COLOUR AND THE LIGHTING APPLICATION OF TOMORROW

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Abstract

To get more knowledge about the lighting design process a literature review was performed and common knowledge of lighting design was written down within a Thesis project and in a still unpublished post doc. project [Säter 2012]. In this paper is the lighting design process (LDP) seen in relation to colours. To be able to handle colour for the indoor environment of tomorrow, it is important to picture the way the future lighting applications will be designed. As a result of the findings about melanopsin and the intrinsic photosensitive ganglion cell (ipRGC) the light of tomorrow will be designed more physiologically supportive by an increased use of daylight [Brainard et al. 2001]. To be able to work in an efficient way, daylight needs to be combined with a complementary lighting application. This can be designed from a template and as a solitary technical application performed with no contact with the space or the user. But the complementary artificial lighting can also be designed in contact with the space and the user's senses, by the use of the four basic steps in the lighting design process. The first step in the design process is concerned the space, the second the user, the third the design of the daylight and the complementary lighting and the fourth is about the design of the technical part of the lighting application. Colour is connected to all four steps of the lighting design process. The coloured surfaces in the space is by transmission, absorption and reflection (TAR) affected in appearance by the photon flows emitted from daylight and from the complementary lighting installed in the space. The visual experience of the interaction of colour and daylight and the complementary lighting as well can give the user an experience related to the level of light and contrasts graded from unpleasant, pleasant and to pain. If the colours and contrasts in a space is well designed and appropriate according to the amount of photons that are emitted into the space in a rhythm, and have a pleasant appearance both in high and low levels of light and if the technical application is flexible and can be regulated by the user, the user have a good possibility to experience visual comfort when staying in the space. If on the other hand the lighting application is done without contact with the space or the user, visual comfort will not be easy to experience for those who stay in the space.

Keywords: Colours and the lighting design process; Visual comfort.

1. Introduction

When investigating the lighting design process, colour is found being an important part of the process, related to visual comfort and to the four basic steps of lighting design. When staying

in a paradigm shift in lighting related to an increased use of daylight and of a new type of energy efficient light sources, how to do a colour scheme for a specific space need to be re-evaluated. When the lighting application is designed in a way that emits light in a static way and the complementary lighting overrules the rhythm of daylight the work with the colour scheme can be done for a more or less static visual situation and with a spectral profile that is possible to evaluate in advance. The span of levels of light are in this situation narrow and the colours in the colour scheme need to be attractive, pleasant and visually comfortable in a very limited span of light and dominantly in the character of the light emitted from the light source in the complementary lighting. When designing a more physiologically supportive light based on daylight, the photon flow of daylight imprint the space the year around in a rhythm of light levels from high to low, in an ever changing light distribution, a constantly changing spectral composition and only with a small amount of complementary lighting used. In the more futuristic lighting might the character of the light sources used for complementary lighting be of two types that differs in light colours. Since the use of the complementary lighting is minor compared to the use of daylight the changing levels of daylight and the changing spectral profile from daylight is the complexity that the work with the colour scheme should handle at first. The design of colours should also handle the more cold and warm light-colour emitted from light sources that have a higher concentration in the short or the long wavelength area used for complementary lighting. In the work with the colours, the colours that should be chosen is the one that are attractive, pleasant and visual comfortable in both high and low levels of daylight at first and well functioning in the complementary artificial lighting as well. If the complementary lighting has two characters, the type used in the later part of the day should be in use as the type of light that the colour should look attractive in because of the higher number of hours that lighting are needed when it is dark outside.

2. Problem area and relevant research

The future lighting increases the importance of the work with the colour scheme for the indoor environment. This development points out the relation between colours and well established light-related goals in society as visual comfort and light-related health. They are connected to each other in visual comfort being the limit of level of light that the more physiological supportive light not should exceed. The design of isolated technical lighting applications that are done in a general way towards predesigned levels of light should be changed into the development of flexible applications that cooperate with the daily changes of daylight and the individual needs of visual support from work task lighting of the user. If the colour is well functioning according to TAR and the spectral composition of the photon flow and the level of light in the space, the possibility of a high fulfilment of the three light-related goals visual comfort, health and energy efficiency increases.

1.2 Research questions

In what way is the colour scheme related to the lighting design method?

2. Methods

The way colour is related to the 4 steps of the lighting design process were evaluated within a Thesis project [Säter 2012] and in a still unpublished post doc. project. Common knowledge

from lighting design was written down. Methods for lighting design developed within the education at Jonkoping University 1999-2011 were the main source of common knowledge.

3. Theory

The users need for visual comfort is in the European standard for indoor environments mentioned as fulfilled by the use of 500 Lux in the working space for all normal sighted workers in Europe. Europe has approx 520 millions of inhabitants. In a study performed at Jonkoping University [Säter 2011, 2012] is visual comfort shown being an individual experience that changes during the day. In the same study is visual comfort evaluated as an almost unique experience. 314 of 318 subjects did unique combinations of the level of light at the worktable and for the ambient light. The reasons to the differences in preferences for visual comfort are the physiological fact that sensitivity in the channels into the central nervous system differs between subjects. The experience of pain related to level of light and to looking at a lit surface is by that different for everybody [Ingvar 1981]. Colours are mentioned by Liljefors [1999] as in interaction with the electromagnetic radiation in the space by transmission, absorption and reflection (TAR). Glass, a dark and a pale colour have different proportions of TAR. If TAR is taken into accountancy in the work with the colour scheme and all four steps of the lighting design process are used, the photon flows in the space will be dimensioned in a way that is suitable for the user with high sensitivity in the channels into the central nervous system. [Säter 2012, Ingvar 1981]. Colour is related to the four steps of lighting design.

Step one of the lighting design process: In the first step are the space and the colours of the surfaces in the space evaluated. Daylight, windows and the complementary lighting is investigated and judged if well functioning or not. The way daylight and the complementary lighting in the space affects the colours and TAR, is investigated on the highest and lowest levels of light that appears during the year.

Step two of the lighting design process: In the second step are the user's sensitivity (if known) and the levels of light that can appear during the year into the space evaluated and related to colours and the view through the window.

Step three of the lighting design process: In the third step is the design of the daylight and the complementary lighting performed. The use of light sources, fixtures and where the fixtures are positioned in the space, creates a level of light into the space and a three dimensional pattern of more or less lit parts. The choice of light sources in the practical application set the circumstances for the emitted photons from the light sources ability to show the colours in a way that are more or less like the way the colours appears in daylight. Since the light sources are developed to show 15 colours in a daylight like way, the performance of colours are restricted when lit by the complementary lighting compared to when shown in daylight. The spectral profile of the light source in combination with the interaction of electromagnetic radiation (EMR) and (TAR) through, into and from the surface, set the circumstances for the appearance of the colours in the space. The sensitivity of the individual user in the channels in to the central nervous system is the foundation for the individual experience of visual comfort.

Step four of the lighting design process: In the fourth step of the lighting design process is the information from the first, second and third step of the LDP used to make the design of the practical application that fits the space and the user in a way that gives a comfortable visual environment. In step four is the technique chosen that gives a well lit space and visually attractive colours despite the changes in spectral profile and level of light during the day.

4. Results

- The literature review shows that the European standard is said to give all normal sighted workers in Europe an experience of visual comfort [Sater 2012].
- Visual comfort is in a study performed at Jonkoping University [Säter 2011, 2012] shown being an almost unique experience. 314 of 318 subjects did unique combinations of the level of light at the worktable and for the ambient light, evaluated as the most visual comfortable. At the same time is shown that the individual preference for level of light evaluated as visual comfort is changing during the day.
- A reason to the differences in preferences for visual comfort is the physiological fact that the sensitivity into the central nervous system differs between subjects [Ingvar 1981].
- Colours is mentioned by Liljefors [1999] as changed in appearance related to the electromagnetic radiation present in the space and by transmission through, absorption into and reflection from the surfaces in the space.
- If the effect of TAR is taken into accountancy in the work with the colour scheme and within the four steps of the LDP, the photon flows in the space will be dimensioned in a way that is suitable to give a beautiful appearance and a visual comfortable experience for the user with high sensitivity into the central nervous system.
- Colour is related to all four steps of the lighting design process.
- *In step one of the LDP* is the effect of daylight and the complementary lighting and TAR according to the colours in the space investigated in changing spectral profile of EMR on the highest and lowest levels of light into the space.
- *In step two of the LDP* is the user's sensitivity (if known) and the levels of light that can appear during the year into the space, evaluated and related to colours on the surfaces and the view through the window.
- *In step three of the LDP* is the design of daylight and the choice of light sources in combination with the effect of TAR, setting the circumstances for the appearance of the colours in the space. The design of daylight and the complementary lighting need to be designed towards the colours and the sensitivity of the individual user in the channels in to the nervous system for the individual experience of looking at lit surfaces and contrasts to contribute to the experience of visual comfort.
- *In step four of the LDP* is the technique chosen that gives a well lit space and visually attractive colours despite the changes in spectral profile and level of light during the day.

5. Discussion of methods and research

It is hard to find articles that describe the lighting design process. Since common knowledge in lighting design is not yet written down in a high extent, it is important to collect this type of

information in a detailed way. The future articles about common knowledge in lighting design need to be analyzed, opposed, criticized and reflected. The process of LDP is developed at Jonkoping University during 12 years of education when I was the Head of the department of lighting science. The literature review can be wider and go deeper into the key questions related to colours as for instance the effect of TAR, daylight and the complementary lighting and the four steps of the lighting design process.

6. Conclusions

The answer to the research question "In what way is the colour scheme related to the lighting design method" can be concluded as colour is crucial for the work with lighting design and related to the all four steps of the LDP. *In step one of the LDP,* colour is crucial since both daylight and the complementary lighting have by TAR an effect on the colours in a way that gives an visual experience of the lit surfaces related to level of light and contrasts that can be disturbing, pleasant or related to pain. *In the second step of the LDP* is colour again crucial since EMR from daylight and the complementary lighting, affect colour, by TAR, in a way that can be related to level of light and to contrasts going from disturbing, pleasant or related to pain. *In the third step of the LDP* is colour also crucial since the design of the amount of photons into the space is done towards the user's sensitivity to levels of light and to look at lit surfaces, contrasts and to the effect of colour and TAR that can give an experience of visual disturbance, pleasure or pain. *In the fourth step of the LDP* is the technical equipment for shadings of daylight and for the complementary lighting application chosen in a way that contribute to the experience of colours in the space being attractive and pleasant in both high and low levels of daylight and in the altered spectral profile of daylight during the day. Additionally is the technique chosen for the shadings of daylight and the complementary lighting and the altered spectral profile in daylight and lighting, in a way that gives visually attractive and pleasant colours into the space. When lighting is designed with only step four in the lighting design process and by the use of a template, the synchronisation of colour and light is not performed. The result from the literature study shows that the work with the colour scheme will be more complicated to handle in the future when daylight is used more as ambient light and when the complementary lighting is used with an altered spectral profile. Light sources that have a high concentration in the spectral profile within the short wavelength area differ in light colours compared to light sources that have a high concentration in the spectral profile within the long wavelength area. Visual comfort is in the same time found out in a study to be an almost unique and constantly changing experience and related to the sensitivity of the channels into the central nervous system. Colours are mentioned by Liljefors [1999] as affected by electromagnetic radiation in the space by transmission, absorption and reflection (TAR) towards the surfaces in the space.

Colour is found related in a crucial way to all four steps of the LDP.

- If the relation of colour and daylight and colour and the complementary lighting is not analysed *in the first step of the LDP*, an important piece of information into the design process that gives visual comfort is missing.
- If the information about the relation of colour and daylight and colour and the complementary lighting collected in step one is not used in *the second step of the LDP*

and related to the span of visual experiences going from unpleasant, pleasant and to pain for the individual user, an important piece of information that is needed to design light in a way that gives an experience of visual comfort for the individual user, is missing.

- If the information of colour and daylight and colour and the complementary lighting and the user's preferences collected in step one and two is not used *in the third step of the LDP* important information is missing that is needed when working with lighting design. Without this information is it hard to set the span of the highest acceptable level of light and the lowest level of light that is appropriate in the specific space and that gives visual comfort of the known or unknown users that stay or will stay in the space.
- If information of the relation of colour and daylight and colour and the complementary lighting, the users preferences and the design of daylight and the complementary lighting is not used *in the fourth step of the LDP* important pieces of information is missing in the work with the choice of the appropriate technique that finally set the span of levels of daylight by the use of shadings of the daylight and by the use of a complementary lighting.

As shown in the study colour is crucial in the work with the LDP. Without designing a by TAR well-functioning relation between colour and light in high and low levels of daylight and in high and low levels of the complementary lighting, the lit environment risk to be unattractive and visually uncomfortable for the user.

It is an important issue for the future to develop a colour scheme that handle daylight on extreme high and low levels in a way that gives both normal sighted and visually impaired an experience of visual comfort and a visually attractive environment and in the same way a safe visual orientation.

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