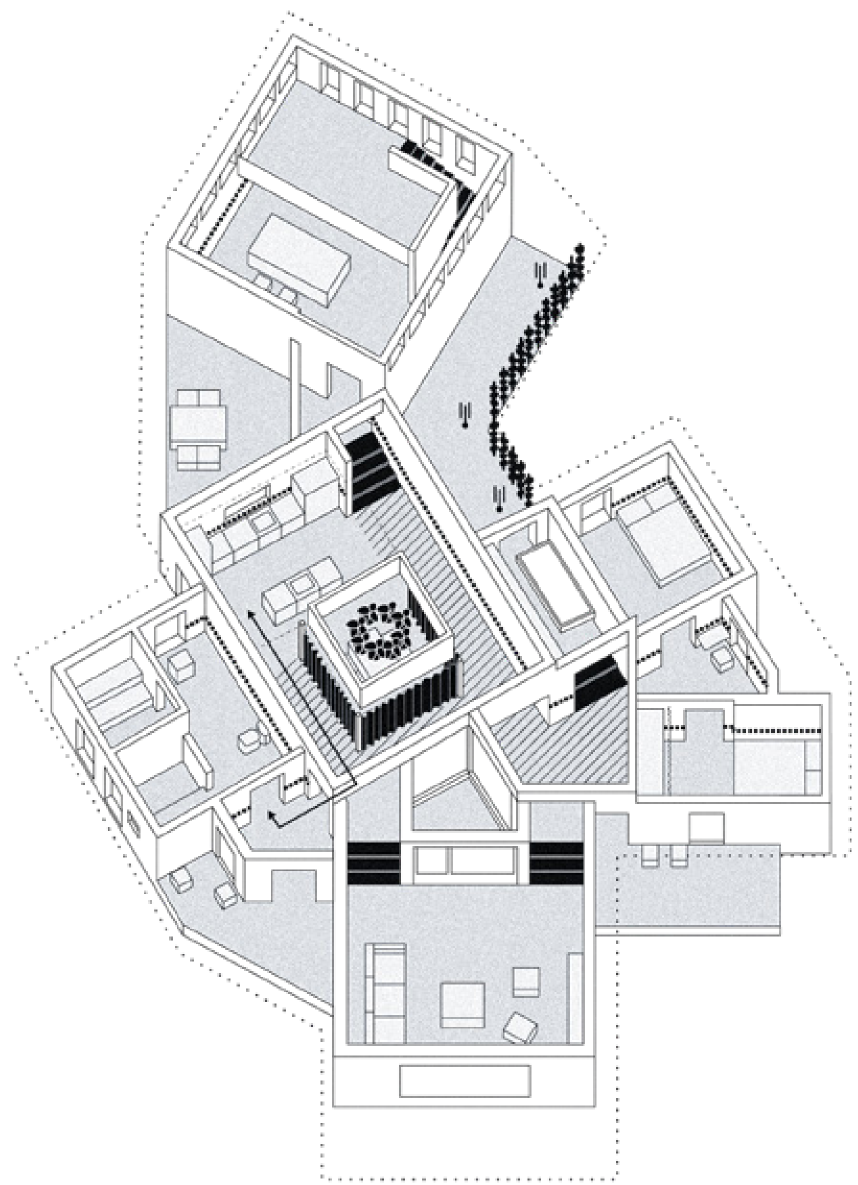
SCENT, TASTE - Kitchen and bathroom separation. No conflicting smells.

TOUCH - Cold stairs compared to warm floor signals that a staircase is in front of you.

TOUCH, VISUAL, SOUND - Curtains bring movement to touch, separates acoustics

TOUCH, VISUAL - Guiding tactile strip of wood through the whole cabin.

Figure 82



The sensory design implemented into the building.

Figure 83

Material differences creates a navigational system with landmarks and guiding lines.

Figure 83

The guiding line that goes through the building becomes handles for the stairs, the handles are then integrated into a wardrobe.

Figure 84

Herb garden to spread scent in the kitchen and the hallway. The direct light from the skylight is diffused by the hanging curtains.

Figure 84

The faint light from the moon, stars and occasional aurora borealis during night is enough to reflect in the metal linings on the floor, helping the user navigate.

PROPOSAL

SPACIAL CHARACTERISTICS

Movement

The movement is planned so that every activity is easy to locate and placed in a manner that supports the natural flow in the building. For example the toilet is placed along the wall between the door to the bathroom and the faucet. This makes the movement from door-toilet-faucet natural and without the need to let go of the wall in the dark.

Resting

Resting zones are placed to not conflict with the movement axis. This separates the resting planes from the movement planes, preventing furniture and users resting from obstructing the movement.

Negative space

Several opportunities for circulation is made in the plan, letting the user find alternate ways of moving around the house without compromising the ease of navigation.

Daylight Factor

The skylights and atrium provides a bright atmosphere even in the central parts of the building. The study was made without the use of any curtains which is why the daylight factor is significantly high in the kitchen. The second bedroom or guest room has quite poor lighting conditions, this is due to a compromise where the placement of the window was made to the north instead of the east to prevent direct sunlight from entering the room during early mornings.

Figure 85

Movement.

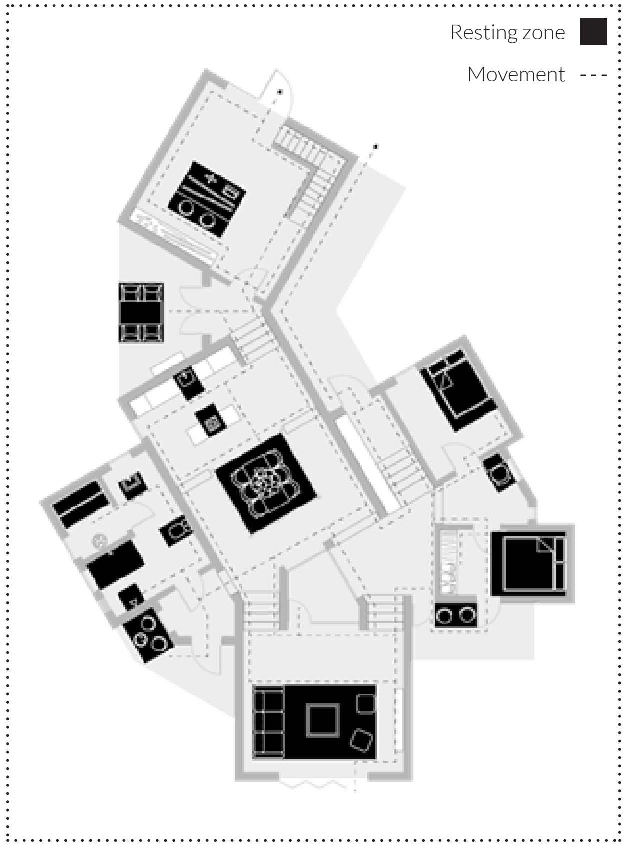


Figure 86

Resting zones.

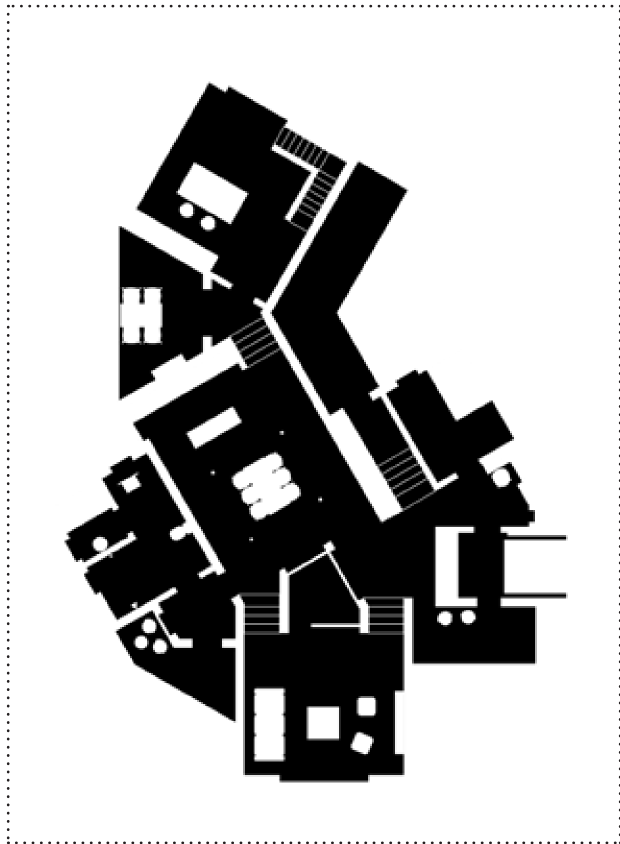


Figure 87

Negative space, movable space.

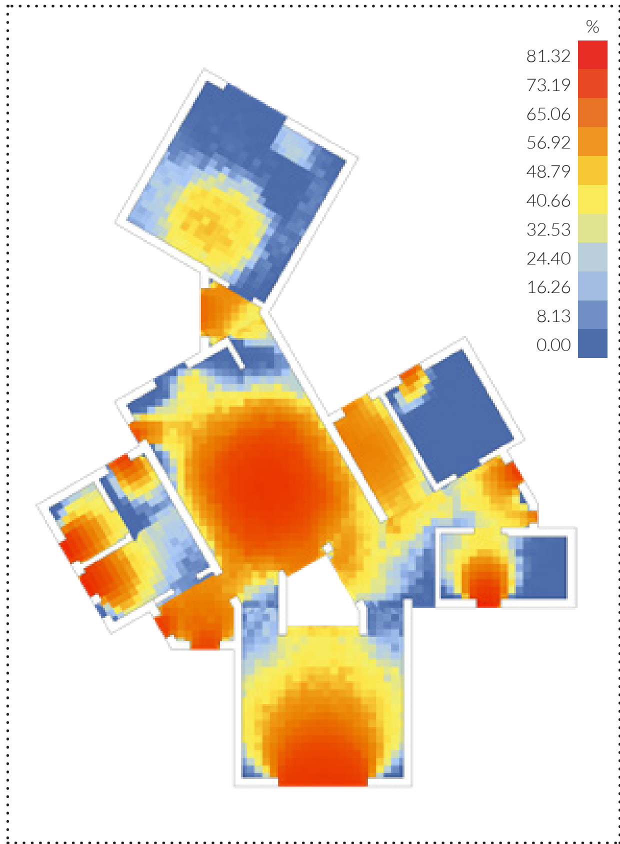


Figure 88

Daylight Factor.

Figure 89

Lighting in different seasons and times during the day. The scenes are exposed for the interior to imitate eye-adaption.

REAL-TIME RENDERING AS A TOOL

As mentioned before, the use of real-time rendering has both been used in the process of design as a feedback loop and as the final representation of the cabin. In the process the software Enscape was used because of it's seamless integration into *Rhinoceros* which is the software I used for the 3D modeling. This allowed me to see the changes I made to the design interact with the daylight and to visualize it instantly. It also let me move around the building freely. The first design iterations were made without using any materials besides a white color. The purpose of this was to focus on design based on the direct sunlight only. Later on materials where added which changed the brightness significantly in many rooms. Rooms with dark materials often became too dark and was therefore adapted to use brighter materials instead. The materials chosen in this step were preliminary and functioned to give a sense of the brightness in each space. Finally, the model was exported to Unreal Engine where the final materials were applied as well as the detailing of the surrounding landscape.

Real-time rendering is good at visualizing space and making it interactive. However, it can still not be compared to experiencing spaces in real life, not even with the use of virtual reality. The reason for this is that everything is viewed through a camera and the camera is limited to the properties of it's lens. No lens is yet able to reproduce the dynamic range and adaption of the human eye. This makes it impossible to reproduce a true to life simulation of light and space. When capturing an interior space with a window where the sun shines and without any artificial light, the contrast between interior and exterior become too large for the camera. This results in an image where either the exterior is too bright or the interior is too dark. There are technologies that try to make it more accurate such as *HDR* (High Dynamic Range).

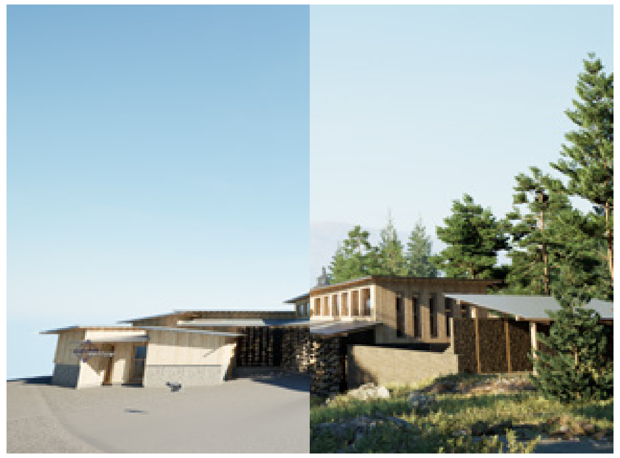
The aim of using real-time rendering in this thesis is therefore not to reproduce reality but to come a bit closer to it. The study made by Chamilothori et.al (2019) suggested that the experienced differences between reality and virtual reality where not significant enough to change the participants answers. A digital model could therefore be adequately used as a form of preliminary evaluation of a building, as long as the input data such as the sun position is corresponding to the real world.

Figure 90

Enscape. Visualizing light.

Enscape. Visualizing light interacting with materials.

Unreal Engine. Finalizing materials.



Unreal Engine. Creating the surrounding landscape.

RESULT

Looking at the two overarching questions:

What needs to be considered in designing a livable and functional house without the use of any artificial light? And how could it be implemented into a proposal?

The theoretical part of the thesis answers the first and the design proposal the second.

The chapter *Design for Natural Light* brings up examples of how to design with daylight for a livable home while the chapter *Design for Senses* and *Design for Darkness* provides examples of how to make it functional during darkness.

The principles and theories these chapters takes into consideration are then implemented into the proposal and simulation. The simulation functions as the final representation of the proposal and the *Proposal* chapter of this thesis functions as an explanation of the design process and concept.

Figure 91

The southern facade on a sunny morning.

EVALUATION

REFLECTION

The biggest challenge has been to limit the vast amount of information there is on natural light and simulation. Since it is a very broad topic with many fields overlapping the information needed to be relevant for the specific aim for designing architecture without artificial light. Very few studies have been made on this specific matter from what I have gathered. Maybe because of the absurdity in the presumption that people would be willing to live without artificial light in the modern world. Studies on multi-sensory design was quite easy to find but sometimes lacking in the practical implementations of them. I therefore took it upon myself to transform the theory of multi-sensory design into practical examples, these being quite obvious, such as wind chimes generating sound to help with navigation.

The combination of the three layers was also a challenge to balance out. Each of them could be expanded in scope to cover three different theses. To dive deeper into each area would have been interesting but difficult to manage within the time-frame. Using Unreal Engine to simulate the building was an uncertainty during the writing of the thesis, as I had not used the software before, i was not aware of the time it would take to learn it properly. This led to many limitations in the quality not being on par with the technical standards necessary to make an accurate physics-based simulation. For this reason the thesis does not evaluate the proposal using methods such as the PILQ formula or the questionnaire from Chamilothori et.al (2019).

Through the design process of the proposal there was also a conflict between favoring the thesis or the competition that it will be submitted to. The competition would need to have a marketing value with a strong, comprehensive concept and context. This could become the opposite of what the theoretical findings would favor. The fields of multi-sensory design and design for natural light are however quite free in their adaptations which would allow me to create a balance in both marketing value and academic value, landing the proposal somewhere in between purely academic and purely artistic.

The cabin offers a lifestyle taken to the extreme. It is a challenge to live a life without any access to electrical lights or even candles. What do you do during the days and evenings in December when most of the time it is completely black? And why would you want to be living here during this time?

Maybe the best use of the building is not for a permanent couple, but better suited as a rentable retreat where the time to develop seasonal affective disorder isn't enough. Which most likely would be a problem for people living here permanently. Reflecting upon the life that the cabin offers I believe that it would not be enough for someone to live here permanently due to the extreme conditions of the climate. This is something that I don't believe architecture can solve just by using natural light and materials, there has to be artificial light for it to be livable enough. I do believe however that the proposal offers enough functionality to live in the cabin permanently by the use of the haptic language and sensory design.

One aspect I wished I would have explored further is the seasonality of the cabin. How different spaces can adapt the arrangement of furniture for example. The chosen method of framing each piece of furniture with other materials brings a very strict placement of furniture where there are no possibilities of moving them around. Maybe the kitchen would have been better placed in the living room during winter, where there is most light for example. Further exploration of this could be in finding a method where the furniture are adaptable and movable while still keeping a rigid system of framing with materials around the furniture for the ease of navigation. A modular system perhaps and less conventional.

I believe the concept principles of *Life follows the sun & season, Lighting typologies, Sensory design and Design for navigation* where successful in their execution and something that can be implemented to achieve a building that can lower the usage of artificial light in other places as well. Designing with this in mind can help lowering the electricity usage, light pollution as well as providing a comfortable environment for the users where everyday activities can be performed without having to first turn on a lamp.

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