An analysis of chromatic and luminous environment of healthcare establishment.

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ABSTRACT

This paper presents a protocol for analyzing the color and light parameters of a sanitary environment, based on the study of the chromatic and luminous atmospheres of the Sanatorium Paimio's main building, designed by the architect Aalvar Alto. Thanks to this protocol, it is a question of identifying and deciphering the sanitary plans of the architect. For this, I based my exploratory work on the development of a chromatic and luminous "identity card" which lists the different colors and lighting modes used. The study is divided into three phases: color observation, light observation and observation of interactive movements. This study highlights the work carried out by the architect on the behavior of chromatic atmospheres under different light and their influence on human reactions and needs, ensuring the most favorable conditions of vision and rest for the patients who stayed at the within the sanatorium thanks to the combination of the fields of physics, aesthetics, physiology and psychology.

KEYWORDS Care, Color-design, Comfort, Hospitalization, Interdisciplinarity, Lighting, Well-being.

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1. Introduction

Finnish architect Alvar Aalto designed the Paimio sanatorium (1929-1933) for welcomed patients from all over the world suffering from tuberculosis. This facility allowed patients to enjoy complete rest in optimal conditions. The architect considered the following situation: a patient lying in bed, forced to spend most of his time there. His primary objective was that the technique serve the needs, sensitivity and emotional demands of patients (Kim, 2009). As convalescence can last several years, the architect designed an environment conducive to community spirit and social cohesion between patients and caregivers through the design of equipment and spaces accessible to all. Moreover, in a functional [1] and biodynamic [2] purpose, he designed an architectural program that makes the built environment itself active during the convalescence of patients. So, the exposure of each wing of the building made it possible to respond to "the deep needs of each person in accordance with nature" (Menin & Samuel 2004, p.57). For each of its architectures, Aalto has relied on color, light, space and materials to design atmospheres conducive to the psychological and physical needs of users (Arnkil, 2018).

Color was therefore one of the major elements in the design of this building, used as a therapeutic principle. The architect designed the color palette of the Paimio Sanatorium in collaboration with the artist Eino Kauria, responsible for coordinating the color scheme and directing the painting work (Eylers *et al.*, 2016). Thanks to the use of various types of psycho-sociological effects, the architect associated the design of atmospheres with the associations of ideas, both subjective and objective, conveyed by the representations associated with the colors. They decided to rely on Western codes, identifiable and recognized by the majority of patients.

But colors also played a physiological role that did not only depend on these cultural representations. Inspired by the principle of chromotherapy, according to which colors can have a curative action, the polychromy of the sanatorium aimed to relieve the ailments of patients. The choice of wavelengths (Kent, 1947) (Déribéré, 1968) was inspired by work involving the physiotherapeutic principle, today called phototherapy, according to experiments carried out between the 19th and 20th centuries, particularly for the treatment of measles (Chatinière, 1900) or smallpox (Rehns, 1904). For example, newborn jaundice is treated by exposure to blue light. This treatment is based on exposing to visible monochromatic blue light between 390 and 495 nm. The wavelength most used today in phototherapy is 450 nm. It effectively reduces the level of bilirubin in the baby's blood. (Ennever, McDonagh and Speck, 1983) (Shirzadfar, 2019).

2. Material and method

The following case study therefore aims to define the chromatic and luminous properties of the Paimio Sanatorium's main building (health establishment) to identify the architectural parameters influencing the recovery of patients. The study is divided into three phases of observations:

1/ Color observation consists of identifying color samples of architectural elements (floors, walls, joinery, stair railings and balustrades). Not having been able to personally experience this place, the study was conducted based on photographs and color board painted by Kauria (Riksman, 2016) and optical color matching [3], compared to the colors of the NCS color chart. A margin of error is therefore inevitable but deemed acceptable because the objective of the study is to translate a thought and not to develop a reproducible reference. The chromaticity values identified in this study can, reduced to their spectral property, present a difference of 1 to 2 nm with the original colors for colors ranging from blue to orange, and up to 6 nm for violet. and reds, values corresponding to the threshold of differentiation of hues in wavelength of the human eye (Wright *et al.*, 1934 cited in Treméau, 2016). In addition, the photographs did not allow me to identify the nature (matte or glossy) of the paints used nor the reflection value of the paints used. The same work was carried out on the furniture (tables, chairs, lights). The main spaces are represented (outdoor environment, reception hall, dining room, meeting room, bedrooms, corridors, stairs) and reproduced in the form of a map [4] making it possible to identify the sociostyles used [5].

2/ The light observation made it possible to identify the different artificial lighting modes used as well as the types of lighting, supplemented by the natural lighting methods. I was unable to collect the elements relating to the characterization of the light sources. Only the different types of artificial lighting and natural light were observed.

3/ The observation of interactive movements (Lassus, 2004) consists of observing all the chromatic variations, according to the principle of light reflection and their mutual influences on our perception.

3. Results

3.1. *Phase 1 – Color Observation*

For the chromatic observation of the interior environment, I therefore rely, in addition to the photographic archives, on the finalized color scheme of the main building painted by Eino Kauria (fig. 1.), which can now be found in the collections of Alvar Aalto museum, Jyväskylä, Finland (Riksman, 2016).

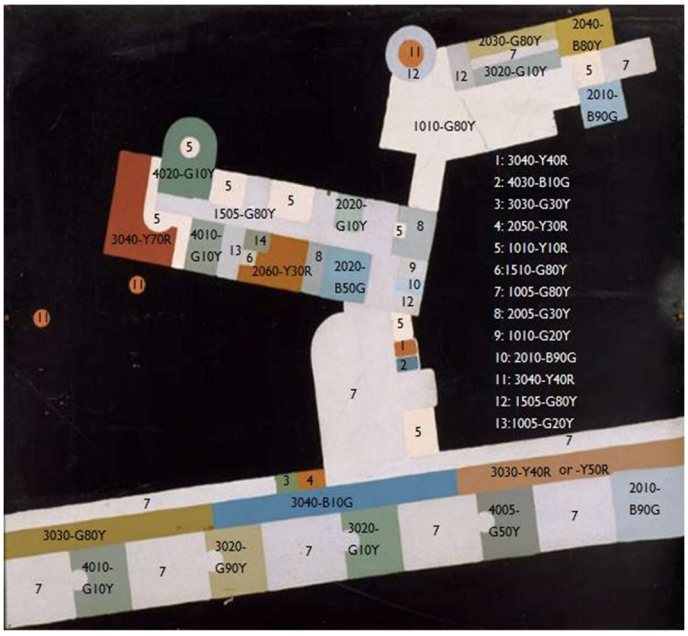

Fig. 1. Color scheme of Paimio Sanatorium's main building. Is probably the original board produced by Eino *Kauria.*

In parallel with the listing of the NCS colors present on board Figure 1, I sought to identify the colors present in the photographs (fig. 2.) in order to then correlate them and obtain a representative referencing of the interior and exterior chromatic program and of the furniture (fig. 3.).

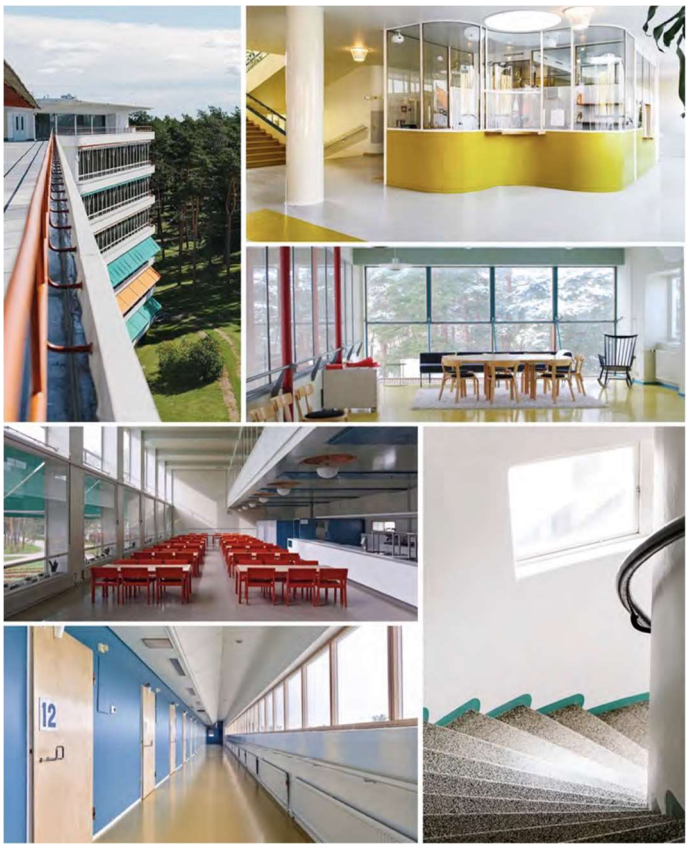

Fig. 2. Photographic sample (interior and exterior environment) of the Paimio Sanatorium based on photographics archives of Alvar Aalto Foundation.

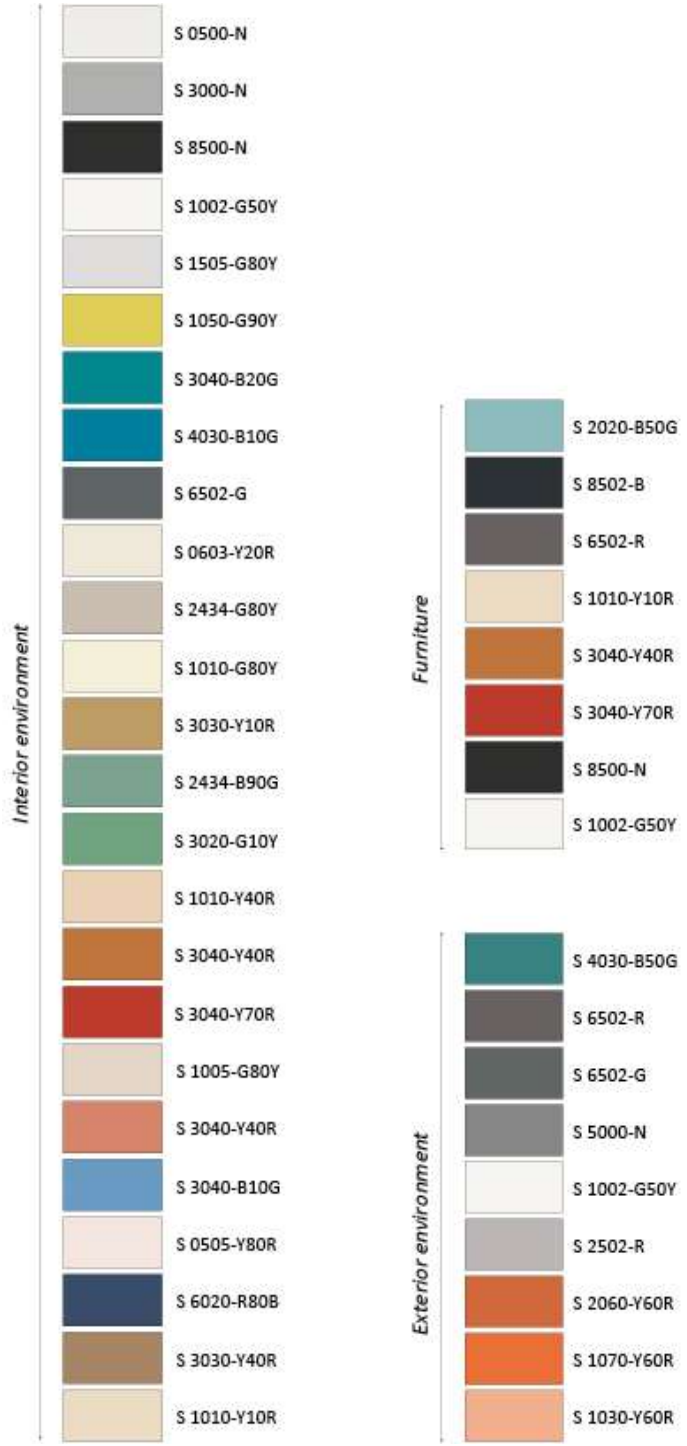

Fig. 3. Color measurements in NCS S based on photographic observation and Kauria's color scheme board.

We observe a wide polychromy built around thirty-five shades (fig. 4). It is divided into four categories of color effects: warm, cool, neutral and achromatic colors. There is also a complementarity between certain colors of the furniture elements, between a blue-green and red, associated with a play of neutrals and punctuated by the use of darks. In addition, we observe a majority of warm colors and achromatic ones, representing almost a third of the colors (table 1).

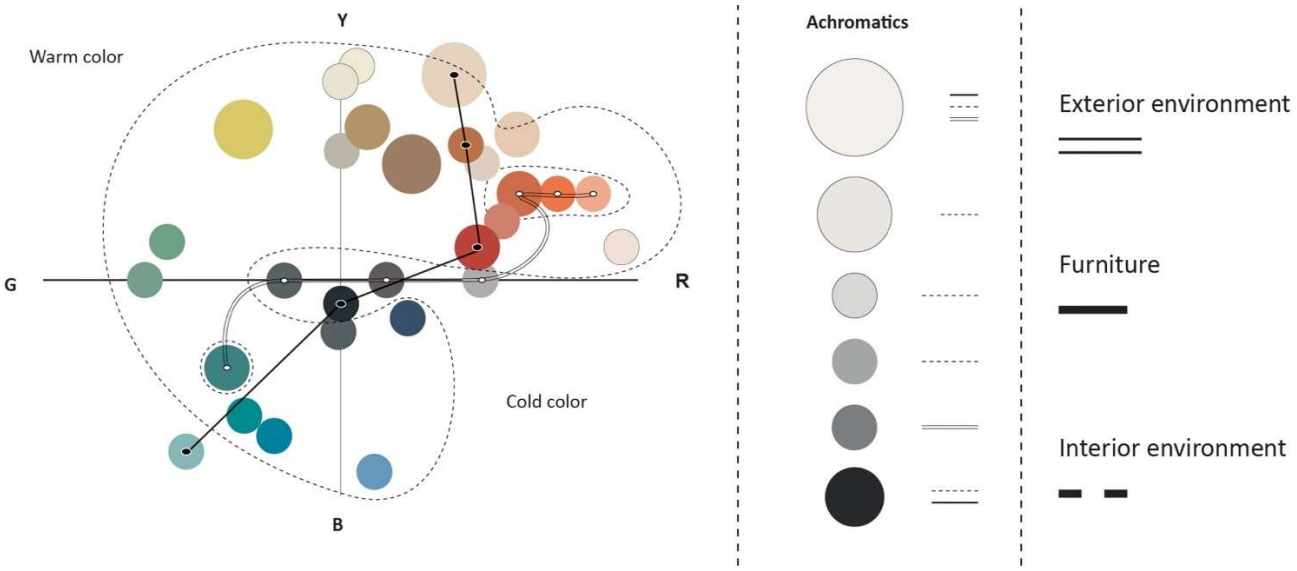

Fig. 4. Chromatic cartography of the sanatorium program. It represents the proportion of each color and their use. Colors are classified according to their hue and achromatic ones according to their degree of lightness.

	Warm	Cool	Neutral	Achromatic
Exterior				
Light	6%	3%	2%	6%
Dark	-	-	3%	-
Interior				
Light	19%	5%	17%	19%
Dark	-	1%	2%	3%
Furniture				
Light	5%	2%	-	3%
Dark	-	-	2%	2%

Table. 1. Chromatic distribution according to hue and lightness degree according to the previous mapping.

Light colors [6] are mainly used and are the only ones used for warm colors [7]. These nuances are distributed between the exterior, interior environment and furniture elements. The colors used for the interior environment represent more than half of the shades used for this architectural program. So, we observe different families of atmosphere in interior spaces according to different color combinations.

The development of chromatic combinations results in the design of combinations that respond to the collective imagination. Relative to specific atmospheres, this schematization is representative of the color universes previously established by the sociostyles. These combinations put into action the qualities of each color in order to transcribe a particular effect. They confer on the subject who benefits from them an identity character which must be recognizable by the user.

A chromatic combination thus inscribes this subject in its time and the use that is made of it. It is defined in terms of chromatic typologies (dominant and tonic) and proportions. The dominants result in light, pastel, neutral, natural tones; the tonics are saturated, lively, dark tones of collective images, of representations conveyed according to the associations.

The different combinations observed on the Paimio program (fig. 5.) are as follows: 1/ natural (similar composition of warm colors and shades), 2/ dynamic (strong contrasts and dominant colors warm), 3/ modern (cold colours, strong contrasts), 4/ relaxed (complementary to contrasting colours, neutrals associated with a tonic), 5/ romantic (neutrals associated with a tonic).

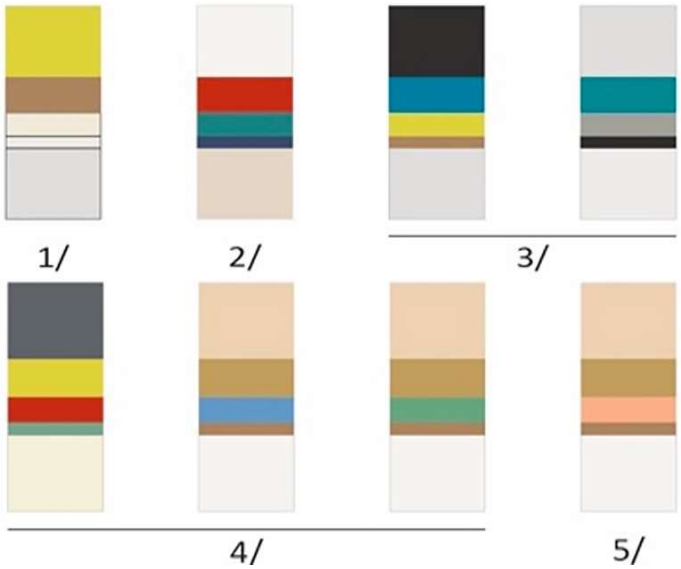

Fig. 5. Set of combinations identified according to families of atmospheres previously observed.

3.2. *Phase 2 – Light observation*

There are two types of dominant openings intended to capture natural light: the zenithal and lateral opening. On the facades, there are window strips and large openings completed by a configuration of multiple leaves. We also observe frames with small footprints, except for large openings, as well as openings in the roof.

	Opening	**Lamp**	**Lighting**
Bedroom	Casement window	Wall lamp, portable lamp.	Task lighting, Mood lighting.
Common Area	Skylight, window banner, casement window, glass facade.	Portable lamp, hanging lamp.	
Passage Area		Wall lamp, hanging lamp, recessed lamp.	General lighting, Mood lighting.
Dining Room	Glass facade.	Hanging lamp.	

Table. 2. Directory of openings, lighting and type of artificial lighting according to the needs of use.

Regarding artificial lighting, there are different types of lighting allowing the production of general lighting (recessed and suspended luminaires), ambient (wall and suspended luminaires) and task lighting (localized extra light thanks to free-standing luminaires and portable lamps).

3.3. *Phase 3 – Observation of interactive movements*

We observe variations in the perception of colors according to four modalities: reflection of exterior elements (fig. 6.), interaction with furniture, between two opposite walls, one of which is white, and between two different opposite walls (fig. 7.).

Fig. 6. Chromatic variations resulting from the reflection of exterior elements.

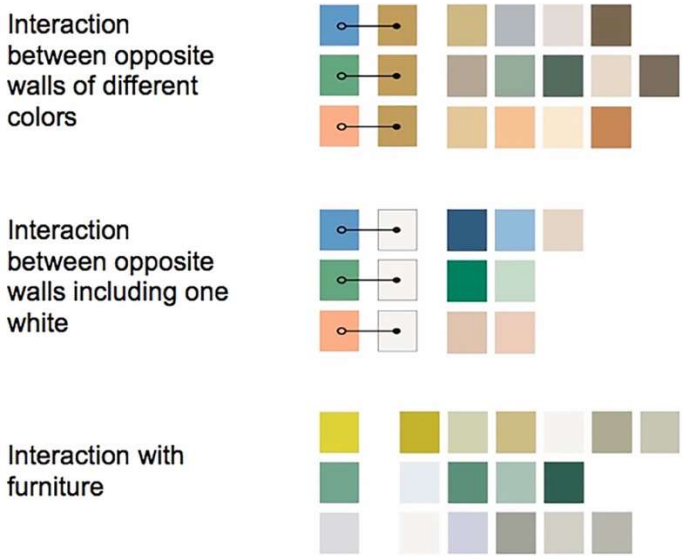

Fig. 7. Directory of the different chromatic variations resulting from the influence of light reflection on the built environment and furniture.

External element reflection relates to the effect of color reflection from blinds when deployed. The blinds, in blue-green and orange colors, slide towards warmer tones. This shift is also taking place on the paintings and the interior furniture. Blue becomes green, neutrals become blue and pink-orange, dulls slip into warm pastels.

The interaction with the furniture leads to the observation of many nuances. It is induced by the shadows cast by the furniture depending on the reflection factor of the floors and/or walls. If the chromatic dominant remains present, we observe a shift towards lighter or darker shades and going as far as a neutralization of the original color but without distortion of its tone. Only saturation and lightness are impacted.

Regarding the interaction between two opposite walls, one of which is white, we can observe the lightening of the original color, to tend towards a neutralization of it. Conversely, taking physical distance leads to a clouded perception of this tone. Finally, the interaction between two different opposite walls leads to the observation of a game of chromatic complementarity.

In the case of the projection of blue on brown, the complementarity of these two colors calls on brown to become dominant and to cancel the projected tonality. Only the nuances of this dominant are perceptible to us, from the clearest to the most flattened, from the most saturated to the most neutral. On the contrary, for a projection of green on brown and pink on brown, leading to similar associations, the perception of green and pink are preserved. They only undergo a slight neutralization. We therefore observe a variation in their saturation, but also in their degree of lightness.

4. Discussion

The chromatic combinations and lighting devices that we have previously observed can reflect the architect's desire to generate a harmonious chromatic and luminous scheme capable of generating a general feeling of well-being, comfort and serenity.

The colors observed for the outdoor environment create a dynamic landscape thanks to the use of complementary colors that punctuate the white architecture. The major use of achromatic (white) generates a strong visual imprint. We can assume that the architect wanted to refer to hygienist representations [8], thus echoing the care provided in the establishment. The neutrals may have been used to attenuate the signal effect of the complements without canceling their function as spatial markers and uses. But the architect made the choice of an assumed polychromy, thus generating multiple atmospheres. It echoes the work of Harry Sherman on visual ergonomics. It was strongly impacted by the omnipresence of whiteness, artificial lighting creating many dazzling situations. The coloring of the environment then becomes a solution to counter this glare (Sherman, 1914). The use of cold colors, minority and applied to the rooms, allowed him to create a peaceful atmosphere, calm and conducive to rest. On the contrary, warm colors and neutrals refer to comfortable and warm living spaces. Yellow, mainly used in the entrance hall and meeting areas, could have been used for its soothing properties on nervousness (assuming the nervousness of patients arriving in this establishment). As for the achromatic ones, they offer breathing spaces in a punctuated and structured atmosphere around the color. The "broken complementary colors" [9] make it possible to neutralize the natural force of the combination of complements in favor of a light dynamic because "in the case of simultaneous perception […] a tone turns towards the complement of the opposite tone" (Dumond , 1957). On the contrary, the "discordant harmony" [10] accentuates the signal effect and makes it possible to underline the spatial landmarks.

Beyond these methods of association, polychromy also makes it possible to generate various universes, according to the use lent to the spaces, recalling the systems of sociostyles (Kobayashi, 1992) anchored in the collective imagination, according to the needs conveyed by the actions carried out in the areas concerned. The natural atmosphere induces a comforting image and an impression of serenity conducive to reassuring users, especially when entering the premises, while waiting to take exams or receive their care. The modern atmospheres, inducing an impersonal image, emphasize the functional character of the spaces. The relaxed atmospheres offer a welcoming and joyful image of these living spaces. The romantic atmosphere is considered ideal for rooms that must be calm, relaxing, conveying tenderness and benevolence. The dynamic atmospheres are also intended to be joyful and welcoming while encouraging action.

But the sensitive dimension of color cannot dispense with its connection to light, which participates in particular in the evolution of visual perceptions. Light, whether natural or artificial, can thus be designed to reinforce chromatic qualities but can also lead to their evolution by the reflection of colors on each other. These interactive movements (Lassus, 2004) thus make the place active and tend to reveal multiple spaces over the course of the day. Weather conditions play a major role in modifying the nature of the available natural light and generate variations in color perception. But above all, natural light improves the well-being and comfort of users, particularly in care practices (Déoux *et al*., 2011). The different openings then have the role of filtering, guiding and distributing the light in order to maximize its capture. The combination of top and side openings then offers optimal autonomy in terms of natural lighting. This combination allows a significant light supply and this throughout the seasons. It also provides optimal exposure to the cyclical rhythm of natural light, known today for its benefits on the circadian rhythm, or biological process, of patients (Zielinska-Dabkowska *et al.,* 2017).

But constrained by natural lighting conditions, it is necessary to use artificial lighting to compensate for natural light variations and thus produce quality lighting, free from the constraints of natural light. The use of different types of luminaire then corresponds to specific functionalities and makes it possible to meet different needs thanks in particular to the production of general, ambient and task lighting. General lighting is used to ensure the movement of users in the corridors and passageways, as well as the execution of common tasks in the common rooms. This type of lighting is characterized by a uniform, diffuse and homogeneous distribution of light thanks in particular to the use of large recessed and suspended luminaires offering direct lighting. Ambient lighting, on the other hand, offers light dedicated to a momentary activity and qualifying a limited space. This type of lighting can be found in all types of interior spaces. The use of wall lights and suspended luminaires are thus conducive to the production of localized and diffuse lighting. The projection of light, thanks to indirect, semi-direct, semi-indirect and mixed lighting, towards light surfaces thus ensures the diffusion of a soft and even light. Finally, task lighting results in an increase in localized light thanks to mixed lighting, combined with general lighting, allowing the execution of tasks requiring a high level of focused and focused lighting.

Mostly seen in common areas and bedrooms, floor standing fixtures or portable lamps provide this directional light that can be adjusted as needed. Thus, if well-designed lighting is therefore defined by a sufficient quantity of light and the choice of a device that eliminates visual discomfort by glare, it is appropriate to choose and combine lighting modes adapted to the needs and thus make the secure interior space conducive to comfortable living.

5. Conclusion

We evolve daily in the midst of color and light, but apprehending a chromatic and luminous environment is above all receiving and interpreting visual information.

They not only convey an aesthetic dimension; they are designed to meet challenges and a defined aim, to give the user a view. Signs thought out by the designer and sent to the user, color and light will be received and interpreted. Whatever the target, these signs must be in line with the images shared collectively, the local culture, the senses and the sensitivity of those who receive them. The designer then defines a color/light combination for its psychological effects (combination appreciated by the receiver, allowing him to invest his affect in the place and for it to provide him with some beneficial effects), and/or visual (choose a combination for its ability to attract the gaze or on the contrary repel it, to play with proportions and architectural organization as a visual landmark), influenced by a trend (so as to identify with what is happening elsewhere and now) or the collective cultural heritage (allowing to federate a community around signs that are common to them as an element of identification) (Caumon, 2017). These reference frames of influence will thus make it possible to build an identifiable and identified chromatic and luminous environment, which can lead to affective reactions of pleasure or displeasure. But whether instinctive or conscious, the social role of lighting and color-design should be considered as a factor of well-being thanks to the combination of "physics, aesthetics, physiology and psychology" (Déribéré, 1964).

This study also questions the healing power of color and light. It is therefore a question of being concerned with the behavior of chromatic and luminous atmospheres and their mutual influences on human reactions, because using light and color is not only to illuminate and decorate, it is above all to ensure the conditions of vision and more particularly in this case study, conditions of rest and healing that are as favorable as possible to the patients. This therefore opens the way to additional studies to affirm or refute their curative effects on health, then considered as non-drug treatment.

6. Conflict of interest declaration

I indicate that no financial and personal interests have affected my objectivity as author. There are no potential conflicts.

7. Funding source declaration

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8. Short biography of the author

Estelle Guerry – Doctor in design-color and design-lighting from the University of Toulouse. Its main scope of research applies to an interdisciplinary definition and application of the parameters of comfort and well-being of users presenting a vulnerability (ageing, handicap, illness, deficiency, etc.). It provides its expertise both in the research environment and in the socio-economic world.

Notes

[1] Functionalism is an architectural principle according to which the form of architecture is the expression of its use. The essence of modern architecture is linked to this principle. Inspired by the teaching of Viollet-le-Duc, Le Corbusier will thus formulate the "Five points of modern architecture" as the synthesis of a new modern architectural conception. These five points relate to the pilotis (disappearance of load-bearing walls in favor of concrete or steel pillars to support the structure), the roof terrace (principle of flat roof intended to accommodate terrace and vegetable garden), the free plan (disappearance of walls load-bearing allowing free modulation of space and being able to accommodate large glazed surfaces), the band window (horizontal windows crossing these non-load-bearing walls along the facades, offering uniform light and a view of the horizon) and the free facade (the load-bearing pillars being present inside the building, the facade becomes a thin and light skin, ensuring no more than an insulating role). The free plan as well as the window in bands will be two recurring points in the work of the Finnish architect Alvar Aalto (Jencks, 1973).

[2] Bioclimatic architecture is based on the exploitation of the properties of the site on which it is established. The climate, vegetation, sunshine, topography thus become key elements on which we can rely to create a comfortable environment for future users. Bioclimatic architecture is also characterized by particular attention paid to respecting pre-existing landscape characteristics, trying to integrate as well as possible into the surrounding environment (Tucci, 2021).

[3] The practice of matching results in the collection of the different colors that make up the architectural program. This involves drawing up an inventory of the colors of the main architectural elements (floors, walls, joinery, stair railings and balustrades) and furniture (tables, chairs, light fixtures). The visual readings are operated by calibration using the NCS color chart. The NCS system, the Natural Color System, is a universal color repository, whose classification logic is based on the human perception of colors. This qualitative inventory is based on a photographic study. Admittedly, photographs cannot be used for accurate color

reproduction, but the conveniences of digital still allow for a representative study to be conducted when field trips are not possible. These chromatic witnesses, extracted from their context, are of major interest when grouping and reconstructing the information which is the basis of the synthesis result.

[4] Developing the maps makes it possible to produce a qualitative and quantitative restitution of the colors previously collected, in order to draw up a visual synthesis. This makes it possible in particular to count the tones and shades composing the chromatic set(s). Analyzing the readings thus makes it possible to transpose them according to their recurrence. The colors of the roofs and the walls make up a first palette made up of the architectural chromatic dominants which represent the major part of the exterior built space. A second palette, the main palette, shows the colors used for the interior built space. It is the most consistent palette due to the large number of tones observed. Finally, the last palette is made up of the tones of the details relating to the furniture. These palettes, represented in the form of maps, make intelligible the visual observation of the chromatic state of the site at an instant T. This synthesis thus constitutes a representative test of the quantitative ratios of the different tones. The samples are classified according to an ordered composition on two axes, each presenting a double reading inspired by the NCS system. A first axis will be readable from yellow to blue, the second from green to red. In addition, the double reading of these axes allows a reading of the degrees of lightness of the samples, the lightest at the ends and the darkest in the center. Achromats have been excluded from the mapping to allow efficient reading of the shades involved.

[5] Applying the Color Image Scale repository produced by Shigenobu Kobayashi, this system based on a principle of tri-chromatic composition makes it possible to categorize the colors observed according to the different universes that they can evoke. This classification of the color samples is carried out according to a purely qualitative criterion, the colors being considered in isolation, according to their representation(s). This sensitive approach leads to the production of chromatic combinations in respect of the interrelation between colors, according to the individual character of each of them, leading to the production of collective images, of representations conveyed according to the associations (Kobayashi, 1992).

[6] In NCS referencing, a so-called "light" color will have a black content index of less than 50, while so-called "dark" colors have an index equal to or greater than 50. (Discover how the NCS System works).

[7] In the West, color design is based on a principle of thermal color polarities, giving colors psychological and thermal properties. Our culture separates colors according to the concept of warm tones (yellow, orange, red...) and those with cold sensations (blue, green...) by placing the "warm" and "cold" poles on a chromatic disc in front of orange and blue (Silvestrini and Fischer, 2011).

[8] Florence Nightingale, a nurse in the middle of the 19th century, is undoubtedly the most significant person in the influence of the relationship between care practices in hospitals and color. Its objective: to achieve an absolute degree of purity, both in terms of cleanliness and fittings. "The indisputable relationship between ventilation and cleanliness is demonstrated by this fact: a light-colored paper keeps clean" (Nightingale, 1860). This will become a majority posture in the health sector, inducing that the idea of clarity leads to that of cleanliness, itself a premise of purity. And conversely, the ideal of purity engenders the notion of cleanliness, itself manifested by lightness, and concretely by whiteness. Architectural design rules are emerging, such as the generalization of a suburban establishment to try to reduce the risk of contagion. Whiteness becomes a quest, then considered as an antibacterial response. The discoloration of textiles by chlorine is born and becomes the disinfectant solution according to the health authorities in the hospital sectors. White then appears gradually, from changing rooms to earthenware, including paintings and furniture. Thus, all aspects of an ornamental or decorative nature are prohibited. Achromatic becomes the norm, a guarantee of cleanliness and health safety (Fagot, 2020).

[9] Association of a color with the two tones located alongside its complementary (Caumon, 2017).

[10] Association of a primary color with one of the adjacent colors of its complementary (Caumon, 2017).

Licensing terms

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