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Abstract:

This study investigates the expansion of library as a public space, the changing needs of the visitors and how to personalize and enhance their library experience through activity zones specific ambient and task lighting. The growth of library functions in the modern and future libraries will be taken into focus, defining the activity zones and visitor needs in a library environment. In order to enhance the experience within the four different activity zones, specific atmospheres through light presets were generated. This study includes two experiments - the lab and the field test. The lab test explores the preferences for correlated colour temperature (CCT) for 10 subjects in regards of both ambient and task lighting in four function zones - the work, cave, play and chat zone. The lab test was conducted in a laboratory with no daylight access, furnished with furniture relevant to the activity zones. The lab test results showed that the most preferred CCT either neutral or cool, with 3600 K and 5300 K winning for the ambient and task light in all of the activity zones. However, 3600 K was mostly preferred for task lighting. The lab test findings did have a number of biases regarding the light intensity, placement and changing dynamics. Therefore, the results were taken into consideration but not for changing the presents in the field test. The field test was conducted in a natural library environment - a below ground level room of a Swedish library with no access to daylight. The space is a part of the library with daily visitors, however not as much used as the other areas so nudging guide signs and face to face invitations were required. During the four-day test period, an overall of 112 individual answers were marked down in all of the four zones. The testing area included the four activity zones (work, cave, play, chat) with function specific furnishing and an option to pick between four light presets via an application on a tablet computer. The presets were a combination of both ambient and task lighting, differing in intensity, direction of the spot and CCT. The field test results indicated that the set activity zone light presets were almost the same as what the test subjects preferred. The experimental results thereby confirmed that different light presets are preferred and needed for different activities. This project is carried out in cooperation between the following partners: Aalborg University Copenhagen, Fagerhult and Halland County in Sweden. It was initiated in September 2017 and ended in May 2018.

Keywords: *library, future library, activity zones, activity specific lighting, human-centered lighting design, dynamic lighting, individual preferences, correlated colour temperature, light presets, light atmospheres, personalized lighting.*

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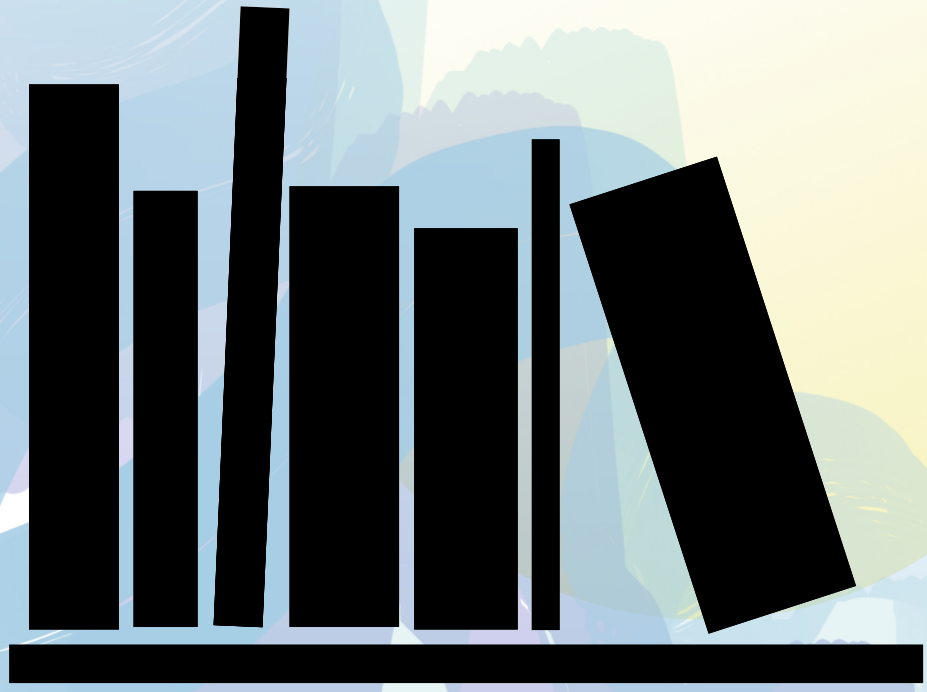
Guidelines for Lighting Activity Zones in Existing and Future Libraries

By Maja Munksgaard Danborg & Mariliis Kundla



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ABSTRACT

This study investigates the expansion of library as a public space, the changing needs of the visitors and how to personalize and enhance their library experience through activity zones specific ambient and task lighting. The growth of library functions in the Modern and Future Libraries will be taken into focus, defining the activity zones and visitor needs in a library environment. In order to enhance the experience within the four different activity zones, specific atmospheres through light presets were generated. This study includes two experiments - the lab and the field test. The lab test explores the preferences for correlated colour temperature (CCT) for 10 subjects in regards of both ambient and task lighting in four function zones - the work, cave, play and chat zone. The lab test was conducted in a laboratory with no daylight access, furnished with furniture relevant to the activity zones. The lab test results showed that the most preferred CCT either neutral or cool, with 3600 K and 5300 K winning for the ambient and task light in all of the activity zones. However, 3600 K was mostly preferred for task lighting. The lab test findings did have a number of biases regarding the light intensity, placement and changing dynamics. Therefore, the results were taken into consideration but not for changing the presents in the field test. The field test was conducted in a natural library environment - a below ground level room of a Swedish library with no access to daylight. The space is a part of the library with daily visitors, however not as much used as the other areas so nudging guide signs and face to face invitations were required. During the four-day test period, an overall of 112 individual answers were marked down in all of the four zones. The testing area included the four activity zones (work, cave, play, chat) with function specific furnishing and an option to pick between four light presets via an application on a tablet computer. The presets were a combination of both ambient and task lighting, differing in intensity, direction of the spot and CCT. The field test results indicated that the set activity zone light presets were almost the same as what the test subjects preferred. The experimental results thereby confirmed that different light presets are preferred and needed for different activities. This project is carried out in cooperation between the following partners: Aalborg University Copenhagen, Fagerhult and Halland County in Sweden. It was initiated in September 2017 and was ended in May 2018.

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Finally, we would also like to offer our special thanks to our families for their support and encouragement throughout our study.

1 INTRODUCTION

Libraries are changing. A library is not merely a warehouse for books, but it is:

"Adapting to the needs of people who want spaces to work, be online, learn new software, write a report, meet friends, hear a lecture, edit a film, start a business, do 3D printing, eat and drink, apply for a job, rest, receive social services, by a gift, get free advice, and feel welcomed and safe." (Deyrup, 2017: p. xi).

It can be argued that libraries have had to continuously prove their worth since the launch of Google in 1998, however the development of technology has its cons as well as pros. The libraries are therefore evolving into multifunctional cultural houses with a large scale of different functions, catering to a wide visitor basis. The spaces and functions of a Modern Library have to adapt with the changing technological, cultural, and economic environment (Deyrup, 2017). Digital revolution has, in a way, liberated libraries by connecting more free resources to more people (Deyrup, 2017). The Modern Library is not merely a place for storing and retrieving printed information but a more dynamic place where any form of information can be exchanged and created (Deyrup, 2017). With the expansion of the physical spaces as well as the functions, meeting visitors' needs has become more challenging but also more into focus as the needs vary greatly.

Extreme example of the evolution of the library interior.

Library of Tsar Nikolaj, Russia (left, Picture 1). Tianjin Binhai Library, China (right, Picture 2).

Creating successful lighting in public spaces requires considering all the elements of the given area. This means that it is inevitable to look past the architecture and furniture of the interior, as they create the direct physical environment that grants our comfort. Even a simple change in the positioning in of the furniture can have a huge impact on the human interaction, *"Moving chairs into a circle rather than a line can invite collaboration amongst strangers."* (Deyrup, 2017: p. xi). However, even if the room is purely functional, it is not sufficient to

base a lighting design solely on the visual, practical tasks - *"the first step in lighting design is to establish the character of the space"* (Tregenza et al., 2014, p. 87). Firstly, the way we work, how we feel about the ambience and what we later remember about the space has to be defined (Tregenza et al., 2014). As living beings, we experience the surroundings as a whole, being influenced by all the sensory inputs of a physical environment. The temperature, architectural shapes, smells, light - all these elements affect how we experience being in a space. People are sensing the environment with every sense, it is a multi-sensory experience (Pallasmaa, 2007). This also means that a library environment and its appeal to the visitors is greatly influenced by the sound levels and thermal comfort in the spaces. The perception of both phenomena can be manipulated by conscious lighting design, e.g. the hue-heat hypothesis which states that *"an environment which has wavelengths predominantly toward the red end of the visual spectrum feels 'warm' and one with wavelengths mainly toward the blue end feels 'cool'"* (Baniya et al., 2018: p. 308) and that classroom noise levels can be significantly reduced with bringing down the visual noise of the room (van Tonder et al., 2015). Furthermore, sufficient lighting inside as well as outside also increases the feeling of safety and discourages illegal activity after hours. (Gibbon, 2002).

However, as sound and temperature are complex topics in themselves, we decided not to go much further into analyzing their effect on library spaces (appendix 3.4.4). However, these phenomena play a great part in a library environment, as students in the field of lighting design, the focus of this report will be about exploring the effects of light.

"When we are designing lighting, we are designing architecture" (Tregenza et al., 2014, p.87). Meaning that light is an essential part of the architecture, elevating the existing features and functions in the interior. In order to design light, one needs to get familiarized with the potential users of the space and their specificities what comes to their habits and preferences. This report investigates the visitors' needs in library spaces, in order to find out how their experience could be enhanced through lighting design. Based on these findings, a set of guidelines are created, which will help to serve these needs with assigning specific lighting in the different activity zones. These lighting design guidelines would serve as a tool for fulfilling the needs of the visitors in the process of redesigning the existing libraries and constructing new libraries. A selection of four libraries were used in the analyzing process. Using qualitative and quantitative methods, we found out the possible insufficiencies in meeting the library visitors' needs and how it can be improved with lighting design. First, observational and survey-based analysis of different libraries was conducted: in KADK

library, DOKK1 library, Albertslund Main Library, and Falkenberg Main Library. This allowed us to define the needs of a visitor in every age group and further develop activity zones which would require different light atmospheres. We came to the conclusion that the dominating functions fit into four main activity zones: the work, chat, cave and play zone, all requiring different spatial design approach. This also translates greatly into the lighting design in the space, which means that "*lighting for the task is key: simply flooding library buildings in a "one-size fits all" approach of even lighting is no longer acceptable."* (Lesneski, 2017, appendix 2.5). In order to have an understanding of the potential visitors' CCT preferences in the created zones, a LAB Test was carried out in a controlled environment of AAU light lab. The AAU light lab is Aalborg university controlled light lab, that can be used to conduct a controlled lab test. Based on the LAB Test results and theory, a FIELD Test was developed, in order to investigate the visitors' light preset preferences in their chosen zones, all in a natural library environment. The FIELD Test was set up in Falkenberg Main Library with simulating the four activity zones (the work, chat, cave and play zone), giving the visitor a freedom to choose from four preset light settings. The presets were available in a user-friendly way, set up on a Samsung tablet computer and through Casambi application, which was connected to marathon tunable white fixtures provided by Fagerhult. The figure below illustrates the overall thesis process and how the different findings were taken further throughout the investigation process.

Figure 1

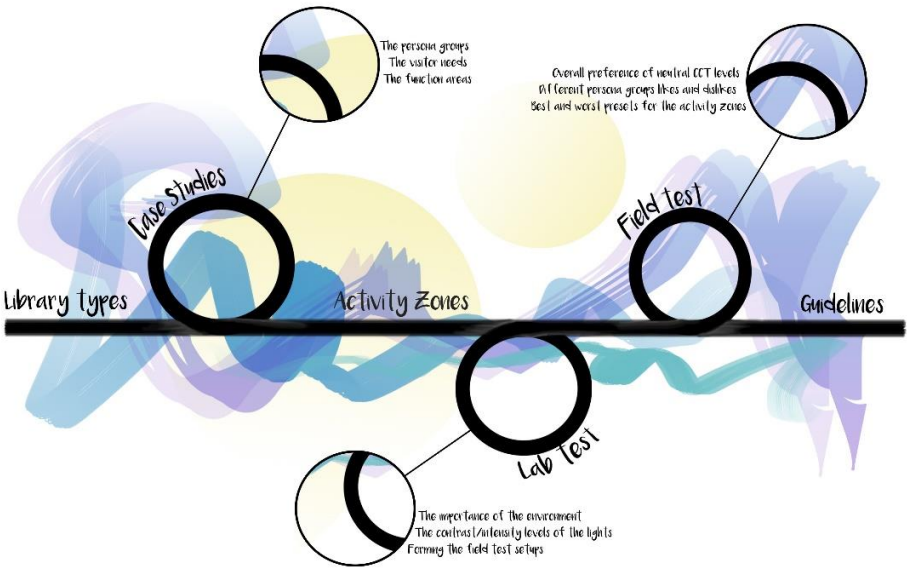


Illustration (Figure 1) showing the investigation process line, what findings were taking on to next level of the process.

2 MOTIVATION

The main motivation for this report arises from the rapid changes the Standard Library is going through in the digital age, where almost all information can be found on the Internet. This creates an opportunity for the library to adapt to the changed times by altering their functions to avoid becoming extinct. As students of the lighting design field, we developed a strong personal motivation for this phenomenon and saw the possibilities of investigating it further. With the digital revolution, most of library spaces need to be rethinked with the focus on the visitors and their needs." *As books, periodicals, and reference collections become available online, those shelf spaces formerly filled with these items can now become spaces for people to meet and work."* (Deyrup, 2017, p. xii). With this expansion of functions in the existing libraries as well as the Future Libraries, they need to adapt and support the specific lighting requirements of the broad visitor spectrum. *"A library should be designed to reflect the different needs of diverse activities."* (Cha & Kim, 2015, p. 274). These new needs have emerged with the expansion of the functions choice of some of the existing libraries, which also brings in more visitors. *"Today's libraries are less about housing collections of books and more about housing collections of people."* (Deyrup, 2017, p. xii) However, with enlarging the library as a building and the functions within, it is easy to lose a sense of personalization. Although a library is first of all a public facility, its core functions like reading, writing and gathering information require a degree of privacy and stillness. As there are a lot of different visitors of both genders, various ages and backgrounds, being able to personalize one's reading or working space is essential, as the needs vary a lot. Based on our academic background and personal experience, the developing library and how can its functions and atmosphere be made more inviting by light, was taken to further exploration. This initial motivation was encouraged by the opportunity for collaboration between the faculty of Lighting Design in Aalborg University Copenhagen, Halland County in Sweden and Fagerhult - one of Europe's leading lighting companies (Fagerhult, N.d). Halland county gave permission to conduct any needed tests in the Main Library of Falkenberg, the explorative library of this study, which will be taken down in 2019 and replaced by a new combined library and culture house, designed by Fojab architects. Fagerhult supported the test with needed light fixtures. (Falkenberg Bibliotek, 2017)

3 LIBRARY TYPES

"The idea of the library as the cornerstone of civilization and an oasis of learning is as old as the scrolls once stored in the ancient Library of Alexandria". (Deyrup, 2017, p. xii) Meaning that the Modern Library, despite having to adjust to the digital revolution, continues to be the social and educational haven, open for every citizen (Deyrup, 2017). However, the library and its role have been changing over time, varying in their visitors, the architecture and the functions within. This mean that although Modern Libraries are built in the same time period does not mean that they have the same visitor basis, the same functions or even the same architecture.

This section will go into the five types of libraries that will be used further in the text and in a way, sets a 'State of The Art' for this report. To get a better general understanding of the library by looking into the visitors and their needs in the specific library type and then looking into the lighting as generally and according to ambient, task and accent light. When looking into general libraries, we decide to create five types, these are mostly based out from the libraries that are still existing as libraries today. The five types of libraries are not all connected by time periods, this is because these are the main library types that have changed most over time, with the visitors, the functions and building style. It is interesting to note down how the American librarians divide the libraries into four basic types: the public libraries, school libraries, special libraries, and academic and research libraries (IES, 2013). However, as this report is focusing also on the lighting as well as the functions of the libraries, the types have been generated through looking further back in the history. In the following section, the lighting of the different library types will be discussed through ambient, the general lighting layer; task, the light aimed at a specific task; and accent, the directional lighting mostly used for decorative purposes, light (IES, 2013).

3.1 CLASSIC LIBRARY

Our definition of a Classical Library is an old university library, with mostly academic books and articles. This type of libraries was *"staid places where printed information was stored and retrieved"* (Deyrup, 2017, p. xii), with the limited functions mostly surrounding around reading books. In the publication "Creating The High-functioning Library Space" (Deyrup, 2017), the rapid evolution of the American library architecture in the second half of the nineteenth century is being discussed. Although it focuses only on the history of American libraries, the evolution has been of a great influence in other Western countries and therefore

relevant for bringing out. The four main types of classical libraries include: the alcove book hall or the *library as sacred place*, the departmental/seminar book room or the *library as laboratory* type, the book stack or the library as stage, and the modular library or *library as functional box* (Deyrup, 2017). However, although mayor architectural changes were being made during that time, the lighting and general atmosphere in the various Classical Libraries remained the same. In this report, a Classical Library is considered too been built in between the 14th and 19th century, with examples from different part of the world below.



Providence Athenaeum, U.S. (left, Picture 3). Old Town Library Copenhagen, Denmark (center, Picture 4). Trinity College Dublin Library, Ireland (right, Picture 5).

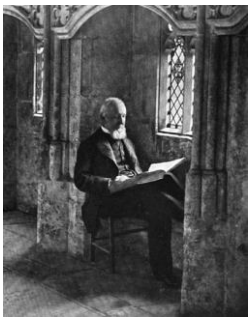
The Classical Library are the oldest university libraries or similar to these, therefore was and are the visitors mostly students. But as these libraries were increasingly used by the public theft also became a problem, this led to chaining the books or scrolls to the bookcase, making sure that you could not take the book with you without damaging it (Lamb, 2018). So, these types of libraries were mostly use for research, reading and working in, therefore are the functions quite basic like finding books, using study tables, reading etc. Even more present classic library will have the same functions as the one back in the 14th century but could have update elements like self-check in service or coffee machines to being able to follow the digital age. These types of libraries are still having their main visitor basis of students.

3.1.1 Lighting in Classic Libraries

The first way to light up Classical Libraries back in the 14th century was by using daylight coming from the windows because of candle lights and lamps being forbidden because of the fear of fire (Lamb, 2018). To get more light in, some Classical Libraries were even designed with skylight windows in the ceiling to provide as much daylight as possible (Lamb, 2018). However, this means that the natural daylight hours greatly influenced the opening hours of the library, as well as the comfort of reading. First around 1885 was electric light introduced to the Classical Library, five years after Edison produced a 16-watt light bulb. Harvard

University Library in the USA was one of the first Classical Library to get the electric bulb system, allowing them to expand the opening hours in the evening and create additional access to the collection of books (Lamb, 2018). Where the American common public first started in mid-1920 to get electrical lighting inside their homes (Novak, 2013)

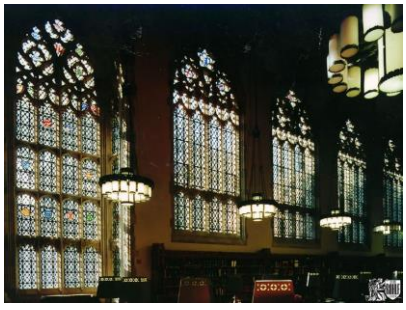
Ambient light in Classic Libraries would have been created by the daylight coming in through the windows from the sides or the ceiling. This would have been the only ambient light that was present in the old Classical Libraries as seen on the pictures below, but later when the electric light would be present in the Classical Library it would had been adding to the ambient feeling of the space. This meant that tables were dark, and due to the chains to prevent theft, it would make it hard for the visitor to move into the light.

Picture of Wells Cathedral Library (left, Picture 6). Picture of a Carrel and a visitor at Gloucester Cathedral Library (right, Picture 7).

Task light in classic libraries was not the most common thing because of the fear of fire. But it would have been task light coming from candle lights or gas lamps, creating a warm glow to illuminate the books making it possible to read the pages in the dark library.

Accent light in classic libraries was connected to the daylights movement, hitting the surfaces create pattern on the floor, walls or ceiling in the libraries. Another way accent light could have been created was with coloured stained glass windows, creating this interested coloured shadow on the floor moving with and according to the Sun's path.




Picture of stained glass at the main reading room of Yale University Library (left, Picture 8). Hackley Public Library (right, Picture 9).

3.2 STANDARD LIBRARY

Our definition of a Standard Library is a library constructed in the time period of the 1950s until 1990s. These types of libraries had more functions than the Classical Library, including children area and youth areas etc. Some Standard Libraries are changing their functions to follow the visitors' new needs and are also creating café areas inside the library. These Standard Libraries are taking the trends from the era and adding colours to the walls, floor and furniture but due to a lot of renovation in Standards library, the colours have been toned down a bit and are not that vivid as seen on the pictures below.



Canton Public Library in the 80s, U.S. (left, Picture 10). Võrumaa Main Library, Estonia (centre, Picture 11). University Library of Toronto, Canada (right, Picture 12).

In the 1960s the librarians began to take a more active role in promoting general public awareness when thinking about library-specific interest. The libraries were changing and going through a cultural and social movements and adding a more multimedia collections with a wide range of audio, visuals and motion materials (Lamb, 2018). Around the 1980s technology-based systems started to become a common tool in libraries, such as fax machines and some low-tech computer to keep an overview over the different books. The visitor basis did also change from the Classical Libraries to the Standard Library, from only having adults to letting in children. Around the 1960s they even started to make special reading rooms for children and having children books with more serious social content, dealing with subjects like death, alcoholism, divorce and child abuse (ibid). Around the 1990s libraries had been used to children in the libraries scene and the decor and children space had changed making it more child-friendly with example different types of toys or wall decoration making the space a children paradise (Bon, Cranfield and Latimer, 2011). With having teens, children and young adults in the libraries it also changed the functions from being only reading on the spot, to having children areas, youth areas, making the functions closer to what they are today.

3.2.1 Lighting in Standard Libraries

In the 19th century when electric lighting took over, it changed the way of thinking about the role libraries. Libraries were not relying merely on daylight anymore and could now work during no matter the weather, time of day or bad architecture. Fluorescents lighting products were the most common light in Standard Libraries, creating this less warm glow in the space. Ambient light in Standard Libraries would be found in the use of daylight and electrical ceiling lighting, a mix of these would have created an ambient light that produced the possibility to observe the surroundings in the Standard Library. The placements of windows in the Standard library was different from the Classical Libraries, were the Classical Library had huge windows to let in a lot of sunlight, the Standard Library windows would be smaller and was according to the trends in that period by architects and the architects' skills with working with daylight. Like stated in the part above, the electric light was mostly placed in the ceiling and having light sources like fluorescent tubes or incandescent. The Standard Libraries would slowly but surely have started to change their lighting into LEDs around 2010s for different reasons like maintenance or an energy saving purposes in their municipality. The pictures below are examples of ambient light in Standard Libraries. First picture showing ambient light in Falkenberg Library in Sweden in form of fluorescent tube lighting and no daylight, this is because the library is in two level and this is showing the basement of the library (Picture 13). Second picture showing another type of ambient light in Albertslund Main Library in Denmark in form of spots lights and daylight (Picture 14).

Part of Falkenberg Library in Sweden (left, Picture 13). Children section in Albertslund Main Library in Denmark (right, Picture 14).

Task light in Standard Libraries would had been seen mostly in the area where there were tables, shelves lighting or where the librarians worked. The picture below shows examples of task light in Standard Libraries, where the first picture shows task light in Falkenberg Library in form of shelf lighting. Second picture shows another type of task light in Albertslund, Denmark in the form of tables task lamps.

Falkenberg Main Library, Sweden (left, Picture 15). Albertslund Main Library, Denmark (right, Picture 16).

Accent light in Standard Libraries would mostly come to life in the use of daylight, because of the more functional view on these types of libraries but do to creative architects of this time they would be placed into the architecture of the building, that would had created this dynamic type of the play with the daylight. The importance of accent light is not to be underrated, as it stimulates the visual senses of the visitor and in the best scenario, inspires and generates curiosity. *"It's important to make places that generate curiosity. You need to create attractive spaces where people will want to work."* (Deyrup, 2017, p. xiii) In the pictures below there are shown examples of accent light in Standard Libraries. First picture shows it in Falkenberg Library in the form of a sunset shining on an art piece hanging in the Library. Second picture showing another type of accent light in Albertslund Main Library in Denmark in the form of daylight being reflected on the different glossy surfaces.

Pictures from the observations in the libraries, Falkenberg Library, Sweden (left, Picture 17). Albertslund Main Library, Denmark (right, Picture 18).

3.3 MODERN LIBRARY

Our definition of the Modern Library is a multifunctional library that has more functions than a Standard Library. These functions include a café, playground, citizen services as well as a being an architectural landmark, a tourist information center and a course center - functions that are normally seen in a culture house. The Modern Library also attracts a bigger variety of visitors than the Standard Library or Classical Library and therefore needs to be adaptable,

supporting human well-being in all of its facets. These libraries were and still are being built around the 2010s and we believe that this type of building trend will be seen some years to come. The Modern Library is working with a lot of daylight intake so big windows are commonly seen in these types of modern buildings. Most common colours and materials are white, bright accent colours, concrete and wood working together to create a modern open space.



Photo of Media Library Thionville in France by Eugeni Pons (left, Picture 19). Photo of Halmstad Library in Sweden by Schmidt Hammer Lassen Architects (center, Picture 20). Photo of Stadtbibliothek in Heidenheim Germany by Kraufmann/Hörner (right, Picture 21).

The Modern Library is not only a library anymore. It is a place with other functions than seen in a library before. When building libraries before, the building was the main focus, but now the designers and the builders are trying to understand that they are building for visitors using the space (EATON, 2016). The Modern Library is going to be able to adapt but also meet the needs of the people, better supporting the specific lighting requirements of different visitor groups, e.g. children preferring bright elements, themed environments with lots of excitement and the light need to be able to support this (EATON, 2016). In the Modern Libraries, the visitors are visitors who are searching for a place that has it all - a space they can relax in and take their children to but also a space where they can take care of business. The Modern Library is a multifunctional space where the visitor can stay all day and have their needs somewhat for filled. The libraries are therefore not only getting the normal visitors, elderly, adults, students or children but also tourist is coming to the Modern Library. It could be to go to the tourist center or to see the architectural landmark the Modern Library has become.

3.3.1 Lighting in Modern Libraries

In the Modern Libraries LEDs and daylight are the most common light sources. Daylight had a setback in the Standards Libraries but regained its importance in the Modern Libraries, with some downsides. What comes to daylighting in 2018, there are only few technical limitations to the window size, which means a lot of large glass facades are being used. This is mainly not for attracting daylight but *"because of the desire to achieve a particular architectural*

expression." (Dahl, 2009, p. 138). However, the large glass areas create problems like excessive light and heat as well as also loss of heat during winter (Dahl, 2009). *"One of the key objectives of window design is to create a gradual transition between outside and inside with variations in brightness which the eye can gradually get used to rather than be exposed to the intense light outside."* (Dahl, 2009, p. 120). If the contrast between inside and outside is too high, there are dark surfaces and lack of deep openings and illuminated areas close to the window, unpleasantly large contrasts and glare is being created (Dahl, 2009). This means that when designed carefully, daylight is the most optimal and sustainable way of lighting up interiors. However, for meeting the shortcomings of the architecture and specific needs of an indoor space, electric light has to be used. LEDs are to be found overall in the Modern Libraries in shelves lighting, ambient lighting and task lighting. Even the accent light in a Modern Library has mostly been created by nature or creative facade designs, but there are also endless possibilities for creating them with modern technology.

Ambient light in Modern Libraries can be found in the modern lamps or spots placed in the ceiling. The higher ceiling in the Modern Libraries often indicate big windows which are going from floor-to-ceiling, these types of windows also increase the daylight in the buildings that also help a lot with the ambient lighting. In the pictures below are two examples shown of how ambient light could be seen in Modern Libraries. The first picture shows how ambient light in DOKK1, in Aarhus, Denmark are in the form of big windows going from the floor and up, letting in a great amount of daylight. The same sees in second example from Halmstad Library, Sweden.

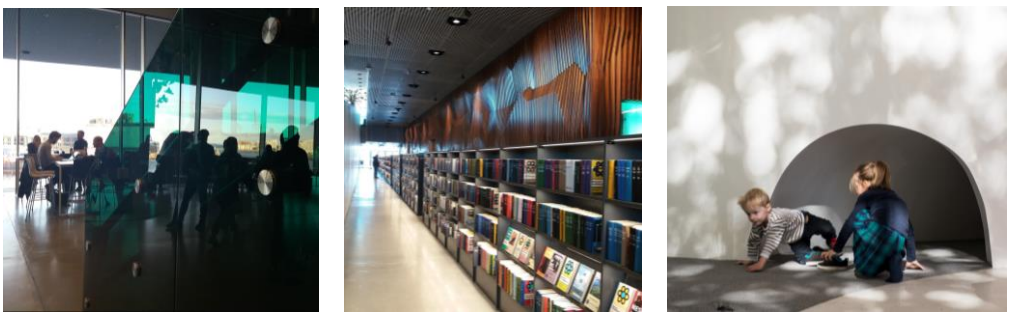
DOKK1, in Aarhus Denmark, by Mariliis Kundla (left, Picture 22). Halmstad Library in Sweden, by Adam Mørk (right, Picture 23).

Task light in Modern libraries can be found in some of the same places as Standard Libraries. The ambient light is in focus in these type of libraries, therefore are the task light more placed on the shelves and as the electrical ambient light are LED shelf lighting. Some types of tables lamps can also be found in Modern Libraries. In the picture examples below are the most

typical task light shown, first picture shows how DOKK1 has LED strips on the shelves and how the ambient light is the main light source in this picture. In the second picture, its shown how task lamps are used to make reading easier at this Modern Library in Finland.

DOKK1, Aarhus in Denmark, by Mariliis Kundla (left, Picture 24). Turku City Main Library in Finland, by Arno de la Chapelle (right, Picture 25).

Accent light in Modern Libraries are mostly not that different from the Standard Libraries. It is mostly an interaction between the dynamic daylight and its surroundings, but the differences are more often found in its architecture. Due to when the different libraries were built and what architectural trend it was following, the accent light would be more built-in in the facades of Modern Libraries than in Standard Libraries. Some Modern Libraries are even playing with accent light in form of electrical light that can create dynamic pattern, this normally would not be seen in Standard Libraries. In the pictures below are three different types of accent light in Modern Libraries shown. First and second picture show how DOKK1 is working with the dynamic light and materials. In the first picture it is shown how different types of material can affect the daylight and the other one shows how dynamic daylight can affect different surfaces. These two pictures are showing how daylight can interact with different material and create interesting dynamic patterns for the eye. Third picture is also showing a Modern Library with accent light effect, here it shows how the daylight and the nature outside the building interact and create a dynamic pattern of the floor and walls that will change over time.



DOKK1 in Aarhus in Denmark, by Mariliis Kundla (left and center, Picture 26 and 27). Thionville Media Library in France, by Dominique Coulon & Associés (right, Picture 28).

3.4 SMART LIBRARY

Our definition of a Smart library is a library with technically smart elements that enhance the visitor experience, e.g. several types of sensors, which enable controlling the environment, giving information to the visitors and being able to personalize one's environment. There are not that many Smart Libraries in the world, however from close proximity, Denmark's Technical University (DTU) can be considered as a Smart Library. This type of library is mostly created when upgrading an already existing Modern Library. Right now, the Smart Libraries are mostly for the use of students and are not yet implemented in public libraries.

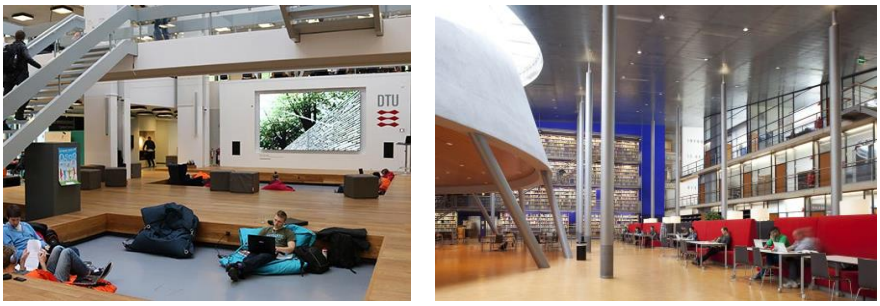


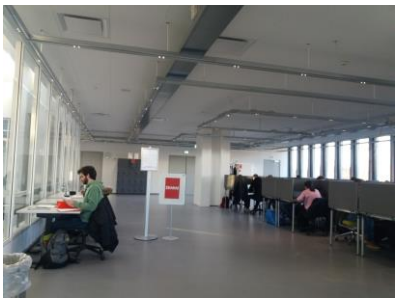
Photo of Danish Technological University Library 'Smart Library', Denmark (left, Picture 29). Photo of Delft university of technology Library, Netherland (right, Picture 30).

Smart Libraries are something that are created in these past years, making it a new player in the library scene. The Smart Libraries are mostly student-based libraries connected to university, were the smart elements can be tested on students. The Smart Libraries are taking known technologies seen in homes and applying them to the public scene, making it possible to personalize light or getting more information of the space the visitor is interaction with (Binau, 2017).

3.4.1 Lighting in Smart Libraries

Ambient light in Smart Libraries are not that different from Standard Libraries when we are talking about daylight. Most of these Smart Libraries are placed at Universities and therefore are not newer building like most Modern Libraries are. Therefore, the windows are mostly placed after the rooms being used to teaching or after the understanding of older libraries, that expensive books and daylight is not the best combo (Lamb, 2018). When looking into electrical light it is here where the Smart Library stands out, by using different sensors to affect the ambient light. Here are daylight sensors or movement sensors use to create dynamic light throughout the day. Light intensity is not the only way of creating dynamic electrical light, but also by changing the LEDs colour temperature to simulate the daylight on example cloudy days. In the pictures below are different examples of ambient light in Smart Libraries shown. First picture shows how the daylight are the most visible ambient light at

daily basis, in the top of the picture we also see how the electrical ambient light are placed on tracks that look more functional than giving architectural value. The second picture are showing how the ceiling lighting can be personalized and adding to the user-freedom in the Smart Library. A good example of a library with a smart vision in the DTU library, which has been gradually changing since 2013 under the leadership of Lars Binau, the Team Manager at DTU Library (Binau, 2017, appendix 1.1). They have replaced around 620 light bulbs and lamps, changing them to smart-LED (Vinge, 2017). The new light fixtures are able to be more personalized, so the visitor is able to change the colour and intensity of the lights in the specific zone that the visitor are in. The fixtures also have different sensors, e.g. for counting the people in the room as well to collect data about the indoor climate (Vinge, 2017). As of early December 2017, the library has been divided into 27 zones that are being monitored by various sensors.

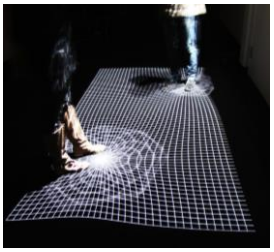
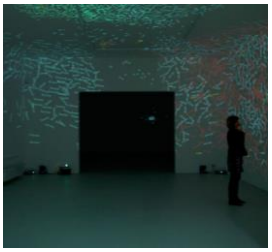



DTU library, Lyngby in Denmark, by Mariliis Kundla (left and right, Picture 31 and 32).

Task lighting in Smart Libraries are somewhat more difficult to find that have a smart element to them. So, the task light is more like Standard Libraries, like table lamps and comfortable light that just can turn on and off. But the personalization of task light is seen a lot outside of libraries, so we believe that it soon would be able to see it in example Smart Libraries as DTU. The first picture below shows how task light could be at Smart libraries, here with an example from BYB Lighting, a lighting company that create light for homes and work space, that shows how it can change the task light correlated colour temperature (CCT). The second shows some of the existing task light at DTU in the form of a hanging task lamp that can be moved.

Task lamp from the brand BYB Lighting (left, Picture 33); task light areas at DTU library in Lyngby in Denmark (right, Picture 34).

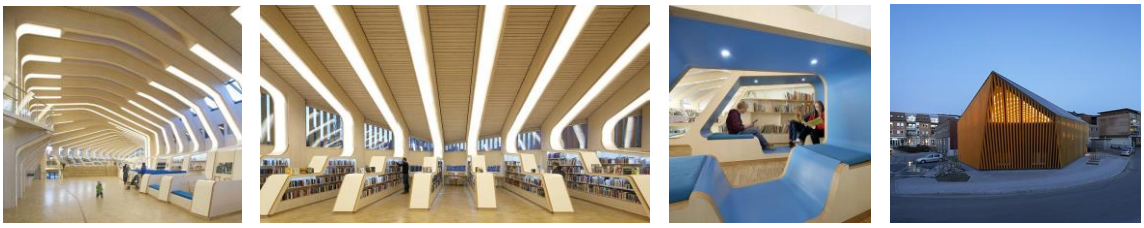
Accent light in Smart Libraries are not visible in the same way as in Modern Libraries, this is due to the more functional way of thinking. Therefore, are the accent light more seen with daylight hiding varied materials and create interesting reflection. DTU or other Smart Libraries would have the possibility to create their own type of accent light with all the data they are getting from the visitors and the space, like numbers of people in the room, daylight numbers or air quality. In the pictures below are examples of how Smart Libraries could create accent light if they took the data they get from the sensors and was thinking more creative than functional with the light, by programing it with the data from sensors to create dynamic light movements. The first picture below shows a fabric test, where daylight is reflection of the material creating this pattern and by moving the fabric creating a dynamic play. This effect could be recreated by using electric light, even programmed light to fabricate movement in the reflections. Second picture are showing an art installation called *Fabric Play* there can be affected by the visitor interactive with the installation. A Smart Library like DTU would also be able to take their data and create an accent light effect like seen in picture three below, this is an installation of data by Charles Sandison.

Examples of accent light. Iridescent material reflecting on the wall, by Maja Danborg (left, Picture 35), an interactive installation by Wanting Guo (center, Picture 36) and a projection installation by Charles Sandison (right, Picture 37).

3.5 FUTURE LIBRARY

Our definition of a Future Library is a library that combines the elements of a Smart library and a Modern Library. Besides including smart sensor driven solutions for customizing the environment and it's lighting, the experience is more dynamic and holistic - a Future Library is a sustainable and multifunctional building that is in sync with the constant flow of different visitors and their needs. As according to our criterion, there are not any Future Library existing yet, this definition is based on what we are seeing changing in the world in technologic as well on how the library must change functions to follow the future use of it. We would not describe either DOKK1 or DTU library as the Future Library, as DOKK1 is lacking the smart elements and DTU in its modernity of architecture.



Vennesla Library and Culture House in Vennesla, Norway (Picture 38, 39, 40, 41).

As stated above, the Future Library is not existing yet, but we believe that it will soon start to be adapted, in the way of thinking and creating libraries. We believe that the functions of the libraries will change into a more of a cultural house-function where most libraries are open after the sun sets, therefore would the electrical light have a greater importance than before. The visitors will be similar to the Modern Library, having functions for elderly, adults, young adults, children and tourist. The functions would evolve and make the space feel less like a library as we know it but adapt more to the visitors needs and culture. This is already happening where the newest library in Finland is adding the function of wellness with a sauna on the board to adjust to the visitor's needs (Davies, 2014). Furthermore, the Vennesla Library and Culture House in Norway, designed by Helen & Hard Architects and opened in 2011, is a fitting example of what a Future Library might look like. Although they are lacking in smart elements, the architecture and concept are very much forward looking (see pictures above). *"The new library in Vennesla comprises a library, a café, meeting places and administrative areas, and links an existing community house and learning centre together"* (Dezeen, 2012).

3.5.1 Lighting in Future Libraries

As the Future Libraries, as they are seen in this report, do not exist yet, the exact lighting can be only speculated about through theory and examples of libraries' evolution. With the multiplication of the functions and growth of different visitors, the architecture and lighting must become more based on human-centered design (HCD). The light must adapt to the specific activities, having different colour, placement and brightness depending which function needs to be supported. The overall lighting masterplans will become more diverse, also bringing down the general light levels as the human eye has excellent adaptation abilities, which have been looked past by engineering focused lighting designs (Hendrup, 2018). Besides elevated, human friendly architecture and lighting, the future Library will also utilize smart technical solutions for a smooth, sustainable environment, constantly adapting to the visitors' flow and needs. First steps towards this have been made with applications like Casambi (changing light CCT and brightness), Ethernet network-based DALI control system (Clipsal, N.d), applications for changing the positioning of the fixture, iBeacons (tracking one's location via Bluetooth) or one of the many e-Sense systems (wireless sensor system for tracking presence, turning on up to 15 luminaires) (Fagerhult, N.d). However, as with any tool, they have to be carefully integrated, otherwise will not give but take from the atmosphere. Too much customizability in a public space, especially in an area with many users, unnecessary discussions or even conflicts can emerge. *"I don't see the benefit of it [Casambi app]. You will get possibilities, yes, but also terror. (...) Colour temperature wise, yes, if you have your own office and are not sharing it with others."* (Hendrup, 2018, 58:47, appendix 1.3) Furthermore, the smart solutions often take even more energy than the lighting itself, defeating the purpose of the sustainability of LED lighting (Hendrup, 2018). The smart solutions should mostly be used for creating and dividing zones in a subtle way, enhancing the experience and allowing customization only in the personal areas. Furthermore, it should also be used for balancing out the daylight and artificial light, especially in the Nordic region where the light is characterized by the Sun's low altitude (Dahl, 2009).

Ambient light in Future Libraries would be something similar to the ambient light in Modern libraries. Where daylight would play a big role in the general lighting of the space, but due to buildings opening hours and also that some geographical area with a lack of daylight, the daylight alone would not be effective enough. This is making us believe the use of daylight simulation are in Future Libraries, where they would use dynamic LEDs to simulate the daylight with their colouring, CRI and adaption to our circadian rhythm, when the daylight is

not efficient enough or even missing in the northern areas. We also believe that these daylight simulations would be designed to mimic the daylights colours as much as possible is such way that there could be talking about circadian rhythm simulation as well.


Thailand Creative and Design Center Library, in Bangkok (left, Picture 42). Helsinki's new central library, Finland (right, Picture 43).

The task light in Future Libraries would have with more smart elements than already existing in Smart Libraries. We believe that due to the change of the libraries use and new functions, there would be more user-friendly light, that would be able to be personalized to the functions and not the area alone. We also believe that by using personalized light it would be able to generate the feeling of a personal space without using more furniture or shelves to create a barrier for the visitor.



Aarhus Royal Library, Denmark (left, Picture 44). Rentemestervej Library, Denmark (center, Picture 45). Library luminaire designed by Anna Gudmundsdottir (right, Picture 46).

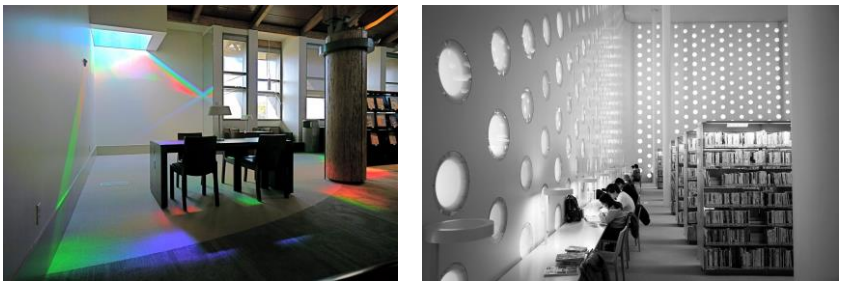
The Swedish-Icelandic industrial designer Anna Gudmundsdottir has created a flexible task light that helps people focus by shielding the surrounding environment and keeping a connection at the same time as people like feeling the sense of community:

"The sound absorbing hood provides a calming sense of space and a reflected light suitable for laptop users while the adjustable, focused light enables users to change the light to best suit their personal needs. The aim of this luminaire is not only to provide a good illumination solution but also to give library visitors a great light experience."

(Anna Gudmundsdottir Design, N.d).

Accent light in Future Libraries would be a mix of the Modern Libraries and Smart Libraries, so a mixture of architecture and technologic. Where conscious architecture would be able to

create accent light with the better usage of the daylight. This would be possible by create shapes and pattern in the building by shading of light as well as letting it in, these would create dynamic daylight pattern. We also believe that we will see how the electrical light are going to mimic the daylight and its dynamic patterns, these would be produced with the data of the visitors, the weather outside etc. This would give the electrical light a greater power that it would have before, and these pattern and effects would be able to change easier than the daylight pattern created by light and material, giving the electric light more possibilities. The pictures below are showing two different examples of how accent light could be used in the Future Library.

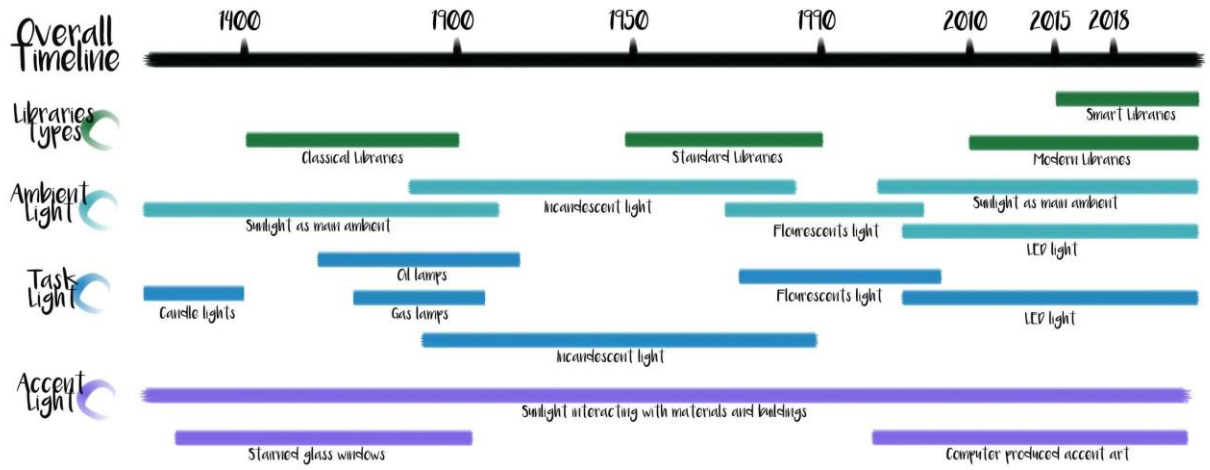


Peter Erskine 'sun painting' art installation at Lafayette Library, in California US (left, Picture 47). Kanazawa Umimirai Library, in Japan, picture by Joseph Kuo (right, Picture 48).

4 LIBRARIES AND LIGHT

Light plays a key role in the creation of a space and its atmosphere - *"Light, like music, fills, reveals and creates the space"* (Brandston, 2008, p. 19). It can improve as well as decrease the quality of the functions of a library space, thereby attracting or repelling visitors. With increasing the feeling of a personalization and comfort, the chosen space can become much more inviting. These aspects can be met with cognizant lighting design. As the role and visitors of a library have changed over the time, so has the lighting. From using only natural daylight, being heavily dependent on the architecture and sun path, to the latest LED fixtures with endless options - different sizes, placement options, a CRI almost as good as daylight and most importantly, high customizability. After defining and analyzing the five library types and their lighting, a clearer historical timeline was formed, mapping down the different eras, what kind of artificial and natural illumination methods were used (Figure 2).

Figure 2



Timeline showing the overall history of ambient, task and accent light in different libraries (Figure 2).

Natural daylight does play an important role in an interior, quoting architect Louis Kahn: *"A room is not a room without natural light"* (Penn, 2009). But due to many variables, daylight will not be the focus of this report (appendix 3.4.3). When discussing the experience of intensity and direction of the electrical light, Richard Kelly's theory of three light elements and the relation between light and architecture was chosen as the analytical tools. By using Kelly's theory, it will create a template that can be used for analyzing the light in the different libraries, but also to create the light in the activity zones that can read in section: GENERATED ACTIVITY ZONES. Through this, we are able to investigate concepts like the feeling of a

personal space and creating atmospheres in specific activity areas. Kelly's theory of the interplay of lights and the surroundings breaks down into three parts, differentiating:

"(...) three elemental kinds of light effect which can be related to the art of painting for easier visualization: (1) focal glow or highlight, (2) ambient luminescence or graded washes, (3) play of brilliants or sharp detail. "(Kelly, 1952, p.24)

Kelly explains focal glow as the pool of light that draws attention and separates important from the unimportant, helps to focus on a specific activity. Ambient luminescence is described as all-surrounding, reassuring, quieting the nerves and restful. Last but not least, Kelly describes the play of brilliants, which excites the optic nerves and in turn stimulates the body and spirit, quickens the appetite, awakens curiosity and sharpens the wit (Kelly, 1952). By using Kelly's theory as some observational lighting criteria, we have a common way of understanding and describing the light layering in the different libraries. This also allows us to define the ways light is meeting the needs of the various tasks and analyze the indoor public areas of the many libraries that are discussed.

Pictures illustration ambient luminescence (left, Picture 49), focal glow (middle, Picture 50) and play of brilliants (right, Picture 51).

As an overview, the three perception orientated ways to describe light according to R. Kelly are: 1. *Ambient light*, overall light to softly lighting up the room, 2. *Focal glow*, lighting up the task in front and 3. *Play of brilliants*, the stimulating lighting that awakens curiosity. To give Kelly's terms a shorter wording, in the following sections 1. Ambient light, 2. Task light and 3. Accent light will be used (Figure 3).

Figure 3

Illustration of 1. ambient light, 2. Task light and 3. Accent light (Figure 3).

As mentioned previously, when investigating light in this report only electric light will be the focus. Electric light provides enough nuances for discussion and its being investigated by using Kelly's theory as a template. Only focusing on electric light in a library setting has been successfully conducted before, where the transformations of a basement floor into an

aesthetic library area (e.g. The Danish Royal Library, in Aarhus Denmark). This library showed how it depends on electric light and the exact way it has been used for creating a specific atmosphere. The room can transform completely through the positioning (height, angle, beam size) and the colour and intensity of the lighting fixtures. As Louis Hartmann wrote about theatre lighting: *"By subtle use of light, and without altering so much as a word of the dramatist's text, it is possible sometimes to change completely the impression a whole scene conveys."* (Brandston, 2008, p. 9). By using these three types of light as a tool, we are also challenging the common practice of uniformly lighting up the whole library space. Giving value to the shadow enriches the interplay between the space, light and surface, enhancing the architecture and atmosphere of the chosen space (Dahl, 2009). *"When you place your head and your eyes in the shadow, your vision becomes more clear and more effective, so it doesn't matter how much light you have, it matter where you are."* (Hendrup, 2018, 4:20, appendix 1.3) Furthermore, the adaptability of the eye should not be underrated, as it is a powerful factor (ibid). Martin Hendrup, area manager of ERCO Lighting AB, believes that people in the lighting industry do not have an in-depth understanding of the exact structure, function and capacities of the eye, which is a real problem (ibid). More focus needs to be put in designing the shadow areas, while lighting up the task areas and wall surfaces but e.g. keeping our faces out of the brightly lit areas. *"The way that our eye and vision is reacting to light is the same as our ear is reacting to sound. (...) We have a logarithmic scale that we use when we are working with acoustics, but in lighting we're working linear. But light doesn't work linear" (*Hendrup, 2018, 20:18, appendix 1.3). From this statement, more confidence emerged to set the human comfort and needs as the primary goal and not to be so fixated with meeting the EN standards (EN, 2009).

5 VISION

The vision statement is a place for imagination, something that can inspire the process and path of the project. It was developed from merging the knowledge from relevant literature about libraries, previous academic knowledge and our subjective experience within the libraries. From the previous analyses of the different library types, it is visible that a library is becoming much more than it used to be some decades ago. The plethora of functions mean that new needs for the visitors have emerged, requiring a more personalized approach and making the widely utilized uniform light outdated. When trying to understand the light needs in a Future Library space, we have to look at the functions and how to support them through light. *"If you are a lighting specialist working on an existing building, you are continuing the work of the original architect. Part of you job is to analyse what exists, to discover if possible the intentions that led to it; and then to enhance its qualities; …"* (Tregenza et al., 2014, p.87). Different functions require different atmospheres, which can be enhanced by lighting. This also gives the space, where the function is being executed, a more personalized feeling. The vision statement stands as:

Imagine if …

A library could enhance the feeling of personal space by creating a comfortable and inviting environment through light.

6 CASE STUDY

In order to further develop our research, we decided to get a better understanding of various libraries within Denmark and Sweden - the KADK library, DOKK1 library, Albertslund Public Library and Falkenberg Main Library. The libraries were chosen according to their differences in location, architecture, year of construction, variety of functions and presumable visitor basis and their library type (Figure 4). The libraries were all either the main library of the region or a municipality, guaranteeing active usage which we could then observe. When approaching the case study, our focus was to mainly investigate and mark down the functions of the existing library spaces, the amount, gender and age of the visitors, and the usage and balance between natural and artificial lighting. Furthermore, we investigated the existence of personalized light spaces, in order to gain inspiration for what the Future Library might have a requirement for.

Figure 4

	NAME	**LOCATION**	**ARCHITECTS**	**YEAR**
Classic Library	The KADK Library of Architecture, Design, Conservation & Performing Arts	Danneskiold-Samsøes Allé 50, 1434, Copenhagen K, Denmark	Holger Schmid Vilhelm Lauritzen Arkitekter Ditte Jessing, later Lise Møller Ericsson (interior architecture modernizing by the library management)	1920 1997 2011
Modern Library	DOKK1	Hack Kampmanns Plads 2, 8000, Aarhus C, Denmark	Schmidt Hammer Lassen Architects	2015
Standard Library	Albertslund Public Library	Bibliotekstorvet 2, 2620, Albertslund, Denmark	Henning Larsen Architects	2004
Standard Library	Falkenberg Main Library	Biblioteksgatan 2, 311 35 Falkenberg, Sweden	Leather factory White Arkitekter AB (transformation to a gymnasium and a library) Present form	- 1971 1996

Figure 4 - Showing the four case studies locations, architects and building periods.

All in all, the case study includes investigating the visitors and the library space, aiming to get an overview of the environmental aspects and the visitor usage patterns of different library spaces and thereby revealing the possible weak spots in the daily function. In order to define the visitors' needs, personas and their maps were created, as well as a fill in survey for the visitors and staff with additional observations. The library space was investigated through mapping down the natural and artificial light as well as sound and temperature. When considering the environmental aspects, sound and temperature play a great part in the dynamics of an indoor space. *"If blue colours are predominant, light will be experienced as cold, and if red colours are predominant, light will be experienced as warm."* (Dahl, 2009, p. 116). The findings provide data for pinpointing the problems in the libraries and gives room for consideration in order to improve the situation with conscious lighting design. The output provides valuable data on how the current functions in a library are being supported or restrained by the environmental aspects as well as the lighting, helping to define the next steps towards creating lighting design guidelines for libraries. These findings further allowed us to understand the current approach to library lighting and to develop a research question.

6.1 METHODOLOGY

The methods applied in these case studies were both quantitative (appendix 3.1 & 3.3) and qualitative (appendix 3.2 & 3.4). The used quantitative method was conducting a survey among the visitors and library staff in order to gather data about the visitor profiles and their preferences. Other methods categorize as qualitative field observations, which include photos, sound recordings, diary and mappings, and allowed us to define and compare the function areas and other environmental aspects of the libraries. These methods were chosen for their ability to inform us with a better understanding of the different types of libraries and also make it easier for us to create persona groups by looking into their needs and movement in the library.

To get a deeper understanding of the visitors' needs and understanding of the library, we were inspired by a paper called Post-Occupancy Evaluation of Public Libraries (Lackney & Zajfen, 2005), which explains how Post-Occupancy Evaluation (POE) provides valuable feedback to the library administrator, with could be used to identify and clarify the need for adjustments in the space as well as justify modifications in the original design. There are three steps in the POE, first step is the planning of the evaluation process, where you would

determine the purpose and scope of the evaluation. The second step would involve the execution of the data collection and analysis of the functions. Final step would be about creating an informal presentation and discussion with the staff about the resolution of the most particular concerns (Lackney and Zajfen, 2005). Inspired by Lackney's and Zajfen's work, we took inspiration in parts of their survey and constructed our own (appendix 3.1). As in the paper, we wanted to ask both visitors and staff members. The parts that we were inspired by included; The background of the visitors (and staff), Functionality and layout, Environmental quality, Accessibility, Safety and Security (Lackney and Zajfen, 2005).

Our survey was slightly varying between the visitors and staff members, including 29 questions for the visitors (appendix 3.1.1 & 3.1.3) and 22 questions for the staff (appendix 3.1.2 & 3.1.4). The survey asks into how our visitors use the library and with who, getting a better understanding of the visitors' needs. It also included questions about the environment including light, safety feeling, temperature and noise, these factors would give us a understand if there was lacking elements in the library. This also means that the visitors are in constant interaction with the environment, making it difficult to detach the visitor from the space (Pallasmaa, 2007)

The observation methods were drawn from various sources in order to get a broad understanding of the usage of the space and the visitors' behavioral patterns. After sending emails to all of the libraries but only gaining answers from two libraries via email (appendix 2.1 & 2.2), the three to five-hour interval observations of visitors' behavior and use of library services were planned.

As Wildemuth (2009), the professor in information and library science at University of North Carolina at Chapel Hill, suggests, *"for many research questions, observation has significant advantages over interviews or questionnaires (or other forms of asking people questions)"* (Wildemuth, 2009, p. 209). Direct observation has two main qualities to it. First, it allows to gather accurate information about events, as the participants can be oblivious about their surroundings - their description might not give the full picture as some elements will be taken for granted or go unnoticed. Secondly, *"direct observation enables you to gather more precise data about the timing, duration, and/or frequency of particular behaviours as well as the sequence"* (Wildemuth, 2009, p.209). The participant might not be aware of these characteristics but noting them down as the observer is important for the analyzing process. Furthermore, it is important to prepare an observational schedule with room for unexpected

behaviors to minimize bias, as *"it is very easy to filter unconsciously what you see, based on your own expectations."* (Wildemuth, 2009, p. 211) Additionally, one of the issues with observational studies is people changing their behavior because of the presence of the observer, the obtrusiveness of being watched - the *Hawthorne effect*, which will, however, reduce over time (Wildemuth, 2009). Therefore, it is important to spend a lot of time on the spot to become one with the environment and gain trust. As Connaway & Radford (2016) discuss, the researchers must decide what kind of relationship they want with the subjects - obtrusive or unobtrusive. Fortunately, as libraries host different visitors, often also working on their laptops and/or taking notes, it was suitable to take on the position of an unobtrusive observer in the background. Doing fields notes, in diary style was one of the ways we used to do observation. To note down our notes we mostly did unstructured observational notes about the weather condition, daylight amount, general ambience, environment and visitors' behavior. This field note style we called diary style.

> *"In planning unstructured observational research, one must take into account the participants or subjects, the setting, the purpose for the subjects' being where they are, the type of behaviour to be observed, and the frequency and duration of the behaviour."*
> (Connaway & Radford, 2016, p. 272)

Unstructured observational notes are flexible and can give a lot of valuable information. However, they should be made simultaneously when the functions are happening to be as precise as possible and the participants' behaviors should not be limited into specific predesignated categories (Connaway & Radford, 2016).

Using the camera to capture and doing visual fields notes, are a way to supplement the writing observational notes. By using camera, you will be able to document the place, the materials and even the movement of the users (Larsen & Meged, 2012). Unfortunately, none of the libraries gave permission for professional photography or video recordings which means only a smartphone was used for taking observational pictures. By using video, we would have been able to capture interactions between the user's and the space, it would also had given us a better understand of the space and the user's because it would both be a moment it time with live picture and the audio (Larsen & Meged, 2012), video would be able to support the observational notes and pictures, because the notes and pictures wouldn't be able to go some much into details as film (Larsen & Meged, 2012). But being aware that pictures and video recordings is only a moment, missing the time before and after the

capturing (Larsen & Meged, 2012). However, there are some significant disadvantages to video recording, as people are self-conscious if being recorded.

> *"Although video recording might be useful for capturing intermittent behaviours without being present all the time, such an approach raises serious ethical issues related to the informed consent of the study participants."* (Wildemuth, 2009, p. 211)

In the small section above we talked about how we didn't get permission to do video recordings at the library, but sound recordings would be a way to capture the element of the video recordings that could create a different layer and supplement to the other observations elements. For capturing the ambience of the surroundings and being able to analyze and compare the noisiness levels between the given libraries, sound recording was made with the H4n stereo recorder by Zoom. Normally sounds recordings are used when doing interview, to capture every word and contextual details (Mack, Woodsong, MacQueen, Guest & Namey 2005). However, we used sounds recordings to capture the atmosphere and the sound level in that area, at noted time and date. Sound notes was also a part of the observations, because recordings can fail so notes are a good way to do backups and supplement the recordings (Mack et al., 2005).

Mapping was one of our visual methods to show and remember the environment. The mappings were done after analyzing the survey results and visiting the libraries and can be divided into two categories: *environmental maps* and *persona maps*. With the environmental maps, we identified the function areas of the library, the temperature, noise levels, safety feeling, daylight, electric light and glare (appendix 3.4). These maps were done with the survey results, but also from our observation notes, pictures and sound recordings. For the persona maps, four different age and gender personas were created and further analyzed if and how would they be using the given library. These four different personas were created out from our observations notes of who are going to the different types of libraries. The personas and their maps would be described in depth in section: Visitors' Needs.

6.2 CASE STUDY HYPOTHESES

The aim of generating hypotheses for the survey is to analyze how do the visitors use the library and thereby conclude their needs in the space. As the purpose of the spaces and visitors differ slightly in all four libraries, it is good to have an overview and a comparative moment with the results. The hypotheses were generated from our previous experience of having visited public libraries and recalling previously studied researches.

Visitors visit the library mostly alone

This hypothesis is created to get an understanding of the most common type of visits the visitors were making. This would add to the understanding of how the different spaces were used, alone or together and also how people interacted with the library space.

Visitors do not feel like there is enough electric light

Daylight was and is the most common way of lighting up libraries (section: LIBRARIES AND LIGHT), because of the change in opening hours and how the space is being used due to new function, this lead us to investigate if there is enough electric lighting for the visitors and the new functions.

Visitors find it hard to find what they are looking for

As the libraries are evolving into bigger cultural houses, besides just being physically larger they will also be hosting a variety of functions which could induce confusion while trying to orientate oneself. Students have been reported of feeling lost, disoriented and unable to locate the materials because of the size of the library and inadequate signage (McPherson, 2015, and Abusin et al., 2011).

Visitors mostly use the libraries to find books and study

In the Classical Library the only function was to find books and study, this lead us to investigate if the still is the most common reason to go to the library or because of the new function it has changed into something else.

Visitors are mostly student and elderly

As students, besides academics, have been the original users of a library, they will always be found in a library space - writing, reading, finding relevant material in a quiet, focused environment. As students are known as one of the main library visitor groups, it is important to cater to their needs. *"A library should be designed to reflect the different needs of diverse activities (e.g., independent study, group work), thus creating better student learning spaces."* (Cha & Kim, 2015, p. 274). Although their needs have expanded with the technological evolution, requiring Wi-Fi and electronic plugs for charging their devices. Furthermore, the elderlies might have a habit of going to the library, either because of something they have become used to over their lifetime, saving money and borrowing books instead of buying them, using the computer as well as reading the daily newspapers or

magazines. Not to mention they have a lot of free time on their hands and maybe wanting to switch up their home routine.

6.3 THE FOUR CASE STUDIES

In this section we will conduct four case studies with three different libraries types, to get a better understanding of the visitors, its needs and the space itself. The four case studies were conducted in Denmark and Sweden, where three libraries were Danish: KADK in Copenhagen, DOKK1 in Aarhus and Albertslund main library and one Swedish, Falkenberg Main library.

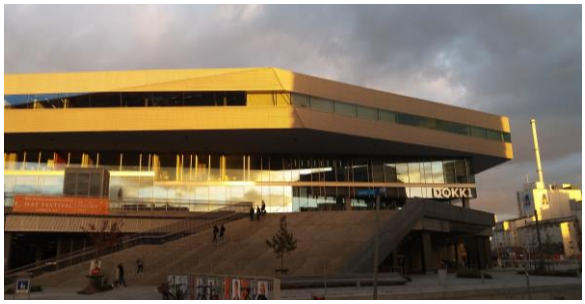
6.3.1 KADK Library, Denmark

The KADK Library is located in Copenhagen and is the largest library of materials in architecture, design, conservation and performing arts in Denmark. Because of its location near The Royal Danish Academy of Fine Arts Schools of Architecture, Design and Conservation and not close to a residential area, there are mostly students visiting the facility. The KADK library also provides an extensive e-library with thousands of articles, e-books, databases and other digital resources. The building was created in 1920 by Holger Schmidt and was used as a smithy, for building and repairing ships (KADK, N.d). In 1997, the architectural firm Vilhelm Lauritzen remodeled and restored the old fleet stations, after which the school of architecture moved in (Vilhelm Lauritzen Architects, N.d). In 2011, there was a merging between The Royal Danish Academy of Fine Arts Library (KASB) and The Danish Design School's Library and the Conservation Science Center (KVIC), that made the library what it is today - a public research and education library with special focus on providing as a study or a group work area (appendix 3.4.5). Like mentioned students are the most common visitor group but do to this being open for the public other visitors than students would be able to be seen but it is rare.


Pictures of KADK - outside and inside taken on the observation day (Picture 52 and 53).

6.3.2 DOKK1 Library, Denmark

The DOKK1 library is located in Aarhus and besides functioning as a library with a great variety of books, audio books, eBooks, magazines, music and games, it also functions as a citizen services' facility. *"The library at DOKK1 is a center for knowledge and culture which disseminates and makes a variety of media come alive across genres and formats. Staff and management of the organisation continually work with public involvement."* (DOKK1, N.d). As for the visitors, every character of any age and gender can find an activity in DOKK1. The highly multifunctional and approachable quality of the library reflects heavily from the architecture itself - the location in the city; wide outdoor platform and children's play elements; outdoor staircases providing access to the building from all sides; indoor 'ramp' for resting and meeting; etc. The library prioritizes digital media but also hold a wide range of paperback books. Furthermore, The International Federation of Library Associations and Institutions (IFLA) named DOKK1 Library as the winner of the Public Library of the Year Award 2016 (Richards, 2016). DOKK1 is a Modern Library with an airport feeling to it because of the movement in the library compared to the others (appendix 3.4.6). The visitors of DOKK1 would be a mixed circle of characters, here would it be possible to see all from tourists, elderly, young children, students and families enjoying the facilities.



Pictures of DOKK1 - outside and inside taken on the observation day (Picture 54 and 55).

6.3.3 Albertslund Main Library, Denmark

The Albertslund Main Library is located in Albertslund, a Copenhagen suburb in Albertslund Municipality and provides a range of books, music, daily newspapers and magazines, computer usage and also citizen services. The library, located in a culturally diverse town, embraces the importance of it being a community meeting place. This also reflects on their webpage: *"Here you encounter old friends and get new acquaintances. (...) There is room for everyone in the diversity at Albertslund Library."* (Albertslund Bibliotek, N.d). Therefore, the library is mainly a gathering place for the local elderly, study place for students around and a time spending place for kids and their parents. Albertslund Main Library was built in 2004 by

Henning Larsen Architects, creating a Standard Library with a modern feel to it creating a space where you want to stay (appendix 3.4.7).


Pictures of Albertslund Main Library - outside and inside taken on observation day (Picture 56 and 57).

6.3.4 Falkenberg Main Library, Sweden

The additional case was made in Falkenberg Main Library in Sweden, as the library is being provided for the research purposes of this study. The current library was part of a bigger building rebuilt in 1994 by the White Arkitekter, but as we are informed by the Falkenberg Main Library director Anders ktorp, the actual library building is older and from around 1971. However, he does not know the precise year of original foundation, neither is it available online (appendix 2.3). The future for Falkenberg Main Library is that the library is to be demolished in the nearest future, the idea is that they are building a new building. The new building is expected to be finished in the end of 2019 and it will be housing the library as well as the tourist information center and the local gymnasium (Falkenberg Bibliotek, 2017). Falkenberg Main Library as it is now, is a pretty Standard Library with students, adults, elderly and families as the main visitors (appendix 3.4.8).


Pictures of Falkenberg Main Library - outside and inside taken on the observation day (Picture 58 and 59).

6.4 CASE STUDY FINDINGS

In this section we will go over some of the findings from the case studies as well as bias' that occurred under the study. The findings from the four case studies were very versatile and gave a lot of interesting material for further processing.

Human bias

When conducting the case studies, we sat one day out for the four libraries, and stayed there at the same hours, to remove bias, but by only doing one day of investigation it made it hard to get at high number of participants. In some of the libraries we also had age barrier meaning that we could not talk to many children about their opinion without talking to the parents. This added also to the element of pickers-choice, when we were walking around talking to the visitor, we picked the people we wanted to talk to and also the one we did not want to talk to. Special in Falkenberg in Sweden were the pickers-choice used because we quickly got aware of the languages barrier, so even though we had translated our survey to inadequate Swedish, we still had some problems talking to elderly, children or newcomers to Sweden.

Observations bias

When doing our observations, we also had a bias of pickers-choice where we as the observer notes down what we wanted to note down (section: METHODOLOGY). Meaning that it is our point of view that were noted down and observed in the libraries. The season, the day, time and even the weather are factors that also could influence the case study findings. Meaning that if the weather was raining or over casted we would had been more visitors and if it had been sunny and warm there would had been less visitors.

6.4.1 Answering the Hypotheses

When looking into answering the hypothesis we are looking into all four case studies using the survey answers and supporting with observations. Survey results are located in the appendix 3.3.

Visitors mostly visit the library alone

TRUE - In our conducted surveys over 50% of the visitors asked where there alone. KADK and Albertslund Main Library 73% said that they mostly where at the library alone, in DOKK1 57% said they mostly visited the library alone and in Falkenberg 89% said that they mostly visited the library alone. These findings are also coexisting with our observations of the different libraries (appendix 3.2), making DOKK1 with the lowers percentages of visitors coming alone this could be because of the more open interior, inviting functions as well as interactive games in the library.

Visitors don't feel like there is enough electric light

FALSE - Most visitors did not seem to complain about the electric light - they just adapt to the situation, by moving or just ignoring bad light. These observations were supported by the survey conducted, where 100% of the asked visitors in DOKK1 said that the electrical light was either good or just right. In KADK was it 91% of the asked visitor, 89% of the asked visitors in Falkenberg and 82% of the asked visitors in Albertslund Main Library said that the electrical light was either good or just right. But when ask if there were places where there was bad electrical light some of the visitors said the same spots in the libraries that was observed by us, as being glary or to dark.

Visitors find it hard to find what they are looking for

FALSE - in the conducted survey we got a clear picture that people don't find it hard to find what they are looking for if that are a book or even a toilet. 0% of the asked visitors in KADK found it hard to find what they were looking for and the same percentages was in Albertslund Main Library. In Falkenberg 11% of the asked visitor found it some hard or somewhat hard to find what they are looking for. DOKK1 had the highest percent of visitor asked at 14%, this could be because of DOKK1 being so big and having so many functions. Our observation supported the survey findings, because it seemed that many of the visitors in KADK, Albertslund Main Library and Falkenberg are common in the library and therefore knew the location of what they wanted to find or else they would ask the librarian for help.

Visitors mostly use the libraries to find books and study

TRUE - These are the main functions in the libraries, in DOKK1 93% of the visitors asked where there to either study or read/lean books, in KADK 91% of the visitors was there for studying or reading books. Falkenberg had 88,8% of the asked visitors there to either study or rent books making Albertslund Main Library the lowest one with 81,9% of the visitors asked being there for reading/lend books. When breaking the numbers more up it is showing that most visitors in KADK are there for studying with 81,9% of the 91% making them the highest percent of visitors studying in the libraries. These numbers are matching with our observations made in KADK, making KADK more use as a study place (appendix 3.2.1). Falkenberg had the highest numbers of visitors using the place for the books, 77,7% visitors are there for either read books or lend them.

Visitors are mostly student and elderly

TRUE - Most of the visitors asked was either elderly or students. 100% of KADK asked visitors were students, this was also supported by our observation showing that all of the visitors going into KADK where there to study. 91% of Albertslund Main Library was either Student or Elderly, in our observation we observed a large number of elderly and student and only one family with a small child in the children section. In DOKK1 78% of the asked visitors were student or elderly and in Falkenberg only 33,3% was either Students or Elderly. Falkenberg's survey findings don't support our observation, that we observed many elderly visitors in the newspaper room, by because of these numbers only being from the asked visitors and not the observed this is the reason of the low percentages (appendix 3.2.4).

6.4.2 Visitors' Needs

In the section: libraries types, we got an understanding of how the different libraries types interacted with light, where in the section: Answering the Hypotheses, it gave a overview of how and what visitors might use the space. But to get an even deeper understanding of the visitors needs we had to get to know the visitors and how they interact with the space. *"We are in constant dialogue and interaction with the environment, to the degree that it is impossible to detach the image of the self from the spatial and situational existence"* (Pallasmaa, 2007, p. 64) The visitor will thereby become a part of the space, therefore it is important to understand all elements within.

"The old-time library, once a warehouse for books, has turned into a department store for learning and as agency for career and social services." (Deyrup, 2017, p. xi). Furthermore, when the first users were mostly male students and academics then nowadays, the library is open for every single person. Therefore, in order to create a successful design for the visitors, it's important to *"identify and prioritize the activities your community needs. Successful evolution is a response to local conditions"* (Deyrup, 2017, p. xi). Therefore, this research focuses on the visitors' needs and will define these needs in a library environment. In order to create a structure of the different visitor basis and their needs, four age groups were used and further developed into four individual personas. The age groups cover every potential library visitor profile and include children (2-11 years), young adults (12-14 years), adults (25-60 years) and elderly (60+).

6.4.2.1 Personas

(Persona Mathias, Picture 60)

Mathias is a 11-year-old school boy. His favorite subject is gym class and in his free time, he enjoys playing soccer and other ball games with his best friend Tim. Keeping active is not Mathias' only enjoyment as he also is a huge fan of multiplayer computer games, which he liked playing with his classmates or Tim. Mathias would be going to the library to use the computers, as he is not allowed to play online games too much at home. He sometimes also needs to get books for different school assignments. The things Mathias are hoping for at a library, is there is some types of games, single player as well as multiplayer that he can play with his friends. He also hopes for being able to go on the computer and he finds it important that there is internet access. The different persona mappings show how Mathias would navigate through the different libraries. The KADK library would not be a place where Mathias would see himself, even though they are having a computer area (appendix 3.4.2). DOKK1 and Albertslund Main Library would be places where Mathias would be able to find material for his school project and classes, as well as playing online games (appendix 3.4.2). Mathias would go to DOKK1 or Albertslund Main library. While doing our observation in the case study libraries we observed there only was a small percentage like Mathias, but we observed more kids like him at Falkenberg Library.

(Persona Lise, Picture 61)

Lise is a 19 years old second semester undergraduate student. Her biggest dream is to become a neurosurgeon and as she is a very hardworking student there is a chance that her dreams will come true. She is still living at home with her father and step-mother. However, as her

studies are rather difficult, she is not looking into moving any time soon because of the comfort and structure at home. Lise likes going to the library for finding information for her projects - either alone or group studies. Additionally, as she is living at home, she is also using the library as a relaxing environment that switches up the routine and gives more privacy. The different persona mappings show how Lise would walk around in the different libraries. KADK would be a place that Lise would go to even though they would not have that many books for her education. She would like to go there for the silent and relaxed atmosphere (appendix 3.4.2). DOKK1 would be the second-best place that Lise would go, but because of the big numbers of students using DOKK1, it will be quite difficult to find a good spot every time she goes there (appendix 3.4.2). Albertslund Main Library would also be possible for Lise, because there are group rooms, tables for her to sit alone and also a lounge area where she would be able to relax (appendix 3.4.2). Lise would be able to use all of the libraries in our case studies. While doing our observations at the different libraries, we observed that in all of the libraries there was study areas for student to be spending time at. In KADK and DOKK1, students were the most prominent visitor group, either sitting and studying alone or doing group work.

(Persona Anne, Picture 62)

Anne is 27 years old and a single mother. She has a two-year-old son called Kasper. She is mostly a stay at home mother but also studying online to become a nurse. Anne has a strong support system - during the exam period, her mother helps with babysitting Kasper. Anne likes going to the library for both getting materials for herself as well as spending some fun time with Kasper. Due to the stress of being a single mom, Anne likes visiting the library to socialize with other mothers, especially single mothers like herself. Anne hopes for a library is that there is a play area for her son, the possibility to meet other single mothers like her. Another one of her hopes is that the places would have comfortable chairs and many sitting areas. The different persona mapping shows how Anne would walk around in the different libraries. The KADK wouldn't be a place that Anne would go to because of the lack of

functions for her child (appendix 3.4.2). DOKK1 would be the most optimal library for Anne and Kasper. On the persona map, we are able to see how she would go to the kids' area which has a playground as well as being able to find books for her education. Because there are so many visitors and especially parents with children, there would be a big chance that she would be able to find other (single) parents with children to socialize with (appendix 3.4.2). Albertslund Main Library would also be possible for Anne, due to the children area and the possibility for Anne to find books for her education. But when doing observation at Albertslund Main Library, there did not seem to be many parents with small children (appendix 3.4.2). While doing our observations at the different libraries, the survey results showed that around ⅓ of DOKK1 visitors were parents with small children like Anne.

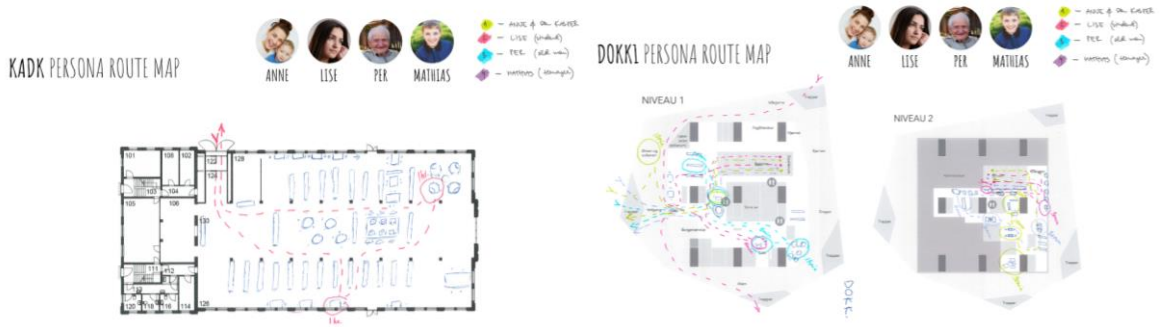
(Persona Per, Picture 63)

Per is a 78-year-old man, living with his beloved wife. His wife has developed bad arthritis and lost a lot of her mobility because of this, so Per is doing all the practical stuff in their household. Before her joints got bad they used to go to the library together to find interesting literature. Per now goes to the library almost every day to get a new crime book that he knows that his wife would like. He also enjoys sitting down and reading the newest newspaper with some of the other elderlies from his area. Per is hoping to be able to chat with some of the other men his age when he visits the library when is isn't sitting and relaxing with a good cup of coffee and read the newest newspaper from the café in the library. The different persona mappings show how Per would walk around in the different libraries. The KADK would not be a place where Per would see himself, due to the lack of crime stories as well as newspapers (appendix 3.4.2). DOKK1 would be a place where Per can get the books for his wife as well as to sit down in a comfortable seat and read the daily newspaper in peace (appendix 3.4.2). Albertslund Main Library would also be possible for Per, where he would also be able to connect with other local elderlies from his area (appendix 3.4.2). Per would go to libraries like Albertslund Main Library and DOKK1. These libraries have an area where he

would be able to read his newspaper but also to find a book for his wife. We observed that in Albertslund Main Library, around ⅓ of the visitors were in the age range of 65 to 85 years.

6.4.2.2 Persona maps

To get a better understand of how the personas would move around and what they would do in the different library spaces, Persona maps were created. The Persona maps are showing the path of the personas' journey in a one day moment. This would be a day in the Persona's life being at that specific library. Because the four personas were created to reflect the potential visitors of the library, considering different ages, genders and thereby interests in the facility, it was these persona route map we created to reflect the different visitors. The different personas would go through the libraries, and if they did not even appear at the library it is because of the libraries normal visitor aspect, like KADK being most for students. We have shown two of the maps below, the other two will be able to find in the appendix 3.4.2.



Persona route maps showing the route the persona would go in the different libraries. KADK route map at left and DOKK1 route map at right. Albertslund and Falkenberg's route map are to be found in appendix 3.4.2.

6.4.3 Function areas

"Almost every built environment is created to house some form of human activity" (Lam, 1977, p. 14) So in order to find a way for supporting the visitors' needs through lighting design, it is important to get an insight to the functions in a library, the visitors' profiles and their library usage patterns. Through analyzing the four cases (section: **Error! Reference s ource not found.**), we detected and mapped down eight main function area which are present in the existing libraries, these maps would be able to find in the appendix (appendix 3.4.1).

- Check in & out

Check in & out are the area where the visitors can check in or out the books or other information formats that they would like to bring home. These areas are normally located close to the entrance.

- Reading tables

Reading tables are the area where the visitors would be able to sit down and read a book in the library. There would be some sort of tables in this area.

- Lounge area

Lounge area are the area where the visitors can lounge in a sofa and relax. Here it would be possible both to relax as well as read.

- Study area (group work tables)

Study area are the area where mostly student visitors would go to and study, it could be in groups or alone. But mostly would the reading tables be used by the students to study alone.

- Children area

Children area are the area where the children would play, read and learn. This area would be visited by children and their parents.

- Youth area (or section)

Youth area are the area where the youth would hang out. This could also just be a book section in the library.

- Computer area

Computer area are the area where the visitors can use computers. In some libraries there would be only a few computers, and in others there would be created a whole area.

- Café

Cafe area are the area that are present mostly in newer libraries. The area would be a place where you would be able to get something to drink or eat.

To get a more intimate and precise insight of which functions areas of a library the visitors of the different age groups used, we create persona groups created out of the persona (Figure 5). The chart is going over the age groups of the persona groups, the profile words, the different function areas they would use and their needs. These findings are based out from our personas in the section above.

Figure 5

PERSONA GROUPS	CHILDREN	YOUNG ADULTS	ADULTS	ELDERLY
PERSONA	Mathias	Lise	Anne	Per
AGE	2-11	12-24	25-60	60+
PROFILE WORDS	Toddlers, early childhood, late childhood or **preteen**	Preteen, teens, or **students**	**Parents**, singles or in relationship	Grandparents, **widow/widower**, single or in relationship
FUNCTION	Check in & out, children area, youth section, computers	Check in & out, reading tables, lounge area, study area / group, computers, café	Check in & out, reading tables, children area, café, reading tables, lounge area	Check in & out, lounge area, reading tables, café
NEEDS	Computers, books for school use	Comfortable chairs and sitting area, good group tables, Silence	Comfortable chairs and sitting area, play areas	Comfortable chairs and sitting area, news papers and possible to meet other elderly

Figure 5 – showing the different persona groups, the functions they would use and their needs.

When understanding the needs and functions of the persona groups, we also focused on their light needs, based on their expected functions. The light needs were also paralleled with the EU standards (EN, 2009), in order to have an understanding of the existing requirements (Figure 6).

Figure 6

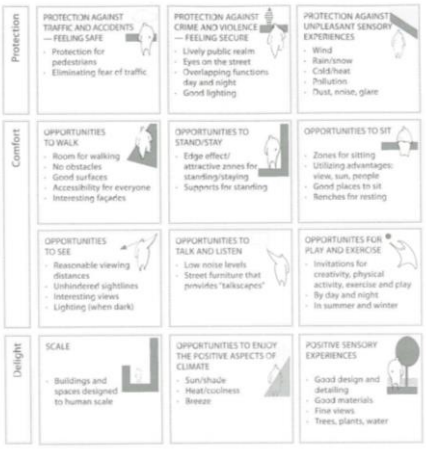
	CHILDREN	YOUNG ADULTS	ADULTS	ELDERLY
PERSONA	Mathias	Lise	Anne	Per
AGE	2-11	12-24	25-60	60+
LIGHT NEEDS	General lighting for playing and stimulation lighting to boost curiosity	Screen friendly light, reading light, stimulation lighting to boost curiosity	General lighting, stimulation lighting to boost curiosity, reading light	Modelling light for communication, bright light for reading
LIGHT STANDARDS	Playroom min 300 lux (EN, 2009)	Computer practice rooms min 300 lux (EN, 2009) School canteens min. 200 lux (EN, 2009)	Bookshelfs min 200 lux (EN, 2009) Reading area min. 500 lux (EN, 2009)	Task light min 1000 lux (Figueiro, 2002)

Figure 6 – Showing the different persona groups light needs and light standards.

The case analyses provided us with information on how the visitors interact with the space and what are their needs while being there. As discussed earlier in section: Function areas, libraries have a variety of function areas which require different lighting design for providing the best experience. Although architecture plays a marginal role in creating the right atmosphere, having good function areas and thereby needs-meeting lighting is becoming more important. As Lesneski (2017) has stated, the 21st Century library must be adaptable with the ever-expanding functions of the space and most importantly, support human well-being with both its psychological and physiological aspects. Through our persona maps, surveys and observations in the different libraries, an idea of what are the needs of the visitors was developed. By using the persona road maps, we got insight to the different visitor profiles, their preferences and behavioral patterns. It is important to consider the biases present during the analyses, which definitely influence the findings. The biases include time of the year, week and day, length of the observation period, selection of the visitors when conducting the survey and number of visitors asked. Through our analyzing the findings we found out that the visitors wanted places where they could relax, sitting down and in a comfortable chair is a big part of the experience for the visitor (appendix 3.3.1). This could mean that the visitors who stayed for more than 10 minutes, would have actually stayed for an hour or even more. This was also visible when we asked the visitors what their favorite place was, and the most popular answers were the lounge area or by the window. This was also supported in a research study which examined how undergraduates prioritize library services and spaces, where they find out that students like to sit close to the windows because they like to see what going on outside and it makes them more productive (Kelly & Young, 2017). This means that the visitors enjoy seeing the outside, surroundings and feeling the sense of community, even though they might be wanting to read or work on their own. The key to a successful Future Library is encouraging interaction between people for better learning and idea exchange, which should be the main purpose of libraries. "Ideas are more likely to flow in spaces that simulate conversation both between users and between staff and users." (Deyrup, 2017, p. xi)

7 ZONES

After completing the four case analyses, a clearer understanding of the space divisions started to emerge. When investigating the library function areas and best ways to develop them further into activity zones, Jan Gehl's city planning ideas were examined. Although Gehl's, the Danish architect and urban designer's criteria is developed for creating urban cityscapes, they fit well when working with the idea of a spacious library on a human scale, especially with its further expanding functions and spatial capacity. What comes to creating and separating human contact with architecture and creating high functioning people friendly spaces, inspiration can be taken from the 12 quality criteria set by Gehl. The key to a successful design in the people orientation and ensuring *"that the spaces offer good comfort and invite people to the most important activities underlying their use of public space - walking, standing, sitting, seeing, talking, hearing and self-expression"* (Gehl, 2010, p. 238). The criteria have to be focused indoor and with the nine library functions in mind, as previously concluded from the case analyses. The visitor needs to have the feelings of protection, comfort and delight - feeling safe; having good accessibility; unhindered viewing area; sitting, talking and play areas; and positive sensory experiences. Guaranteeing these factors, adding conscious lighting design can really elevate the zones and enhance the activity that is taking place. Although these criteria are set for pedestrian landscape, they should be kept in mind when designing activity zones for a large cultural house and a public space, which the Future Library will be.



Jan Gehl's 12 quality criteria concerning the pedestrian landscape (Gehl, 2010, p. 239).

After being linked to Det Kgl. Bibliotek (Royal Danish Library) in Aarhus, an immediate spark of interest emerged as the interior, created by Arkitema architecture company, seemed

to have been made with a like-minded approach to the space divisions. They started with a similar workflow, investigating the needs of the students, the main users of the space: *"One of the things the student said to be important for them, was the clear division of reading spaces and other activities, so there could be silence for reading."* (Jyllands-Posten, 2017). This was also backed up by the Vice Director of the Aarhus Royal library, after their focus group workshops: *"We found out that the students wanted clear zones, there must be a relaxing zone, a zone where they could talk, one where they could eat, and a silence zone where they could only read and so on"* (Hofmeister, 2018, 5:24, appendix 1.4). The Aarhus Royal Library basement area is very thought-through design, taking into account the needs of the users and aims to provide a relaxing atmosphere for various functions.

When discussing lighting in the activity zones, it is clear that light plays a great role in the creation of the zones, especially the atmosphere. The overall experience of the activity zones can be supported by a conscious use of lighting design, enhancing the general well-being of the visitor and dividing the space into many different ones. Zones require different ambient and task light intensity, colour and direction as the functions in them differ. DTU library has applied an option to change the ambient light from cold to warmer in four zones of their Smart Library but it does not work too well as the created zones are too big and cover an area with too many users, so it loses the moment of personalization. When investigating inspirational cases, the Aarhus Royal Library basement and TCDC library come forward as something to take notes and precaution from.

We propose that the widely used approach of uniform library lighting should be questioned as *"visual qualities emerge in the interplay between light and darkness, where shadows draw the shape and show us the position of objects. Light and shadow show us something about a materials' character, and many shades in brightness give the eyes something to rest on."* (Dahl, 2009, p.138) This kind of approach is rather new in the library community, as most of the spaces are usually being lit up uniformly and with a cooler CCT value. The EU standards, however, should be considered as a helping tool not completely a rule. *"My obligation in doing lighting is not to obey the standards but to play on the edge and challenge them. As long as I live, I'll try to put the human head and the eye in the shadow, looking into the light, because it creates much more comfort"* (Hendrup, 2018, 30:19, appendix 1.3). This means that there should be so much more focus on designing also the shadow, lighting up the tasks and walls, and keeping the transitioning areas and faces out of direct light. Playing with different light intensities in a space feel more natural to us as human beings and when

designing library spaces, we should not be afraid to leave the walking areas even down to 20-50 lux with the task areas at a higher illuminance, from 200 lux up to 1000 lux. This led us to a forest landscape inspiration, where warm light beams are seemingly randomly scattered throughout the room, creating a natural, calm atmosphere where. As visible from the case analyses, this home like cozy feeling is what the visitors are most looking for and the libraries are currently lacking (appendix 3.3.1). Furthermore, this is supported by the visitors' needs, in the case study when asked what they favorite spot in the library the lounge area with sofas were the places people preferred (appendix 3.3.1). This is adding to the support of diving the space into zones, that can create a specific experience, like a homely feeling where you can relax and feel safe.

Lighting inspired by sunbeams in a forest. TCDC library (left, Picture 42), forest scenery (center, Picture 64), Aarhus Royal Library students' basement (right, Picture 65).

Aarhus Royal Library

Aarhus Royal Library is originally a university library - it is located on the Aarhus University campus and was established in 1967. On January 1st of 2017, the State and University Library in Aarhus, and The Royal Library in Copenhagen merged. The institutions came to be collectively known as the Royal Danish Library (Statsbiblioteket, N.d). The interior went through a lot of changes during their 2015-2018 library transformation strategy (Statsbiblioteket, N.d), especially the basement, which was adjusted to the needs of the student visitors.

Space transformations in Aarhus Royal Library's basement (left, Picture 66), atrium (center, Picture 67) and computer area (right, Picture 68).

Anna Kathrine Bisgaard, the architect and creative leader in Arkitema, was behind the overall architectural design process and especially stresses the importance of good lighting in the student basement space: *"We are in a basement, so why not start with the lights? We were ready to start with some cheaper floor, cheaper furniture - everything! But the light was important (...)"* (Bisgaard, 2018, appendix 1.2) Lighting design plays a great role in our experience in spaces. With the importance of furniture, light alone cannot fully give us a feeling of coziness, but it can definitely be used to enhance the feeling when using fixtures with 2500K instead of 5500K. The first colour temperature feels very intimate, inviting, calm and cozy while the second is very bright, vibrant and even invigorating. The lighting creates a natural, forest like landscape together with the architectural choices and furniture. Using ERCO light fixtures with the CCT of 3000K, Arkitema's team tried to simulate the feeling of daylight, especially as the space is a basement with no natural light input. They experimented with 4000K and 3000K and decided for the latter in the basement and 4000K in the upstairs areas, as it is a good transition CCT to spaces which have daylight input (Bisgaard, 2018). The light is seemingly scattered through the space, creating spots of different intensity as well as reflecting it off of the white surfaces of the pillars, walls and ceiling. Similar approach with the light spots and warm light to create a forest atmosphere can also be seen in the Thailand Creative and Design Center Library.

"We told ERCO we would like to create the same light down here as in the forest. When you go to the forest there are some columns as the trees, sometimes you meet a more of an open space where you have the light and you also have the shadows. We would like to work with the shadow. That you are not always in uniform light." Anna Kathrine Bisgaard (Bisgaard, 2018, appendix 1.2)

Lighting and forest inspiration in Aarhus Royal Library students' basement (Picture 69, 70 and 71).

Before starting the design process, Arkitema's team made a thorough analysis of the library, its users and their habits and needs. As 80% of the visitors of Aarhus Royal Library are students (Hofmeister, 2018), they carried out focus group interviews where it was found out that *"many of them [students] are here from 8 o'clock in the morning and spending almost the whole day here, so they use a lot of their time at the library"* (Hofmeister, 2018, 1:40,

appendix 1.4). According to these findings, the students' needs were noted down and further realized in the space, having a variety of functions in the basement area that would meet these needs. *"Dividing the spaces into zones is really important"* (Hofmeister, 2018, 05:45, appendix 1.4) As derived from our observations, the architecture team satisfied the students' needs brilliantly as the new space includes areas for studying alone, with a group, reading, preparing food, having a shower or a meeting and even a little exercise with a boxing bag or playing table tennis. All of these functions are seemingly in the same room, however, they are cleverly divided, creating a specific flow and atmosphere in the room. The architects used different methods for dividing the different function areas of the space. The space uses a variety of natural materials like wood, leather, felt and also concrete. The colour scheme includes cream, dark blue, dark green, white, soft pink and a touch of gold. The flooring is concrete with a natural shape of wood on top of it, elevated 2.5 cm from the ground to enhance the feeling of a landscape. Different functions are divided by glass, felt curtains and white illuminated columns. The room is a successful combination of natural shapes and creates a feeling of a forest landscape - with its naked tree-like coat hangers, cave-like sitting openings, natural materials and most importantly, the seemingly scattered light beams.



Function area division in Aarhus Royal Library students' basement (Picture 72, 73 and 74).

Technical University of Denmark (DTU) Smart Library

DTU's library is a forward-thinking library when it comes to involving sensor technologies into the space. *"The vision of DTU Smart Library is to create an "indoor living lab", where students and researchers can develop, test and present smart technologies."* (DTU, 2018). During 2017, approx. 620 lamps were replaced with LED fixtures, as they are very energy efficient and offer an opportunity to adjust both light intensity as well as the CCT, all via the user's smartphone or a switch on the wall (DTU, 2018). There is a big amount of daylight coming into the library spaces. The changing of the movement and intensity has been tried to balance out with the applied LEDs, being able to adjust the electric light warmer or colder.

Currently, the library visitors are able to adjust light only in four zones of the library, but this will be further developed in the near future. As a visit to the DTU library showed, they have attempted to create different zones for different purposes and support them with respective lighting (appendix 3.4.9). However, it is visible that there is room for improvement when it comes to the user experience, as the created light zones are too big for personalization. The changes in lighting, as minor as they will be, are affecting too many students at once. Although they have installed a variety of sensors, which can be used to detect the changes in the environment, daylight and visitor movement - when it comes to lighting, it has not been taken a maximum out of yet.

Daylight and electric light in DTU library (Picture 75, 76 and 77).

What comes to the function areas, there has been a good attempt to create and divide different functions from each other. For example, there are special studying booths on the first floor that they call 'the walls' as well as an area for relaxing in bean bags. On the 2nd and 3rd floor, it is a mixture of group area tables, individual work, computer work and small relaxation areas - all, besides group work tables, undivided. As mentioned above, the changeable ambient light does not work that great in this space as it affects too many students at once. However, we believe that the experience of the spaces could be successfully elevated through applying personalized task light.

Function area division in DTU library (Picture 78, 79 and 80).

TCDC (Thailand Creative & Design Center)

The Thailand Creative & Design Center was opened in two locations, in Bangkok in 2004 and in Chiang Mai in 2013, established as a resource and information center in creativity and design in Thai society. They describe themselves as a 'playground for creativity': *"TCDC is performing the role as an 'intellectual entertainment', inspiring and aspiring Thai society with creativity through international learning process from exhibitions, lectures, workshops to a resource center sparking creativities in various dimensions."* (TCDC, N.d.). The Bangkok establishment, which is also used as an example is this report, was closed in October 2016 and relocated to the Grand Postal Building on Charoenkrung Road in May 2017 (BK, 2016). The design reflects the center's ideas and approach, being very open and user friendly. While the library's content is similar to KADK, with the focus on design and architecture, the lighting design in the TCDC library is very similar to the Aarhus Royal Library with the use of bright light spots and dim ambient light. The circular function area division with curtains in picture 82, is also something we have seen before in Gentofte Main Library (appendix 3.4.10).

Lighting in TCDC library (left, Picture 42) and Aarhus Royal Library (center, Picture 81). Function area division in TCDC library (right, Picture 82).

8 RESEARCH QUESTION

The vision statement to the project stands: *"Imagine if a library could enhance the feeling of personal space by creating a comfortable and inviting environment through light."* Following this vision, an analyze had to be made of the visitors' different use of the library spaces and depending on their age, gender and background, what are the different needs in these spaces. We had to look into the functions, dividing them into activity zones that would have a distinct atmosphere to them. Only this way, the best possible space can be created, which would be both comfortable and inviting to the library visitor. This personalized approach must most of all reflect in the lighting of the space, enhancing the experience of the space through the ambient as well as task light. The research question will function as a tool to investigate and later evaluate how the ambient and task light can create different zones. After looking thorough into the existing cases, gathering relevant knowledge on how can lighting support and divide different functions and analyzing the needs of the library visitors, a **research question** was generated:

How can library light create different activity zones by meeting the visitors' needs and thereby enhancing the experience and atmosphere through ambient and task light?

To answer this research question, we would need to get a better understanding of the activity zones, by generate some zones that can have more function areas in them. These zones would have a specific experience and lighting design to enhance that experience. To understand the experience, the method; mood boards and light boards would be created, these boards would make it easier to understand the overall feeling in the zones. When understanding the experience are in place, getting the experience out is the next step. This would mean that understanding how we can create the experience by looking into furniture setup but most important through lighting. This would be conducted by testing out how different coloured white light enhance the experience when being in the zone. This would be tested in a lab environment to make sure that no daylight will interfere with the test. After the lab test a field test will be conducted to make sure that the coloured white light selected in the lab test would adapt to the library environment and this will be tested on real visitors in the library.

9 GENERATED ACTIVITY ZONES

As mentioned in the section above the first step to answer the research question will be to understand and generate activity zones. Therefore, our definition of the visitors needs and use of the spaces as shown in Figure 5 where the key to create the different activity zones. Creating the activity zones allow us to merge some of the similar functions together and moving the functions that are very different away from each other. Creating four zones with different purpose, experience and functions, that can create a more personal space where the visitors can coexist with each other although they focus on different functions in the library space. To generate the different zones, tools was created to make sure the zones was generated from the same template.

9.1 TOOLS FOR GENERATED EXPERIENCE IN THE ACTIVITY ZONES

In order to formulate the different zones, the atmosphere and experience of the zones were all defined by their function, experience, light and settings (Figure 7). This allowed to get a better understanding of the general feeling the visitors would experience in the zone. The functions is to get a better understanding of what function could be found in the different zones, these are developed out from our observation conducted at the four case study libraries. To get a better understanding of what experience the different zones should radiate, three adjective words creating an overall feeling of the zones, there will be transformed into mood boards to show the experience through nature.

Figure 7

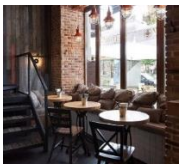
	WORK ZONE	**PLAY ZONE**	**CAVE ZONE**	**CHAT ZONE**
FUNCTION	Computers, Reading tables, Study area	Children area, Youth section	Lounge area, Reading tables	Café, Lounge area
EXPERIENCE	*focus, calm and inspiration*	*play, curiosity and innovation*	*comfort, safety and privacy*	*chat, comfort and privacy*
LIGHT	Bright, cool	Bright, cool	Relaxed, warm	Bright, warm
FURNITURE/ SETTINGS				

Figure 7 – Showing the different spatial elements to create a specific atmosphere in an activity zone (from left: Picture 83, 84, 85 and 86).

Additionally, as this research highlights the importance of the visitor, their needs and habits, a chart of the different persona groups was created. This was made for a better understanding of who would be using which zone (Figure 8).

Figure 8

	WORK ZONE	CAVE ZONE	PLAY ZONE	CHAT ZONE
FUNCTION IN THE ZONE	Study area/ group work, computers, reading tables	Lounge area, reading tables	Computers, Children area, Youth section	Lounge area, study area/group work, café
CHILDREN	Would **not** use it	Would **maybe use** it	Would **use** it	Would **not** use it
YOUNG ADULTS	Would **use** it	Would **use** it	Would **maybe use** it	Would **use** it
ADULTS	Would **use** it	Would **use** it	Would **maybe use** it	Would **use** it
ELDERLY	Would **not** use it	Would **use** it	Would **maybe use** it	Would **use** it

Figure 8 – Showing the persona groups' preferred functions in the library space.

After trying to understand the space and how the visitors might use the different zones, we started to look into which of the different zones the persona groups would use (Figure 8). This would give us a better understand of the different zones and what it could add to the experience of the zone. When creating the chart, we got aware that some of the persona groups might not want to use all of the spaces, especially the elderly and the children would be persona groups some might only use two or three zones depending if they were alone or with other people. Example would the children persona group not use the work zone or the chat zone because they would not use the functions in that zone, but they could be seen in the cave zone and would normally be seen in the play zone. The play zone has a lot of *would maybe use it* this is because we observed in our case studies that children would not be there alone, and they would have parents, grandparents, siblings etc. to be there observing them or interaction with them in the zone.

9.2 TOOLS FOR GENERATED LIGHT IN THE ACTIVITY ZONES

Generated the light in the zones needed similar tools as the experience. Light can be discussed and described by its three main variables; *intensity, colour and direction* (Dahl, 2009). Brandston also adds a fourth characteristic and writes that it can be *"characterized by four important properties: intensity, colour, distribution and movement."* (Brandston, 2008,

p. 31) However, as light movement affects mostly the accent light and daylight, it will not be taken further in this discussion. The three elements will impact both ambient and task light.

Illustrational symbol for 1. ambient light and 2. task light (Figure 3).

Picking the lighting intensity, would be different for ambient and task light do to the directional intensity of a light source varies from direct to diffuse (Dahl, 2009). Because of this reason we created three different intensity for ambient light as well as task light. These lux numbers are basis on the EU standards, findings and theory. Ambient light intensity; low intensity would be 20-60 lux, mid intensity would be 100-300 lux, and high intensity would be 500-800 lux. Task light intensity; low intensity would be 100-200 lux, mid intensity would be 300-500 lux, and high intensity would be 800-1500 lux.

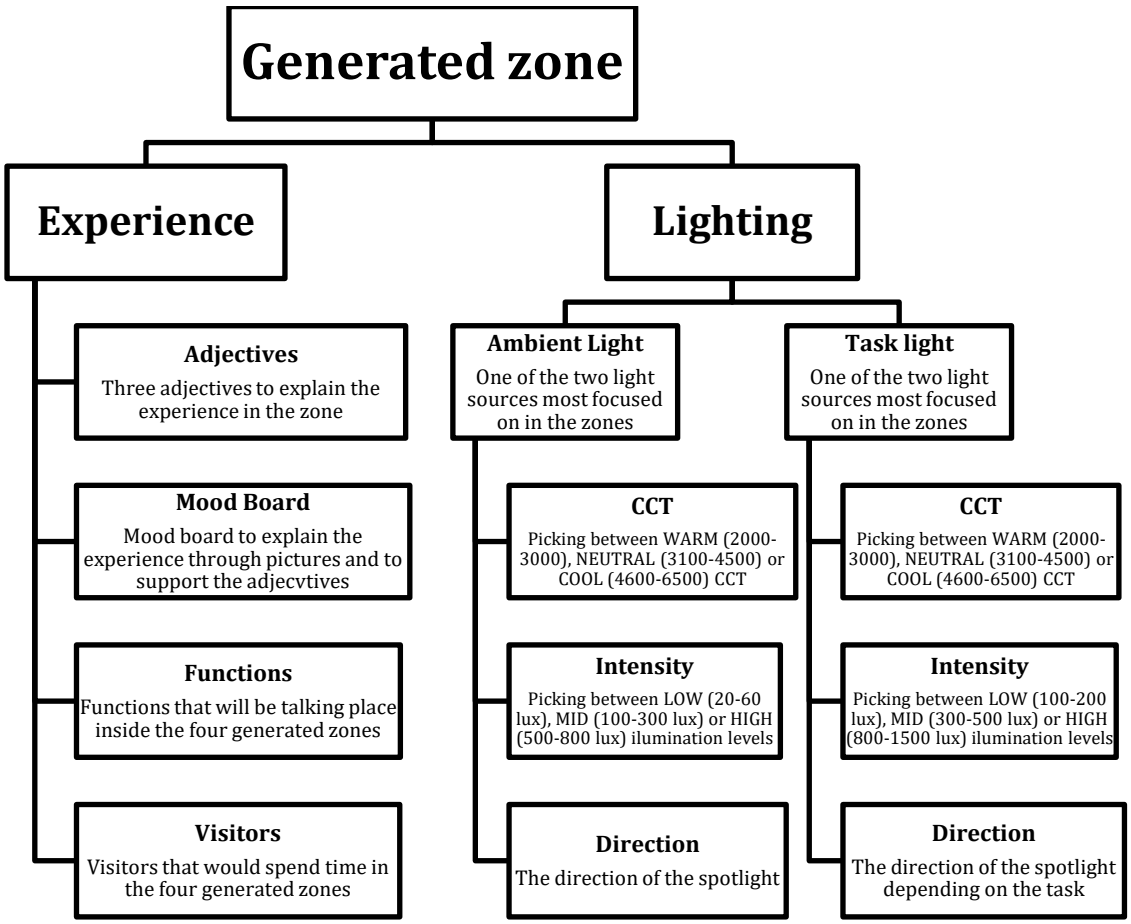
When picking the exact CCT for the white light sources, we decided to work with three variables: warm, neutral and cool. As seen on the chart below, the warm light falls under 3300K, neutral between 3300K and 5300K, and cool light above 5300K. During further discussion, the three colours will be described as ranges: warm as 2000K-3000K, neutral as 3100K-4500K, cool as 4600K-6500K.

Colour appearance	Correlated colour temperature T_{CP}
warm	below 3300 K
intermediate	3300 to 5300 K
cool	above 5300 K

Colour appearances as described in the European Standard (EN, 2009)

When discussing the direction of a light source, the creation of shadows has a great importance. *"Direct light gives a shadow with an exact delimitation, but the greater the light source in relation to that which it illuminates, the more gradual the transition between light and shadow. When the light is completely diffuse, no shadow will be seen."* (Dahl, 2009, p. 117) This means that while positioning the light sources for different functions, the severity of shadows must be considered, e.g. in an area where movement or human interaction takes place, it is important to have good modelling - no hard shadow contrasts on the face. However, in a stationary reading area, the contrast can be higher, taking that the light source comes from above. Furthermore, the different activities require a different direction and

intensity of the task light. As the results of a study on task lighting effects on office worker satisfaction and performance (Newsham et al., 2005) suggest, task lighting is associated with performance improvements on some tasks in an office setting, meaning that e.g. in the work zone, bright and focused task light is required.



Overview of tools for generating the activity zones.

9.3 THE FOUR GENERATED ACTIVITY ZONES

In this section, the four generated activity zones will be presented. The four different activity zone sections will look into the experiences including descriptive adjectives and mood boards of inspirational nature. *"The eye collaborates with the body and the others senses"* (Pallasmaa, 2007, p. 41). Meaning that the space will not be only experienced through seeing but *"every touching experience of architecture is multi-sensory; qualities of spaces, matter and scale are measured equally by the eye, ear, nose, skin, tongue, skeleton and muscle"* (Pallasmaa, 2007, p. 41). Creating the four activity zones is therefore a full body experience. But importantly, the four generated zones will also go through the lighting using the tools above. This means that both ambient and task light would be shown through the elements;

intensity, colour and direction. The lighting in the zones will only be focused on the ambient and task light as mentioned above, but accent light would still be present in the zones, although it is not described. The overall light experience will also be shown through a light board.

9.3.1 Work zone

The work zone should be a zone with focused functions as *Study area*, *computers and reading tables*. This would create a zone where group work and studying would most optimal in the library. The most common visitor of this zone would be the young adults or adults, while the children and elderly are mostly being seen in other zones in the library. The experience that should be created in the work zone would be similar to an office workspace with the adjective would be; *focus, calm and inspiration*. Focus in this context would mean that people use this zone to read books or work with a screen, where they need to focus on the task at hand. Calm means creating an environment where the visitors would have not stress, with the zone creating a calm space where work would be possible. William M. C. Lam, the pioneer of architectural lighting talks about how we need to inspire our brain to be able to work in longer periods of time, therefore the adjective inspiration (Lam, 1977). With these adjectives we created a mood board to show the experience through pictures.

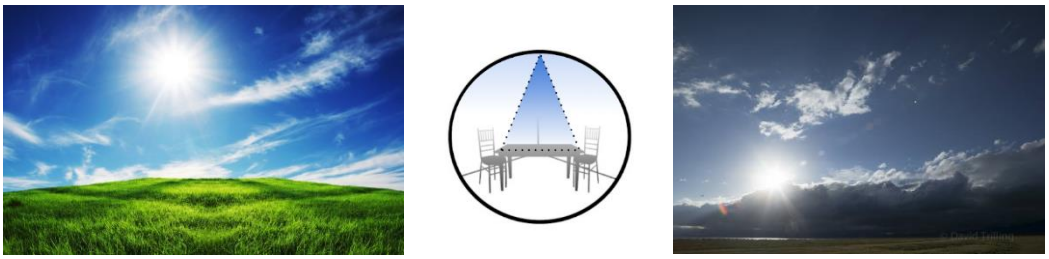
Mood board of the work zone (from left: Picture 87 and 88).

Light in the work zone will create a calm but inspired environment where great through process could blossom. Light should be dynamic, so it would inspire and calm the mind. Relaxation of the body and mind are important to keep during work, this could be done by providing visual focus, like artworks, accent light with different patterns of light, views etc. (Lam, 1977).

Good ambient light, inspired by daylight would create the surroundings for successful office environment. The ambient CCT would be around 3100K-4500K to create a natural feeling in the work zone. Furthermore, research testing 17000K fluorescent lighting in a busy work space confirms that high CCT light shows improvements in people's wellbeing, reducing tiredness and increasing work performance (Mills et al. 2007). The

ambient would have a high intensity around 500-800 lux focusing the spots on the walls and ceilings to create indirect lighting.

The task light would have a cooler light giving a contrast to the ambient surrounding the space. The task lights CCT would be around 4600-6500K with cooler light, invigorating the visitor and making them more focused on the task at hand. The intensity would be the same as the ambient high but around 800-1500 lux. The task light would be focusing on the table where the task will be conducted. The lighting in a work zone should be created according to the data in Figure 9.



Lightboard of the work zone (from left: Picture 89, 90 and 91).

Figure 9

Light source	**CCT**	**Intensity**	**Direction of spot**
Ambient light	3100-4500K	500-800 lux	Wall and Ceiling
Task light	4600-6500K	800-1500 lux	Table

9.3.2 Cave zone

The cave zone should be a zone where people can engage in relaxing activities like taking a moment to themselves, listening to music, reading, spending time online via an electronic device, etc. This would create a zone where visitors can relax and even be in their own little bubble without the noise or interruptions of the other visitors, this would be like the silence zone on the trains. As library anxiety is becoming more prominent among students due to the relatively big, and growing, library spaces and other factors (McPherson, 2015), having a calm cave zone with soothing atmosphere is essential. The zone would attract and can be used by everyone, but it would not be common to see children in this zone do to the fact that they should be silent. The experience that should be created in the cave zone would be somewhat similar to a living-room at home. Where the adjective would be; *comfort, safety and privacy*. Comfort is something every visitor wants, the feeling that you are safe inside the

space you are sitting. In the cave zone, the placement is important to create a feeling of comfort, because if the elements like chairs are placed open and with its back to the other zones, the feeling of safety would diminish. Privacy would be to create smaller space inside the zone where people would have a feeling of own space. With these adjectives we have create a mood board to show the experience through pictures.

Mood board of the cave zone (from left: Picture 92, 93 and 94).

In the cave zone, the light should create a comfort, safety and private feeling. By creating a light board, it would be possible to show how these could come to life, for example by using warm CCT inspired by a bonfire or in the cave light ray lighting up the space. This could be reflected into less light sources with a mixture of soft and sharper light in a warm tone, there would be able to create "dark spaces" within the cave zone. When designing shadow inside the cave zone, it is important to not make it dark with no light at all (Lam, 1977). Making a space too dark it can make us fear the space because of the information it is not giving us, like the possibility to orientate us and thereby feel safe (ibid). Where it can be fine to turn off the lights in our own living room, because we know it and the information's it is giving us, another space would maybe give us unpleasant feeling. But darkness is not always feared:

> *"When no danger is expected, such as during an evening walk on a pleasant country lane, identical luminance levels might be perceived as intimate or romantic, rather than dark and threatening"* (Lam, 1997, p. 56).

The ambient light is inspired by the soft surroundings around a bonfire. The ambient CCT would be around 2000K-3000K to create a warm and cozy feeling in the cave zone with a low intensity around 20-60 lux focusing the spots on the walls and ceilings to create indirect lighting creating a soft ambient.

Task light would have a cooler light giving a contrast to the ambient surrounding the space. The task lights CCT would be around 3100-4500K to create a natural feeling, creating the opinion for the visitor to read books. The intensity would be brighter than the ambient around

300-500 lux be focusing the narrow task light spot on the lap making it feel like being inside a cave. The lighting in a cave zone should be created according to the data in Figure 10.

Lightboard of the cave zone (from left: Picture 95, 96 and 97).

Figure 10

Light source	**CCT**	**Intensity**	**Direction of spot**
Ambient light	2000-3000K	20-60 lux	Wall and Ceiling
Task light	3100-4500K	300-500 lux	Lap

9.3.3 Play zone

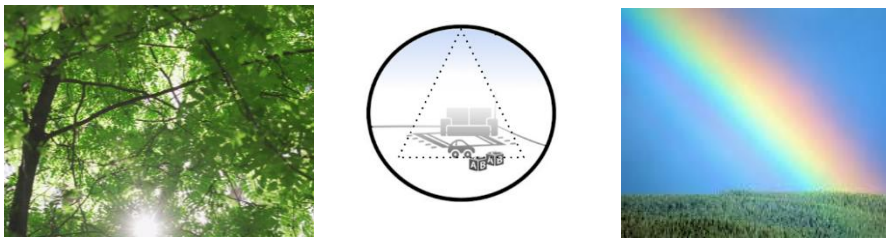
The play zone should be a zone where visitors can do playful functions as computers, children area and youth section. This would create a zone where visitors can play around and let go of their imagination. The visitors in this zone would mostly be children, where the others persona groups would be seen there mostly with a child. The zone should also try to break down the already existing understanding that adults are too big to play, by letting the space not only invite children but also curious souls in all age groups. The experience that should be created in the play zone would be somewhat similar to a museum or a playground. The adjective would be: *play, curiosity and innovative.* The play is adding to the feeling of freedom and imagination, giving also possibilities to integrate interactive designs. Curiosity goes hand in hand with play, *"curiosity in play is never isolated or totally independent, it is always interconnected with enjoyment, challenge, and other principles"* (Tieben et al., 2011, p. 369). Leading to the adjective of innovation, the zones should spark the curiosity in children as well as adults this could be done through innovative projects. With these adjectives we have create a mood board to show the experience through pictures.

Mood board of the play zone (from left: Picture 98, 99 and 100).

In the play zone the light should both support and create a playful environment. It should be light with movement to evoke the curiosity in both adults and children, this could be from the natural daylight playing and creating shadows on the surfaces in the library. Reflection could also peak interest and curiosity, these could appear through materials interplay or be recreated through computer science. The inspiration for the play zone light is in the light board below.

The ambient light CCT would be around 3100K-4500K to create natural feeling in the play zone. The ambient would be with a high illumination intensity around 500-800 lux focusing the spots on the walls and ceilings to create indirect lighting.

The task light would have the same CCT in order to not create a colour contrast but when using spots, this would create a contrast between the shadow and the light. The CCT of the task lights would therefore be around 3100K-4500K to make the furniture, books and colours in the space more clear and true to reality. The intensity would be the same as the ambient being high intensity so around 800-1500 lux but focusing these task light spots on the table or floor where the task will be conducted. The lighting in a play zone should be created according to the data in Figure 11.



Lightboard of the play zone (from left: Picture 101, 102 and 103).

Figure 11

Light source	**CCT**	**Intensity**	**Direction of spot**
Ambient light	3100-4500K	500-800 lux	Walls or Ceilings
Task light	3100-4500K	800-1500 lux	Floor or table

9.3.4 Chat zone

The chat zone should be a zone where people can engage in functions as *lounge area, alone or group study area* and *café*. This would create a zone where visitors can talk freely and relax with friends, study groups or family. The visitors in this zone would be young adults, adults and elderly, where children mostly would be found in the play and cave zone. The experience that should be created in the chat zone would be somewhat similar to a café or living room area. Where the adjective would be; *chat, comfort and privacy.* Chat and privacy are combine in the chat zone, in this space visitors should be able to talk and have conversation without feeling that their conversation is being shared with everyone in the zone and outside it. Therefore, is important to create a zone where privacy and comfort are in focus. Comfort would be found in the light as well in the furniture's, where they need to invite to talk as well create a comforting space where the visitors can relax. With these adjectives we have create a mood board to show the experience through pictures.

Mood board of the chat zone (from left: Picture 104, 105 and 106).

The chat zone has the focus to create a space where visitors can talk in a comfortable environment. The light would be able to create a space where it invites people to sit down and chat.

The ambient light, inspired by the soft, diffused daylight to create a comfortable space. The ambient CCT would be around 3100K-4500K to create a natural feeling in the chat zone with a high intensity around 500-800 lux focusing the spots on the walls and ceilings to create indirect lighting creating a soft ambient.

Task light would have a warmer light giving a contrast to the ambient surrounding the space. The task lights CCT would be around 2000K-3000K to create a cozy feeling, but also making the visitors faces warm and inviting. The intensity would be lower than the ambient around 300-500 lux to create a soft environment and invite to privacy. The lighting in a work zone should be created according to the data in Figure 12.

Lightboard of the chat zone (from left: Picture 107, 108 and 109).

Figure 12

Light source	CCT	Intensity	Direction of spot
Ambient light	3100-4500K	500-800 lux	Walls and ceiling
Task light	2000-3000K	300-500 lux	Torso and faces

9.3.5 Transition zone

By using activity zones, a transition zone will occur, this will be the space in between the zones. The transition zone is the zone the visitors will use to move between the zones, this space is as important as the zones. If the transition zone is too bright or to dim, it can disturb the feeling inside the zones and change the experience. For example, if the transition zone between or close to the cave zone would be too bright it could light up the surroundings and create a higher lux ambient in the zone, taking away the cave feeling and distorting the atmospheric experience. On the other hand, test participants have shown to prefer maintaining the illuminance levels of the transitioning zone by not dimming the ambient light too low to avoid extreme contrasts. (Newsham et al., 2005).

Mood board illustration the transition zone (Picture 110).

The experience in the transition zone would be similar to walking in the forest, with the light rays hitting the leaves in the treetops create a contrast between the light and shadow. The transition zone would not be a dark spot but a area were you would be able to see the surroundings and the distances. Designing the shadow areas should be encouraged, as it creates more visual dynamics in the space and

the eye is a very flexible sensory organ, easily *"adjusting to the great variations of light intensity on Earth. We are able to move about on bright beaches in sunshine and in dark forests at dusk and still see where we walk"* (Dahl, 2009, p. 120). However, with great changes in brightness, the retina of the eye needs some time to adjust its sensitivity (Dahl, 2009).

The transition zones lighting would be somewhat different from the zones. The ambient light would be the only present light due to the transition zone being in between the zones, it will create privacy. The transition zone will not be overly lit, it will have a low ambient like the Royal library in Aarhus showed that the lux levels does not need to be higher than 50 lux to be able to see what is in front of you (Section: ZONES). Other light sources that would be interacting with the transition zone would be shelf lighting and daylight (Pictures 111-113).

Pictures showing examples of shelf lighting adding ambient light to the transition zone. DOKK1 in Aarhus, Denmark (left, Picture 111). KADK library in Copenhagen, Denmark (center, Picture 112). Gentofte library, Denmark (right, picture 113).

10 THE TESTS

To answer the research question, we wanted to create different tests to come closer to creating and enhancing the experience and atmosphere is the various zones. To do this we wanted to limit some of the variables of creating the specific light for the different zones. Because the zones are so different with their functions and focus groups as the outcome light presets in them. Therefore, in order to limit some of the variables we only looked into ambient light and task light, setting accent light aside. As accent light or the play of brilliants is more creative and can interpreted in so many different ways, it is a case on its own and would not be providing precise scientific results. However, we do believe that in some zones, if not all, accent light would be necessary in the lighting design process, in order to create a holistic design.

The test process was divided into two separate tests: the LAB test and the FIELD test. The aim of the LAB test was to find out the correlated colour temperature (CCT) preferences for both ambient and task light, within all four persona groups and within all zones. The LAB test results provided information that allowed it to further generate ambient and task light combination presets for the FIELD test. The aim of the FIELD test was to apply the four light presets to four physical zones with suitable furniture, allowing and nudging the user to try out all four light presets in their chosen zone. From the results, we could compare the visitors' preferences to our set hypotheses of which light preset fits which zone the best. At this stage, the specific correlated colour temperatures were chosen: 2700K for WARM, 3600K for NEUTRAL and 5600K for COOL (Ledspot, 2018). These colours are used for both the Lab and the Field test. The WARM setting compares to standards incandescent light (2700K), enhancing reds and making blues appear darker, adding a yellow tint to whites and greens. The NEUTRAL setting is a warm white that enhances most colours equally. The COOL setting is closer to daylight, enhancing blues and flattening reds, giving a blue tint to whites and greens.

Kelvin Color Temperature	2700K	3000K	3500K	4100K	5000K	6500K
Associated Effects and Moods	Ambiant Intimate Personal	Calm Warm	Friendly Inviting	Precise Clean Efficient	Daylight Vibrant	Daylight Alert
Appropriate Applications	Living/Family Rooms Commercial/ Hospitality	Living/Family Rooms Commercial/ Hospitality	Kitchen/Bath Light Commercial	Garage Commercial	Commercial Industrial Institutional	Commercial Industrial Institutional

Chart of CCT values (K) and their atmospheric influences (Ledspot, 2018).

10.1 TEST OF THE ACTIVITY ZONES IN RELATION TO CCT A.K.A. LAB TEST

The purpose of the LAB TEST was to find out people's preference of correlated colour temperature (CCT) for ambient and task light in all four activity zones. The test was carried out in a controlled lab environment in Aalborg University Copenhagen campus. Although the ideal light setting would also include accent light, it was decided not to be tested as it requires a more creative approach and could be subjective to the test volunteers. Furthermore, the LAB TEST would have ideally also included finding out the preferred brightness of the lights amongst the colour temperature. However, the range of the testing variables would have become too wide and the fixtures used for the LAB TEST did not provide the smoothest procedure. The test was carried out with a total of 10 potential library visitors from both genders and all four age groups: children, young adults, adults and elderly (Figure 13). One of the goals of the lab test was to get more or less even number of participants from every four age groups, although this was not met. Due to the test subject low number it created some limitation of the results.

Figure 13

Persona Group	CHILDREN	Y. ADULT	ADULT	ELDERLY
Total no. of test subjects	4	2	3	1
Gender	2 Boys 2 Girls	1 Man 1 Woman	2 Men 1 Woman	1 Man
Activity zones the persona group was tested in	cave, play	work, cave, play, chat	work, cave, play, chat	cave, play, chat

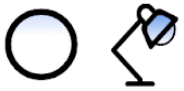
Figure 13 - Showing the different persona groups and which zone they tested out.

As discussed in section: GENERATED ACTIVITY ZONES, The Persona group would only test the zones that they would be visiting in a library setting. The reason for keeping the persona groups in specific zones in the test was to get results that could be relevant in a library setting. The test also became more precise and it cut down on the testing time, by doing this.

10.1.1.1 Lab Test Hypotheses

When creating the hypotheses, they were made out from how the zones was generated in section: GENERATED ACTIVITY ZONES.

In the work zone ambient NEUTRAL and task COOL colour are preferred



In the section: GENERATED ACTIVITY ZONES, the work zone would have ambient light in a NEUTRAL CCT (3600K). The task light would be COOL CCT (5600K).

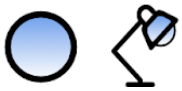
In the work zone neither ambient or task light will be preferred as WARM colour

In the section: GENERATED ACTIVITY ZONES, the work zone would not have neither ambient or task light as WARM CCT (2700K). This were based on theory that you work better in higher CCT levels than lower (Mills et al., 2007).

In the cave zone ambient WARM and task NEUTRAL colour are preferred

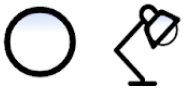
In the section: GENERATED ACTIVITY ZONES, the cave zone would have ambient light in a WARM CCT (2700K). Where the task light would be a NEUTRAL CCT (3600K).

In the cave zone neither ambient or task light will be preferred as COOL colour



In the section: GENERATED ACTIVITY ZONES, the cave zone would not have neither ambient or task light as COOL CCT (5600K).

In the play zone ambient NEUTRAL and task NEUTRAL colour are preferred

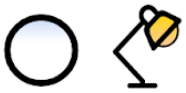


In the section: GENERATED ACTIVITY ZONES, the cave zone would have ambient light in a NEUTRAL CCT (3600K). The same would task light be so meaning it would be NEUTRAL CCT (3600K).

In the play zone neither ambient or task light will be preferred as WARM colour

In the section: GENERATED ACTIVITY ZONES, the cave zone would not have neither ambient or task light as COOL CCT (5600K).

In the chat zone ambient NEUTRAL and task WARM colour are preferred



In the section: GENERATED ACTIVITY ZONES, the chat zone would have ambient light in a NEUTRAL CCT (3600K). Where the task light would be WARM CCT (2700K).

In the chat zone focus will not be preferred as NEUTRAL or COOL

In the section: GENERATED ACTIVITY ZONES, the chat zone task light would not be preferred as either NEUTRAL CCT (3600K) or COOL CCT (5600K).

10.1.1.2 Methods

In this section the methods used to create the lab test will be explained (appendix 4). The reason for conducting a lab test were to have a controlled environment that could enlighten what the persona groups would preferred in the four different activity zones. The methods used for the LAB TEST included gathering quantitative data with a survey as well as qualitative approach by observing the test volunteers and noting down their extra comments. Although the survey was prepared beforehand and followed the same structure for every answerer, it was continuously filled out by one of the two test conductors. The structure of the survey allowed the volunteer to experience all of the colour temperatures and thereby ascertain their preferences (appendix 4.2). The observations were very valuable to note down as every individual is unique in their background and pointing out different elements.

It is important to be aware of the pros and cons of a controlled, laboratory environment. Because it is something taking out of it natural environment and brought into a controlled area, there will also miss the natural elements that interfere and effect the experiment (Koskinen et al, 2011). In our case that could be daylight, the library context and the real visitors. Where the cons are that it can be recreated again if needed, because the factors are controlled (ibid).

10.1.1.3 Procedure

When starting the test, the subject was told short about the project letting them know that they could not say anything wrong and we were interested in their views on the light. Depending on the persona group they were placed in, they started in either Chat zone, Cave zone or Play zone. When placed in a new zone, they were told about the feeling and experience we wanted our test subject to have in the zone (appendix 4.1 and section: THE FOUR GENERATED ACTIVITY ZONES). This way of conducting the lab test could create potential bias because the test subject could have different ways of understanding the experience the different zone should create (more in section: Lab Test Conclusion).



Pictures of the set-up (left, Picture 114), procedure (center, Picture 115) and task light CCT differences of work and play zones (right, Picture 116).

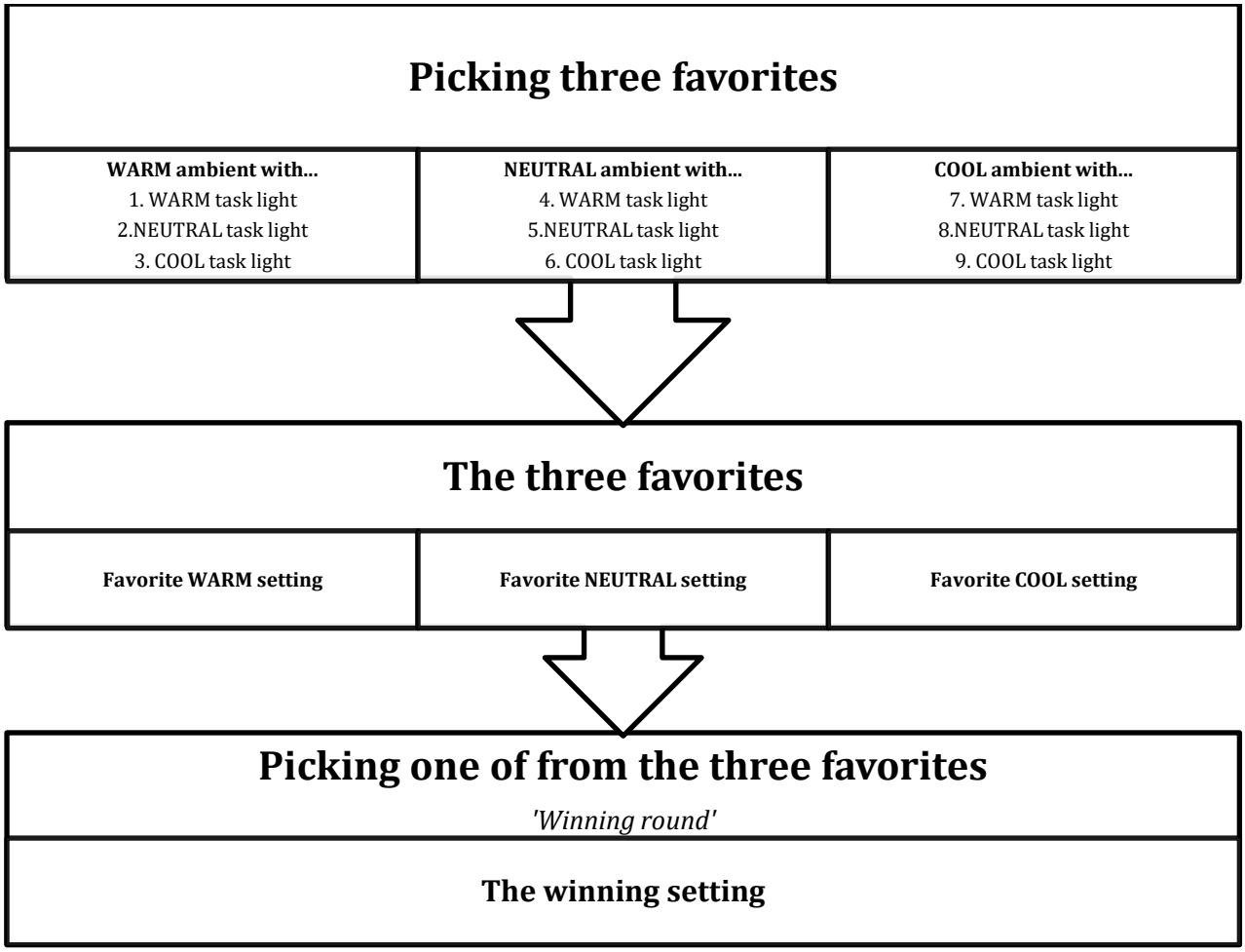
First round would be with the ambient set at WARM and changing between the three different task light, going from WARM to NEUTRAL and ending with COOL. Then the test subjects will be asked which of the three lights they think was best and fitting to the experience told, using the numbers one, two or three when shown the different light settings. If the test subject was in doubt, the three setting would be shown again. Their favorite pick in this round would be noted down in a survey (see illustration below).

Second round would be with the ambient set at NEUTRAL and changing between the three different task light, again going from WARM, NEUTRAL and ending with COOL. The test subjects would again be asked about their favorite and their favorite would be noted down in the survey kept (appendix 4.4).

Third round would be with the ambient set at COOL and changing between the three different task light, again going from WARM, NEUTRAL and ending with COOL. The test subject would be ask about their favorite and this would be noted down as well.

After going through all of the different settings, their favorite of each round would become the three favorites. These three favorites would be shown again in the 'winning round' where they were ask to pick their favorite light for the zone they was in (see illustration below).

This would be carried out in all of the zones the test subject should go through depending on their persona group. Example would an adult go through all of the zones and an elderly only go through three zones.



10.1.1.4 Settings

The LAB TEST was carried out over two weekend days in the Light Lab of Aalborg University Copenhagen. The Light Lab is a room of 4m x 4m x 3m with no windows, which provided a very controlled environment to conduct a lab test (appendix 4.5). The light settings were divided into four activity zones with furniture characteristic to the function in the zone (see picture below, Picture 117-119) and consisted of two changeable lights: ambient and task light.

Pictures showing the ambient ceiling light (left, Picture 117) and the Stairville lamps (center, Picture 118); the DMX controller with the different settings (left, Picture 119).

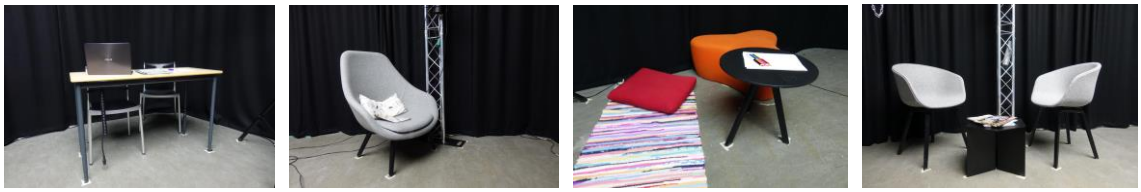
For the ambient light a newly installed ceiling fixture was used, the ambient light was one big square diffused screen with many small OSRAM DRAGON chain tunable white LED lights underneath (see pictures above). The ambient light includes 6 CCT presets, changeable with a button controller on the wall. In full brightness, the ambient fixture provides 400 lx for 2600K, 750 lx for 3600K and 510 lx for 5600K, all from the height of 75 centimeters. However, the light was dimmed every time accordingly to the zone's function and in relation to the task light, creating the appropriate contrast. The ambient light was measured when changed to make sure it hit around the same lux every time.

For the task light, three Stairville LED Par 36 COB RGBW 12W and one Stairville LED Par 56 COB RGBW 30W spotlights were used (see pictures below). All of the Stairville fixtures were positioned custom to the zones to create the right experience in the activity zone. The spotlights were controlled by a Stairville DDC-12 DMX controller, to create a smooth and as precise transition we use tape on the controller to remember the settings (see picture above, picture 119).

Pictures illustrating only the task light illumination in the work, cave, play and chat zone (from left: Picture 120, 121, 122 and 123).

Because the activity zones were different the test zones could not have been furnished identically, as the physical environment forms our experience the most with light being the secondary, yet also important element. The furniture was picked to simulate the possible interior in the activity zones. The work zone included a 60 cm high desk with usual work supplies on the top: a laptop, couple magazines, white A4 paper and a pen. The cave zone

included a comfortable grey high back armchair with a pillow and couple magazines on the side. The play zone included bright coloured seats, colourful rug and a table with white A4 paper and drawing pencils. Lastly, the chat zone included two grey low back armchairs, low coffee table with some magazines. The pictures below show the setup of the environment, to create a feeling of the four-activity zone. It also shows the pictures with the hypotheses light settings beside the setup.



Work zone, cave zone, play zone an chat zone furniture setup in the Lab test (from left: Picture 124, 125, 126 and 127).

Work zone, cave zone, play zone and chat zone light settings according to the hypotheses (from left: Picture 128, 129, 130 and 131).

10.1.1.5 Lab Test Conclusion

This section will go over the different bias that occurred in the lab test, these could be due to technical problems or to do with working with people and children. In this section there will also be notes, these notes were noted down as observation throughout the lab test.

Human bias and notes

We had problems getting elderly to take our test, this bias could make the findings more related to young adults and adults. When changing between the different light would it had been more ideally if we would had let people sit for longer periods of time in the different light setting than 20 sec. This would had let the test subjects' eyes get more use to the different coloured light if left in longer period of time and could had affected the results.

In the last 'winning' round, specific in the cave zone, people did not sit in the WARM setting long enough, when changing between the three favorites picks. A big among of the test subject didn't pick the WARM setting as their winner, we believe that the reason for this could be that NEUTRAL and COOL settings contrast to the WARM setting. Making the

WARM setting stand out alone and because of not letting the test subjects staying in the three favorite picks longer, made the WARM feel more orange/yellow and made it feel odd. Another reason could also be due to the low CRI levels of the WARM setting task light had, even being in the 70 range (appendix 4.1).

Doing this test we wasn't fully prepare for the smaller children around the ages 2-5 years and we didn't know how to get answers from them that we could use. When letting them play between the three CCT settings of ambient light and asking them what colour the light was, they seemed to have a preference for brighter light, e.g NEUTRAL or COOL settings (see picture 133).

This was also visible in one of the children breaks, where a 'play of brilliants' occurred in the hallway and the child show a deep interest in the brighter light on the floor by running only near the wall (see picture 132). When asked which of the intensity show on the floor she liked, she placed herself in the brightest spot of the three asked. The children also showed an interest in coloured light, like green, blue etc.

(from left: Picture 132 and 133).

Technical bias and notes

When starting to plan the lab test we wanted to use the same light fixtures that we would use in our field test, but doe to delivery issues that was not possible. Therefore, we ended up working with the Stairville fixtures and the intensity as well as the CRI on these luminaires were much lower than we expected. Which meant that we needed to bring everything down in lux and just focusing on creating a contrast between the ambient and task light, where the ambient was lower than the task light. This would get us closer to our wanted setting.

The ambient ceiling light was a 2,40 cm x 2,40 cm uniform square in the ceiling, the uniform light that it created wasn't a part of our main concept. Ideally, the ambient light would be reflecting off the ceiling or walls (appendix 6.1) with a more natural, randomized feel creating more spots of lower lux in the space. Working with the Stairville fixtures also create

a bias in form of not having narrow spots and it would ideally had been more narrow, brighter and with a soft spot edge.

The placement of the task light in the chat zone was not ideally placed. The light didn't hit the face and got overpowered by the ambient light, but if the fixture would had been angled onto the face or at a closer angle, it would had created a bad modelling and casted shadows on the face (see pictures below, picture 134-135). Although people prefer having their face in the shadow and task in front of them lit up (Hendrup, 2018), the chat zone is special as it focuses on human interaction, requiring higher ambient illumination levels and CRI over 90.

Pictures showing the spot light direction in chat zone. With only task light on (left, Picture 134). With both task light and ambient light on (right, Picture 135).

10.1.2 Answering the Hypotheses

When answering these hypotheses, we took the findings from the test subjects in both the 'winning round' as well as looking into the picking of the three favorites leading to the winner or winners of the 'winning round'. Both the ambient and focus light had three CCT settings: WARM, NEUTRAL and COOL, corresponding to 2600K, 3600K and 5600K.

In the work zone ambient NEUTRAL and task COOL colours are preferred

TRUE - NEUTRAL ambient and COOL focus are preferred but also NEUTRAL ambient and NEUTRAL focus are preferred, theses got the same score in the 'winning round'. This means that the ambient preferred in a work zone would be around 3600K and the task light would either be 3600K or 5600K or in between.

In the work zone neither ambient or task light will be preferred as WARM colour

TRUE - In the 'winning round' the battle was between NEUTRAL or COOL as focus light, and NEUTRAL as ambient light. This means that the ambient or task light would not be preferred in a work zone.

In the cave zone ambient WARM and task NEUTRAL colour are preferred

FALSE - COOL ambient and NEUTRAL focus or COOL ambient and COOL focus was preferred in the 'winning round'. This means that the ambient preferred in a cave zone would be around 5600K and the task light would either be 3600 or 5600 or in between. Making the light setting in the cave zone bluer than in the work zone.

In the cave zone neither ambient or task light will be preferred as COOL colour

FALSE - COOL in ambient and focus was picked in the 'winning round' as one of the two winners by most people but when picking the three favorites the one with the most common picks was NEUTRAL ambient and WARM focus with 60% of the votes in the test round.

In the play zone ambient NEUTRAL and focus NEUTRAL colour are preferred

TRUE - NEUTRAL ambient and NEUTRAL focus as well as COOL ambient and NEUTRAL focus are preferred and had the same number of votes in the 'winning round'. This means that the ambient preferred in a cave zone would be 3600 or 5600K or in between and the task light would be around 3600K.

In the play zone neither ambient or focus will be preferred to be set on WARM

TRUE - But in the WARM ambient setting the test subjects were even divide between picking WARM ambient and WARM focus (40%) and WARM ambient and COOL focus (40%) as the favorite winner in WARM ambient setting.

In the chat zone ambient NEUTRAL and focus WARM colour are preferred

FALSE - In the 'winning round' COOL ambient and NEUTRAL focus was preferred by most test subjects. when picking their three favorites COOL ambient and NEUTRAL focus was the one everyone picked with 100% of the votes. This means that the ambient preferred in a chat zone would be around 5600K and the task light would be around 3600K.

In the chat zone task light will not be preferred as NEUTRAL or COOL

FALSE - Focus light is preferred as NEUTRAL in the 'winning round'. This could be to the contrast between COOL and WARM being too big, but by picking NEUTRAL that is a warmer colour than DAY creating that contrast that still will make the face warmer than the surroundings.

10.1.3 Lab test findings

When the lab test was conducted we also got other findings that did not answer our hypotheses but were interesting for how to conduct the field test that would enlighten the research question as well as the vision.

The findings for the lab test made it clear to us that not every test can be created in a lab environment. Because the light tested would not had been able to stand alone without the furniture setting, and the same can be said about the light. This lead to the small conclusion that this type of test would had been better in the right environment, meaning that a field test could had made the outcome different. The hypotheses results were not valid because of the high amount of bias' in the test, this lead to the decision to go with our experience and keep the light settings like the hypothesis was, meaning that the light settings that would be tested in the field test would be the same settings (Figure 14). This decision is also backed up by the theory mentioned in section: THE FOUR GENERATED ACTIVITY ZONES. The results were not all unusable, we got a clear understanding of the impact the environment had on the test, as well on how important the right furniture setting was. The results also showed us that the different intensity levels could create a different experience for the test subject, this lead us to set up more precise intensity levels for the field test, where we in the lab test were more focused on a contrast between the ambient and task, and not the intensity itself. This made the light really dim and the contrast not that visible.

Working with four different age groups as test subjects also gave us an insight into using children under 5 years as test subjects. This finding gave us knowledge for when conducting the field test that not every child would give us data that could be used, this made the children the hardest persona group to get data from.

So the overall conclusion is that we from the Lab test results were able to create the Field test setup. This were developed for setting the CCT of the ambient and task light as well as the intensity for both ambient and task light. Meaning that the ambient and task light CCT would be the same as the lab test hypotheses (Figure 14). The three intensity levels were created out from the European standards, forming high intensity levels, mid intensity levels and low intensity levels (EU, 2010). These levels were different for ambient and task light to be sure there was a contrast even if they both had high intensity levels, were the contrast would be more visible with different intensity levels. The high ambient intensity levels would be 500-800 lux, were the mid intensity levels would be 100-300 lux and the low intensity levels would be 20-60 lux (section: TOOLS FOR GENERATED LIGHT IN THE ACTIVITY ZONES). The

high task light intensity levels would be 800-1500 lux, were the mid would be 300-500 lux and the low intensity levels would be 100-200 lux (section: TOOLS FOR GENERATED LIGHT IN THE ACTIVITY ZONES).

Figure 14

ZONE	Work Zone	Cave Zone	Play Zone	Chat Zone
Direction	Table	Lap	Ground & table	Torso & face
LAB TEST HYPOTHESES				
Ambient	3600K	2600K	3600K	3600K
Task	5600K	3600K	3600K	2600K
LAB TEST RESULTS				
Ambient	3600K	5600K	3600K	5600K
Light Contrast	Contrast low	Contrast low	Contrast low	Contrast low
Task	5600K	3600K	3600K	3600K
Light Contrast	Contrast high	Contrast high	Contrast high	Contrast high
FIELD TEST SETUP				
Ambient	3600K	2600K	3600K	3600K
Intensity	HIGH	LOW	HIGH	MID
Task	5600K	3600K	3600K	WARM
Intensity	HIGH	MID	HIGH	LOW

Figure 14 - Shows the different activity zone and what lab test hypotheses, the results as well on what results were taking forward to the field test. (2600K = WARM, 3600K = NEUTRAL, 5600K = COOL)

The four-zone light, that would be tested in the field test would be work light, cave light, play light and chat light. As mentioned in the section: GENERATED ACTIVITY ZONES, the light would be different for the four zones. Work light would be with a NEUTRAL CCT ambient and high level of intensity, where the task light would be more blueish and have a COOL CCT also with a high level of intensity this would be to support the experience. This lighting

should create an environment where work would be possible and optimate the work inside the zone.

The cave light would be warmer than the work light, having a WARM CCT ambient with low levels of intensity, where the task light would be with a NEUTRAL CCT with a high level of intensity making it easy to read. This would support the experience of coziness and create a relaxing environment but where it still would be able to read a book or two.

The play light would be the most uniform light setup, with a NEUTRAL CCT ambient with a high level of intensity. The same would the task light, with NEUTRAL CCT ambient with a high level of intensity. This lighting would support the experience in the zone and create a overall neutral environment were play or accent light could be the focus.

The Chat zone would have a NEUTRAL CCT ambient with high levels of intensity to lighten up the surroundings. Where the task light would be softer with a WARM CCT and mid-level of intensity. This lighting would create a comfy environment were a conversation could occur.

Figure 15

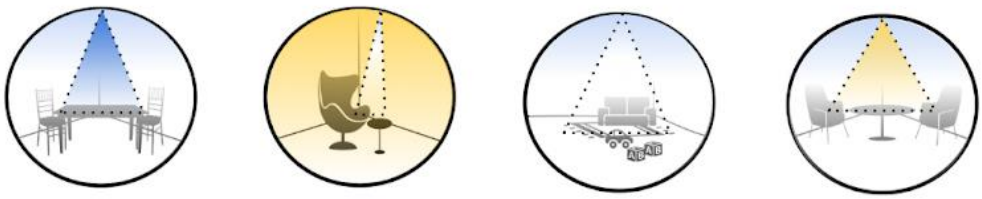


Illustration of the light CCT ambient and task light combination presets (Figure 15).

10.2 TEST OF THE ACTIVITY ZONES IN RELATION TO LIGHT PRESETS A.K.A. FIELD TEST

The purpose of testing the activity zones in relation to light presets were to investigate the visitors' light preferences in their chosen zones in a natural library environment. The test was carried out through setting hypotheses and testing in a natural library environment in order to confirm or disprove the hypotheses. This investigation would make it possible to answer the research question, through applying the four-light preset to the four activity zones in a field test. The zones would be with suitable furniture to create the experience in the space, and using the light preset to enhance or decrease the experience. By nudging the visitor to try out all the four light presets in their zone, it

would allow them to find the one that they feel enhance their experience as well as the one light settings that decrease the experience. This would also give us results about what light preset there fit the activity zone the best and what are the worst.

Figure 16

Persona Group	CHILDREN	Y. ADULT	ADULT	ELDERLY
Total no. of visits made by the persona group	12	34	52	14
Gender	5 boys, 7 girls	10 men, 24 women	22 men, 30 women	6 men, 8 women
Activity zones the persona group would visit	cave, play	work, cave, play, chat	work, cave, play, chat	cave, play, chat

Figure 16 - Showing the different amount of persona groups and which zone they tested out.

During the four-day test period, 112 individual answers were marked down in all of the four zones (Figure 16). The 112 answers mean that most of the subjects tested more than one activity zone. Altogether, there were 12 answers from children (only in the cave in play zone), 34 from young adults (all four zones), 52 from adults (all four zones) and 14 from the elderly (only in the cave, play and chat zone). The goal of getting a more or less even number of participants in all four zones was met, with 23 visits in work, 34 visits in cave, 24 visits in play and 31 visits in chat.

10.2.1.1 Field Test Hypotheses

When creating the field test hypotheses, we believe that the specific light created for the zones and tested out in the lab test was the right light settings for the four different zones. In the section: Lab test findings we argued why these four light settings were created and why we decided to keep the original presets even after analyzing the test results. There we also came up with the four zone presets, creating WORK light, CAVE light, PLAY light and CHAT light.

In the work zone the visitors will mostly use WORK light or CHAT light

The work zones functions are close to the chat zones functions, therefore believed that both type of light setting could be use in the work zone, because of the similarity in these two zones.

In the cave zone the visitors will mostly use CAVE light

Even though the lab results for the cave zone, resulted in our colder white light that the hypotheses, we hold on to our experience because that was based on theory and the zone experience.

In the play zone the visitors will mostly use PLAY light

The play zone will need a lot of light and have a high true colour render index (CRI), to make the colours in the play zone 'pop' therefore we believe that the PLAY light will be the most used in the play zone.

In the chat zone the visitors will mostly use WORK light or CHAT light.

As mentioned in the work zone hypotheses, the two zones functions are close, therefore believed that both type of light setting could be use in the chat zone, because of the similarity in functions, persona group etc. in these two zones.

10.2.1.2 Methods

The methods used for the FIELD TEST included gathering both quantitative data as well as qualitative (appendix 5). The qualitative data was conducted through an interview were the visitor were asked what light setting was preferred in the activity zone they were in as well as the one they disliked the most. Because the interview was kept really simple it allowed us to create quantitative data from parts of the interview, that included the most liked preset and most disliked preset in the zone (appendix 5.3 & 5.4).

Observations was also conducted to get more qualitative data about how the visitors interacted with the space and the presets when observed, these observations was noted down (appendix 5.3 and appendix 5.5). The observation was not only qualitative, some of the data were quantitative; the visitors gender and what persona group they were connected to.

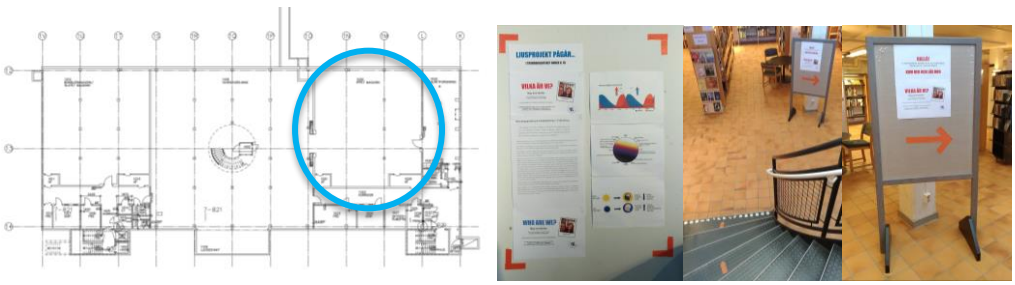
Measurement were also conducted to make sure that the presets were adding up to the experience in the space. The measurements that were conducted were lux measurements as well as basic measurements of the furniture heights. The lux measurements were conducted to be sure the right lux levels were created in the activity zones as well to get an overview on how the light affected the visitors (appendix 5.1). This was investigated through lux measurements taking from three places vertical around the face (see pictures below and appendix 5.1).

Pictures showing of the modelling measurements (from left: Picture 136, 137 and 138).

By conduction a field test, it is important to be aware of the pros and cons. Light perception is very subjective and cannot be fully measured. *"I have never seen a light meter that had eyes, nor one that can measure emotion. At least a thermometer can confirm why we are hot or cold, but a light meter can't tell us very much about seeing, or how we feel - the things we really need to know."* (Brandston, 2008, p. 25) That is why qualitative testing and conducting the field test is essential when it comes to creating specific atmospheres through lighting design. In the lab test we had the possibility to be in an environment that could be controlled, but by creating a field test that opinion is not possible (Koskinen et al, 2011). Variables like daylight and visitors are some of the factors that can influence the data in both good and bad. The cons would be that by having daylight and visitors that it creates the environment and how the library could feel on a normal day. Where the cons could be visitors not interaction with the space or not wanting to be a part of the test. The daylight could also become overpowering making the electrical light preset not visible and becoming redundant. These are some of the factors that we needed to be aware of when conducting our field test.

10.2.1.3 Settings

The testing area was set up on the basement floor of the library. This would allow us to control the light environment because the daylight intake was not that big in the basement. The back part of the basement (see picture 139) allowed us to turn off the existing lighting, making only the activity zones visible with light. This part of the library was normally used by foreigners because the space stored the books with other languages than Swedish. The space was also used two times a week for language café and was told that it was the least used space in the library.



The basement floor plan of the library showing the test area (left, Picture 139). Information signs and the guiding arrows (three to the right, Picture 140, 141 and 142).

To get visitors into the space, guiding arrows from the first floor to the test area was set up. With the arrows also posters with information of the test in both English and Swedish was places on walls and boards (Picture 140-142).

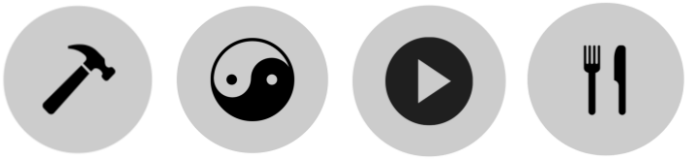
Pictures showing the furniture setups in the four activity zones, in Falkenberg. Work zone (left, Picture 143). Cave zone (middle left, Picture 144). Play zone (middle right, Picture 145). Chat zone (right, Picture 146).

In the four-activity zone different experience were created through the placement of furniture (Picture 143-146). The placement of the four activity zones was placed so they would not interaction to much but still being able to see each other. The four-activity zone had different light settings, but the same light fixtures was used. Fagerhult provided Marathon White Tunable fixtures, that allowed us to change the CCT (Picture 147). The Fixtures also allowed us to connect over Bluetooth with the Casambi application that made it possible for us to create four fixed light presets for the visitors to choose from in every activity zone.

In all of the zones, a total of 15 Fagerhult Marathon White Tunable fixtures were used. The four zones had different numbers of luminaires to create the right environment and experience. Work zone had the most fixtures with five, because the space needed to be well lit and there were many tables that needed task light. In the work zone, one fixture was use as ambient reflection of the ceiling and the rest were task lights on the four tables. In the cave zone only three fixtures were used, two were used as task light on the chairs and one was used as ambient on the ceiling creating indirect lighting. The play zone had also three fixtures, two were also as task lights on the floor and on a small table and the last one was used as ambient light on the wall to create some indirect light. In the chat zone four fixtures were used, two on the ceiling creating indirect ambient light and two on the tables as task light.

Fagerhult Marathon White Tuneable fixtures (left, Picture 147). Samsung S2 tablets used (middle, Picture 148). Casambi app, with the four light setups (right, Picture 149).

In all of the four zones a Samsung tablet was placed with the Casambi app open, the app allowed the visitor to change the light between four light setup, there were created for the four activity zones. They had four different icons, the hammer was the work light, the yin-yang sign was cave light, the play button was play light and the cutlery icon were the chat light.



Hammer icon: Work light (left). Yin-yang icon: Cave light (center-left). Play button icon: Play light (center-right). Cutlery icon: Chat light (right).

To get the right experience in the activity zone, the light beams angles were changed as well as intensity. In all of the zones barn doors or cap corn were used to narrow down the light beam and making the angle less wide, this was done to create the forest feeling that the transition zone experience needed.

In the work light, both ambient and task light were at 100%, meaning that the intensity levels had not been tampered with. In the cave light ambient were set at 50% of the normal intensity, this created a big contrast from the ambient to the task light that were at 100%. The play light was as the work light set at 100% of the normal intensity, meaning that it was not tampered with to create the right intensity in the activity zone. The chat light task light had only 90% of its normal intensity, the 10% less of the intensity created a softer light on the face, where the ambient light were at 100%.

The Figure 17 shows how the four different light settings; work light, cave light, play light and chat light looks in the different activity zones; work zone, cave zone, play zone and chat zone.

Figure 17

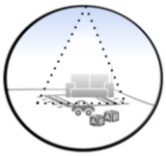
Activity zones (right) & light presets (below)	 WORK ZONE	 CAVE ZONE	 PLAY ZONE	 CHAT ZONE
WORK preset Ambient 100% Task 100% 				
CAVE preset Ambient 50% Task 100% 				
PLAY preset Ambient 100% Task 100% 				
CHAT preset Ambient 100% Task 90% 				

Figure 17 - Showing the four light setups in the different activity zones

10.2.1.4 Field Test Conclusion

This section will go over the different bias that occurred in the test. These biases could be due to working with variety of subjects or simple technical bias. Notes taking under the field test will also be shown, these will be able to show how the visitors interacted with the space, these notes were observations noted down under the field test (appendix 5.3).

Human bias and notes

The first day of testing we got aware of our idea of letting the visitors come to us was not realistic, we therefore needed to invite the visitors into the space (appendix 5.2). So, most of the visitors we tested with was invited into the space, but we had visitors there come by them self by following the arrows on the floor or had red about the test on Falkenberg library homepage (Picture 150-152). Even though we had a translator for two out of the four day the test conducted, we still had problems getting children and elderly to test the light settings in the zones. This was because of the language barrier and that made the numbers of the elderly (14 visitors) and children (12 visitors) lower than young adults (34 visitors) and adults (52 visitors). This also had the outcome that some of the findings are weak and cannot be used alone, this is specific when only looking into one persona groups answers.

Pictures showing how the visitors could be informed or nudged to go downstairs to the field test area (from left: Picture 150, 151 and 152).

When conducting the test, we informed the visitor that they could stay in the activity zone if they wanted to, because this created an option to observe the visitor and its behavior with the light. The visitors had different behavior patterns while being alone or in a group, if the visitor were alone and wanted to stay for a bit they mostly just pick the light setting they committed to like in the test. If they were in a group, they needed to discuss which light setting they could agree on in that specific zone.

Technical bias and notes

Technical bias was also something we had to deal with, but we found a solution when conducting the test. Because the space we used also stored books and we had to turn off the existing light in the space, so our zone light would stand alone, this lead to a standstill when visitors came by for looking for books meaning that we had to turn on the existing light making it not possible to conduct the test in the short time the visitors was finding a book.

Another technical bias was also that our field test area was rather dark this lead to many coming over to the door and looking in and then go away again, this would had worked better if the space letting up to the test area had not been that well-lit (Picture 153 and 154).

Under the test we even had a visitor looking in and turning on the existing light to go over to the spot he normally used. Here we had to inform him about the test and that he of course was allowed to come into the room, but the existing light needed to be turn off, this resulted in him leaving because he did not think there was enough light. This made us aware of how big a contrast the two rooms had and if you had not been inside the test area for some time would find it dark, this would change when the eyes had adapted to the light contrast.

Pictures showing the contrast between the lighting in the below ground floor room (left, Picture 153) and looking into the room where the test took part (right, Picture 154).

10.2.2 Answering the Hypotheses

Answering the hypotheses will be conducted with the findings from the field test, specific the overall result from the visitors in all four zones. Where the visitor was asked to pick the best and worst light setup for the zone they were in. Due to many of the visitors had problem only picking one they liked and one they disliked, the findings will be shown in two different colours.

Green = All the answers from the visitors, so were the visitor answered more than one light setting that they liked or disliked in the activity zone. Example: 'Elderly' visitor was in the cave zone, liked both cave light and work light but disliked chat light. Here the results were all noted down and proceed into the findings.

Blue = Only one answer each from the visitor were collected, so even through the visitors answered more light settings they liked or disliked in the activity zone. Only the first were noted down and proceed into findings. Example: 'Elderly' visitor was in the cave zone, liked both work light and play light but disliked chat light. In this case, only the work light would be noted down as the liked setting and the chat light as the disliked.

In the work zone the visitors will mostly use WORK light or CHAT light

FALSE - The most picked/liked lighting for the work zone was PLAY light with 36% and the most disliked light was CHAT light with 48%.

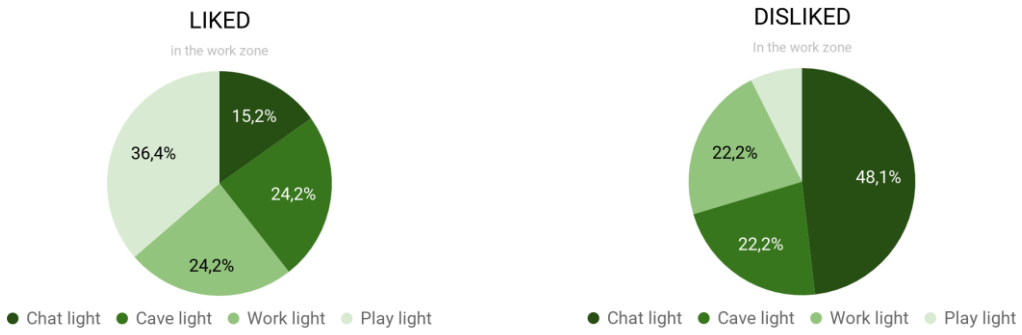


Chart of all answers given of liked in work zone in % (left). Chart of all answers given of disliked in work zone in % (right).

FALSE - The most picked/liked lighting for the work zone was CAVE light with 30% of the votes, but right behind was WORK light and PLAY light that both got 26% of the votes. Where the most disliked light setting in the work zone was CHAT light getting 48% of the votes.

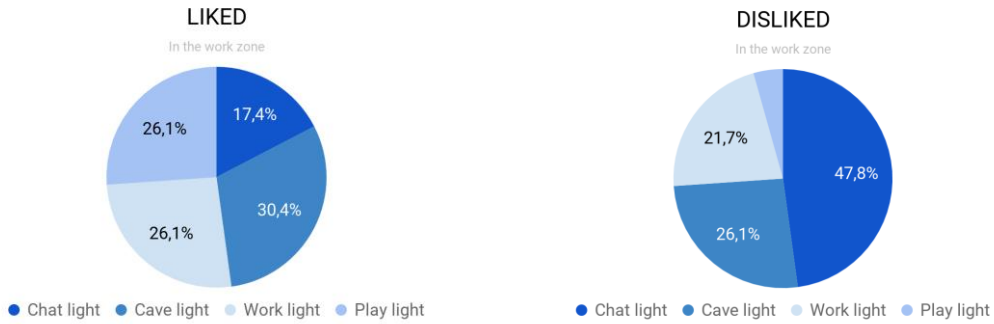


Chart of first answer given of liked in work zone in % (left). Chart of first answer given of disliked in work zone in %(right).

In the cave zone the visitors will mostly use CAVE light

TRUE - The most picked/liked lighting for the cave zone was CAVE light with 47% of all the votes. Where the WORK light and CHAT light got the highest percentage of dislike in the Cave zone with 45% to work light and 35% to the chat light.

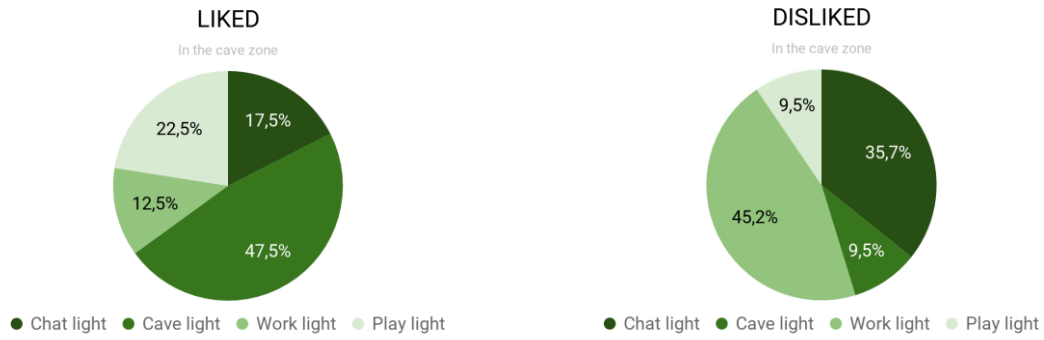


Chart of all answers given of liked in cave zone in % (left). Chart of all answers given of disliked in cave zone in % (right)

TRUE - The most picked/liked lighting for the cave zone was CAVE light with 47% of all the votes, were only 23% voted for PLAY light as the next most liked light setting. The most disliked light setting in the cave zone was WORK light with 44% of the votes but also CHAT light had a high number of dislikes will 41% of the votes.

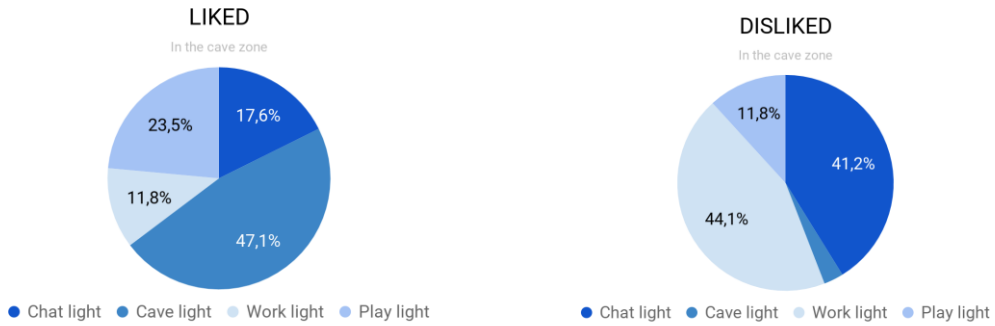


Chart of first answer given of liked in cave zone in % (left). Chart of first answer given of disliked in cave zone in % (right).

In the play zone the visitors will mostly use PLAY light

TRUE - The most picked/liked lighting for the play zone was PLAY light with 40% of all the votes, where the WORK light again had the most disliked with 45% of the votes.

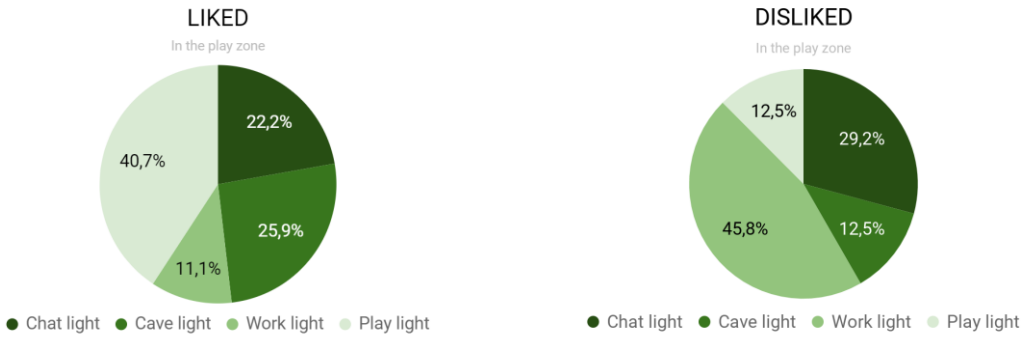


Chart of all answers given of liked in play zone in % (left). Chart of all answers given of disliked in play zone in % (right)

TRUE - The most picked/liked light setting for the play zone was PLAY light with 45% of all the votes, where the second best most picked was CHAT light with 25%. The most disliked light setting in the play zone were WORK light with 47% of the votes.

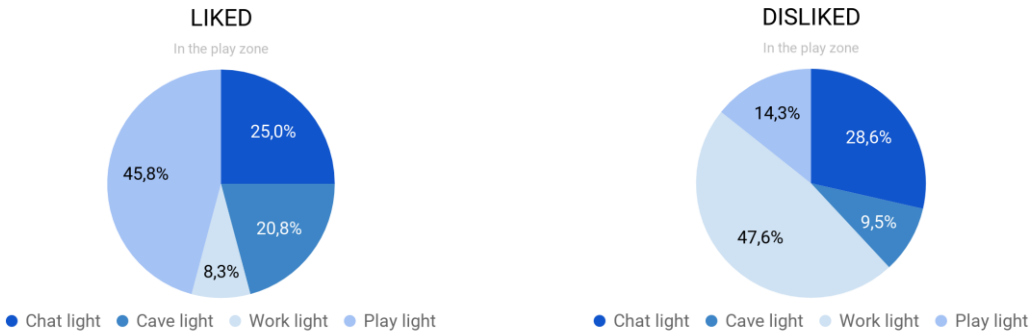


Chart of first answer given of liked in play zone in % (left). Chart of first answer given of disliked in play zone in % (right).

In the chat zone the visitors will mostly use WORK light or CHAT light.

TRUE - The most picked/liked lighting for the chat zone was CHAT light, but with only 33% compared with the other zones. The reason for the low percentage for the CHAT light were that the second most liked light setting was PLAY light with 27% of the votes. The most disliked light was WORK light with 48% of the votes.

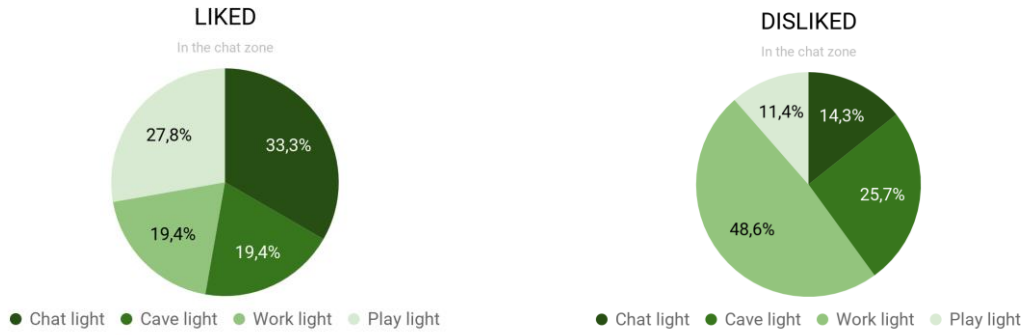


Chart of all answers given of liked in chat zone in % (left). Chart of all answers given of disliked in chat zone in % (right)

TRUE - The most picked/liked light setting for the chat zone was CHAT light with only 35% of all the votes, where the second best most picked was PLAY light with 25%. The most disliked light setting in the chat zone was WORK light with 42% of the votes.

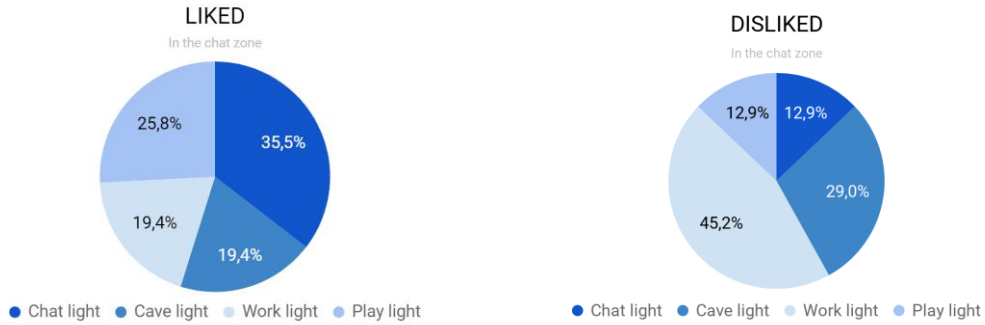


Chart of first answer given of liked in chat zone in % (left). Chart of first answer given of disliked in chat zone in % (right).

10.2.3 Field test findings

When the field test was conducted we also got other findings that didn't answer our hypotheses but were interesting in relation to the research question and the vision. These findings were interesting in relation to the research question and the vision because they add information to how the visitors interact with the space and light and what they prefer based on their gender, person group, if they are alone or in a group etc.

When not looking into the different zones, gender or even persona groups but looking into the overall results of the most liked light setting and the most with most disliked. The most liked

light setting would be the PLAY light, were the most disliked light setting is WORK light (appendix 5.4). The visitors had thereby an overall like towards the play light, there also was the overall least disliked one of the four light settings.

When looking into the persona group and digging down in their answers, the children had a personal favorite. The light setting, they liked the most were the chat light and the one they disliked most was work light, these findings was interesting founds because after the lab test we had this understand and believe that children were attracted to brighter more blue-white light (section: Lab Test Conclusion). When looking deeper into the children's dislike of light setting in general, the girls had a clear dislike (work light) were the boys did not (appendix 5.4). This could be supported by the study that shows a decrease in the negative moods of women in warm CCT light and increase in COOL CCT lighting (McCloughan et al., 1998).

When looking deeper into the young adults group a broader liking appears, were cave light has the highest likes, but right behind that were chat light and play light (appendix 5.4). The most disliked of the light settings, were work light, but not far behind were chat light and even cave light. Here the play light has some kind of pull because even though the play light did not get many likes it did not get many dislikes either, meaning that the play light is the most liked light for the young adults when canceling out the dislikes (appendix 5.4). When also going deeper into the men vs. women in the young adult group there was not this clear like or dislike for the men, were the women showed a clear disliked through specific work light and chat light with a high number of votes compared to cave light or play light (appendix 5.4).

The adults were in general leaning towards cave light as being their most liked one, were work light was the one of the four light settings with least pick as their favorite. This is supported in the general disliking from the adults, were work light had the highest picks for most disliked one (appendix 5.4). When looking more into how the different genders had their likes and dislikes, the findings were interesting. Where both children and young adults' men did not have a completely clear favorite, the adults' men did. The adult men were leaning most towards cave light with the highest picks for liked light setting, here the women had a more overall liking of three of the light settings being, chat light, cave light and play light (appendix 5.4). But when looking into the dislikes of the adults' women had a clear favorite being work light, were the men were leaning towards two dislikes being both chat light and work light with the same numbers of votes (appendix 5.4). Again, as seen in the

young adults, the adults had the least disliked towards play light, making play light the second most liked light setting when the disliked were withdrawn (appendix 5.4).

The elderly had some interesting findings as well, were the adults and young adults in generally had a liking towards cave light the elderly had a strong liking for work light. This support the theory about elderly needing more bright light and them not see blue light as blue as younger would due to their eyes aging and becoming more yellow (Hendrup, 2018). Furthermore, high CCT light shows improvements in people's wellbeing and work performance and should be therefore utilized in a work zone (Mills et al. 2007). The light setting with most dislikes were the warmer light setting chat light, this was a main disliked for both men and women. When looking deeper into the dislikes, men did not dislike play light at all, while it was the cave light that the women did not give any dislikes to (appendix 5.4). These findings are something to take into consideration when moving forward. The findings would help developing clear guidelines that can assist in creating light that can support activity zone and thereby the visitor's needs.

11 THE GUIDELINES

In this section guidelines were conducted out from the field test findings, the four activity zones and the visitors' needs. The guidelines were developed to assist architects, engineers and lighting designer to understand how the library light are changing and how to create lighting that support different experience for activity zones in the space. As mentioned in section: Function areas, a library space has many different functions to support the needs of the visitors, it is therefore important to have supporting lighting. The four activity zones created the possibility to put more functions in the same space and creating four experiences and four different light settings that could support it.

Humans want to create their own space wherever they go or whatever they do, the tendency to personalize their home and their office space is important (Lam, 1977). But taking over a public space is not always that easy. *"In public spaces such as libraries, control over local lighting and furniture arrangement may be the only available means by which the user can carve a personal niche out of the general public turf"* (Lam, 1977, p. 29). Creating lighting that has to support the visitors' needs, the different function in an existing or Future Library and create the right experience for the zone. The more personal light would be, the more able to support the needs of the visitors but still be able to be inside the experience of the activity zones. By applying personal lighting to the activity zones, it would allow the visitors to take over the space and create something of their own inside a public space. But by creating limits to the personal light it will allow the experience to still be present in the activity zone. This would also allow the visitors not to create lighting that would damage their experience or the efficiency of their functions, like low intensity warm CCT lighting inside the work zone making the visitor tired and not focused (Mills et al., 2007).

Guidelines would help to create limits to the personal lighting and help to keep the experience inside the zones. In general, the guidelines would still be to keep using narrow spot lights to create an overall forest vibe. As mentioned in our field test we got aware of how the NEUTRAL CCT around 3600K were the CCT levels with least disliked and was a high overall like (appendix 5.4). If the guidelines would not be able to adapt to the library, for some reason, the NEUTRAL CCT levels should be used, as well as creating contrast between the ambient and task light inside the zones. The lighting should also be for the visitors though the functions in the space, meaning that the light should light up the function and support them.

The guidelines for the work zone were supported of the field test findings. The findings showed that the work light was not the most liked lighting but the play light was, these findings helped develop the CCT for the guidelines. The NEUTRAL CCT would be used in both ambient and task light, but in the task light there would be an option to change the neutral into a COOL CCT to optimize the visitors' focus. The intensity would be high in both ambient and task light but still having a contrast due to the different lux levels in ambient and task light (section: TOOLS FOR GENERATED LIGHT IN THE ACTIVITY ZONES).

The guidelines for the cave zone were also supported of the field test findings (Figure 18). The findings showed that the most liked lighting in the cave zone was the cave light. These findings affected the guidelines in that way that the guidelines stayed with the same ambient CCT, were the task light CCT should have the possibility to change from NEUTRAL CCT to COOL CCT. The reason for this decision is because through the findings, the elderly show a big like towards COOL CCT lighting in the cave zone, making it easier for them to read a book. The intensity guidelines would be fixed meaning that it would not be possible to dim or increase the brightness in the zone, so the ambient would be low and the task light would be mid (Figure 18).

As the guidelines for the work zone and cave zone were supported by the field test findings, as well were the play zone. The findings showed that the most liked light in the play zone was the play light, but when talking with parents they showed a liking towards the dimmed chat light or cave light if they had to read for the children. This finding shaped the guidelines in that way that the ambient CCT should have the possibility to change between the warm CCT to the NEUTRAL CCT. The reason for this is to create a cozy environment if reading is the focused function in the zone, were the task light CCT would be fixed on NEUTRAL CCT to make reading or playing easy. The ambient intensity should also be able to dim going from high lux levels down to mid lux levels, this could add to the cozy environment the parent liked in the field test.

The guidelines for the chat zone will like the other zones be supported by the findings in the field test. The most liked light setting in the chat zone in the field test were the chat light, the second most liked light setting was the play light. These two light settings were implemented into the guidelines for the chat zone. The ambient CCT should be able to change between the warm CCT to the NEUTRAL CCT, were the task light would have the same option. Were the

intensity of the ambient light would have the option to change between high lux levels to mid lux levels, the task light would be fixed at mid. The reason for this is to create the cozy feeling that the chat light setting created when the field test was conducted.

Figure 18

	Work zone	**Cave zone**	**Play zone**	**Chat zone**
Ambient CCT	3600K	2700K	2700K or 3600K	2700K or 3600K
Ambient Intensity	High 500-800 lux	Low 20-60 lux	Mid or High 100-300 lux or 500-800 lux	Mid or High 100-300 lux or 500-800 lux
Ambient Direction	Ceiling or walls	Ceiling or walls	Ceiling or walls	Ceiling or walls
Task CCT	3600K or 5600K	3600K or 5600K	3600K	2700K or 3600K
Task Intensity	High 800-1500 lux	Mid 300-500 lux	High 800-1500 lux	Mid 300-500 lux
Task Direction	Table	Lap	Floor or table	Torso
Accent light	Low	Low	High	Low

Figure 18 - Showing the guidelines for personal lighting in the four activity zones.

12 CONCLUSION

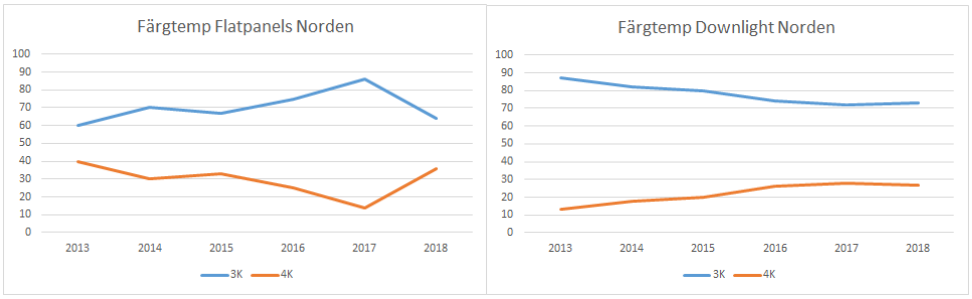
The linking element through the whole study is creating human-centered lighting design guidelines, which the results of the case analyses and two tests have successfully done. As the physical nature of libraries has changed significantly over the past decades. *"Each of these new features has led to changes in library building design, library illumination requirements and controls"* (IES, 2013, p. 1). When elaborating on the **vision** of: *Imagine if a library could enhance the feeling of personal space by creating a comfortable and inviting environment through light,* it can be said that the new knowledge acquired throughout the study can be applied for improving the existing libraries and yet to be constructed Future Libraries. The investigation in the library types created an overall knowledge of different library types and how the light had been used throughout the history. Though the case study, the visitors' needs were defined through looking into the visitors' daily habits in a library space. From this, the generated function areas opened up ideas for designing specific lighting for the different functions and creating activity zones. The case study investigation also looked into how the visitor was using the space, this lead to creating four different persona groups that was used to understand who used the different activity zones and thereby how the light presets should be set. The case study therefore leads to an overall understanding of how the visitors used the space and which visitors used what. The two tests findings lead to an understanding of how the different light setups affected the potential library visitors as well as how the light setups impacted the overall experience. This lead to the understanding that the light setups alone, without the environment (the furniture, books, overall architecture etc.), would not be able to enhance the space experience. However, that it is the same the other way around. As the field test results showed, the overall most liked preset was 'play preset', meaning that 3600K is a golden medium for both ambient and task light and could be utilized more in other spaces. The preset had both ambient and task light with CCT of 3600K, making it more preferred than 2700K or 5600K. This pattern was also seen in a study on the effect of correlated colour temperature and thermal sensation, which results showed that 4000K showed higher thermal comfort than 2700K or 6200K (Baniya et al., 2018). Therefore, the use of 3600K-4000K CCT would be recommended for better thermal comfort in an indoor space. Furthermore, the 'cave preset' was predominantly preferred in the cave zone, which indicates that the subjects appreciate the combination of dim surroundings and bright task light when they are reading or relaxing alone. The activity zones are thereby an important finding and with the right

supporting light setup would be able to enhance the experience and atmosphere through ambient and task light. With these findings and with knowledge of the library space creating or redesigning we believe that this would be able to improve the overall experience in the space. Creating human-centered lighting design means going through all the steps taken in this report. As revealed in the findings of the field test, the set hypotheses showed to be mostly true. Strong preference patterns revealed in the work zone, where the subjects do not like warm dimmed light at all (chat preset) (appendix 5.4); the cave zone, where the predicted dimmed surroundings with neutral task light was most favored (cave preset) (ibid); the chat zone, where cool ambient was strongly disliked (work preset) (ibid); and the play zone, where the predicted neutral (play preset) was liked and cool (work preset) disliked (ibid). As the previously raised **research question** stands: *How can library light create different activity zones by meeting the visitors' needs and thereby enhancing the experience and atmosphere through ambient and task light?* The answer lays in starting with the human in the space, observing and analyzing their activities and after this, designing or enhancing the atmosphere. This principle of 'form follows function' is not new, mostly being associated with 20th-century modernist architecture, which says that the shape of a building should primarily relate to its intended function or purpose. (Michl, 2009) We believe this idea needs to be taken a step further in the creation of Future Library spaces, emphasizing the importance, flexibility and innovation of lighting design. As control over local lighting and furniture arrangement are the only ways for the user to personalize their private area in a public place such as a library (Lam, 1977), the option should be there in a Future Library. However inevitably, *"with the diversity of tasks occurring within a library, as well as the differing ages of the target audience, it is not possible to provide complete comprehensive recommendations for every possible situation"* (IES, 2013). This means that not all the activities can be covered by the generated zone light presets in this report, but they need to be designed with the human and its needs in mind.

13 DISCUSSION

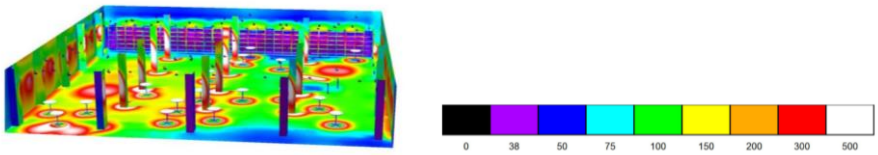
When finding a place amongst the five different library types (the classical, standard, modern, smart and Future Library (sections: LIBRARY TYPES) for the generated guidelines, we can suggest that they would mostly fit into the Modern Library as of now and into the Future Library, if the smart elements are included. As for the four types of division for American librarians (public libraries, school libraries, special libraries, and academic and research libraries), the guidelines can be utilized in all four, as they are all including people with different needs in the spaces - some libraries with a wider (the public and school library), some with lesser functionality spectrum (the special, academic and research libraries) (IES, 2013).

When using the element of daylight in a space, it is essential to keep the amount of natural ambient light at a reasonable level. It has become a trend amongst constructing bigger public buildings as well as libraries, to have enormous windows have a number of downsides to them. Although natural daylight is very much needed and visually pleasing, not to mention sustainable, the amount and direction of it should be very well balanced with the electric light. Daylight can provide too high illuminances and luminance that are not necessarily needed in an interior space and the extreme contrasts between luminance in visual areas can result in glare: *"Uncontrolled direct daylight penetrations can create luminance ratios of more than 1000:1, which is unacceptable for most visual tasks."* (IES, 2009, p.103). When jumping from the brightness to colours and discussing the popular CCT preference of 'play preset' with 3600K for both the ambient and task light, the tendency to like NEUTRAL CCT is very visible. Our findings are also backed up by a study where 4000K showed higher thermal comfort than 2700K or 6200K (Baniya et al., 2018) and Fagerhult's sales patterns. The company mostly manufactures lighting systems for indoor and outdoor public environments (Fagerhult, N.d) and as the sales trends for two product groups (Flat panels and Downlights) in the Scandinavian market for CCT show, there has been a noticeable rise in the preference of 4000K since 2017 (appendix 2.4). When previously, slightly warmer fixtures with 3000K were on the rise and 4000K declining, then after 2017, the trend has reversed.



Fagerhult sales trends for 3000K and 4000K fixtures between 2013 and 2018 (Appendix 2.4)

Although 4000K is more effective than 3000K by providing 30% more light (Hendrup, 2018), the intensity has to be increased when using colder light, otherwise it deceases our colour vision. This means that when creating dimmed transitional areas, it is not beneficial for our visual comfort to use 4000K or higher CCT lighting. It is also visible from the Field test results, that work light presets with 5600K was noticeably not preferred in the chat and play zone (appendix 5.4), giving the human skin and faces an unpleasant, blue hue. When adjusting the contrast balances between the ambient and task light in relation to the transition zones, it is important not to make the difference too big. For example, the contrast between the light spot and the shadow area in the Aarhus Royal Library basement might appear be a little too big, with measured 4000 lux on the brightest spot, 450 lux next to it and 50 lux in the shadow (appendix 6.2). Great differences in brightness levels cause glare, which often gives the impression that there is not enough light, because the eye adapts to the brighter areas (Dahl, 2009). Research results have also shown that with the option of dimming ambient light, people do not dim it too far down because they prefer to maintain some illumination on 'nontask' surfaces and to avoid extreme luminance ratios (Newsham et al., 2005). This means that the contrast between the brightness levels in task lighting and ambient lighting cannot be too wide, keeping both closer to a medium. However, while experiencing the space, the contrast did not feel so drastic as the measurements and pictures seem to reveal, because the human eye has very good adaptability, which is often overlooked (Hendrup, 2018). Also, the DIALux illumination calculations show that although the values differ, there is enough light, which can easily be increased by rotating the spots.



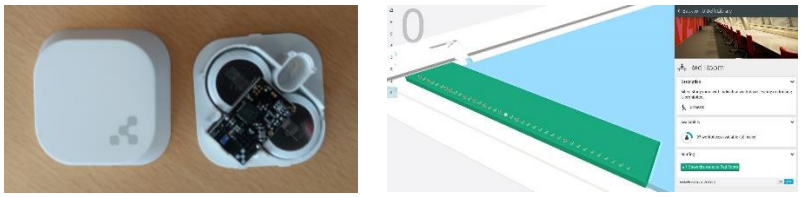
DIALux false colour rendering showing the illumination levels (lux) in Aarhus Royal Library's basement (Appendix 2.6).

The shadow needs to become more into focus when designing light in library spaces, as it creates visual variety and when designed well, does provide sufficient light amounts for reading. Inspiration can be drawn from cafes, museums and other public spaces that have been using more comfort and creativity when creating their lighting designs.

Contrast of the light spot and the transition zone illumination levels in Aarhus Royal Library's basement (from left: Picture 155, 156 and 157).

The created light zones can also definitely be elevated by applying some cutting edge smart technologies and design that is already slowly being applied in the library world. We looked for information and examples of good practice of new buildings as well as transformational projects, there are creating spaces for the visitors and their needs. For example, Denmark's Technical University (DTU) Library has gone through a transformation as a part of DTU's Smart Campus project. The project has also extended into the library, which has been working with the term 'Smart Library' and is already implementing various smart solution sensors since the renovation, completed in October 2017. *"Part of the library renovation in 2017 consisted of the installation of Modcams to measure, count and monitor the use of the library. In addition, various sensors have been put up to measure temperature, humidity, particles, CO2 and sound level etc. and thus gather data about the indoor climate"* (DTU, 2018). Sensors can be used for enhancing various sensory experiences in the space, also for controlling natural and artificial light. A good example of a public space adapting to the daylight input is the Ny Carlsberg Glyptotek in Copenhagen (Denmark), that has DALI control system with adaptability for three scenarios: daylight, blue hour, darkness (Hendrup, 2018). When talking about the future and libraries Binau clarify that he believe that voice controlled smart elements will be something that the future will bring to the library, he also explains the is skeptical about how the Smart Library elements would work in a public library like DOKK1: *"We are a research library so I believe that students and researchers out here [at DTU] are more willing to give [out their] data (...) so it might be more difficult for a*

public library to do what we are doing" (Binau, 2017, appendix 1.1). Another technology-oriented library is the multifunctional DOKK1, trying to add smart elements to their library in order to get new knowledge about the visitors and the movement in the library space. The data would be used to optimize the visitor's experience, interior design, wayfinding, even opening hours, facilities and so on. Besides gathering data through observations and surveillance cameras, they also collect info about the visitors through Wi-Fi and Bluetooth (Aarhus bibliotekerne, N.d). The reason why Binau is skeptical about that DOKK1 and other public libraries that are trying to become a Smart Library is because he believes the visitors would not be that easy convinced to give up data about themselves, especially if the data would be private or personal data (Binau, 2017). Although, companies like Google have access to a lot of personal data, which people do not seem to mind or are not aware of (Binau, 2017). Additionally, the smart elements called iBeacons are being taken into use, e.g. in Delft University of Technology (TU Delft), Holland. The iBeacons are connected to an iOS application that work on Location Services and detect via Bluetooth when one is close to an iBeacon, e.g. checkout counter in a retail store or library study rooms (Apple, 2017). The downside to iBeacons is that they can only be used with iOS system, meaning with an Apple Inc. device. DTU library also tried out them in 2016 (Binau, 2017).



iBeacon from DTU (left, Picture 158) and example screen shot of Mapiq application in TU Delft Library (right, Appendix 2.7).

The head of library of TU Delft, Karin Clavel explains that besides iBeacons, they are working on getting more smart elements to the library (Clavel, 2017). They are also using an application called Mapiq, used for booking project rooms and finding vacant study places (Appendix 2.7). That are working side-by-side with more than 100 smart movement sensors that monitor occupation and run through the same application (Clavel, 2017). However, as the project is still a pilot, the sensors are not yet in every room. The illustration above shows how the info is being used, displaying free or taken seating areas in the Red Room at TU Delft Library.

When discussing the new needs of a visitor further, it is impossible to look past the fact that electronics have become a tight companion in our everyday life and a majority of library

visitors use their laptops, tablets or smartphones. This digitalization is only expected to grow in the coming years and has to be considered in any future designs. With the widespread usage of Wi-Fi and various sensors, it is becoming more and more accessible to make the libraries smarter, more sustainable and also providing more personalized experiences for the visitor. However, it is important not to disregard the human liking to making the space their own through physical changes - pushing a switch, moving the beam or being able to rotate the chair they are sitting in. When creating smart personalize lighting systems then the interface needs to be evoking curiosity and very user friendly, as the first encounters create a sharp memory and dictate if there will be further usage of the system (Tieben et al., 2011). For example, if a tablet computer on the table or wall is too unnoticeable and complicated, it will not probably be used, and the user would rather turn to a simple, ready to use switch.

People generally like having technology around that make their experience easier, but it has to be seamless and not too intrusive. When creating human-centered designs, the way we experience and sense the space has to be kept in focus, as it affects the way we carry out activities. The visitors make the spaces their own, changing it from a space into a place with their unique way of practices and behaviors. Therefore, having zones for similar activities is important, creating an atmosphere where the visitors can feel at home and dwell in the chosen library space.

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