The power of daylight

Daylight influencing emotions and spatial perception of indoor space

ANTREA IOANNOU
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Course Code: AF270X
May 2023
ABSTRACT

The present thesis derived from a personal need to explore how daylight can shape the emotional state of users and consequently their indoor experience. As a lighting design student I appreciated even more the power that light and shadows have upon indoor experiences. To investigate this further, an experiment with five panels was conducted. Moreover, since daylight conditions vary according to the latitude the spaces were simulated in Sweden and Cyprus, and subjects from both locations participated in the experiment.

The results suggest that daylight distributed in horizontal, vertical and squared shapes evokes mainly pleasant or activating emotions. Circular shapes provoke pleasant feelings and the organic: unpleasant and deactivating. The outcome indicates that emotions, perception of light levels, light distribution and shadows can alter considerably among individuals from different latitudes. Participants from northern latitude perceived the space darker than those from southeastern latitude. Additionally, when the subjects felt happy in a space they perceived it brighter than other spaces. The analysis suggests a link between memories, familiarity and emotions. Lastly, the importance of considering preferences of different groups of users is emphasized.

KEYWORDS: DAYLIGHT, SHADOWS, SPATIAL PERCEPTION, EMOTIONS, MEMORIES
ACKNOWLEDGMENTS

Many thank to ...

My tutor, Martina Frattura, for her guidance and valuable insights throughout the thesis process, and for being an inspiring tutor.

Federico Favero, for his academic support and constructive criticism. His encouragement has been instrumental in shaping the direction of this thesis.

Foteini Kyriakidou and Rodrigo Muro, for introducing me to the world of lighting design and teaching me to appreciate darkness too.

The participants of this experiment based thesis, whose willingness to share their time, contributed significantly to the findings.

My family and my friends. I could not have undertaken this journey without their support.
“In great architectural spaces, there is a constant, deep breathing of shadow and light; shadow inhales and illumination exhales light” (Pallasmaa, 2012, p.47).
1 INTRODUCTION
In architectural design windows can turn out to be an ally or an opponent for the building and the dweller. The window is the mediator for the connection of the viewer with the outer world, the mere way to guide the daylight indoors and the most natural ventilation system. At the same time some disadvantages appear with the installation of a window, such as glare, uncomfortable contrasts in the visual field, privacy issues or thermal discomfort. In order to deal with these issues, a shading system is chosen by the architects. Often the main factor in selecting a shading system is the appearance of the building, but architectural and lighting design is much more than just creating a beautiful volume. The ultimate goal should be to design the most suitable atmosphere according to the user’s needs. Architecture of the recent years mainly emphasizes the functional and morphological perspective of the building. The goal of a human – centered design and the aim to build a strong relationship of the user with the interior space are partially neglected. This brings us face to face with a visual oriented architecture where the visual experience prevails over sensory reactions. While the real meaning of architecture lies in creating the sense of belonging in the space, the large windows of today’s architecture have led to a loss of the intimate life, often weakening the connection of the user with the indoor space and force us to live public lives.

The indoor space is a combination of the architectural elements with the user’s perception, and their spatial and emotional experience. Only when all these are awakened is the room transformed into a place, the house is transformed into a home; when the dweller and the space are merged into one. Any decision taken during the design process related to natural illumination is impactful not only on the building, but also on the experience of the user. This leads me to the following question: Do architects consider windows and their shading systems thoroughly enough to comprehend their influence on the spatial experience of the user, and not only on the exterior of the building? Currently, there is lack of information regarding the psychological impact of the dynamic changes of daylight, its altering patterns and the shadows on the spatial experience of the user. Little emphasis is made about the fact that the whole meaning of architecture lies in between a building’s walls. As extensively explained by Juhani Pallasmaa architecture is a multi-sensory experience, where the eye, ear, nose, skin, tongue, skeleton and muscle measure every spatial stimulus (Pallasmaa, 2012). Do architects, lighting designers and users have this still in mind? Or does vision dominate the decision-making processes? Did the decision to make daylight dominate the indoor space, lead to frivolous design of large windows without having in mind their implications on the users’ perception and emotional state?

In our time, light has turned into a mere quantitative matter and the window has lost its significance as a mediator between two worlds, between enclosed and open, interiority and exteriority, private and public, shadow and light. Having lost its ontological meaning, the window has turned into a mere absence of the wall. (Pallasmaa, 2012) (p.47)
Furthermore, as mentioned by Pallasmaa the homogenous bright lit spaces paralyze imagination, since it needs dim light and shadows to be triggered (Pallasmaa, 2012). What is usually absent from today’s architecture is the interplay of light and shadow that activates synchronously the imagination, the body and the space. In some cases, shading solutions, like panels, are selected to minimize the disadvantages that a big glass surface generates in the indoor space. Nevertheless, the shadows created in the space are rarely examined and considered, in relation to the effects they have in the space and its users. Despite the fact that the phenomenology of architectural space is analyzed through numerous studies, not enough attention is given on the spatial experience of the user, and how the emotional responses can enhance the quality of architecture.

Factors such as the size, distribution, and visual prominence of luminous scenarios are considered as influential on individuals’ lighting preferences (Veitch & Newsham, 2000). Despite that, current lighting research does not focus on how humans respond to various characteristics of light distribution (Boyce, 2014). Furthermore, little is known about the façade openings and their impact on users (Chamilothori, et al., 2022). Although the existing literature indicates that diverse populations across the world present varying responses to lighting, the potential regional differences within the range of latitudes in Europe is not explored. On that account, this thesis aims to provide useful results to enrich the aforementioned research gaps. Specifically, to explore how daylighting design can achieve a deeper connection between the user and the indoor space, and to investigate different patterns of shadows to clarify the power that darkness has over the space and the user, in the context of different geographical latitudes in Europe.

**MAIN RESEARCH QUESTIONS**

How do different distributions of daylight in the indoor space shape the user’s spatial experience? Does geographical latitude influence it?

**SUBQUESTION**

Is there an imbalance between the opinions of designers and non-designers?

**SUSTAINABILITY STATEMENT**

Can we use daylight to improve the psychological well-being of the user during their spatial experience (United Nations, SDGs, 2015)? (Good health and Well-being, Target 3.4)
2 BACKGROUND
2.1. Spatial experience

Architecture provides a multi-sensory experience where every aspect within the space has an impact on the user, and vice versa. When we enter an indoor space, our brain creates various predictions which prepare our body for potential movements and actions. These predictions influence our emotions (Barrett, 2020). As we navigate through the space, our brain continuously evaluates different aspects, forming our spatial experience and perception. This evaluation includes assessing the atmosphere, ambience, and drawing upon our personal previous experiences, ultimately shaping our perception of the space. Consequently, the interactive relationship between the brain and the body has the ability to arise emotions in users.

2.2. Emotional connection with the space

The emotions that a space generates in its occupants are not similar for everyone. A mental model of the world as it will be in the upcoming moment exists in our brain, based on former experiences. This mental model attempts to create meaning from the world and the body through those memories (Barrett, 2020). During the spatial experience, the brain utilizes glimpses from previous moments of our life time, to steer our actions and find the meaning behind every sensation we feel. Thus the perception of the space and the emotional connection we acquire with it, are defined by our own memories and predictions, and not solely by the architectural elements. According to studies, people assess things as special when they have memories or any kind of associations with them which evoke emotions (Grayling, 2002). Feeling attached to an object does not mean a user is connected with the thing; it actually means they are connected to the relation and the feelings it represents (Norman, 2004). Therefore, in order for the occupant to feel emotionally connected to the architectural space, the latter has to evoke precious memories. All the aforementioned: the indoor space, the emotional response and the memories, orchestrate the user, which enables them to understand the architectural space. In other words the spatial experience consists of three main elements: a person that moves in the space, the spatial perception which is influenced by the materials and the architectural form of this space and the provoked emotions. Hence, the architecture that aims to stimulate emotion and it is not driven only by the sense of vision, induces the multi-sensory experience.

2.3. Light, Shadow and Space

The user interacts with every piece that forms the puzzle of space. Among those pieces there are some intangible elements such as light and shadow. Even though artificial and natural light is an inseparable part of architecture, we have to appreciate the shadow too, in order to have a captivating spatial experience. The darkness that a space holds inspires us to explore it, awakens our curiosity and stimulates our imagination to find out what is hidden there. Architectural space cannot be seen without light but there is no light without darkness. Shadow is as impactful as light on the interior experience of the user, their perception of the space and their emotional state. Humans in order to create a place to live threw a shadow on the earth by using a parasol and designed a house under
the pale light of the shadow, Tanizaki describes (Tanizaki, 1977). That is the strength of shadow. No matter how much we look for natural illumination, we will always seek for shadow. Daylight and shadows in a space are constantly in flux, creating a dynamic environment. As the body moves and interacts with the space, it communicates with the changing light and shadows. The patterns of light and shadow are powerful enough to designate the user’s movement and influence their thoughts. This underlines that the interior experience is not just a cognitive process, but also an emotional and communicative one, as it involves the engagement of the body. The materiality and immateriality of space act as mediators in the connection of the body with the space. The way people perceive, experience, and feel within the indoor space is reflected in the space itself. Illumination is the one that determines the parts of the room that are going to be used, the spaces that look safe and functional for the user to interact. Therefore, to achieve the emotional connection of the user with architecture, the space ought to engage the body, and light and darkness are influential tools for this.

Figure 1. Connections among the main elements of spatial experience.
3 METHODOLOGY
3.1. Flow of thesis

As the main goal of this thesis is to investigate how daylight can shape the indoor spatial experience, an experiment with physical models and online survey was done. In order to examine the power of daylight thoroughly, five spaces which varied in daylight distribution were designed on Rhino. Minimal square rooms were designed with a window opening on their south wall and a different panel was tested in each one of them as a shading system. An equal amount of daylight was allowed through every panel while nonidentical shadows were created in the interior. The five rooms were tested in two different latitudes: in Stockholm, Sweden and Nicosia, Cyprus.

The following step was the site analysis of the selected latitudes. Data such as annual day length and the sun path for each location were found and a shadow analysis was conducted. The next step was the daylight measurements, where no external obstructions or furnishing were considered. The illuminance levels and daylight factor of each room were calculated using Climate Studio.

Five physical models in scale 1:10 were made. The materials used were gray cardboard for the room and wood for the shading panels. The lighting conditions on Spring Equinox at 12:00 pm were simulated for both latitudes and photos were taken and edited in Photoshop, where a window view was added for a more realistic representation of the space.

In order to contact the targeted subjects an online questionnaire was conducted. Firstly the participants were asked personal questions related to their academic background and their country of origin.

The next step was a short description of the space and questions related to memories and emotions were asked. Subsequently, the ten photos were presented. The assessment of participants’ emotional state was achieved through the Russell emotion model and the following emotions were taken into account: alert, happy, contented, calm, fatigued, sad, upset and tense (Russell, 1980). Furthermore, for the evaluation of the subjects’ spatial perception a modified version of the seven factors of V/P Theory with scale 1-5 was used (Ejhed, Lijefors, 1990). Three factors were taken into consideration: Level of light, Light distribution and Shadows. In the last section of the questionnaire the participants were asked if any space seems familiar and what use they would consider them to have.

The questionnaires were divided in two groups. The first one presented the five rooms simulated in Sweden first and then the five rooms which simulated in Cyprus. The second group of questionnaires had the order of photos inversed. The questionnaires were sent to ten people from Sweden and ten people from Cyprus. The first group of questionnaires was sent to the ten participants from Sweden and the second one to the participants from Cyprus. In this way the five most familiar rooms in terms of the sun’s settings were presented to the subjects, followed by the five unfamiliar.
INTRODUCTION & RESEARCH QUESTION
How do different distributions of daylight in the indoor space shape the user’s spatial experience? Does geographical latitude influence it?

BACKGROUND
Light, shadow & space
Emotional connection
Spatial experience

METHODOLOGY
Flow of thesis
Design phase
Site analysis

RESULTS
Online questionnaires
Daylight measurements
Physical models

DISCUSSION
Overview of findings
Influence of latitude
Memory and Familiarity
Field of education
Sustainability
Generalization
Limitations

CONCLUSION

Figure 2. Methodology flow chart.
3.2. Design of rooms and Panels

The designed room is 6,00x6,00 m with height 3,00 m. The size of the window is 3,60 x 2,40 m and is placed on the south wall so that the room benefits from direct daylight as much as possible. The decision to design simple square rooms aimed to set the daylight as the main character of the experiment and to avoid confusing the viewer with the presence of other elements. The space is designed as a room of a public building. Five panels were designed and adjusted so that the opening-to-total surface area ratio was equal among them, with ratio 37%. A variation of shadow patterns and distribution of daylight was achieved in the indoor space. The panels were inspired by five existing architectural examples. In this paper the patterns will be referred to as panel 1, 2, 3, 4 and 5.
3.3. Site analysis

The chosen sites are located in the northern hemisphere. Sweden is in the northmost part of Europe with coordinates 63°N, 16°E. Cyprus is located at a moderate position in the northern hemisphere and lies in the Southeastern part of Europe, with coordinates 35°07′N, 33°24′E. The chosen sites are located in each country’s capital, Stockholm and Nicosia, with coordinates 59°21′N, 18°4′E and 35°10′N, 33°22′E respectively. (Figure 10)

Figure 11 shows the relationship of latitude and annual solar conditions, and reveals the difference of day length between the two locations. The winter days in Sweden are noticeable shorter and Cyprus has shorter days during the summer months. Moreover the sun path chart shows that the highest altitude of the sun in Sweden is 54,06° while in Cyprus is 78,00°.
The solar data in the two sites present not extreme variations, but still noticeable. Sunrise and sunset times during the summer solstice have a gap of two hours each, resulting to an amount of 18:37 hours of daylight for Stockholm and 14:32 hours for Nicosia. On the contrary, winter solstice is longer in Nicosia, which is 09:47 hours, while Stockholm has 06:04 hours of daylight. During spring equinox the azimuth of the sun at 12:00pm is nearly equal for the two cities. Also, the sunrise time, sunset time and amount of daylight is almost identical.

Furthermore, for a deeper comparison of the two locations, a shadow analysis was conducted during summer solstice, winter solstice and spring equinox. This revealed the huge difference of shadow’s length over the year. Sweden appeared to have a variation in the length of shadows, whereas Cyprus did not reveal huge alterations throughout the year. The sun path and shadow analysis led to the decision to carry out the thesis’ experiment during spring equinox. This aim to avoid huge dissimilarities in the shadows created in the indoor space, which might result to distorted outcomes.

### Table 1
Solar information for Sweden and Cyprus

<table>
<thead>
<tr>
<th></th>
<th>SWEDEN</th>
<th>CYPRUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMER SOLSTICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azimuth</td>
<td>-175.86°</td>
<td>-167.03°</td>
</tr>
<tr>
<td>Altitude</td>
<td>54.06°</td>
<td>78.00°</td>
</tr>
<tr>
<td>Sunrise</td>
<td>02:31</td>
<td>04:33</td>
</tr>
<tr>
<td>Sunset</td>
<td>21:08</td>
<td>19:04</td>
</tr>
<tr>
<td>Daylight</td>
<td>18:37 Hrs</td>
<td>14:32 Hrs</td>
</tr>
<tr>
<td>WINTER SOLSTICE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azimuth</td>
<td>-176.73°</td>
<td>-175.64°</td>
</tr>
<tr>
<td>Altitude</td>
<td>07.29°</td>
<td>31.31°</td>
</tr>
<tr>
<td>Sunrise</td>
<td>08:44</td>
<td>06:50</td>
</tr>
<tr>
<td>Sunset</td>
<td>14:48</td>
<td>16:37</td>
</tr>
<tr>
<td>Daylight</td>
<td>06:04 Hrs</td>
<td>09:47 Hrs</td>
</tr>
<tr>
<td>SPRING EQUINOX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azimuth</td>
<td>-178.72°</td>
<td>-177.63°</td>
</tr>
<tr>
<td>Altitude</td>
<td>30.42°</td>
<td>54.56°</td>
</tr>
<tr>
<td>Sunrise</td>
<td>05:51</td>
<td>05:51</td>
</tr>
<tr>
<td>Sunset</td>
<td>18:00</td>
<td>17:58</td>
</tr>
<tr>
<td>Daylight</td>
<td>12:10 Hrs</td>
<td>12:07 Hrs</td>
</tr>
</tbody>
</table>

Note. Data from Dr. Andrew Marsh’s blog andrewmarsh.com

### Table 2
Shadow analysis during the year in Sweden and Cyprus

Note. Renders generated in Revit.
4 RESULTS
4.1. Daylight measurements

4.1.1. Daylight factor
The daylight factor (DF) of the indoor space was measured with the reference plane located 0.85m above the floor, as recommended by the European Standards (European Committee for Standardization, 2018). The average DF is 2.9%, calculated by placing each panel, at the exterior side of the south wall. Hence the designed space is qualified as a daylit room, since spaces with average DF above 2% are evaluated as naturally illuminated (Society of Light, Lighting, & Chartered Institution of Building Services Engineers, 2002).

4.1.2. Illuminance levels
The mean lux levels are almost equal for panels 2-5 in Sweden and the same applies for Cyprus. This is an outcome of the fact that all panels have the same opening - to - total surface area ratio. While the illuminance levels with panel 1 appears moderately decreased, in both latitudes. Additionally, a comparison of the two locations reveals that the mean lux levels in Sweden is slightly higher than in Cyprus, due to the sun’s lower altitude which allows greater amount of sunlight to penetrate through the panels’ openings. (30.42° in Sweden, 54.56° in Cyprus) According to the European Standards it is suggested that 50% of the surfaces in areas where individuals spend extended periods of time should have an illumination level of at least 300 lux (European Committee for Standardization, 2018). Therefore the illuminance levels of the ten designed spaces are sufficient, considering the calculated median and mean lux. (Figure 13)
<table>
<thead>
<tr>
<th>Panel 1</th>
<th>Panel 2</th>
<th>Panel 3</th>
<th>Panel 4</th>
<th>Panel 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SWEDEN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean lux 1382</td>
<td>Mean lux 1512</td>
<td>Mean lux 1509</td>
<td>Mean lux 1509</td>
<td>Mean lux 1511</td>
</tr>
<tr>
<td>Median lux 467</td>
<td>Median lux 565</td>
<td>Median lux 541</td>
<td>Median lux 560</td>
<td>Median lux 573</td>
</tr>
<tr>
<td><strong>CYPRUS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean lux 870</td>
<td>Mean lux 1240</td>
<td>Mean lux 1234</td>
<td>Mean lux 1234</td>
<td>Mean lux 1235</td>
</tr>
<tr>
<td>Median lux 405</td>
<td>Median lux 469</td>
<td>Median lux 469</td>
<td>Median lux 461</td>
<td>Median lux 469</td>
</tr>
</tbody>
</table>

Figure 13 Illuminance levels in the interior calculated on Spring Equinox, 12:00pm in Sweden and Cyprus, in Climate Studio.
4.2. Physical models

In figure 14 the ten physical models are presented. The light penetrates further in the room, when the room is simulated in Sweden, on Spring Equinox at 12:00pm. This is due to the lower altitude of the sun in Sweden which is 30.51°, whereas in Cyprus on the same day and time the altitude of the sun is 54.63°.
4.3. Questionnaires

4.3.1. Spatial experience, Memory and Imagination

Before revealing the images, a written description of each room was given to the subjects in order to trigger their imagination and awake memories to them. Firstly, they had to choose which characteristics are the most impactful on their spatial experience and the most rated was Daylight coming through. Then they were asked which characteristics they keep in their memory after they experience the room. The Architectural elements of the space and the Daylight were the mode. Afterwards, each panel was described and the participants were asked if they would feel activated, deactivated, pleasant or unpleasant in each room. When patterns 1, 3 and 5 were described, the highest voted feeling was pleasant. P2 generated an unpleasant feeling to the subjects. Lastly, the description of a room with P4 divided the subjects to three equal groups where they felt activated, pleasant and unpleasant.

![Diagram](image.png)

Figure 15. Most impactful characteristics of the space on the spatial experience of the subjects and their memory.

![Diagram](image.png)

Figure 16. Majority vote on the emotional state elicited when the five rooms are described through text.
4.3.2. Spaces simulated in Sweden

Figure 17. Emotional state of the subjects when they are exposed to the panels simulated in Sweden.
Regarding the emotional state of the subjects when viewing the rooms simulated in Sweden, a variety of emotions were evoked. P1 made most of the subjects feel tensed. Furthermore, with P2 a great number of participants felt calm while an equal amount of participants felt tensed. P3 made most of the subjects feel contented and P4 mainly arouse a feeling of happiness. The latter was the most voted feeling in all cases. Lastly, P5 evoked feelings of calmness, but simultaneously the same number of subjects felt upset.

The light levels in the five rooms were perceived from dark to very bright by the subjects. None of them was perceived as very dark. Panels 1, 2 and 3 made the room perceived as medium to bright. The room with P4 was perceived slightly brighter than the rest and the room with P5 was perceived moderately darker.

Due to the variety of shapes in the panels’ openings the light distribution in each room was perceived differently. In details, most subjects perceived the light distribution of the space as dramatic when P1 was installed. According to the subjects P2 transformed the distribution of light into a less dramatic, but P3 was perceived by an equal number of people as dramatic and medium. P4 distributed the light moderately uniform and P5 nearly dramatic, according to the majority of subjects.

The participants evaluated the shadows of each room with scale 1 to 5, vague to marked. An equal amount of participants perceived the shadows marked, medium marked and nearly vague when they evaluated P1. On the other hand, in the cases of P2 and P3, most subjects perceived the shadows as marked. Regarding P4 the perception of shadows is divided equally in four groups: marked, almost marked, medium and almost vague. The shadows created by P5 were assessed as medium by the greatest amount of participants.
Figure 21. Emotional state of the subjects when they are exposed to the panels simulated in Cyprus.
In general, the simulations in Cyprus evoked to the subjects both negative and positive feelings. P1 and P2 made most of the subjects feel contented. The rooms with P3 and P4 made the majority of subjects alert and happy, respectively. Lastly, P5 arouse mainly negative feelings and tense was voted the most.

The light levels in the rooms were rated from very dark to bright by the participants, when the rooms were simulated in Cyprus. None of them was perceived as very bright. An equal number of participants perceived the room as dark and as medium when P1 was installed. Panels 2, 3 and 4 created the perception of medium light levels to most of the subjects, while P5 was mainly perceived as dark.

In the scale 1 to 5, where 1 was uniform distribution of light and 5 was dramatic, all the panels, except P2, were evaluated as nearly uniform by most of the subjects. The panel 2 transformed the perceived distribution of light to a nearly dramatic one according to the greatest amount of subjects.

Considering the perception of shadows, with P1 they were perceived as medium, whereas the shadows generated by P2 and P3 were perceived more marked. The room with P4 changed the subjects’ perception to right in the middle of the scale vague to marked. The shadows generated by P5 gave complex results.
4.3.4. Differences caused by subjects’ country of origin
Subjects’ evaluation of the spaces simulated in Sweden

Figure 25. Subjects’ emotional state when they are exposed to the panels simulated in Sweden, in combination with the expected feeling when imagining the space.

Figure 26. Subjects’ perception of the level of light in the room, for the panels simulated in Sweden.

Figure 27. Subjects’ perception of light distribution in the room, for the panels simulated in Sweden.

Figure 28. Subjects’ perception of the shadows in the room, for the panels simulated in Sweden.
Subjects’ evaluation of the spaces simulated in Cyprus

Figure 29. Subjects’ emotional state when they are exposed to the panels simulated in Cyprus, in combination with the expected feeling when imagining the space.

Figure 30. Subjects’ perception of the level of light in the room, for the panels simulated in Cyprus.

Figure 31. Subjects’ perception of light distribution in the room, for the panels simulated in Cyprus.

Figure 32. Subjects’ perception of the shadows in the room, for the panels simulated in Cyprus.
4.3.5. Differences among the fields
Designers and non designers evaluating the spaces simulated in Sweden

Figure 33. Subjects’ emotional state when they are exposed to the panels simulated in Sweden.

Figure 34. Subjects’ perception of the level of light in the room, for the panels simulated in Sweden.

Figure 35. Subjects’ perception of light distribution in the room, for the panels simulated in Sweden.

Figure 36. Subjects’ perception of the shadows in the room, for the panels simulated in Sweden.
Designers and non designers evaluating the spaces simulated in Cyprus

Figure 37. Subjects’ emotional state when they are exposed to the panels simulated in Cyprus.

Figure 38. Subjects’ perception of the level of light in the room, for the panels simulated in Cyprus.

Figure 39. Subjects’ perception of light distribution in the room, for the panels simulated in Cyprus.

Figure 40. Subjects’ perception of the shadows in the room, for the panels simulated in Cyprus.
4.3.6. Familiarity and Use of space

In the final section of the questionnaire, the participants had to select their most familiar room and to choose the use of space. For Swedes P1 simulated in Cyprus was the most familiar, while for Cypriots it was P2 simulated in Sweden.

Furthermore, regarding the use of space the greatest number of participants stated that they would consider these rooms to be a part of an office building. People from Sweden could imagine these spaces in five different public buildings - offices, hotels, churches, schools and hospitals. On the other hand Cypriots would consider these rooms to be part of office buildings, hotels and hospitals.

Finally, most people from Sweden responded that they would not consider these rooms to be a part of a house, while the same amount of Cypriots would do so.
5 DISCUSSION
5.1. Overview of main findings

The analysis of results shows that there are alterations in the emotional state of the subjects and their perception of the space when different distributions of daylight are tested in the exact same space. Whenever a new panel was presented within Sweden or Cyprus, subjects experienced a different emotion and as a consequence of this, their spatial perception was altered. Notwithstanding, the discovery that changing solely the panel affects the perception and the emotions of the users holds significant importance for applying these findings in real-world architectural and lighting settings. Moreover, it highlights the crucial role of façade design as a powerful tool for shaping the overall experience of the user in the indoor space. This finding comes to align with the study of Abboushi et al. (2021) and Chamilothori et al. (2022b) where façade design was found to be the only factor that changed the appraisal of the space. A remarkable fact is that none of the groups realized the equal illumination levels of the rooms within Sweden or Cyprus, the variation of patterns deceived the participants and led them to perceive variations in light levels that were not actually present. This observation highlights the potential impact of design elements on individuals’ perception of light and space.

5.2. Differences caused by latitude

The geographical latitude appeared to influence the spatial experience, since in some cases the same panel tested in different latitudes evoked opposite emotions and alterative spatial perception. For example P1 simulated in Sweden evoked a tense feeling to the majority of subjects, while in Cyprus most of them felt contented. The spatial perception of the subjects was also affected by the latitude. It is noteworthy that P4 evoked happy feeling regardless the change of latitude and it is the only one that made half the participants agree. Additionally, P4 was evaluated as the brightest room in both latitudes. These data support the theory that people who feel happy perceive the room brighter than sad people, as Zhang et al. (2016) showed. The constant happy feeling of most participants in the rooms with P4, regardless the latitude, the subjects’ country of origin and their field of education, might imply a preference to the shape of circle: a simple shape but not frequently used in architectural design.

Other studies disclose that people from northern latitudes assess the space as less excited and bright than those from southern latitudes (Moscoso et al., 2022; Chamilothori et al., 2022a). This indicates that the country of origin affects the users’ impression, hence the regional division of participants of the present study was essential.

Despite being exposed to the same visual stimuli, different emotional and spatial responses were observed between the two groups. The emotional state of Swedes changed not only when a different panel was presented, but also when it was simulated in different latitude. On the other hand the majority of Cypriots experienced pleasant and activating feelings and the difference of latitude did not affect their evaluation tremendously. Furthermore, the majority of Swedes perceived the level of light in the rooms as medium to dark, while Cypriots perceived the spaces brighter. The outcome is in line with the studies of Moscoso et al. (2022) and Chamilothori et al. (2022a), since people from a northern latitude perceived the spaces as less bright. The importance of considering whom we are designing for is underlined, as the same environment might be evaluated negatively by a group of people and positively by another, and cultural differences are a probable cause. The findings suggest that when the participants felt pleasant in a room they assessed it brighter, whereas if a space evoked unpleasant feelings it was perceived darker.
5.3. Memory and Familiarity

The comparison of participants’ emotional state during the mental visualization and the exposure to the space indicates a link between memories and emotions. Specifically, when Swedes were exposed to P1, P2, P3 and P5 simulated in Sweden they experienced the emotions they expected. On the other hand, when they evaluated the spaces simulated in Cyprus the evoked emotions were not utterly compatible with the expected ones. The interdependence of memory and emotions is apparent for Cypriots too. The descriptions of P1, P2, P3 and P5 made the subjects feel pleasant and after the disclosure of the models simulated in Cyprus, most participants felt so. Additionally, the descriptive text of P4 activated them likewise with the image. The spaces simulated in Sweden evoked slightly different emotions to Cypriots. These findings highlight the complex relationship between memories, emotions, and spatial experiences. Previous experiences can shape the emotional responses to architectural spaces, despite that, the results of the present thesis imply that daylight patterns and geometries are captured in our memory shaped by the features the sunlight has in our country, or the country we lived for a long time.

5.4. Differences among the fields

Another topic that the present thesis aimed to investigate was whether the users’ field of study influences their assessment. In order to do so, the answers given from Designers were compared with the ones from Non-designers. The groups displayed dissimilar emotional and spatial responses for the simulations within Sweden and Cyprus, indicating that the groups have distinct sensitivities and preferences. This suggests that the users’ educational background might affect how they interpret and evaluate daylight characteristics within an indoor space. Undoubtedly, the field of studies is an impactful factor in spatial perception, but it is crucial to note that personal preferences may also affect it. Moreover, P5 provided mixed emotional responses, which implies that irregular organic openings provoke perplexity to the participants and a negative evaluation of the space. This was not expected since according to research patterns with irregularly distributed openings or medium to high complexity are evaluated as interesting (Chamilothori, Chinazzo, et al., 2019; Abboushi et al., 2019). However, the number of participants was limited and in order to generalize this discovery, more experiments should be conducted with greater number of participants.

5.5. Sustainability statement

The results intimate the significance of facade design as a powerful stimulus for shaping the spatial experience. Regarding the psychological well-being of the user during their spatial experience, the panel with circular openings, P4, affected positively the subjects. Considering the use of space, the participants chose office buildings and according to studies, appreciation of work environment improves wellbeing (Veitch et al., 2008). These findings could be used as guidelines for designing work environments that aim to ameliorate not only comfort and energy efficiency, but also to create delightful and enjoyable spatial conditions for their users.
5.6. Generalization of analysis

The generalization of results suggests that when users feel familiar within a space, pleasant or activating emotions are evoked, since the most familiar panels of the experiment, generated mainly positive emotions to the participants. Moreover, when users feel pleasant in a room they perceive it brighter. This finding could be used in cases where access to daylight is limited but a pleasant emotional state of the user is needed. However, the same visual stimuli can evoke contrasting emotional responses and perceptual experiences, so the need for tailored designs that accommodate specific user expectations and needs is required. Participants from Sweden experienced all the unpleasant and deactivating emotions during the experiment and they stated that they would not consider the panels as an element of a house. These imply that people from the north prefer direct access to daylight due to the limited amount of sunlight they receive throughout the year. While in Cyprus sunlight is more consistent and abundant during the year due to the island’s southern latitude and people tend to look for shading solutions and restriction of daylight penetrating indoors. Lighting designers should propose spaces that satisfy the preferences of the targeted users. To do so, the client-centric approach of architect Richard Neutra, who asked numerous personal questions in order to comprehend completely the clients’ lifestyle and needs, could be adopted by lighting designers too (Rost Architects, 2020). Furthermore, the techniques of lighting designers Elettra Bordonaro and Luciana Martinez such as semi-permanent installations and users’ reviews can enhance the connection of the user with the design (Light Follows Behaviour, 2021). Lighting design proposals for public buildings should follow similar methods, by focusing on the background, the needs and the preferences of the potential users and the precise location settings of the building.

5.7. Limitations

The chosen methodology might have impacted the findings. Firstly, the fact that the subjects evaluated the spaces through their laptop screens and not in a real-life environment might have influenced the results. Specifically, their screen settings and the brightness of their surroundings are potential implications. Moreover, the differences in the weather conditions of each subjects’ location is another possible influence on the collected data. Last but not least, the participants’ emotional state during or before the experiment might have affected their answers regarding the evoked emotions. Further research is required, with greater amount of participants and an evaluation of spaces in real life, to corroborate the results of the present study.
6 CONCLUSION
This experimental thesis presented how five shading panels shaped the spatial experience of the participants, in rooms simulated in two different geographical latitudes. The analysis suggests that the distribution of daylight and shadows can influence the spatial experience of the user, both their emotional state and their perception. Additionally, the impact of latitude is highlighted and the research gap concerning regional differences within the range of latitudes in Europe is slightly filled.

The importance of taking into account what we are designing, where we are designing it and who we are designing it for is emphasized. The way we manipulate light in an indoor space not only can change the spatial perception of the user, but also it can alterate their feelings. The decisions of a lighting designer should be an outcome of a thorough thinking, which is focused on the precise requirements and needs of the context.
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Sample of questionnaire

Do you work or do you have an academic background in the design field? *(Architect, Lighting designer, Interior designer, etc.)*
- Yes
- No

Where are you from? *
- Sweden
- Cyprus
- I have been living in Sweden for years
- I have been living in Cyprus for years

Do you believe that an interior space is able to evoke emotions to the user? *

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Imagination

Imagine yourself in an indoor space. It is the 20th of March and it is midday. The room is a minimal square room, without any furniture and it has a big window on the south wall. The walls, the ceiling and the floor have a white color. A panel with openings is placed on the exterior part of the window as a shading system and is made of bright colored wood. Daylight is penetrating through the openings of the panel and on the floor you can see different shapes of shadows and different distributions of daylight.

Which characteristic has the greatest impact on your spatial experience while you are in the room? *(Select as many as you want)*
- Architectural elements of the space (floor, walls, ceiling, etc.)
- Daylight coming through
- Artificial light
- Shadows in the space

Which characteristic do you keep in your memory after you experience the room? *(Select as many as you want)*
- Architectural elements of the space (floor, walls, ceiling, etc.)
- Daylight coming through
- Artificial light
- Shadows in the space
How would you feel in this room if the openings of the panel were horizontal and the daylight was formed into a pattern of horizontal stripes on the floor?
- Activated
- Deactivated
- Pleasant
- Unpleasant

How would you feel in this room if the openings of the panel were vertical and the daylight was formed into a pattern of vertical stripes on the floor?
- Activated
- Deactivated
- Pleasant
- Unpleasant

How would you feel in this room if the openings of the panel were square and the daylight was formed into a pattern of square shapes on the floor?
- Activated
- Deactivated
- Pleasant
- Unpleasant

How would you feel in this room if the openings of the panel were circular and the daylight was formed into a pattern of circular shapes on the floor?
- Activated
- Deactivated
- Pleasant
- Unpleasant

How would you feel in this room if the openings of the panel were organic and the daylight was formed into a pattern of organic shapes on the floor?
- Activated
- Deactivated
- Pleasant
- Unpleasant
Perception of the indoor space and emotional state.

To answer the following questions, imagine yourself in the space of the presented photo and observe the whole space, not only the openings.

How does this space make you feel? *

- Alert
- Happy
- Contented
- Calm
- Fatigued
- Sad
- Upset
- Tense

Evaluate the space according to the following characteristics *

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How does this space make you feel? *

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| Shadows (1 is |
| vague - 5 is |
| marked) |
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How does this space make you feel? *

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- Contented
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- Tense

**Evaluate the space according to the following characteristics**

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| marked)           |   |   |   |   |   |
Perception of the indoor space and emotional state. (Part 2)

To answer the following questions, imagine yourself in the space of the presented photo and observe the whole space, not only the openings.

How does this space make you feel? *

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Evaluate the space according to the following characteristics *

1 2 3 4 5

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  - Level distribution (1 is uniform - 5 is dramatic)
  - Shadows (1 is vague - 5 is marked)
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Familiarity

Do you consider any image familiar? *

- Option 1
- Option 2
- Option 3
- Option 4
- Option 5
- Option 6

- Option 7
- Option 8
- Option 9
- Option 10

What use would you consider that these rooms have? *

- Office buildings
- Theaters
- Hotels
- Churches
- Schools
- Hospitals

Would you consider these rooms being a part of a house? *

- Yes
- No