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Abstract:

The following thesis presents the development process for a new lighting hierarchy for museums. Based on findings from literature reviews and a series of on-site investigations of the interaction between light and surrounding surfaces in five museums, this thesis seeks to understand the relationship between light and surrounding surfaces and how visitors appreciate artworks and perceive the entire space in a better museum context.

Through a survey of 5 museums in Denmark, three main points were observed to better understand how people perceive the museums, each one associated with space, materials and light. The impact of light distribution and characteristics of materials in the museum spaces contributed to the problems summarized by the findings. In order to allow problems in the museum spaces to be analyzed more precisely, the museum space was divided into three small areas: the display area, sitting area, and transition area. This thesis uncovers and then solves the problems in each small-scale space to combine them into a large-scale space.

In line with the objective of this thesis, the on-site investigations and literature reviews directly informed the design ideas and criteria of the proposed lighting hierarchy. Moreover, a concrete place, Thorvaldsen's Museum was proposed to implement the recommendations in. Lab experiments and 3D simulations were used to test whether the goal in each area (to focus, to guide or to blend into the background) was met.

As neither the final solutions nor user interviews were carried out, further investigation is necessary. However, the proposed new lighting hierarchy offers a better lighting distribution for supporting the display objects and the entire museum environment as a whole.

A new lighting hierarchy for museums

Wei-Ting Tsao

Master Thesis
M.Sc. Lighting Design
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ABSTRACT

The following thesis presents the development process for a new lighting hierarchy for museums. Based on findings from literature reviews and a series of on-site investigations of the interaction between light and surrounding surfaces in five museums, this thesis seeks to understand the relationship between light and surrounding surfaces and how visitors appreciate artworks and perceive the entire space in a better museum context.

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01 INTRODUCTION

01-1 The rationale

A museum is an institution that preserves and maintains objects of scientific, artistic, or historical importance. However, the museum is also becoming a leisure space for the public and a part of everyone's lives. Today, museums can be considered an essential part of modern life.

In the past, museums were primarily places for researchers and experts to conduct research and surveys. Over time, museums' target demographic has gradually changed to include everyone. The display of collections gives the public an opportunity to see what is in the museums and access the museums. As such, the purpose of visiting museums is no longer only to gain new knowledge, but also to experience different activities that museums provide. Thus, the museum has recently come to serve as a public and educational building for everyone, and being "people-oriented" should be a core value of museums [1].

The museum space's transition from one with the sole purpose of private preservation into one that also welcomes the public, sparked my interest in the spatial elements that support the appreciation of artwork. Specifically, I became curious about how these elements can be hidden behind the artworks but still exert their influence to enable the artworks to be appreciated in a better spatial context. Therefore, the aim of this paper is to determine how to support visitors' perceptions of the artwork and the space in a better environmental context, without taking away attention from the beauty of the artworks.

01-2 The fascination with space attracts people

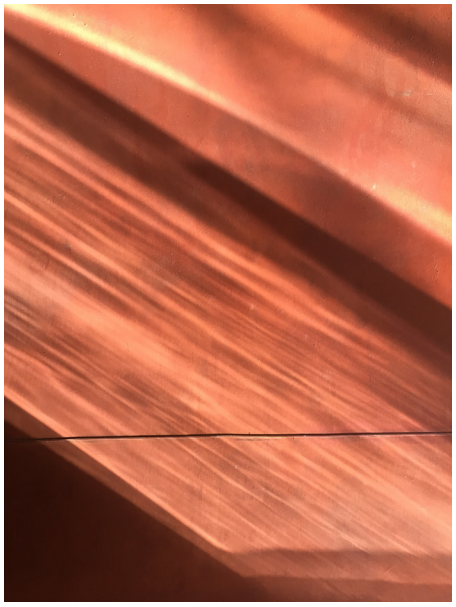
"Architecture is the masterly, correct and magnificent play of masses brought together in light"-Le Corbusier [2]

Light has always been recognized as one of the most powerful formgivers available to the designer, and great architects have always understood its importance as the principal medium that puts man in touch with his environment [2]. Materials likewise play a very important role in spatial design. The characteristics of various materials affect the spatial environment and produce different visual languages and texture effects. The characteristics of diverse materials, such as form, color, texture, luster, and durability should be applied carefully because they impact people's psychological feelings about a spatial environment.

Light and materials are inseparably connected. Indeed, they actually define one another: neither is visible to the human eye until the two come together. For this reason, great architects have always allowed themselves to be directed by the light in the choice of their building materials. They use light to draw out contrasts between different materials, and they use materials that allow them to create a very specific distribution of light in a room [3].

Based on my experience as an interior designer, I am not only interested in the content of the exhibitions themselves, but also the elements that structure the museum space when I visit museums. The interaction between structural elements, different surface materials, and the lighting creates a very positive perception for the visitors.

01. INTRODUCTION



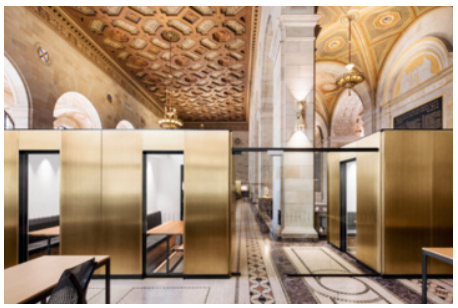


Figure 01-2-1 Inspiration image [self-produced]
Figure 01-2-2 Inspiration image [4]
Figure 01-2-3 Inspiration image [5]
Figure 01-2-4 Inspiration image [6]

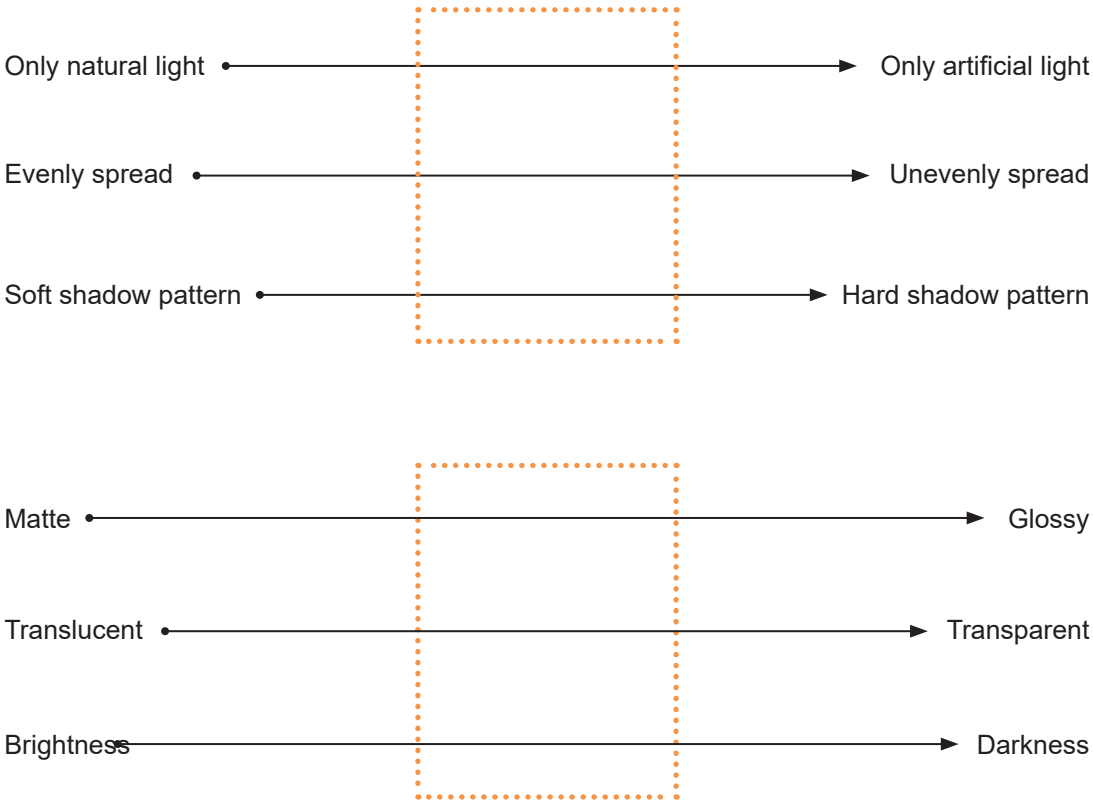
01-3 The vision

This project seeks to observe the relationship between light and structural elements and how these elements influence visitors' perception of the space and appreciation of the collections in a better context of museum space. Following this line of thought leads to the proposed vision:

"Imagine if light interacting with surface materials could help enhance people's perception of museum spaces."

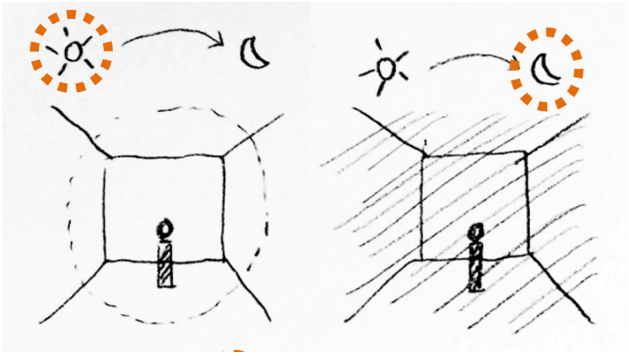
02 MUSEUM SURVEYS

In order to further understand museums, five museums were selected for further investigation and analysis, in which the five museums had not only retained their original architecture, but also had similar types of objects in their collections. To better understand the museum space in its current lighting state, its display approach and its spatial context, three perceptions (space, material and light) were identified to determine the different problems museums that incurred under different lighting environments, and the effects of the surrounding surfaces.

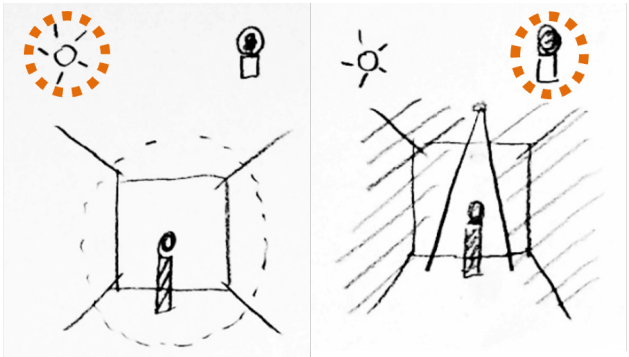


02. MUSEUM SURVEYS

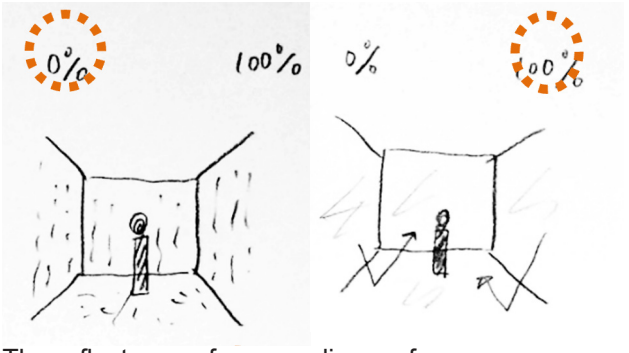
02-1 Survey findings



Daylight



Artificial light



The reflectance of surrounding surfaces

Figure 02-1-1 The diagram of the museum problem with daylight [self-produced]
Figure 02-1-2 The diagram of the museum problem with artificial daylight [self-produced]
Figure 02-1-3 The diagram of the museum problem with surrounding surfaces [self-produced]

- Vulnerability to changes in time

A series of observations and analyses revealed that the two extreme results did not have the best effect on the space in terms of lighting distribution and materials. When a space has only daylight, the entire space and exhibits allow good perception of 3D objects and the surrounding environment, but when the daylight disappears, the whole space will fall into darkness.

- Disappearing spaces

In addition, in most cases when a museum space has only artificial light, the lighting is focused on the display and does not pay much attention to the surrounding context, which causes the surrounding spatial elements to be ignored. When visitors access the space, their eyes are only drawn to display objects rather than taking in the overall sense of space, which greatly reduces the experience of visiting the museum space.

- Visual disturbances

In terms of material properties, when light reacts on a matte material, the surface of the material is relatively rough. This rough surface will reflect the incident light at a different angle, so it does not tend to give a particularly clear image. Although this type of material does not clearly highlight the image of the object, it is more suitable for creating a spatial atmosphere, expressing the texture of the surface and expressing the rhythm of the material. However, when matte materials are seen very clearly, it creates the perception of a messy space. On the other hand, as light interacts with glossy materials, when the surface of the material is very smooth, this extremely smooth surface reflects the image of the incoming and outgoing light clearly, which easily creates strong light spots on the material.

Therefore, whether the lighting is interpreted on very low-reflective materials, (which make the matte texture too prominent in the visual field while detracting from the space's display purpose), or in highly-reflective materials, (which tend to form obvious light dots and reflections), inappropriate interactions between light and materials can easily lead to visual disturbances and fatigue when people visit a museum space.

02-2 Problem statement

In order to analyze problems in museum spaces more clearly, I divide the museum space into three small areas: the display area, sitting area, and transition area. To uncover the problems in the small-scale space, solve the problems in each area, and thereby combine them into a large-scale space, I intend to let visitors perceive the entire spatial environment from a small scale to a large scale.

- Current museum lighting situation

After visiting the museum in person and making observations, the exhibition space was divided into three specific purpose areas, which showed that there were no rules in the lighting hierarchy for the exhibition space even though they shared the same purposes. The section below describes each lighting hierarchy under different lighting conditions, and the results.

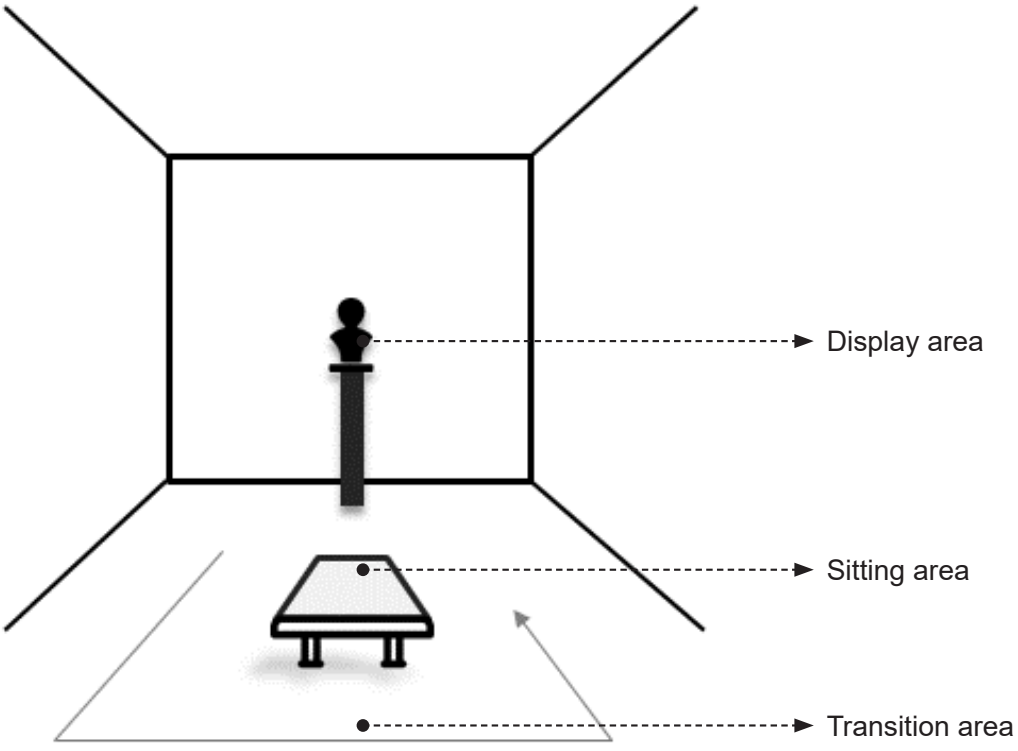


Figure 02-2-1 The image of the museum space is divided into three areas [self-produced]

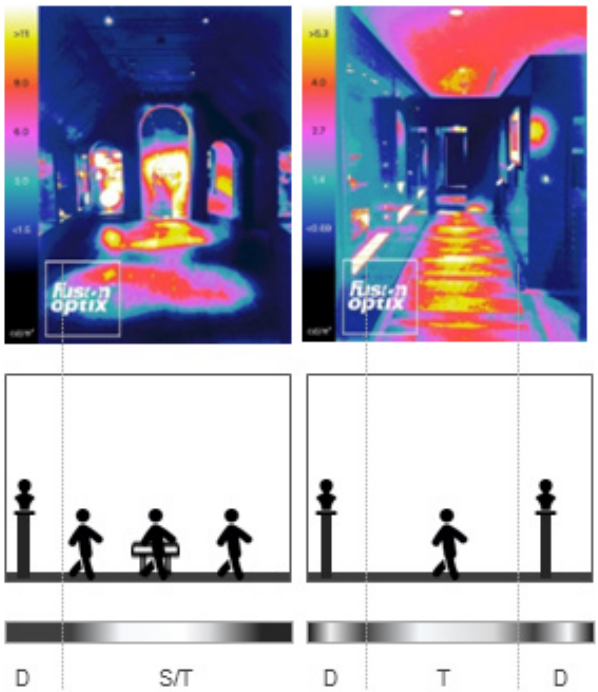
02. MUSEUM SURVEYS

- Only daylight

In the museum space with only daylight, there is no obvious contrast on the D, which is either too bright or too dark, causing the display objects to blend into the background; S is the brightest place of the whole room, causing misunderstanding of the purpose of the space; Light level of T is overlapping with S in the space, causing visual misunderstanding and interference.

D: Display area / T: Transition area / S: Sitting area

Figure 02-2-2
Photos taken in the museum under daylight condition and the image of different light level for different areas [self-produced]



- Only artificial light

When there is only artificial lighting, a strong contrast is formed in D. Although the display items are in a conspicuous position, the effect causes the surrounding background to disappear completely; S is the brightest place in the whole space, causing a misunderstanding about the purpose of the space; the large brighter space is taken by the T area in the space, which creates visual confusion.

D: Display area / T: Transition area / S: Sitting area

Figure 02-2-3
Photos taken in the museum under artificial light condition and the image of different light level for different areas [self-produced]

02. MUSEUM SURVEYS

- Both natural and artificial light

When the space has both sunlight light and artificial light, D has contrast, but due to the location of the windows, the change from daylight to fixed artificial lighting means the lighting solution for the display is not flexible. S is in the darkest area of the space, which will not take away from the display purpose; T is in the second-brightest spot in the room, which subtly guides visitors to follow the flow.

D: Display area / T: Transition area / S: Sitting area

Figure 02-2-4
Photos taken in the museum under both daylight and artificial light condition and the image of different light level for different areas [self-produced]

In conclusion, even though each independent small area has the same purpose, different lighting conditions in each area can create potential confusion among visitors about the space's purpose and misdirect them from the correct flow. The lack of a structured lighting hierarchy in the museum space causes the lighting hierarchy in the museums to be very confusing and messy.

02-3 Research question

To explore the previous analysis and findings further, the following research question is proposed for deep insight and further study.

"How can a new lighting hierarchy interacting with the surrounding surface in museum spaces enhance the appreciation of artworks and strengthen the perception of entire environments?"

03 LITERATURE REVIEW

03-1 How to perceive space - Shadows

"Ultimately it is the magic of shadows. Were the shadows to be banished from their corner, the alcove in that instant would revert to mere void. [7]"

Shadow is an indispensable element in space. When there is no shadow in space, everything in space will become a blank. “In the Praise of Shadows” posits that many feelings can be realized in the darkness from the small objects used in everyday life, from the lacquerware used for meals, to stage art and architecture. The importance of shadows is mentioned from different perspectives. Take Japanese architecture as an example: whether it is a temple, a palace, or a residential house, the most conspicuous aspect of its exterior is the large roof and the different shades of darkness under its eaves.

"To avoid direct sunlight, Japanese extend the eaves or building on a veranda, putting the sunlight at still greater a remove. The light from the garden steals in, but dimly through paper-paneled doors, and it is precisely this indirect light that makes for us the charm of a room. [7]"

"A Japanese room might be likened to an ink wash painting, the paper-paneled shoji being the expanse where the ink is thinnest, and the alcove where it is the darkest. [7]"

Therefore, if you want to see a space, you can't see the whole thing in a light place; you have to see all parts of it in a dark place. Shadows are powerful influences on a space. The balance of varied shade created by shadows and light is utilized skillfully in the space. That is the magic of perceiving space.

When one wants to feel a space clearly, there must be shadows.

We can understand how shadow works and how it interacts with space and objects according to Liljefors, who proposed four types of shadows [8].

1. The big room shadow:
Shadows seen on the walls, ceiling and floor, describing the distribution of light from windows and/or lamps. This type of shadow is difficult to distinguish, since it is easily mixed up with the spatial distribution of brightness.

2. The big object shadow:
Shadows cast by big objects like furniture, cupboards, tables and chairs etc.

3. The small object shadow:
Shadows cast by small objects like a book, a cup, a hand etc.

4. The detail shadow:
Shadows cast by the tip of a pen or by the texture of a surface.

When shadows are cast by different lighting positions, shapes and intensity, the different resulting shadow patterns will directly affect the perception of space. Shadows can not only become helpers and define a space, but can also contribute to visual interference and visual fatigue. Therefore, shadow is a very important factor in forming the sense of three-dimensionality. When we are doing design, we must carefully consider how the shadow works with the objects and space.

03-2 How to appreciate artworks - Illuminating 3D objects

Display is one of the main purposes of a museum. Display lighting is more about task-to background-contrast, while a display is a visual task where the principle aim is to make an object distinct from its surroundings - to draw attention to a particular piece in a shop window or to make a special picture immediately obvious to a visitor entering a gallery [9].

The aim of this chapter is to determine how to properly illuminate 3D objects in museums so that viewers can clearly see and appreciate their details. Unlike 2D objects, 3D objects need to be illuminated with appropriate lighting to enhance the sense of three-dimensionality and make the details visible on the object itself.

A beam of light at 45° to the direction of view is a good starting point for lighting three-dimensional forms [9]. With different lighting angles and sources to illuminate objects, the shadows and effects formed will be different. The shadows enhance the details on the 3D objects, so that the viewer can see the display objects more clearly, not only the borders of the objects, but also the details carved on the objects. The book [9] proposed a table of different techniques for illuminating objects according to different display purposes.

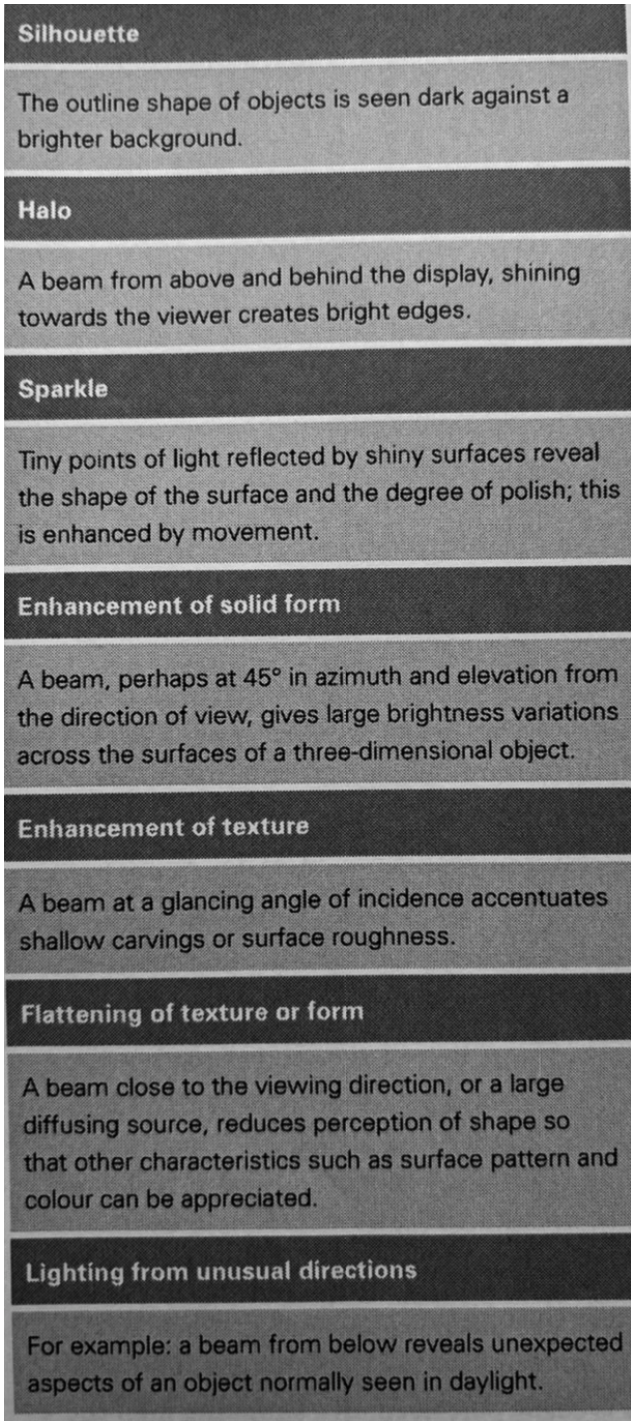


Figure 03-2-1 Some display lighting techniques [9]

03. LITERATURE REVIEW

Daylight is another indispensable element for 3D objects because most of those artworks were created under daylight settings. Thus, in order to copy the original production environment, many museums will attempt to simulate daylight conditions. From the perspective of preservation, daylight will not damage display objects that are made of stone due to their low sensitivity to light. Therefore, the interaction between natural light and 3D sculpture allows display objects to be properly appreciated with a good effect while simultaneously maintaining the original creation environment.

One example of a museum that simulates daylight is the new Acropolis Museum in Athens. This museum tries to simulate daylight environment; the lighting from the ceiling shines down onto 3D statues. This results in good shade for the statues and allows them to be well appreciated in detail, since there is a positive effect on the spatial perception as well.

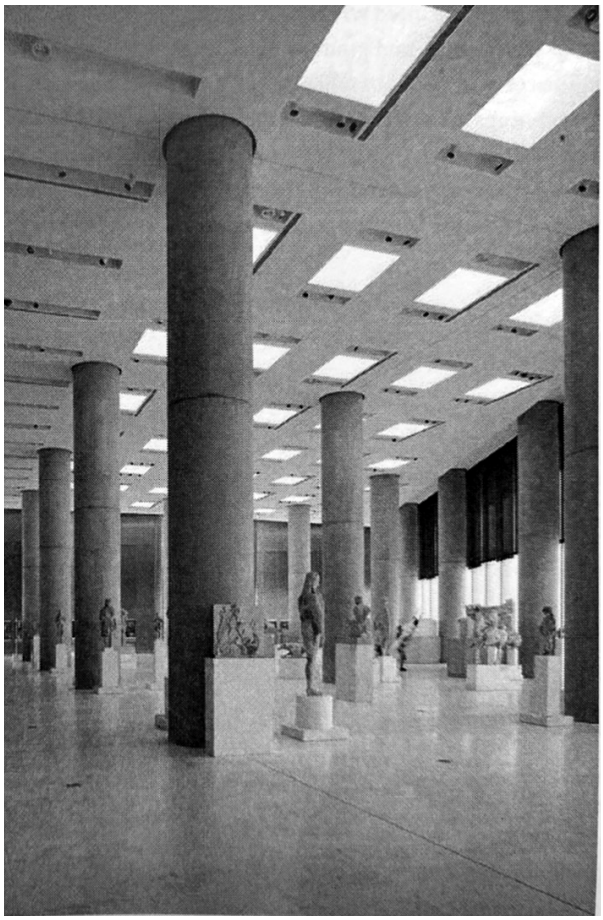


Figure 03-2-2
The photo of the new Acropolis Museum from the book "The Design of Light."[9]

03-3 How to strengthen the perception of specific spaces - Sitting area and Transition area

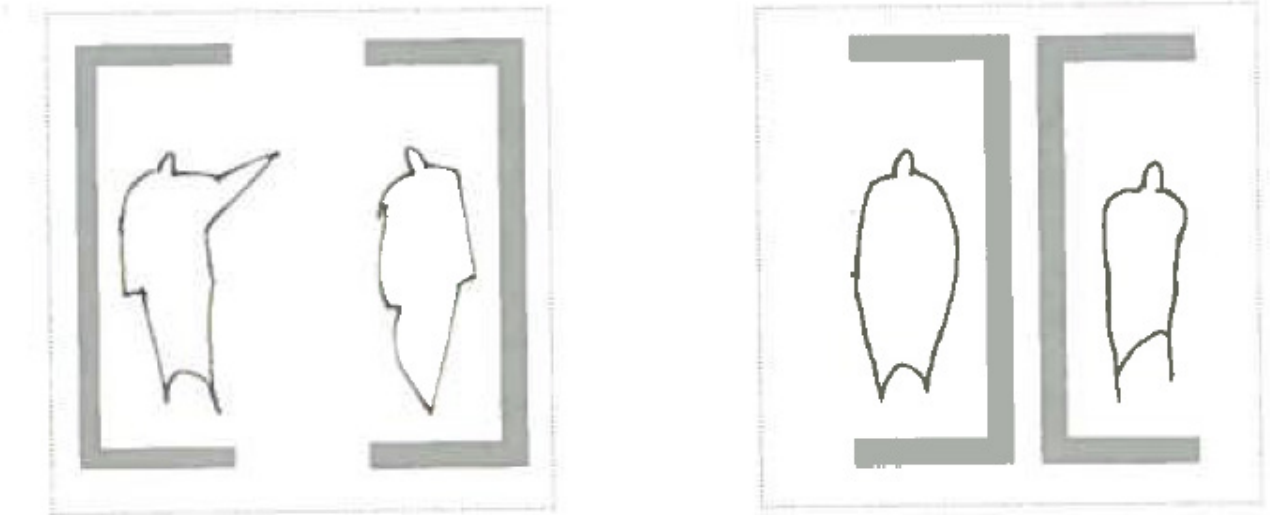
Different spaces have different purposes, so how can we strengthen the purpose of each specific space while making the visitor aware of the function it provides?

The word "atmosphere" is often mentioned with regard to space.

"Atmosphere is therefore a fundamental fact of human perception, that is, of the way in which people sense at once where they are, through their disposition. Seen in this way, atmospheres shape a person's being-in-the-world as a whole: the relationships to environments, to other people, to things, and to works of art. That is why atmospheres are extraordinarily significant for the theory and practice of architecture. [10]"

Atmosphere not only allows people to perceive where they are, but also defines the purpose of different spaces by creating different atmospheres. Atmosphere can be created in many ways, and one of them is through spatial configurations to create different spatial sensations. For example, when creating a welcoming atmosphere, spatial configurations allow a space to be open to each other, or conversely, to form a closed and forbidden atmosphere.

Different lighting angles, light sources, distances, and intensities can help to interpret the different purposes of the space, and support people to be aware of the different purposes of the space.



Face-to-face orientation

Back-to-bace orientation

Figure 03-3-1 The diagram of spatial arrangement from Jan Gehl's book "Life Between Buildings." [11]

- Transition area

The transition space is usually in the middle of the light intensity in the space. It is neither the key point to emphasize, nor the darkest area that does not require lighting. Lighting in the transition area needs to implicitly provide the function of wayfinding. Take outdoor lighting as an example: a footpath is an intermediary transition space that links public and private buildings [12].

The light should provide orientation in the transition area without causing a strong glare, and create a mid-level of contrast between the darkest and brightest areas so that people will subconsciously follow the direction of the light in the transitional space.

Figure 03-3-2 An sketched example of wayfinding with in-ground light points from Ulrike Brandi's book "Light for Cities." [12]

- Sitting area

The sitting area is a small platform that provides chairs for rest and interaction, allowing visitors to sit and relax in a comfortable and relaxing atmosphere while viewing the exhibits.
Benches have a significant social and cultural meaning. As noted by Jan Gehl [11], there is great enjoyment in sitting outside while watching others, which reduces the feeling of isolation in modern, technological life. Therefore, the sitting area should bring a welcoming atmosphere into this space through its spatial arrangement, and combine different levels of lighting to make the space unobtrusive in the entire room. The museum's sitting area should be a comfortable and dimmer corner that does not detract from the main purpose of the exhibition space.

In conclusion, the contrast between light and shadow at different levels not only enhances the ability to see the details of the display objects, but also enlightens audiences toward the different purposes of each specific space, thereby providing a means through which to perceive the entire space.

04 METHODOLOGY

The methodology applied in this thesis is a mixed approach. The architecture process model and evidence-based design [13] are used as a foundation. The mixed approach is used to integrate and translate the findings from the site observations, extensive literature study and testing, to develop a concrete plan for the implementation of the final design.

- Design development model

Light is a multidimensional design element that needs to be analyzed from different fields in order to produce proper design solutions for each specific project. For this reason, the structure followed in this thesis is based on the architectural experiment process model [13] that proposes a method integrating humanities, social science and natural science.

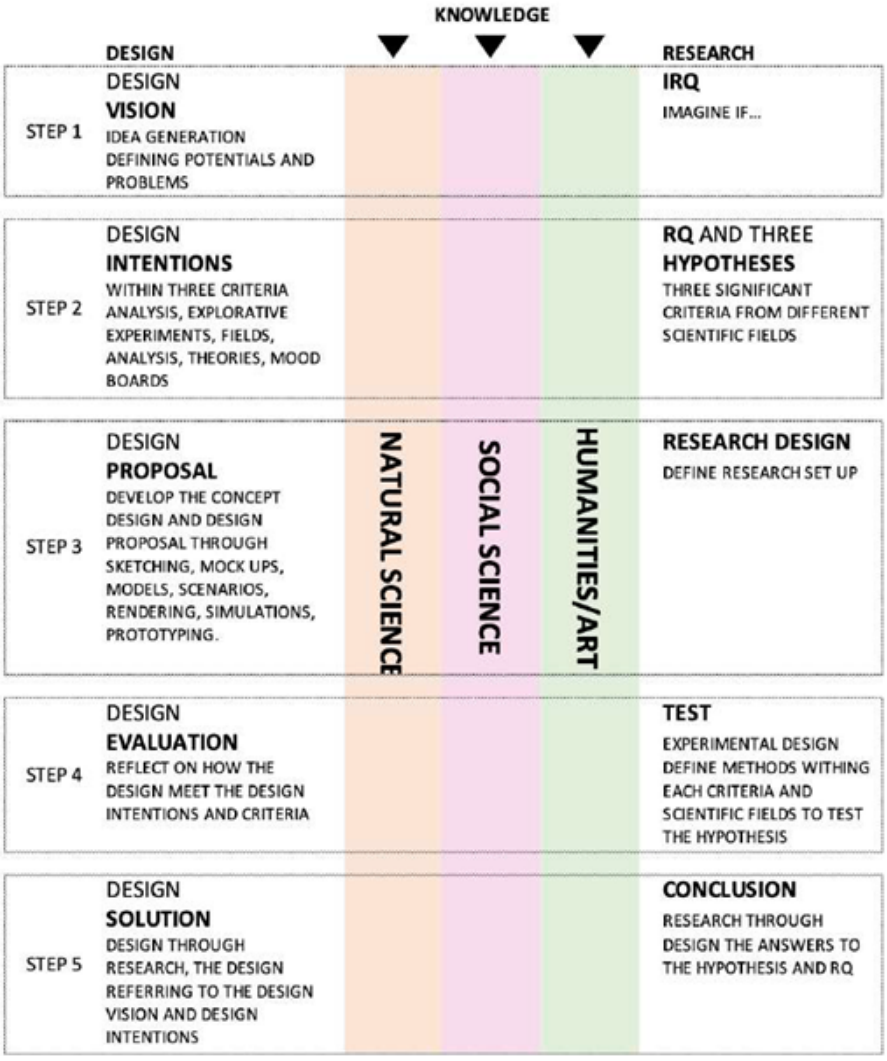


Figure 04-1 Architecture experiment process model [13]

04. METHODOLOGY

- Evidence-based design

Evidence-based design is a research-based approach used to understand how people interact with the built environment and how the built environment influences behavior. It does not consist of ready-made answers, but a complex process through which the designer finds reliable information from different sources to inspire new thoughts and ideas [14].

• Literature review: provides and discusses relevant theories related to how people perceive space with lighting, surface and other elements in order to gain knowledge from previous experiences and research.

• Quantitative analysis of the space: on-site measurements (luminance, position of the existing luminaires) and digital simulations to show the existing uneven spread of problems.

- A concrete implementation place

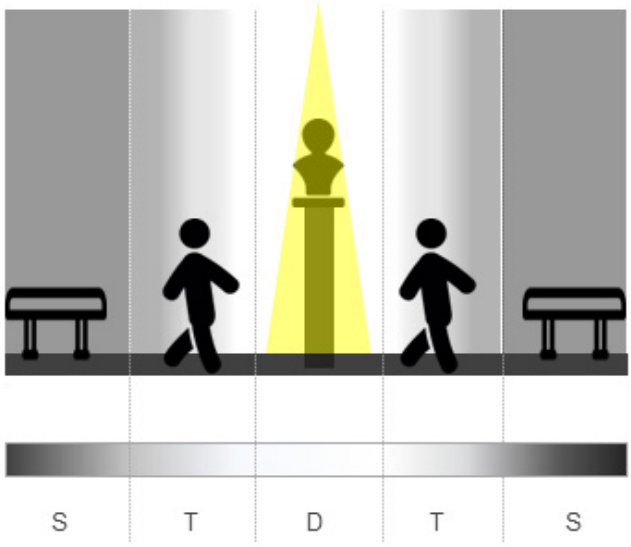
All the information from the previous observation is combined and translated into a design framework that is implemented in a concrete place. Based on the space, a lighting design is developed. The purpose of this approach is to explore how to utilize the design criteria derived from findings from the literature review and the space analysis. Moreover, design testing with different solutions was performed repeatedly by simulating the same conditions for the chosen place in the lab and creating a 3D model in order to find the best approach to implement in the final design in the concrete place.

05 THE INITIAL DESIGN IDEAS

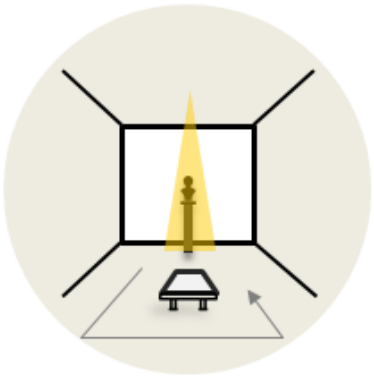
05-1 Design concept

"Light and shadow describes the space while the space describes the light. [8]"

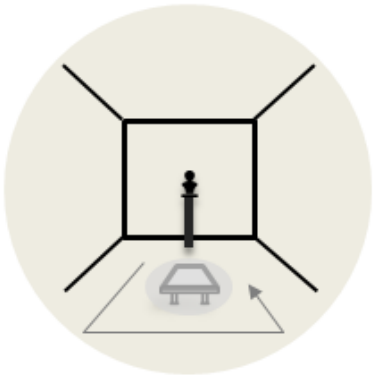
In the previous literature study, many authors pointed out that the contrast in space is an important factor for people to perceive and see the space. The element that forms the contrast in space is the interaction between light and shadow. Different amounts of light and shadow can define the specific purpose of different spaces and potentially influence the atmosphere and experience in the space. Therefore, I will propose a concept to create a new lighting hierarchy for museum exhibition spaces by arranging different proportions of light and shadow to convey different spatial purposes and support viewers' ability to perceive the entire space.



My intention is to divide the space into three small areas according to different purposes and to transform these three areas into a conceptual structure to create a hierarchy that solves the lighting problems. Each small scale is defined as a unit. Combining three small units into a large-scale completed space helps the viewers experience the differences between the small areas by expressing a specific purpose and different light level, and thereby allowing visitors to feel the overall space. These three elements can be seen as individual modules for which different goals and options were explored and tested.



To focus



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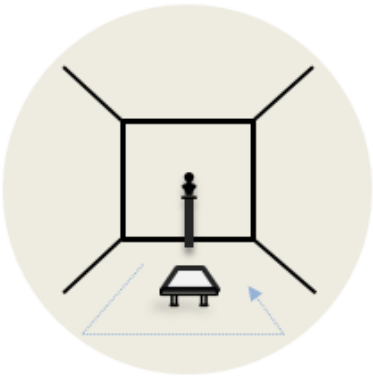


To guide in between

05. THE INITIAL DESIGN IDEAS

05-2 Design criteria

A criterion table was created to help clearly structure the design testing phase related to the individual intentions that were previously mentioned. Knowledge from the museum surveys, literature study and analysis was used to determine a lighting approach to solve the problems. More detailed requirements to consider for the lighting solution were then defined based on the research. The aim of applying design criteria was to narrow the potential directions for explorations. Ultimately, each goal or intention was then tested either on the laboratory or with 3D simulations and evaluated to give a clear design structure to the final design.

	Intention	Light intensity	Lighting pattern	Lighting effect	Luminaire	Material characteristics	Reflectance
Display area	To focus	Highest	Shading pattern Highlight pattern Shadow pattern	Focused	Spotlight (Hard light)	It depends on the displayed objects	It depends on the displayed objects
Sitting area	To be hidden	Lowest	Shading pattern Shadow pattern	Diffused	Conceal light (Soft light)	Matt	Lower
Transition area	To guide	Middle	Shading pattern Shadow pattern	Focused/ Diffused	Both	Matt-Glossy	Higher

06 DESIGN IMPLEMENTATION

The design criteria were presented in the previous chapter. A museum was selected to implement these criteria, with the goal of determining if the proposed design could support and improve the problems in the chosen space.

Thorvaldsen's Museum was proposed as an implementation space for several reasons. First, the composition of the space is relatively simple; most of the exhibition space is composed of one window and wall with the same color. Moreover, there are no complicated structures forming a variety of exhibition spaces, so the survey of the space can be based on the same elements, reducing the variables. Secondly, the display objects are clearly distributed in the space; all the objects in the main floor and corridor on the upper floor are statues, which are the objects I am interested in. The simple composition of the space and the clear arrangement of the display objects were the main reasons that I chose this museum.

Figure 06-1 Thorvaldsen's Museum [15]

06. DESIGN IMPLEMENTATION

06-1 Site analysis

- Location & Surrounding context / Geographical conditions & Open hours

Thorvaldsen's museum is located north of Christiansborg Slot and faces a canal. The height of the palace blocks sunlight at certain times of the day; therefore the brightness of exhibition space varies over time because of the building's location. This causes some spaces to be very dark at certain times of the day and especially on cloudy days, when the entire exhibition space is very dark and artificial lighting needs to be turned on.

In addition to the surrounding context, Copenhagen has a geographical setting at a high latitude, which significantly impacts daylight hours. The number of sunlight hours between summer time and winter time varies widely in Scandinavian countries. During summer time, there are 15 hours of daylight hours, while during winter there are only 8 hours. Based on the Torvaldsen's Museum opening hours from 10:00 to 17:00, artificial lighting must be considered to solve the problems arising from very limited daylight hours during winter.

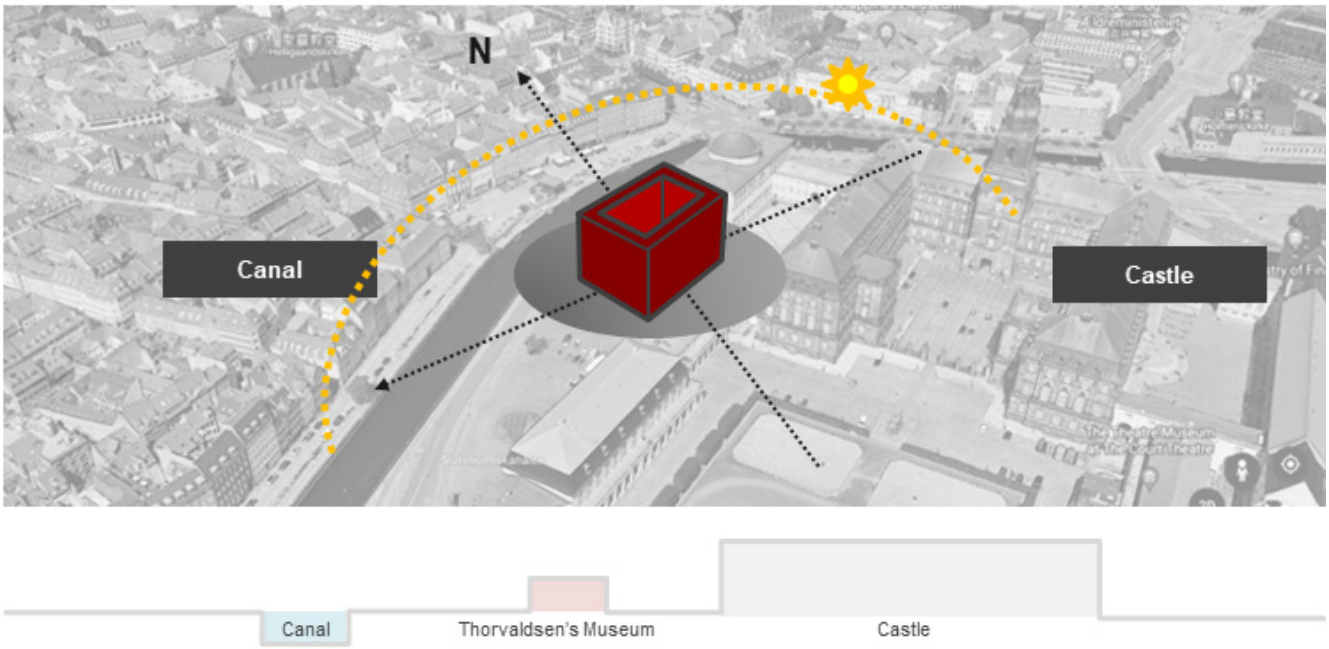
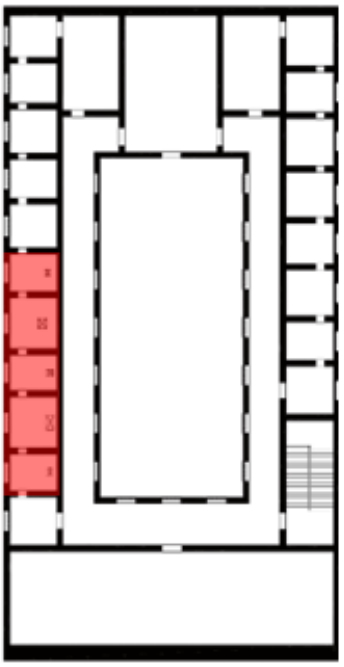


Figure 06-1-1 The location of Thorvaldsen's Museum

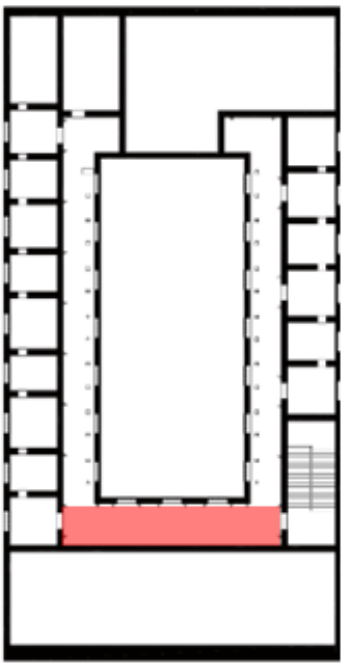
06. DESIGN IMPLEMENTATION

- Two spaces are chosen in the museum:
A room on the main floor /
Corridor on the upper floor

Based on the reasons from the previous analysis (similarity in spatial structures, 3D objects as the main display items, and changes in sunlight in the spaces as the sun moves over time), these two specific spaces - a room on the Main floor and the corridor on the Upper floor - were chosen for further study and implementation of the design.



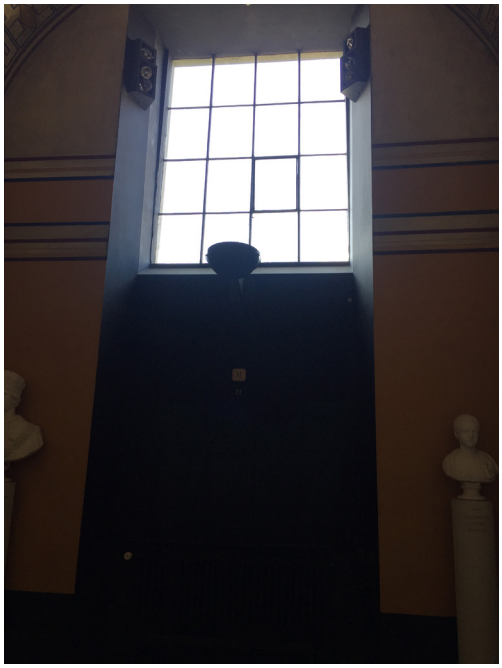
Main floor



Upper floor

Figure 06-1-2 The layout of Thorvaldsen's Museum [self-produced]

06. DESIGN IMPLEMENTATION



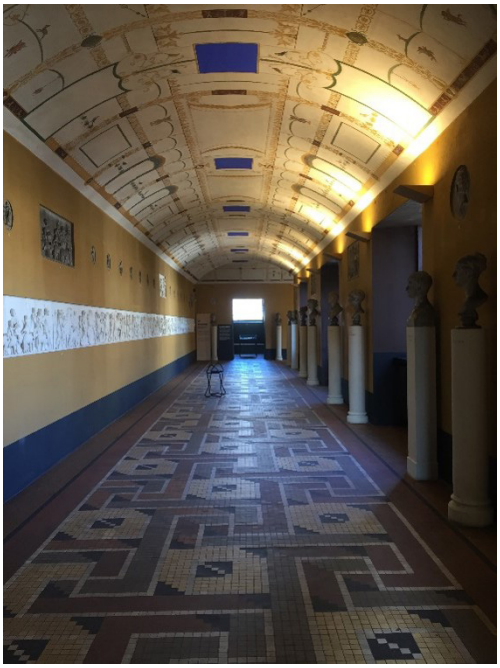
Main floor

- Current lighting situation

Main floor:

On the Main floor, because of the arched ceiling and the need to prevent damage to the existing art in the building as much as possible (by preserving the overhead painting), no artificial lights had been installed on the ceiling. The existing artificial lighting had been installed on the same wall where the window is. Six spotlights were installed on the wall on either side of the window and directed towards the central statue, and one semi-circular wall light illuminated upwards.

Figure 06-1-3 The position of artificial light in the main floor of Thorvaldsen's Museum [self-produced]



Upper floor

Upper floor:

In the corridor on the upper floor, no artificial lighting had been installed on the ceiling for the same reason (to protect the existing art of the building as much as possible), and the only existing artificial lights were installed on the same wall as the windows, with spotlights on both sides of each window shining upwards.

Figure 06-1-4 The position of artificial light in the upper floor of Thorvaldsen's Museum [self-produced]

06. DESIGN IMPLEMENTATION

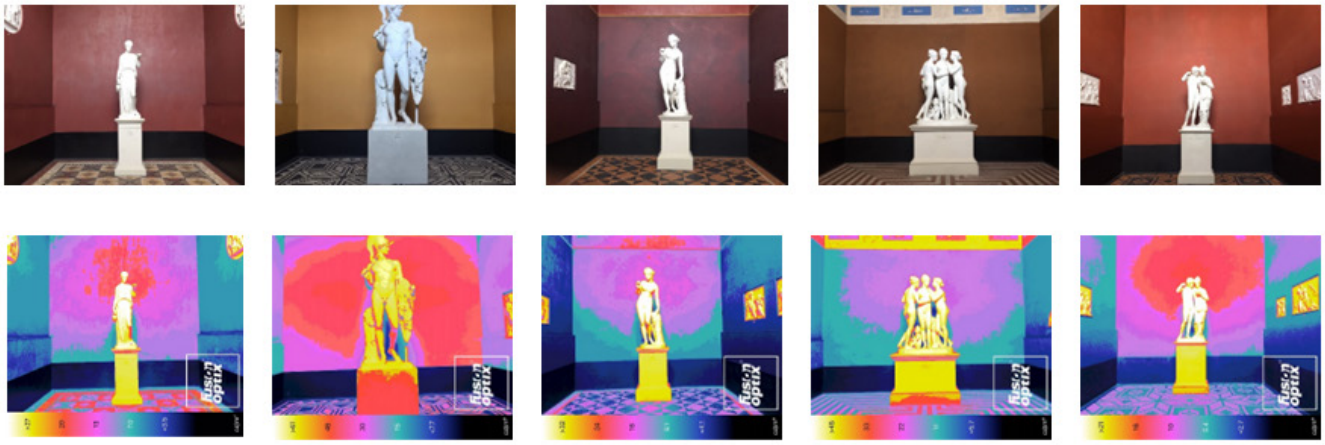
- Lighting hierarchy & Visual comfort with daylight and with artificial light

Main floor:

It can be seen that the space under daylight has a positive effect on the statue, and the perception of the surroundings can be clearly appreciated. Further transforming the space into luminance mapping to observe the distribution of light in the space, and the overall distribution of the space comes close to my proposed concept in each specific area; however, during winter, when the artificial lights are turned on, the lighting in the space is completely focused on the statue and creates various giant light dots in the space, while the beautiful patterns on the surrounding walls and floor fade into the darkness.

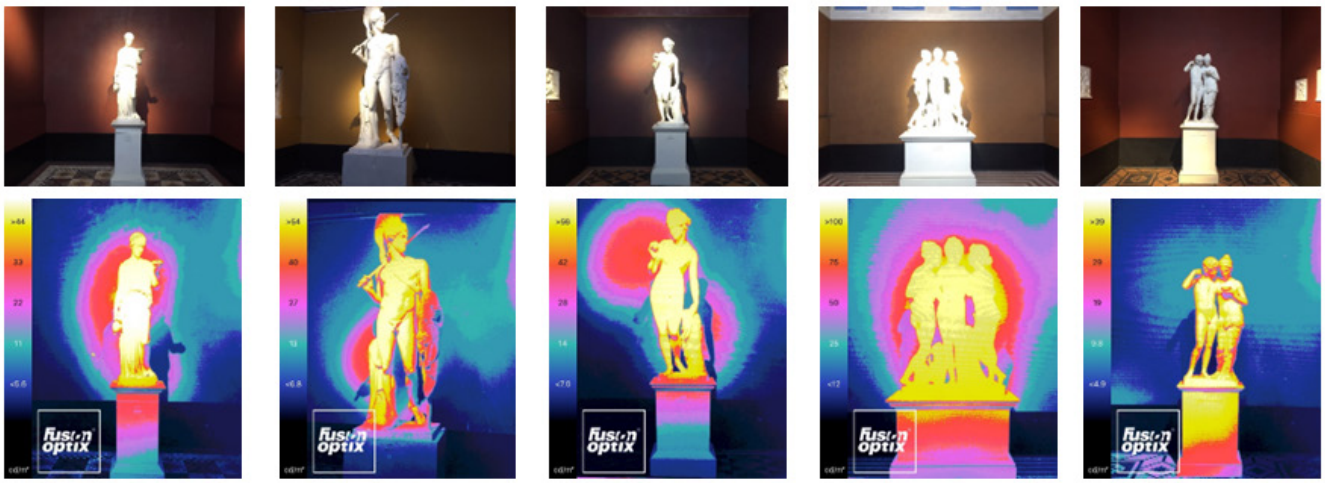
Only daylight - 4/13 In the morning 10:00-12:00

Figure 06-1-5 The statues illuminated under daylight condition and their luminance mapping [self-produced]



With artificial light - 12/8 In the afternoon 15:00-17:00

Figure 06-1-6 The statues illuminated under artificial light condition and their luminance mapping [self-produced]



06. DESIGN IMPLEMENTATION

Upper floor:
The display objects and the surrounding surface can also be fully experienced under daylight. In winter time, when artificial lights are turned on, the spotlights on the display objects in the space disappear completely, and the only artificial lighting illuminates the ceiling. The textured details on the display objects and the walls and beautiful patterns on the floors all fade into dim environments.

Only daylight - 4/13 In the morning 10:00-12:00

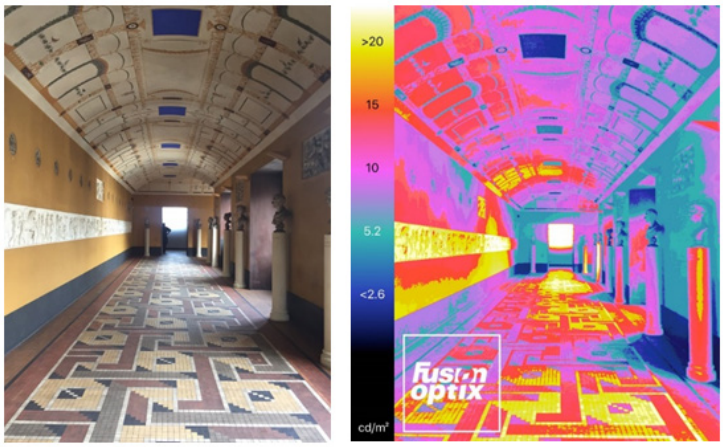


Figure 06-1-7 The corridor illuminated under daylight condition and its luminance mapping [self-produced]

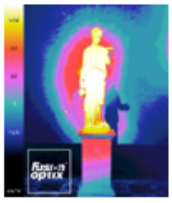
With artificial light - 12/8 In the afternoon 15:00-17:00

Figure 06-1-8 The corridor illuminated under artificial light condition and its luminance mapping [self-produced]

06-2 Key challenges

In short, the above site analysis and investigation found that the overall lighting conditions had good results under daylight, whether for the display items or on the surrounding environment. With regard to the small unit space in each division, the lighting distribution level aligned with the proposed concept; however, when the daylight disappeared and artificial lights were turned on, problems emerged one by one. The artificial lighting was neither focused on the display items, nor provided the appropriate lighting based on the purpose of each space, so that the experience of the entire space disappeared.

Main floor

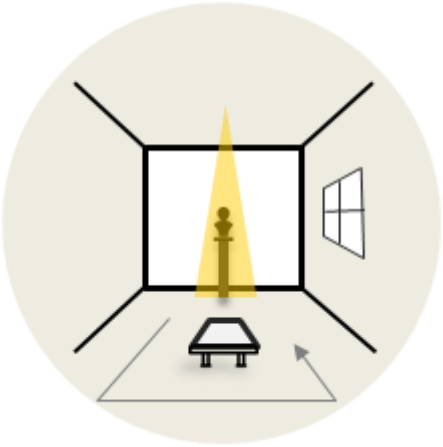
		Sculpture	Background	Floor
Summertime 4/13 with daylight (Morning)		It is bright on the sculpture without apparent contrast.	The background is noticeable.	The floor is recognizable. It is easy to see the patterns and colors which are used on the ground.
Wintertime 12/8 with artificial light (Afternoon)		It is too bright on the sculpture without apparent contrast.	The background is dissolving in the space.	The floor is quite dark. It is hard to recognize the flow and direction.

Upper floor

		Sculpture	Environment	Floor
Summertime 4/13 with daylight (Morning)		The sculpture is dark. It is brighter on the bottom part than the upper part of the sculpture.	The environment is relative spreading evenly. It is easier to recognize objects in space.	The floor is recognizable. It is easy to see the patterns and colors which are used on the ground.
Wintertime 12/8 with artificial light (Afternoon)		It is quite dark in the sculpture without apparent contrast.	The entire environment is gloomy but artificial light creates a higher light level in space. It creates a strong contrast.	The floor is quite dark. It is dissolving in the space.

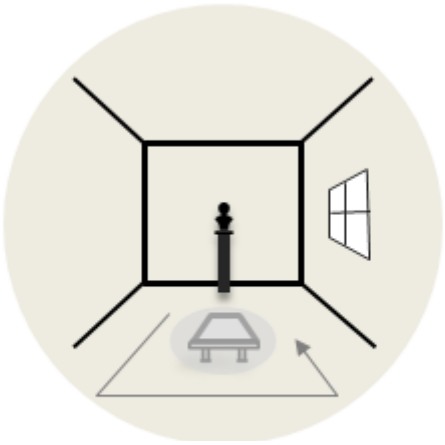
06-3 Design framework

The previous analysis and comparison found that in an environment with windows that brings in daylight, whether on the display objects or on the surroundings, the overall spatial context had a good distribution of light. Therefore, I will propose a simulated window linking three specific spaces with different purposes to create a new display space lighting hierarchy.



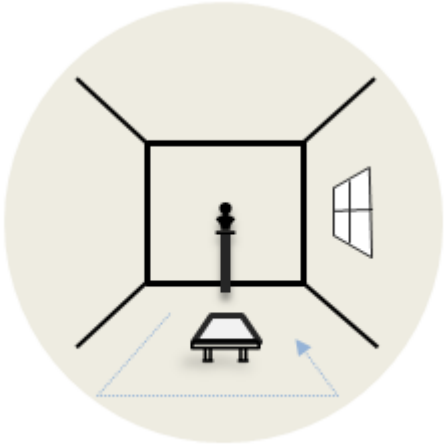
- Display area - To focus

ENHANCE
- See the detail (background and foreground)
- Visual attraction
- Thereby perceive the entire space context



- Sitting area - To be hidden

IMPROVE
- Comfort to see and sit between different light levels
- Comfortable to be hidden and feel cozy in a quite big space



- Transition area - To guide

STRENGTHEN / IMPROVE
- Without visual disturbing
- People's perception of transition space and the purpose

06-4 Design testing

- Display area

In order to find out which angle and position of light would have a better effect on the statue that should be the focus in the space, an experiment to light the statue was carried out in the lighting laboratory to simulate a statue similar to the one in the concrete space. A black curtain was hung behind the statue as the background in order to exclude other variables. The first experiment used one light source from one direction. When the light source was on one side of the statue and shone upward from the ground, it had a better effect on the statue. The distribution of shadows and lights on the statue allowed the whole statue to be seen clearly.

The second experiment used two light sources combined with different angles and heights to illuminate the statue. In this experiment, when the statue was illuminated by one frontal light and one spotlight from the ground, the whole statue was more clearly and obviously visible. There was a good contrast of shadows on the statue to support viewers in seeing the details of statues.

Therefore, this experimental investigation found that light from two directions could create a proper shadow and light distribution on the statues to highlight the statue itself and create the effect of being noticed in the space.

Figure 06-4-1 (from left to right)

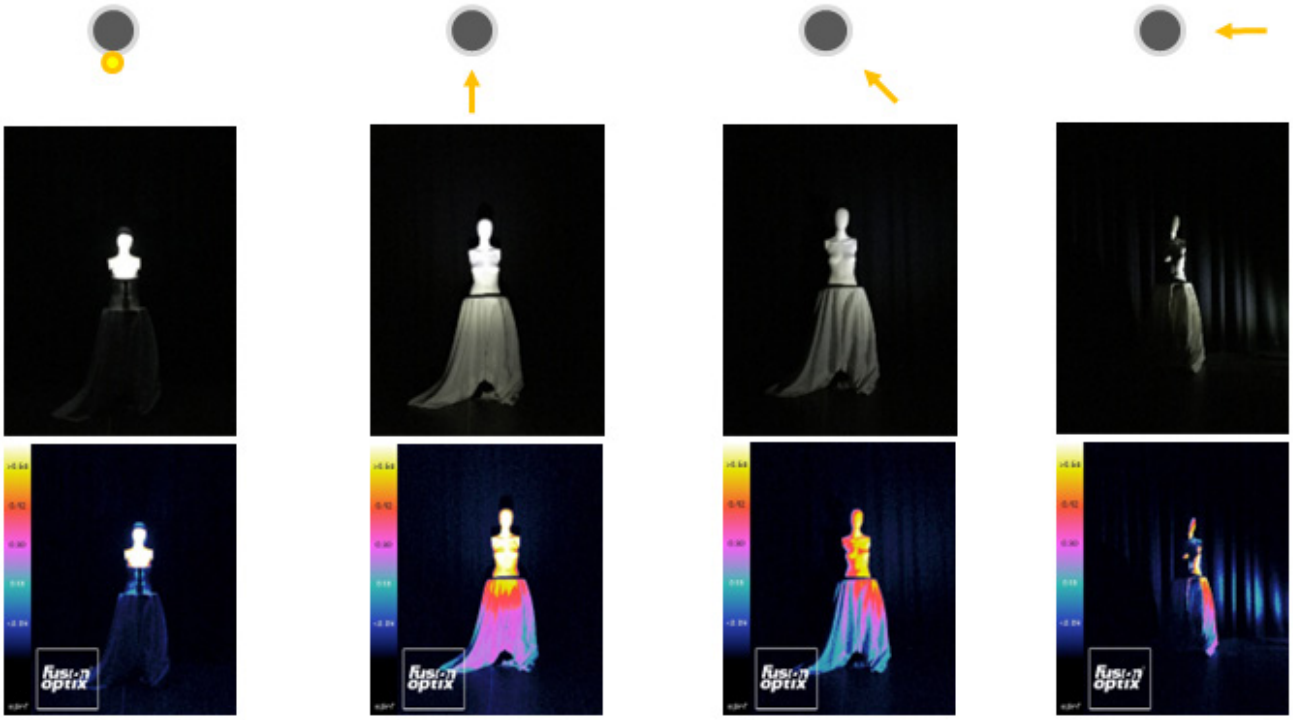
Statue illuminated from top of the base,
Statue illuminated frontally from the ground,
Statue illuminated diagonal direction from the ground,
Statue illuminated one side from the ground,
[self-produced]

Figure 06-4-2 (from left to right)

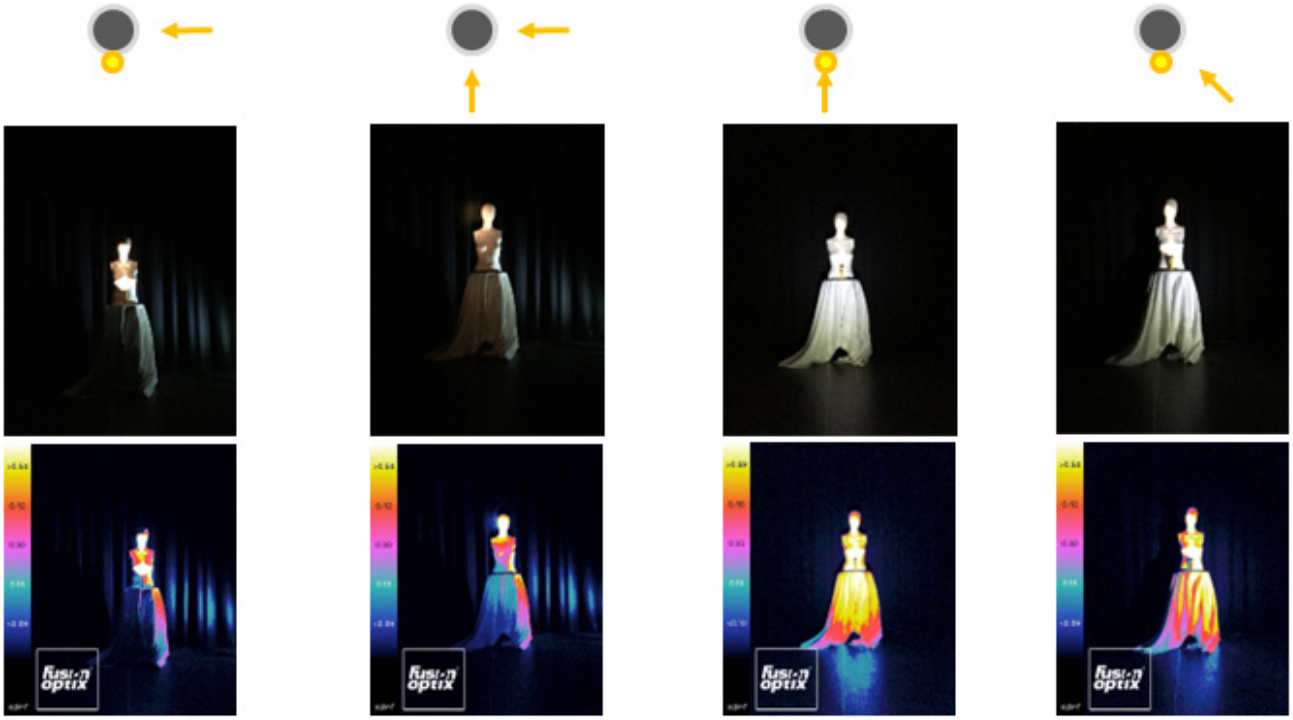
Statue illuminated from top of the base and one side from the ground,
Statue illuminated frontally and one side from the ground,
Statue illuminated from top of the base and frontally from the ground,
Statue illuminated from top of the base and diagonal direction from the ground,
[self-produced]

06. DESIGN IMPLEMENTATION

One direction



Two directions



- Transition area & Sitting area

In order to test both the sitting area and transition area, the museum space was simulated using a 3D simulation program, and the statues were illuminated in the 3D program with different angles and directions to see if the sitting area and transition area had a proper level of light and shadow, so that the overall space formed a good new lighting hierarchy.

Test 1 illuminated statues from the floor so that the statue could be seen as a whole, but there was no place to install additional artificial lighting fixtures. In order not to damage the floor itself, Test 2 was conducted by illuminating the statue from the ceiling on both sides, shining light downwards toward the statues. One downward light was installed in the existing fixtures on one side, and one similar lighting fixture was added on the other side of the other wall, but the new lighting fixtures ruined the overall aesthetics of the space.

Therefore Test 3 was carried out. The concept of simulated windows was incorporated, and the existing lighting equipment were used to add two more downward spotlights. The angle was set at a diagonal to illuminate the statues standing on both sides of the window. The idea of setting a diagonal spotlight derived from the concept of light from the window. The statues were illuminated by the light introduced from the windows. A new sitting area was added, and an upward-facing light was installed into the movable benches. The statues were illuminated from below. The sitting area and transition area both had an appropriate light level.

Figure 06-4-3 Test 1-The statue illuminated from the ground in the middle of corridor [self-produced]

Figure 06-4-4 Test 2-The statue illuminated downwards from both sides of corridoridor [self-produced]

Figure 06-4-5 Test 3-The statue illuminated downwards in diagonal directions from the existing lighting fixtures [self-produced]

06. DESIGN IMPLEMENTATION

Test 1

Test 2

Test 3

07 FINAL DESIGN

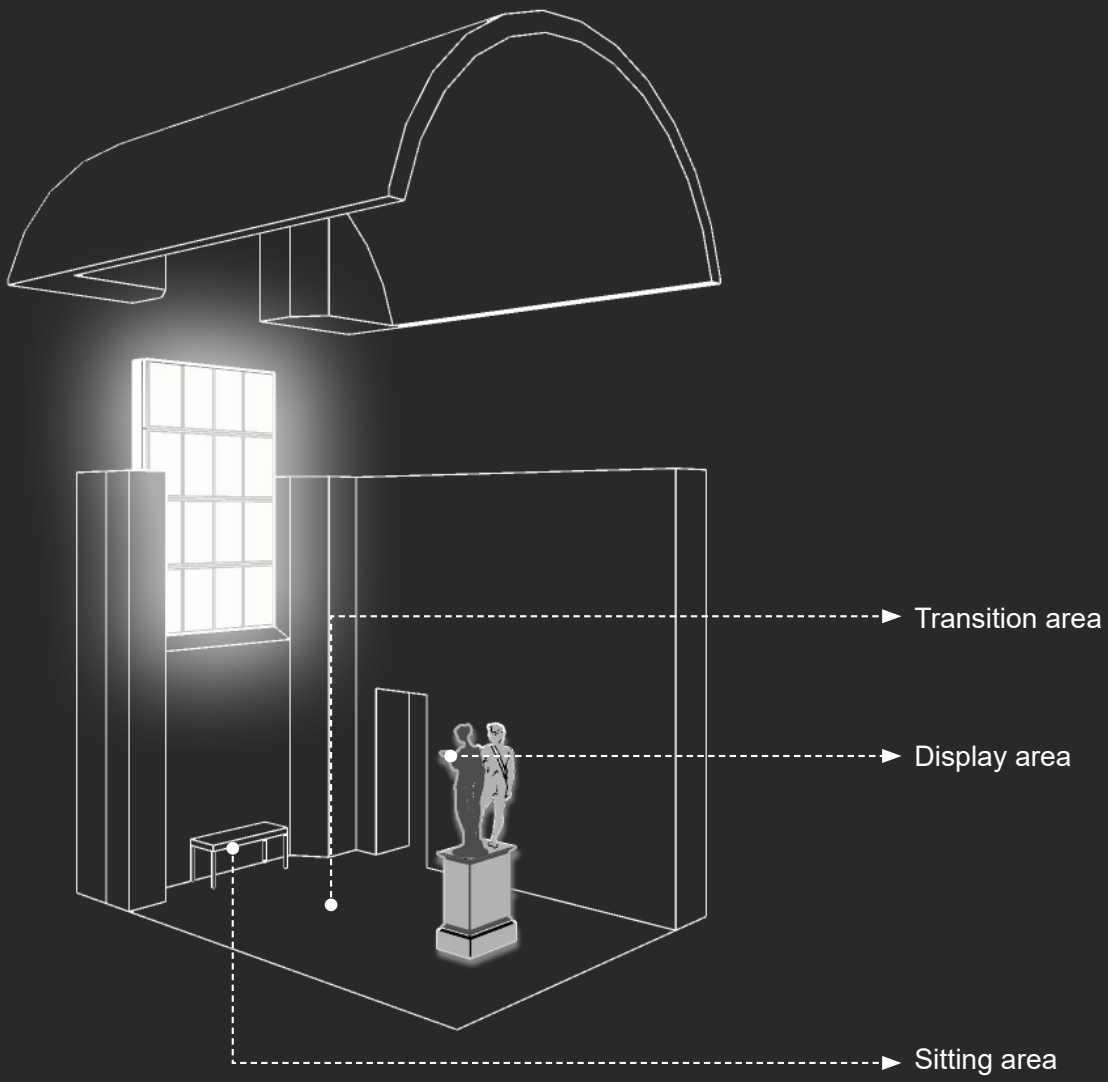
07-1 A room on the main floor

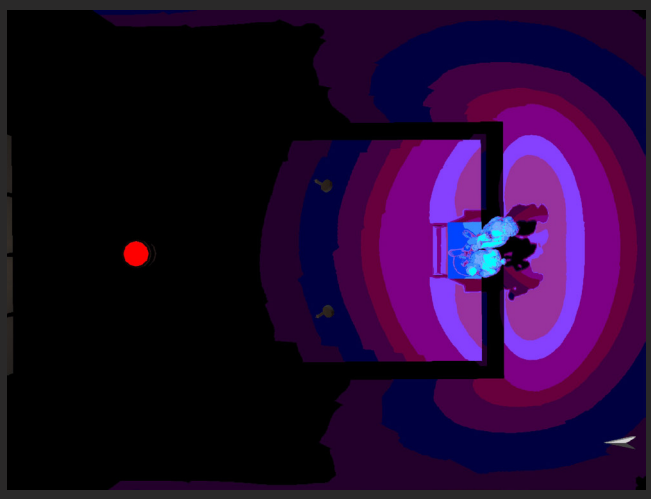
When there is no daylight entering the exhibition space on the main floor, the entire background dissolves into the space. The only visible thing is the statue, which is illuminated by the mounted spotlights on the walls from above. This lighting condition causes dazzling effects on the display object in the viewer's sight; however, when the simulated windows are designed, the entire background of the space gradually emerges, and the simulated daylight from the simulated windows illuminates the entire space evenly from above, creating an even distribution on the statues and a subtle gradation on the surrounding walls.

The space under the window is also relatively situated in the darker part of the space, allowing the visitor to be hidden when sitting in this area. The lighting hierarchy keeps the right purpose of each space unit, and the statue remains the focus of the exhibition space.

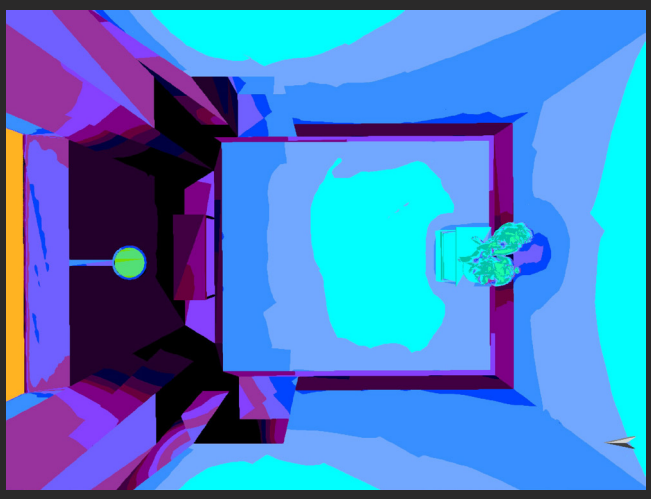
The concept of simulating a window does not destroy the existing architectural elements of the space, but brings a good contrast to the specific areas of the space respectively, and unifies them to create an overall space, forming a good perception for viewers.

07. FINAL DESIGN





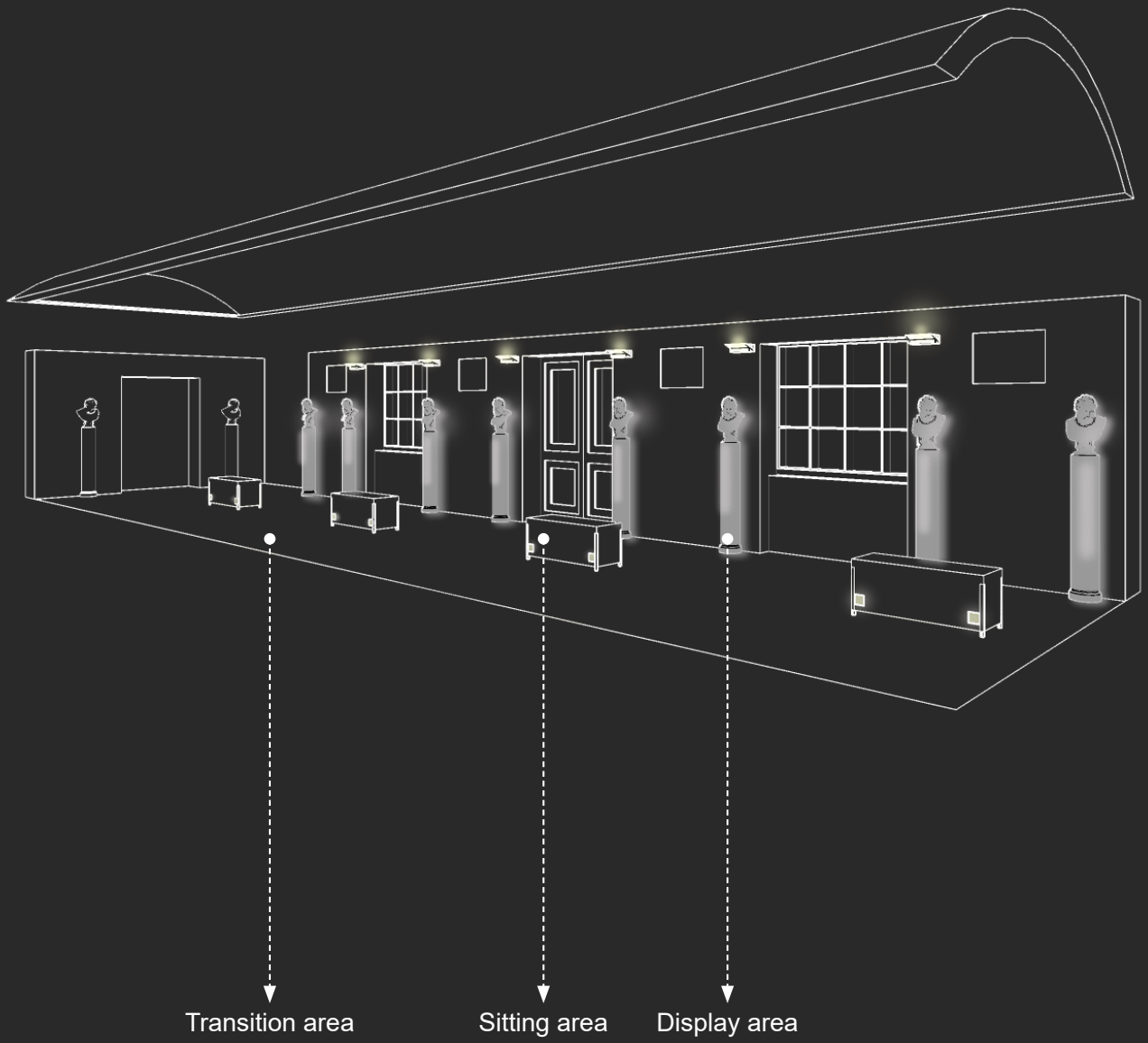
Luminance mapping of existing lighting condition



Luminance mapping after design

07. FINAL DESIGN

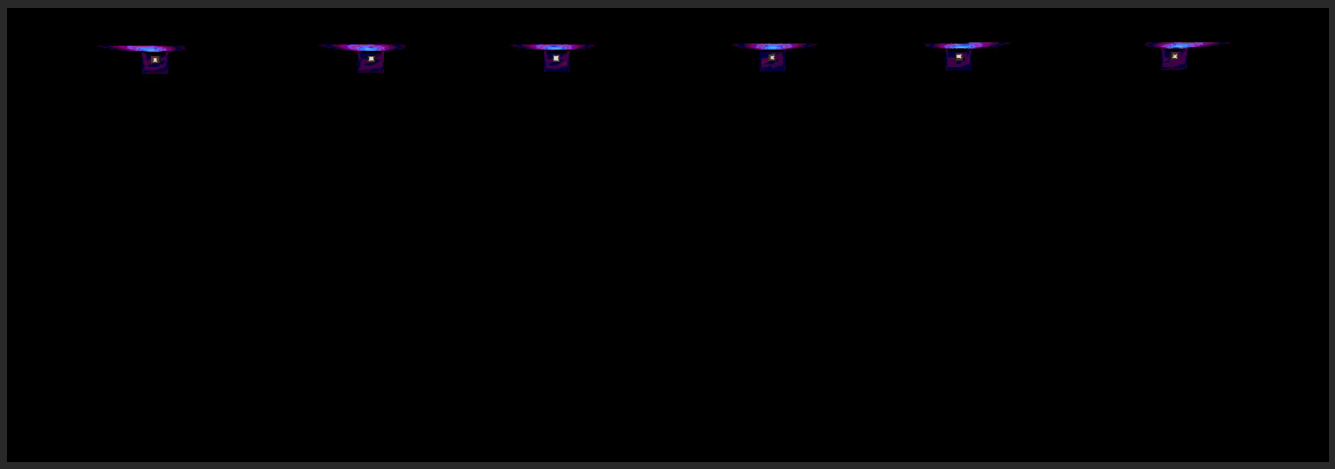
07-2 Corridor on the upper floor



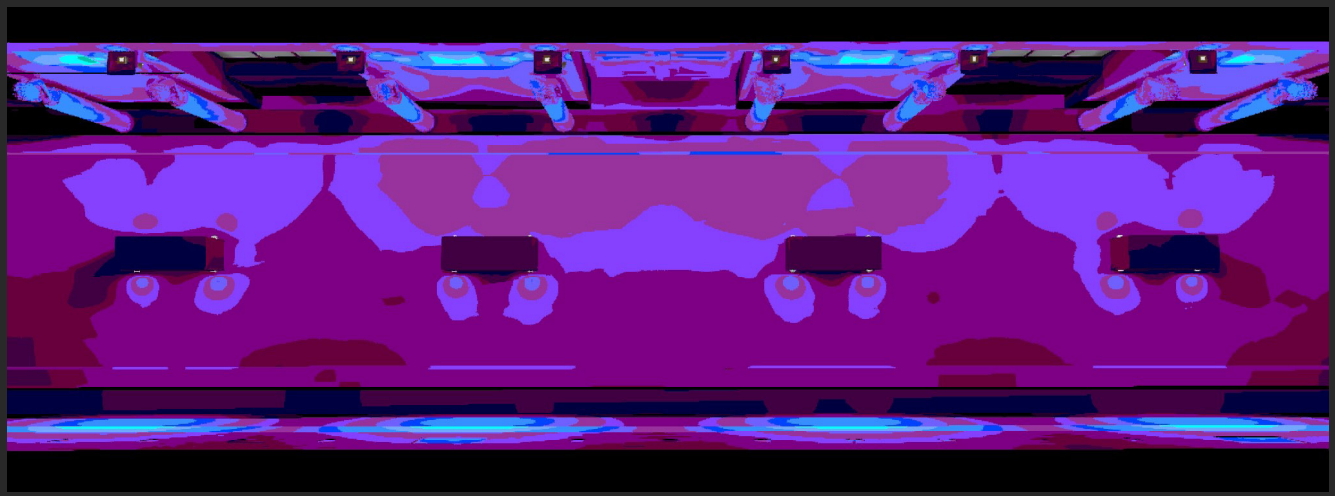
07. FINAL DESIGN

When entering the second floor through the staircase, a straight corridor leads to the exhibition space. The existing lighting in the existing space is only installed on the wall on the same side as the window, and the lighting is directed toward the ceiling, making the whole space gloomy in times when there is no daylight. Two spotlights were installed in the existing lighting equipment with lighting diagonal to both sides of the statues. The aim was to simulate statues that are illuminated by the daylight from the window in order to create the natural light distribution on the statues and make the statue the visual priority.

In addition, two movable benches were placed in the middle of space, not only to provide a sitting area, but to implicitly hint to visitors to follow the small light dots. The benches were equipped with spotlights facing upward to illuminate the statues. Without damaging the existing architecture of the space, the spotlights on both sides of the benches were installed to illuminate the statues and to give the statues a proper lighting distribution to make them visible. The overall space is well illuminated under the new lighting hierarchy, which helps visitors clearly distinguish the purpose of each small area as soon as they enter the space and experience the museum space comfortably.



Luminance mapping of existing lighting condition



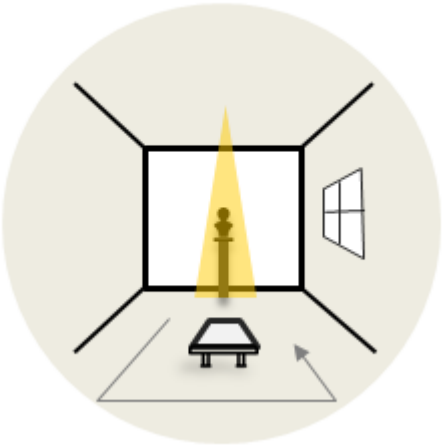
Luminance mapping of existing lighting condition

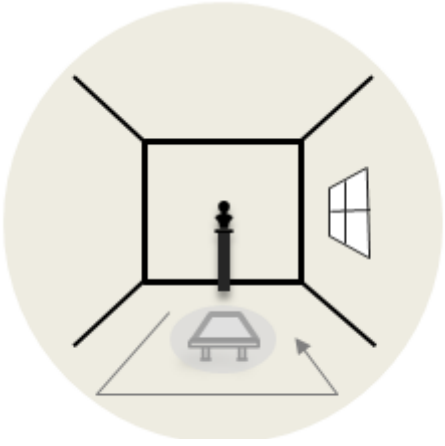
07. FINAL DESIGN

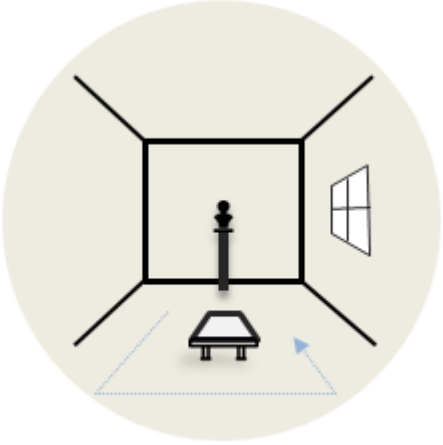
07. FINAL DESIGN

08 EVALUATION

Through a series of design processes, design decisions were made based on previous research and findings and the best solutions were identified during the testing phase, which were carried forward to the final design phase. In order to ensure that the final design still met the proposed requirements and criteria, the design was evaluated against the proposed criteria.







- Display area - To focus

ENHANCE
- See the detail (background and foreground)
- Visual attraction
- Thereby perceive the entire space context

- Sitting area - To be hidden

IMPROVE
- Comfort to see and sit between different light levels
- Comfortable to be hidden and feel cozy in a quite big space

---

- Transition area - To guide

STRENGTHEN / IMPROVE
- Without visual disturbing
- People's perception of transition space and the purpose

08. EVALUATION

To focus

Drawing from the concept of simulated window lighting, the statue is provided with a complete and good distribution of light. The statue becomes the main character in the space and can be recognized directly, and the purpose of the display space is clear after entering the space.

To be hidden

Through the placement and the use of color, the sitting area is situated in a relatively dark area of the space, so that when visitors sit in this area to appreciate the objects, they will not steal the focus of the space, and can sit invisibly in this area to comfortably appreciate the space and the display objects.

To guide

The transition area is cleverly arranged in the middle of the display area and sitting area, forming a place between the brightest and the darkest zone. The visual lighting feeling of this space through the contrast between the brightness and darkness aims to provide guidance to visitors.

09 CONCLUSION

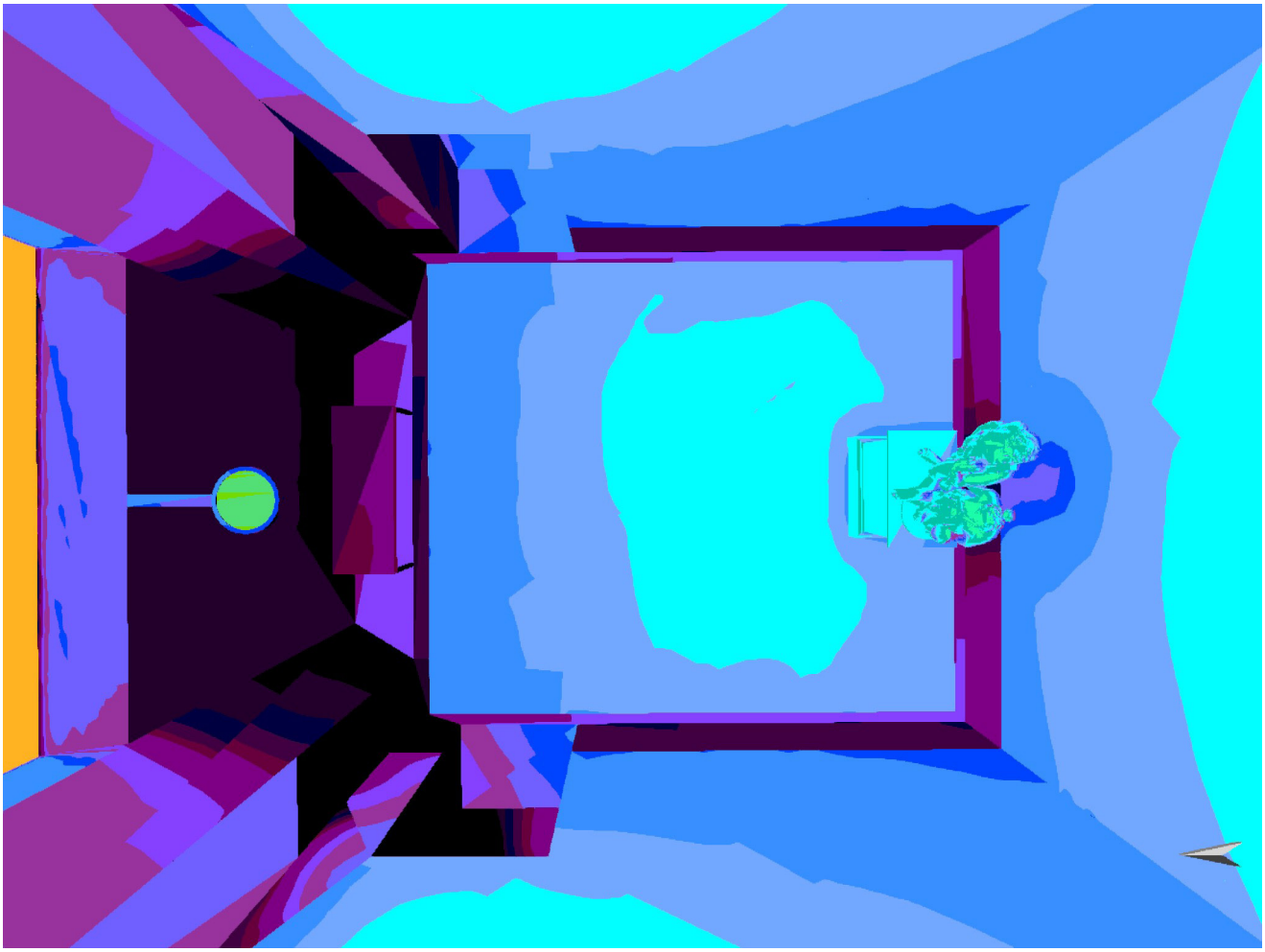
The goal of this thesis is to create a new lighting hierarchy for museum spaces and to support visitors achieving a better experience of viewing museum spaces through the interaction of light with the surrounding environment.

Finally, by proposing the idea of layering the space with simulated windows and simulated sunlight streaming from windows, the interaction between light and the surrounding surfaces can create a gradient contrast. This not only satisfies the need for a display-oriented museum space, and supports viewers in appreciating the details of the 3D objects while helping visitors to perceive each specific functional area, but also provides a new lighting idea that allows visitors to enjoy the display objects through artificial lighting while delivering a better museum space experience at night or when sunlight is not available.

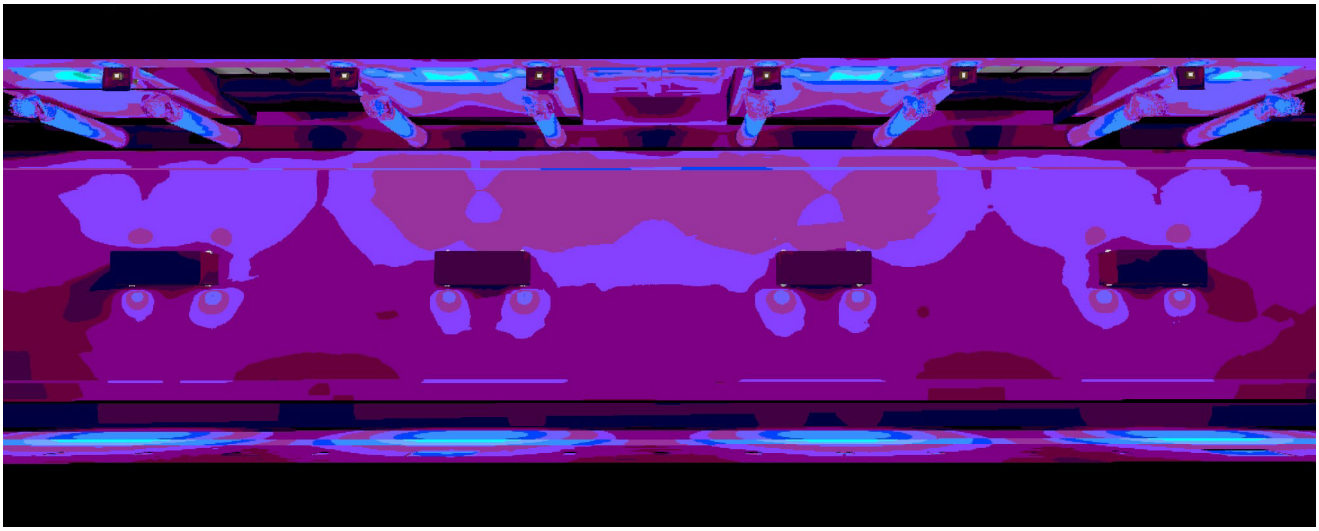
As the final solutions were not carried out, nor were interviews with people, further investigation is needed to determine whether the proposed hierarchy enhances the appreciation of objects and strengthens the perception of entire environments for people.

However, in 3D simulations of the final design, the luminance maps indicate that the new lighting hierarchy with surrounding surfaces achieves better lighting distribution on 3D objects and entire environments.

09. CONCLUSION



Luminance mapping of the room on the main floor



Luminance mapping of the corridor on the upper floor

10 FUTURE WORK

Further research is necessary in order to ensure that the proposed lighting solution is the best approach for the museum space. I hope that the simulated window concept can be easily installed and dismantled and allow different sizes to be chosen, but such an idea has not yet appeared in a well-designed product. Currently, similar products are available on the market, such as soft LED, soft LED panels and paper-like lighting. However, some difficulties still need to be considered. The sizes should be flexible to match windows with different dimensions, installation should be easy and moveable, and the price should be reasonable. Therefore, this solution relies on further technological development before it can be readily implemented.

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LIST OF TOOLS

Luminance Mapping /
Fusion Optix (BrightMinds-Luminance Canera)

Illustrations /
Adobe Illustrator CC
Adobe Photoshop CC

Photos /
Apple iPhone13 Camera
Adobe Photoshop CC

Layout /
Adobe InDesign CC

3D Modelling /
SketchUp Pro 2018

3D Rendering Engine /
Enscape Plug-in for SketchUp

Light Calculation /
DiaLux evo x86