USER CENTRED LIGHTING DESIGN AND PUBLIC HEALTH

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Two processes for lighting design can be seen in use, the computer calculated lighting design process (CCLDP) and the user centred (UCLDP). When the processes are evaluated in relation to goals set out for lighting design, the CCLDP is done without contact with the individual user or to the colours and surfaces in the room, do not fulfill goals set out for light of visual comfort or light-related health. The UCLDP on the other hand has the possibility to support the individual user psychologically, physiologically and visually (PPV) with light. Recommendations for the UCLDP that support users´ PPV focus on support for light-related visual comfort, homeostatic balance, diurnal rhythm and a release of hormones close to the one seen in the outdoor environment as well as to stay in contact with the daylight at the site where the user lives.

Keywords: User centred lighting design; visual comfort; light-related public health

1. Introduction

The study is concerned lighting design and goals set out for visual comfort and public health. The study describes schematically the differences between the CCLDP and UCLDP method for lighting design and describe recommendations for lighting design that have the possibility to fulfill goals set out for lighting design. In the same way is the process of the buildup of the recommendations for the standard for lighting design described.

1.1Problem area and relevant research

Light sources today are developed to show 15 colours in a way similar to daylight. Since light is as important for humans as air and water, to show colours is only partly supporting the human visual system but supports in the same way in an extremely restricted way humans psychologically and physiologically. Society needs to put high demands on the artificial light that is used as a complement to daylight in order to avoid high costs for medical treatments of lack of vitamin D and future verified medical health problems related to the use of artificial light sources [Pauley 2004]. The same research as performed about vitamin D needs to be done on other light-related health issues in order to see if other diseases can be identified and to find out the magnitude of them as well as the yearly costs for medical treatment [Pauley 2004]. It is likely that light-related homeostatic unbalance and in the same way light–related disturbances in the diurnal rhythm are the start up for diseases psychologically, physiologically, but this is for future research to verify. Pauley argues for precaution in the use of artificial light in the same

way as Hollwich did. Since the vitamin D problem is found out being epidemic in the US by Holick [2005-2011] and Scandinavia is further away from the equator, the situation in Sweden can be similar. Taken together this background points out the benefits of health authorities protecting the use of light, the need for a synchronisation between authorities producing legislation on light and the need for an improvement of the lighting design process. A comparison between the two most frequent methods of lighting design, the computer calculation and the user centred process, shows that the computer calculated lighting design process (CCLDP) do not meet goals set out on light compared to the user centred. The UCLDP has as a focus to create well-functioning connections of man, light, colour and space (MLCS) and support humans PPV. Questions related to recommendations for light put a focus on whom and in what way recommendations for lighting design are developed.

It is not an easy task to find literature about the process of the fulfillment of goals for lighting design. The literature is concerned to a large extent the technical part of lighting design, the design or the user responses and preferences. Aspects on the lighting design process and public health can partly be found in the work of Fritz Hollwich and Dieckhues [Hollwich 1979; Hollwich and Dieckhues 1980]. Hollwich wrote about daylight and artificial light being merely a substitute for daylight and about artificial light mimicking daylight giving less stress response among subjects compared to fluorescent tubes. Steven Pauley [2004] put words on the need of being careful with the use of artificial light. This is an opinion close to the one Hollwich and Dieckhues had. He questions if artificial light has become a health problem. Martau et al. [2010] performed research with the purpose of figuring out the impact from daylight and different light sources when staying at work. Steven et al. [2007] reported about the role of environmental lighting and circadian disruption in cancer and other diseases. Despite research in the importance of daylight from Hollwich and other researchers since 1948, the design of light is still focused on a general technical and visual approach. Research shows the need of daylight in the first hand in lighting design combined with a daylight mimicking artificial light as a complement. In the same way is the development of a lighting design as a tool for the individual user for light-related visual comfort, homeostatic balance and a well-functioning diurnal rhythm. The research in the area points out the need for authorities that produce legislations and recommendations concerning light to cooperate in order to protect the user from a misuse of artificial light. Authorities should promote a healthy use of daylight and of a complementary daylight mimicking artificial light. The way recommendations are build-up needs to be guarded by health authorities as well.

1.2 Aims

The aims in the study are:

-To describe schematically connections of lighting design and public health.

-To describe schematically differences between CCLDP and UCLDP.

-To investigate if goals set out for light in EN 12464-1:2011 or EC Treaty 137 or WHO target 3, 13-17 are fulfilled by the use of CCLDP and UCLDP.

-To develop recommendations for the UCLDP that gives PPV support.
-To describe the process behind the development of recommendations for lighting design.

1.3 Problem formulation

Despite being an important part of all humans' everyday life, connections between lighting design and health are not well known. The interaction of MLCS affects everyone every day and night throughout life but is still not seen described in literature. The process of lighting design, daylight and the artificial light sources used in the design are the tools for society to ensure that all workers in Europe stay in a healthy light. Despite this, the process of lighting design is not seen evaluated from the perspective of the meeting of goals set out for health. The process of lighting design in itself is not often seen described or evaluated in literature. The differences when it comes to PPV support for the end user when staying in the light from a lighting application done by the CCLDP or the UCLDP is not well known. To be able to investigate if goals set out for light in EN 12464-1:2011, EC Treaty 137 or WHO target 3 and 13-17 are fulfilled by the use of CCLDP and UCLDP, more needs to be known about this two typical lighting design processes. Recommendations for lighting design need to be developed in a multidisciplinary group of scientists to be useful as a tool for the decrease of light-related health problems.

1.4 Research questions

In what way can connections between lighting design and public health be described schematically?
How can the use of CCLDP and UCLDP be described and be evaluated from the individual user´s aspect PPV?
Are goals set out for light in EN 12464-1:2011, EC Treaty 137 or WHO fulfilled by the use of CCLDP and UCLDP?
How can recommendations for the UCLDP be formulated in a way that gives a PPV support?
How can the buildup of recommendations for lighting design be described?

2. Methods used in the study

Literature reviews are done in the study on light-related topics, such as photobiology and physiology. The investigation about International commission of illumination (CIE), The European Committee for standardisation (CEN) and Swedish Standards Institute (SIS) was done during 12 years as a teacher in lighting design at Jonkoping University.

3. Results

3.1 In what way can connections between lighting design and public health be described schematically?

The result of the literature review shows that light is fundamental for life on the planet and of equal importance as air and water [Brainard & Hanifin 2005, Hollwich 1979, Hollwich and Dieckhues 1980]. "Better practice now" Pauley argues [2004 p. 593] and mention that recent research indicates that the use of artificial light has become a public health issue. Holick [2005-

11] shows the health consequences of the light-related vitamin D epidemic. When staying in the indoor environment behind windows that do not let through the wavelengths of 290-315 Nm neither daylight nor artificial light contribute to the production of vitamin D. Since the complementary artificial light source is developed to show 15 colours in an appropriate way, 290-315 nm is not supplied from daylight or from the artificial light sources when staying in the indoor environment. Holick mentions:

"*Vitamin D deficiency is now recognized as an epidemic in the United States. Vitamin D deficiency causes poor mineralization of the collagen matrix in young children's bones leading to growth retardation and bone deformities known as rickets. In adults, vitamin D deficiency induces secondary hyperparathyroidism, which causes a loss of matrix and minerals, thus increasing the risk of osteoporosis and fractures. In addition, the poor mineralization of newly laid down bone matrix in adult bone results in the painful bone disease of osteomalacia. Vitamin D deficiency causes muscle weakness, increasing the risk of falling and fractures. There is mounting scientific evidence that implicates vitamin D deficiency with an increased risk of type I diabetes, multiple sclerosis, rheumatoid arthritis, hypertension, cardiovascular heart disease, and many common deadly cancers"[Michael F. Holick 2005-11].*

Roenneberg et al. [2007] show the variability in the wake up time and bedtime among 55,000 subjects. They mention that some subjects go to bed when others go to sleep. The way daylight and artificial light are used in the indoor environment has an impact on light-related homeostatic balance [Hollwich & Dieckhues 1980, p.p. 188-197], diurnal rhythm, hormonal release and production of vitamin D [Holick 2005-11 p.p. 2739S-27341S]. Taken together, these are aspects of human physiology that if disturbed for a long time lead to diseases [Robbins et al. 1984; Davydov et al. 2007; Ingvar 1980 p.p. 53].

"Just as we live in a constantly changing world, so do the cells and tissues survive in a constantly changing microenvironment. The 'normal' or 'physiologic' state then is achieved by adaptive responses to the ebb and flow of various stimuli permitting the cells and tissues to adapt and to live in harmony within their microenvironment. Thus, homeostasis is preserved. It is only when the stimuli become more severe, or the response of the organism breaks down, that disease results - a generalization as true for the whole organism as it is for the individual cell." [Robbins et al.1984].

"Homeostasis is an ideal state of equilibrium, when all the body´s different parts and subsystems is functioning in an optimal way and fulfil all needs of the individual, both psychologically and physiologically. When homeostasis is disturbed, the body tries to recover by, adjusting one or more of the body´s functions. This stress adapting process includes an activating of the HPA-axis (Hypothalamic-Pituitary- Adrenal Axis). A chain of events that control the release of Cortisol which is in a prosaic talk a part of the stressystem in the body that together with the autonomonys nerv system and the endocrinological functions prepares the body for stress. Severe and long lasting stress can lead to an unbalance in the homeostasis. This can lead to not only psychological injury but also psychosomatic symptoms"[Martin Winkler 2008 Web4help, accessed 2012-01-11].

Lighting design holds the possibility to design light in a supportive way for the individual user.

3.2. How can the use of CCLDP and UCLDP be described and evaluated from the individual user's aspect?

The steps of the lighting design process: The process can be described as being done in 4 steps; *Step 1*: Analyses of the space, colours, surfaces, daylight and artificial light in the room. *Step 2*: Analyses of the humans PPV needs and the visual needs for support of activities in the room. *Step 3:* Design of daylight and artificial light in the indoor environment related to the colours in

the room and to the daylight at the site where the user lives. *Step 4*: The design of the lighting application technically. Development of instructions in how to maintain the application.

CCLDP: The computer calculated lighting design process is restricted to use step 4 in the complete lighting design process of step 1-4. CCLDP is done to meet a pre-decided level of artificial light. The design has no connection with the user's sensitivity for viewing contrasts or the humans need for living in the diurnal rhythm, transmission, absorption, reflection (TAR) of the colours and surfaces in the room. The design is concerned with the calculation of light to a specific level. *UCLDP:* The UCLDP uses steps 1-4 in the complete lighting design process and concerns the user's preferences as well as the colours and surfaces in the room. UCLDP focuses on adaption of the amount of light to the individual user's sensitivity and to the colours and surfaces in the room and to the daylight at the place where the user lives. The use of UCLDP has the possibility to enhance light-related homeostatic balance, well-functioning diurnal rhythm and a hormonal release close to the one that can be seen in daylight.
When compared, the CCLDP is a user and space unspecific process and concerns light visually. UCLDP is a user centred, and space specific process.

3.3 Are the goals set out for light in EN 12464-1:2011, EC Treaty 137 or WHO fulfilled by the use of CCLDP and UCLDP?

Goals set out for lighting design in Europe are listed in the following; 1) EC Treaty 137, the health issue within the European Union should be seen as a part of maintenance of the competitiveness of the economy of the Community. In the EU-Charter of Fundamental Rights article 31, fair and just working conditions are addressed. EC treaty 137 concerns every worker´s right to working conditions which respect to his or her health, safety and dignity; 2) Directive 89/391. The aim of the directive is to introduce measures to encourage improvements in the safety and health of workers at work. It applies to all sectors of activity, public and private; 3) EN 12464-1:2011, the standard for indoor lighting and office work and 4) WHO target 3 and 13-17.

CCLDP: The goals for visual comfort or light-related health are by physiological reasons not met by the use of only step 4 of the complete lighting design process of four steps. To create an experience of visual comfort, the amount of light needs to produce a contrast situation in the environment that suits the individual user's sensitivity and changing needs PPV during the day. This is not possible to do with one recommended static level of light. The development of artificial light sources used in the indoor environment is related to showing 15 colours in a good way and not to support humans physiologically. Taken together the use of CCLDP does not meet the light-related goals set out in EC Treaty 137, EN 12464-1:2011 or WHO adapted by Member states of the European Region by the use of CCLDP.

UCLDP: The use of the UCLDP and steps 1-4 of the complete lighting design process possess the possibility to fulfill goals about visual comfort and light-related health. Since the user´s sensitivity and preferences are known as well as the colours and surfaces in the room, the lighting application (LA) will be PPV supportive. Since the LA prioritises daylight, the user will

stay in contact with the light at the place where the user lives. The level of support for PPV is dependent on if a daylight mimicking light source is available on the market or if it is possible to blend the light from different light sources in a way that is similar to daylight while managing technically to follow daylight. The result is dependent on if the light source that is used in the LA is close to the spectral profile of daylight during the day.
The comparison between CCLDP and UCLDP seen as a process: 1) CCLDP= lighting design process (LDP) Step 4= (non well-functioning support for individual users) =NWFS (non well-functioning support of) MLCS=NWFS PPV=NWFS LQ= Low realisation of goals set out (LROGS). CCLDP=LDP Step 4=NWFS MLCS=NWFS PPV= NWFS LQ=LROGS; 2) UCLDP=LDP Steps 1, 2, 3 and 4= well-functioning support of (WFS) MLCS=WFS PPV=WFS LQ =HROGS.
Opposite to the CCLDP is the UCLDP extensive and can be verified by the literature review and studies done in the thesis project in the following way: 1) *the ambient light:* should be designed with daylight and a daylight mimicking artificial ambient light and be in contact with the light at the site where the subject lives. This will provide the subjects with a healthy light physiologically [Hanifin & Brainard 2007]; 2) *Task lighting:* A glare free type of flexible task lighting that has a range from low to high levels of light will support the subjects ergonomically [Ronchi 2009, Säter Paper VI]; 3) *The dimension of PS*: When PS is designed to fit the users of the space and the actual transmission, absorption and reflection in the room according to colour and surfaces, the room will be perceived as visually comfortable [Säter 2011, Säter Paper VI]; 4) *Stay in contact with daylight:* Daylight and a daylight mimicking artificial ambient light in contact with the light at the site where the subject lives will provide the subjects with a healthy light physiologically [Pechaceck, Andersen & Lockley 2008]; 5) *Support the individual visual needs:* A glare free flexible task lighting that has a range from low to high in levels of light will support the subjects in a visually comfortable way [Ronchi 2009; Säter 2011]; 6) *Designed related to the colours and surfaces in the room:* When PS is designed to meet the actual transmission, absorption and reflection as well as the colour and surfaces in a soft way, the room will be perceived as visually comfortable [Liljefors 2010]; 7) Designed *to suit the subject's diurnal rhythm:* The information from daylight about the start up and end of the day should reach the user.
Design of well-functioning connections of MLCS and reaching of goals for light: Well-functioning connections of MLCS engage the four steps in lighting design. If some of these are excluded, goals for the lighting design will not be reached.

3.4 How can recommendations for the UCLDP that gives PPV support be formulated?
Based on common knowledge, the studies in the thesis and the literature review the following recommendation is developed; 1) Use all four steps in the general lighting design process and create an individual PPV support [Pechaceck, Andersen & Lockley 2008]; 2) Design a flexible lighting application with daylight mimicking light sources that suits the users´ needs during the day and as well as an ambient light that prioritises daylight and uses as little artificial light as possible [Hollwich 1979]; 3) Pay attention to the onset and offset of the diurnal rhythm and help the subjects to stay in contact with daylight and with the daylight rhythm [Wirz-Justice &

Fournier 2010]; 4) Ensure that the artificial light has more emitted wavelengths from the area around 530 Nm in the morning and 450-600 Nm during the day [Pechaceck, Andersen & Lockley 2008]; 5) Increase the amount of middle and long wavelengths in the afternoon. Follow the rhythm of daylight for the season to a certain lowest level of light for security and pleasure in the environment [Hollwich 1979]. Make the levels of light suitable to the contrast situation in the specific space [Liljefors 2010].

3.5 How are recommendations for light constructed?

Background to recommendations: Since light is fundamental to humans, animals and plants, it is not positive that the results here revealed show a systematic low redeem of goals for the most frequent used lighting design process (CCLDP). The literature survey shows the following picture of the way recommendations of light are constructed from a Swedish perspective.

CIE, CEN, *and SIS: "The way lighting design is performed is to a great extent regulated by recommendations. Until now lighting in the building process is mainly seen as a practical function needed for visual security and for work tasks. As a result of light being important merely from a visual point of view, light is planned with a predefined specific level of light and with an even light distribution. The static and even light is commonly seen as secure. The Swedish Work Environment Authority is, together with SIS, the main actor in the field of the build up of regulations for lighting design in Sweden. The Swedish Work Environment Authority develops the decree for the work environment law. To promote a secure and healthy light in the work environment is the background for the work with light-related standards. CIE, CEN and the national standardisation committees (SIS in Sweden) together form the standard for lighting used in Europe. CIE has an agreement to deliver reports to CEN. The CEN group writes resolutions. The resolutions are forwarded to the national standardisation committees (SIS in Sweden) for a voting process. The Swedish Work Environment Authority contributes to the build-up of the standards within the SIS National Committee in cooperation with representatives for the companies working with production of luminaries and light sources. Since lighting design is a rather new skill, it is unusual that lighting designers have been involved in the development of recommendations about how to design light. Researchers in lighting design are rare both nationally and globally, so it is not common that researchers work with the development of the standards for lighting. It is those who can afford to travel that have the opportunity to contribute to the technical committees within CIE and CEN and to the national committees of standardisation. The national committees (SIS in Sweden) have no financial opportunities to secure the standards being scientifically proven or to invite researchers to join the work. They have to trust the expert group that attend the meetings at CIE, CEN and SIS. The expert group votes for acceptance of a new member. It is to a large extent the luminaries and light source companies that are travelling to the different meetings and acting as lighting experts. The background for the expert group in CIE, CEN and SIS can in this case be to a great extent commercial with a focus on control of the market for light sources and luminaries. If suitable, it is possible to use the voting process to control if a person will be accepted or not in the national standard committees within SIS and by doing so, the members in CEN. The development of the standard for the use of luminaries and light sources can by the voting process for new members in the national committees and CEN be controlled. If the work of CIE, CEN and the national committees for standardisation becomes directives, the commercial actors have a strong tool to control the market and decide in advance the way their products will be used. When researchers in lighting design are absent, there is a risk that the standard will be developed solely towards the*

interests of the producers and not toward the ambitions of health authorities or the companies that are lighting designers. SIS is a member organisation with a goal to financially promote the members in the organisation.

Swedish Energy Agency: *Good examples for energy efficient lighting applications. The ambition to reduce energy consumed for lighting purposes is another reason for the development of recommendations in the field of lighting and is performed by the Energy Agency in Sweden. It is seldom lighting designers or researchers trained in the four steps of lighting design that work as consultants to the Energy Agency when writing recommendations. It is more often engineers in general not trained in any of the 4 steps of lighting design and representatives for companies that is trained in the first hand in the fourth step of the LDP that are seen as experts and help out the authorities with the development of recommendations.*

Recommendations from the producers of luminaries and light sources: *Representatives from the industry have developed recommendations for the standard for indoor lighting. The text describes man, light and lighting quality. The standard with predefined static levels of light is added to the text. [Ljus och Rum, SIS]. These two perspectives contradict each other.*

Hierarchy of recommendations: The hierarchy of the national recommendations shows from a Swedish horizon that the work environment department´s decree for the work environment law is of the highest range and mandatory at penalty all other recommendations developed by CIE, CEN, SIS, the Energy Agency and the producers of light sources and luminaries is voluntary to use. The only mandatory with a standard is if the standard is accepted it will be the only standard used for the purpose nationally. The standard can be used in the building process as a demand and a reference to if the lighting is satisfactory or not (at penalty). On a European level the EC Treaty 137 is of the highest range in law for light-related health for the working environment and the EN12464-1:2011 is the only standard (recommendation) in use for indoor workplaces within the EU. [Monica Säter].

4. Discussion of results

The results show two typical processes of lighting design. CCLDP is not a user and space specific process, nor related to daylight and without PPV support for the user individually. UCLDP is user and space specific process, related to daylight and has PPV support for the user individually PPV. It can be discussed if the CCLDP is more neutral and usable for the unknown user compared to the UCLDP. Studies in visual preferences contradict the argument. Differences in the range of 50 times and a constant change in preferences for light during the day can be seen in literature [Säter 2011]. However, it is stated in the law that all workers are guaranteed a healthy environment, and this includes a well-functioning connection between MLCS individually; and results show that this cannot be done with the CCLDP but is possible with the UCLDP.

4.1 Discussion of methods

The method used is a literature review. The review can be increased in multidisciplinarity and include more aspects of the interaction man and light.

5. Conclusion

The way connections between lighting design and public health can be described schematically is here concluded : Connections between lighting design and public health can be described schematically: 1) visual comfort (eyestrain, fatigue, headache); 2) light-related homeostatic balance (disturbance of homeostatic balance) ; 3) light-related well-functioning diurnal rhythm (sleep disturbances, tiredness); 4) light-related hormonal release (too low or too high levels of hormones compared to in daylight). Syntetisation of Vitamin D (too low levels in the bloodstream).

The use of CCLDP and UCLDP described and evaluated from the individual user´s aspect PPV is here revealed: The CCLDP described as a process; 1) CCLDP=LDP Step 4=none well functioning support of man, light, colour and space (NWFS MLCS) = NWFS PPV= NWFS of Lighting quality (LQ) =Low fulfilment of goals set out (LFOGS); 2) UCLDP=LDP Steps 1, 2, 3 and 4=WFS MLCS=WFS PPV=WFS LQ =HFOGS.

If goals set out for light in EN 12464-1:2011, EC Treaty 137 or WHO are fulfilled by the use of CCLDP and UCLDP is here revealed: The goals set out for light about visual comfort and light-related health in EN 12464-1:2011, EC Treaty 137 or WHO are not fulfilled by the use of CCLDP, but UCLDP has the possibility to do so.

Recommendations for the UCLDP that gives a PPV support is here formulated:
Recommendations for the UCLDP based on the literature review: 1) Use all four steps in the lighting design process and create an individual PPV support [Pechaceck, Andersen & Lockley 2008; Paper X]; 2) Design a flexible lighting application based on daylight and equipped with daylight mimicking light sources that suits the users´ needs during the day. Create an ambient light that prioritises daylight and uses as little artificial light as possible during the day [Hollwich 1979]; 3) Pay attention to the onset and offset of the diurnal rhythm and help the subjects to stay in contact with daylight and the rhythm in daylight at the site were the subject lives. [Pechaceck, Andersen & Lockley 2008; Wirz-Justice & Fournier 2010]; 4) Ensure that the artificial light emits wavelengths around 530 Nm in the morning and 450-460 Nm during the day [Pechaceck, Andersen & Lockley 2008]; 5) Increase the amount of light emitted from middle and long wavelengths in daylight in the afternoon. Follow the rhythm of daylight for the season to a certain lowest level of light (for security and pleasure) [Hollwich 1979]. Make the levels of light suitable to the contrast situation in the specific space [Liljefors 2010].

The buildup of recommendations for the standard for the design of lighting applications can be described in the following way: Technical committees in CIE deliver information to CEN that write resolutions to the national standards organizations. The standard originations vote for implementation in the standards. The standard is renewed each fifth year. CIE is a scientific

organization that is opened for non scientists and the work is on a voluntary basis. The members in the technical committees are in a high extent commercial and from producers of lighting equipment. By the voting process in the national committees can the commercial members be in a majority.
There are no financial resources in the national standardorganisation to secure that the standard is scientifically correct. The standard is the only standard allowed nationally.
The standard is related to ergonomics in the standardiasation committees. The goal for the development of the standard is to benefit the member organizations financially.

The standard state that the use of the recommendation of the standard gives visual comfort and a good performance for the European workers (a population of 502 millions 2011, the third largest population in the world after China and India). The study reveals that the recommendation in the standard do not give 1 single worker a visual comfort or a good performance or light-related health and as a conclusion of that nor fulfill the needs of the other of the workers in the population of 502 millions in Europe. The standard need by that is developed in a way that makes the goal visual comfort and light-related health possible to fulfill.

The build-up process of recommendations for lighting design is, in the literature review shown to be of high importance to society [Holick 2005-2011]. The way we choose to design daylight and develop a complementary artificial light will decide the medical cost for treatment of light-related problems. Lighting design has in the same way the possibility to reduce the costs for this treatment [Holick 2011]. It is likely that the cost for lighting design is negligible compared to the yearly medical costs for medical treatment for light-related diseases. Improvement in this field will make Europe more competitive.

5.1 Future work

The process of lighting design should be developed by research with the goal to decrease light-related public health problems such as lack of vitamin D, light at night (LAN) and disturbances in diurnal rhythm and homeostatic balance. Research in the interaction of MLCS is needed. The interaction should be investigated and connections identified that gives a good PPV support and reduce light-related public health problems initiated by the misuse of artificial light.

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