

Lighting quality in hospital wards - State of the art

Design parameters for a pleasurable light atmosphere

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by

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[Abstract]

When constructing and designing hospitals for the future, patients, staff and guests are in focus. Designing a healing hospital environment is a very important factor when planning new hospitals. How can aspects such as design, architecture, arts, lights, sounds and materials support and improve the patients' recovery rate and the satisfaction of staff and guests?

Literature and research on this subject are full of contrasting theories, myths and contradictions as well as lack of understanding of the interplay between different design parameters in an integrated design.

The physical settings, the furnishing, the acoustics and light are essential in evaluating of the experience of an environment. The light is crucial for the physical and psychological experience of wellbeing and the feeling of safety.

The ward is a complex and interesting architectural space to design. It has a wide range of functions and a multitude of users with many different needs and requirements. It is a public domain with many references to the design of homes in the private sphere.

The aim of the report is to display the existing research in the area of lighting design in hospital wards, and to present new lighting design strategies focusing at the dynamic qualities of light, and the lights ability to support a pleasurable light atmosphere at hospital wards.

[Designing Hospital Environments]

Our familiar understanding of light and our culture of using light affect our assessment of the surroundings. To create attractive surroundings, we should aim the consistency between our expectations and our experience.

The quality of the lighting design is mostly measured and evaluated in levels and horizontal light distribution. The written standards Danish Standard (DS700)¹ for visual experience including with other sensory perception is often hardly described, equivocal and without specific requirements. The quality of experienced light needs to be specified and integrated in future regulations of lighting standards.

What kind of dynamic light qualities are relevant to the experience of a pleasurable light atmosphere? What kind of natural connection is beneficial for patient recovery? Is there an interesting inspiration for lighting design that respects the connection between our daylight experiences and the way we use artificial lighting? Is there a greater likelihood of achieving wellbeing when we see consistency in the dynamics between daylight and artificial light?

With a holistic approach for lighting design in hospital wards, I will present the model "design parameters for a pleasurable light atmosphere in hospital wards" as the framework of this State of the art showing some of the research that has been done in this field.

Guidelines

There are a number of research projects studying single issues of lighting design. Literature and research are full of contrasting theories, myths and contradictions and has a lack of understanding of the interplay between different design parameters in an integrated design.

Recently a focus on research in healing architecture and hospital design has been done. Ulrich et al² conduct a study to link "healing" hospital design to patient outcomes. The effects of physical environment have been paradigmatically categorized into a general research subject.

The areas are:

- Reducing stress and effectiveness in delivering care
- Patients safety
- Reducing stress and improve outcomes
- Improving overall health quality.

Mullins et al, 2009³ presents in the report "Helende arkitektur"(Healing Architecture) a review of hospital research and outline the potentials for research areas in evidence based hospital design. They summarize the present challenges for the Danish healthcare system and the design of new hospitals in the nearest future.

The model categorizes the three primary levels respectively: Physical environment, factors and consequences. The model's central starting point is the factors. By turning up those parameters and down for it affects both decisions about the overall physical environment and the extent and severity of the physiological, psychological and economic consequences.

- Physical environment: (Location, disposition, plan, interior design, materials and equipment).
- Factors: Body (light, art, sound, air and locomotion), relationships (personal space, social space, outdoor), safety (hygiene, damage and defects).
- Consequences: Physiology (Healing, Pain, immune response, infection, sleep, circadian rhythm, appetite, exercise, length of hospitalization, re-hospitalization, medication errors, Accident / decrease, mortality) Psychology (Comfort, stress, anxiety, calmness, distractions, trust, confidence, depression, seclusion, mourning, control, access, satisfaction, communication, concentration, motivation, mood / happiness, orientation). Financial (sick days, economic, work-related injury, resignation).

Veitch, J.A, (2008)⁴ is mounting evidence that the conditions of buildings can have an influence human health. Currently the topic includes in-door exposures to lighting, noise, and chemicals, the availability of windows;

and, overall housing quality. Veitch demonstrates the connection between light settings and wellbeing. And say: "People who rated the lighting as of higher quality (regardless of the type of lighting they experienced) considered the environment to be more attractive, were happier, and had better health and well-being on the form of less discomfort and greater satisfaction with their environment and their work".

Dirckinck-Holmfeld et al (2007)⁵ emphasize the importance of a more holistic and stimulating approach for hospital design. A stimulating environment combined with the technology and staff knowledge will assist a healing process for the patients and provide better working conditions for employees. He list different epochs of Danish hospital design and present the "aesthetic hospital" with fantastic aesthetic design but many hygienic problems and the 70s "machinery hospitals" focusing on the function. The general conclusion is, that there are many parameters affecting our evaluation of the hospital environment.

Van de Glind (2007)⁶ summarizes the history of "patient-centred care" and "healing environment" and concludes that the concept emerged in the early 1990. Lately a greater emphasis has been placed on the impact of patients' physical and psychological comfort on healing and satisfaction. Glind mention examples as light and sight, sound, ambiance, (fresh) air, green and nature, ergonomics, and nourishment.

Department of Health (DoH) Simpson M (2004)⁷ shows that over the last 15 years, throughput per bed has increased by 150 % - and over the last 30 years, the average length of stay has dropped from 16 days to 6 days. Patients who have greater access to daylight have shown improved recovery rates, so the benefit of windows, or artificial daylight systems, is important in the design. In addition to lighting design at wards a more social elements to the lighting should be added.

Dalke, 2006⁸ presents a guideline for colour and lighting design in hospitals environments commenting literature and research in the field of "Colour and lighting in hospital design". She found it full of contrasting

theories, myths and contradictions and a lack of understanding the interplay between different design parameters in an integrated design.

Further she says colour and lighting design have not been established as a definite cure for illness, but certainly monotony and poor conditions in premises that have not been refurbished with any care, have had a detrimental affect on recovery rates and staff morale.

To improve the effect of the visual environment of hospitals the main strategy is to provide tools for the specifiers and staff who may be empowered to managing change within the hospitals. Some of the benefits will be improvements in:

- Ambience
- Confidence and safety
- Accessibility and inclusion
- Attractive environments and visual stimulation
- Stress reduction
- Sense of place and spatial orientation
- Enhanced patient recovery, staff productivity
- Ease of navigation and way finding
- Energy efficiency
- Compliance with the Disability Discrimination Act
- Empower specifiers and design teams
- Corporate badging of key areas

Dalke demonstrates that a well balanced and attractive environment is of major importance to patients' health is not a new idea. Florence Nightingale observed "a variety of form and brilliance of Colour in the objects presented to patients are an actual means of recovery.

Foqué et al ⁹ note that it is a complex and challenging condition for designing an attractive and stimulating recreational environment. It is important to have a holistic approach to the problem and consider the importance of age, mental and physical conditions, the stressful and burdensome working environment for the staff, the high tech of the medical profession versus the family atmosphere of a home, functional yet friendly facilities focused on wheel chair, etc.

Tackling the design problems with a set of straight conditions and a focused strategy.

According to Altieri (2004)¹⁰ the incorporation of a healing environment into the health care setting not only optimizing clinical care and outcomes, it also optimizes staff satisfaction, morale, retention, and fosters repeat business. He pointed out, that certain design choices and strategies work for or against the wellbeing of patients and staff and that health care environments can lower stress and support wellness if they are designed to foster calming physical social surroundings and promote access to social supports.

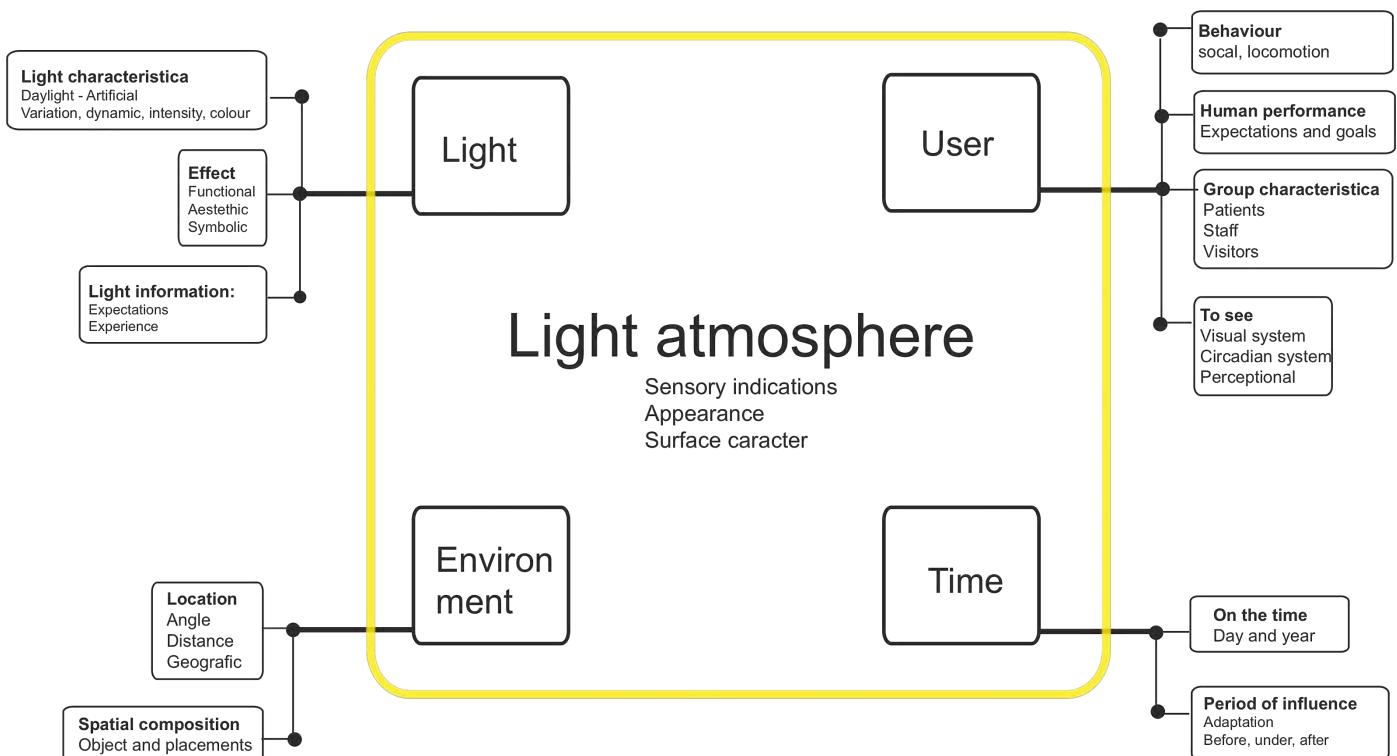
In the following chapter a model of the important factors in qualifying a pleasurable light atmosphere is presented and explained. The purpose of the model is to display the parameters influencing the judgments of the lighting design and form the basis parameters of a pleasant hospitalization; achieve an attractive experience of the ward for the patients and a better working space for the

staff. The model will include the areas: Atmosphere, User, Environment, Light and Time

The model constitutes the outline of the state of the art and is displaying the perspectives for lighting design parameters for a pleasurable light atmosphere in hospital wards.

Many research projects investigate separate important factors of the quality of lighting design in many different settings. Looking at the quality of lighting design as a polyphonic analyze, and by upgrading the light as important factor as a parameter and promote the sensory similarity, the wards identity and ambience can easily change and the possibility of chance of mood is present. The ward atmosphere can be changed in relation to users perception.

Figure 1: Design parameters for a pleasurable light atmosphere



[Atmosphere]

To achieve a comfortable light atmosphere in a hospital ward, we need to define the concept of atmosphere. Böhme, G (1993)¹¹, Böhme (1993)¹², Böhme (2007)¹³, Albertsen, N. (1999)¹⁴ present an aesthetic theory of atmosphere and a category "bodily sphere". The bodily representation in the environment are placed in line with other objects and viewed in a perspective based on embodiment, the human body and a bodily locomotion from here and out in the room. The subject is observed as involved in the surroundings and it is a part of the room existential nature. The bodily involvement is the way a subject is present in the environment, and the way the subject is aware of others thing than the subject in the room. – Böhme defines atmosphere in three categories:

- The sphere of action
- The sphere of mood
- The sphere of sensory perception

By defining the bodily sphere Böhme place the body in a central position in relation to environment and objects in room. The body is no longer on par with other objects, but become the underlying basis for human meeting with the surroundings. There is thus something more at stake than the "measurable" elements that were found in both "sphere as the production medium" and "the presence of bodily sphere".

The body is storing sensory experience from previous meetings with spaces, surfaces and materials. It recognizes the material, even in a new context. The body expects the appearance of environment is consistent with previous experience. The physically touch of a material is not necessary for recognizing that. The body perceive it and go out beyond its borders in order to "feel" / and recognize it from a distance as with this example: A soft "wodden" sofa produced by Moroso.



Figure 2: "Soft Wood" sofa, seen at Moroso Stand at the Furniture Fair 2009 in Milan. We expect to sit at a hard wooden bench, but in reality it is a soft bench with a printed fabric with the motive of wooden structure.



Figure 3: "Soft wood" sofa at the furniture fair 2009 in Milan, Moroso.

The subject relates basically by a bodily presence. The bodily sphere is a substantive human attendance sphere and the body transcendence constant body boundaries. Our bodily presence has an emotional dimension. The bodily experience and extensive is not emotionally neutral, but have an impact on our state of mind. It is based on how we find ourselves in the space that we sense. The characteristic of the environment we live in and the way we perceive it.

If the aim is to describe how the body emotionally involve us in an environment and an absolute "here" appears. Since architecture is "true" experience instruments consist of creating a bodily feeling, "where" you are, and the architectural design of space to influence the 'how' you are. This is "how", according to Böhme argument appears in precisely the concept of atmosphere where it open new perspectives in architecture - both

from a perspective of understanding the way it is practiced. Architecture is a kind of art rather than a visual art form.

There should be an understanding of the spatial structures of the building for people experiencing "something".

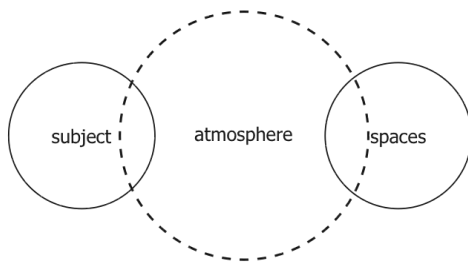


Figure 4: Peter Dalsgaard and Karen Johann Kortbek,s model from the article: "Staging Urban Atmospheres in Interaction Design"

Peter Dalsgaard and Karen- Johanne Kortbak¹⁵ supplemented a social factor "The others" and technology to Böhmes model and tells that this factors is contributing to have an effect in a design context. They point out that time is essential because atmosphere is a procedural phenomenon.

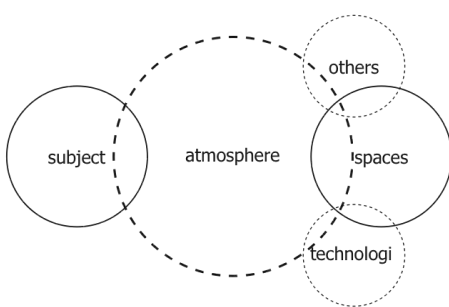


Figure 5: Peter Dalsgaard and Karen Johann Kortbek,s model from the article: "Staging Urban Atmospheres in Interaction Design"

Zumthor, Peter. (2006)¹⁶ An approach is used to tell that we perceive atmosphere through our emotional sensibility - a form of perception that works incredibly quickly, and which we humans evidently need to help us

survive. The big question is "What is the magic of the Real"?

Jørgensen, K.N (2009)¹⁷ studied the associations between ward atmosphere and patient satisfaction and outcome. The result showed that differences in the treatment environment between the ward units were associated with differences in patient satisfaction. There was mixed evidence for associations between atmosphere and outcome, while no associations were found between ward atmosphere and self-efficacy and life satisfaction. The result showed that the relationship between ward atmosphere and outcomes of treatment might be of a more indirect character than the relationship between ward atmosphere and satisfaction.

Stamps, A. (2007)¹⁸ purpose in his experiment was to estimate the strengths of the relationships between judgments of mystery an amount of light, depth of view, and occlusion whether visual and locomotive occlusion or just visual occlusion The experiments showed that light had the largest effect on mystery, followed by occlusion of both vision and locomotion. This experiment attempts to explore that mystery by identifying properties of the physical environment that predict impressions of mystery.

Looking at Dalsgaards-Korbeks model I find it necessary to expand the model of atmosphere with the categories Socio Culture and with the timeline Dalsgaard-Kortbek proposed. The Socio Culture is an important category because of our different cultural understanding of our surroundings and it is placed somewhere between atmosphere and subject. The timeline is important because the experience of atmosphere is momentary.

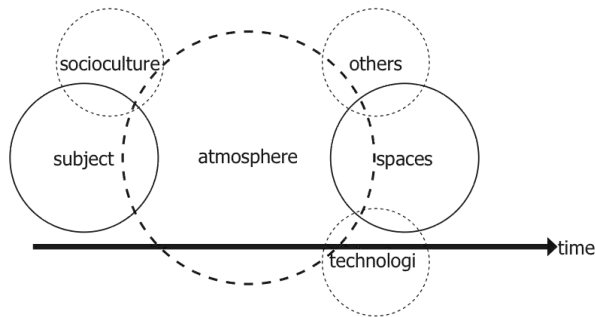


Figure 6: Sofie Bech and Lone Stidsens model presented at Aarhus School of Architectural studying "Atmosphere", Researchers, PhD students and teachers.

The atmosphere of the ward is crucial for the users (patients, relatives and staff) experience of wellbeing. The different user groups have individual preferences and needs to support. In the following chapters I will introduce main categories "User", "Space", "Light", and "Time" and display the important parameters for holistic approach to lighting design and how they can provide the opportunity of achieving a pleasurable light atmosphere at a hospital ward.

[Users]

The users of the ward are the focus point in a light evaluation or lighting design. The environmental appraisal is important, the experience and expectations of the light is individual, there are different types of users and our perceptual, circadian and visual system is important to know.

Kaplan, R. (2001)¹⁹ presents an Information-processing model of environmental appraisal: The extent to which information is available in the scene is central to our appraisal. People need to make sense of what they see and to become involved in it. The four dimensions of appraisal in their model are:

- Coherence (presence of information)
- Legibility (presence of information)
- Mystery (the need to be an active interpreter of the information)
- Complexity (the need to be an active interpreter of the information)

Jordan, P.W (2000)²⁰ divide pleasure presents four categories:

- physio pleasure
- socio pleasure
- psycho pleasure
- ideo pleasure

Experience and expectations

We use all our senses to experience and enter a environment. We are using all our senses at the same time, and trying to connect the information's from the senses. We try to create a line of sensory information. The body doesn't only rely on the senses, but attempts to form links between the senses - a sensory integration. Consciously or unconsciously we decide whether we like being in a room and thus relax, or whether the body must adapt to the surroundings.

Architect and lighting designer James Carpenter²¹ point out two levels of information of light telling us about our world, and an "conscious observation" that becomes the framework for our memory and then "unacknowledged visual information" that becomes the substance of our dreams.

Our experience with light and our dream of the light we wish to see is important for our perception of light and appraisal of its quality. James Turrell's light installations give gestalt theoretical explanations of our experience. If there is a connection between our "inner light" and "external light" we will accept the light setting and maybe do not see it or recognize it as an important factor. We see everything as it is used to be and it won't trick the expectations for the accordance of inner and external light. James Turrell²² writes: "There is a light that has a clarity as great or greater than the daylight vision, and a lucidity of colour that is beyond how we see colour now. It has a fully formed vision, with characters involved and everything else – this is a seeing that is totally present and it is with the eyes closed. I'm interested in the point where this imaginative vision meets the seeing that comes from what we want to think of as outside physical reality – how we function. And a lot of the places I do will at times be on the edge of how we think about reality.

Human performance

Lighting conditions can affect task performance through three systems,

- The visual system,
- The circadian system, and
- The perceptual system.

The physical environment, the organization structure, can influence the affect. There are different ways that lighting conditions can affect the environment. Boyce presents in Human factors of lighting design three routes of how lighting conditions can affect work: He explains the difference between task performance and visual performance, the affect through the circadian system and the affect through the perceptual system. Boyce²³ presents in his model conceptual framework setting out the three routes whereby lighting conditions can influence human performance

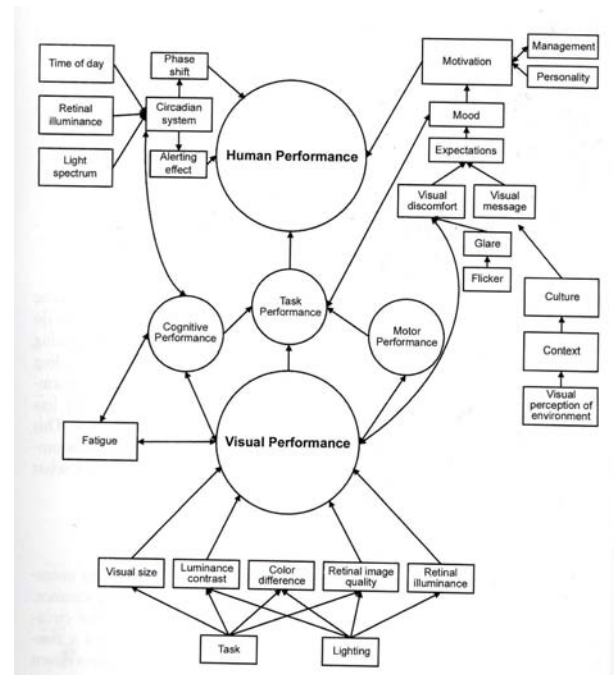


Figure 7: Peter Boyce model: A conceptual framework setting out the three routes whereby lighting conditions can influence human performance. The arrows in the diagram indicate the direction of effect.

There are many ways to stimulate the visual system, but any stimulus to the visual system can be described by five parameters and they are important in determining the extent to which the visual system can detect and identify the stimulus. The parameters imply the interaction between the object to be seen, the background against which it is seen and the lighting of both object and background that determine the stimulus the object presents to the visual system and the operating state of the visual system. It is the stimulus and the operating state of the visual system that determine the level of visual performance achieved. The visual performance then contributes to task performance.

- Visual size: Usually given by the solid angle the stimulus subtends at the eye. The solid angle is given by the quotient of the areal extent of the object and the square of the distance from which it is viewed. The larger is the solid angle, the easier the stimulus is to detect.
- Luminance contrasts: Expresses its luminance relative to its immediate background. The higher the luminance

contrasts, the easier it is to detect the stimulus. There are different forms of luminance contrasts, so it is important to know which definition is used.

- Colour difference: It is possible to have zero luminance contrast which still can be detected because it differs from the background in colour. Colour difference only becomes important for detection of an object when luminance contrasts are low, although colour can be an important factor for enhancing visual search. Lighting can alter the colour difference between the object and its background when light sources with different spectral contents are used.
- Retinal image quality: The sharpness of the stimulus can be quantified by the spatial frequency distribution of the stimulus. A sharp image will have high spatial frequency components present: a blurred image will not.
- Retinal illumination: The state of adaptation of the visual system and therefore alters the capabilities of the visual system. Produced by a surface luminance is determined by the equation.

Visual comfort and discomfort:

The light is important for visual comfort and discomfort. The definition of visual comfort is: The absence of visual discomfort. Boyce²⁴ The characteristics of visual discomfort are “large differences”. People have expectations about all sorts of things in life, from relatively simple pieces of hardware such as cars and computers to more sophisticated concerns such as healthcare and personal relationships, and these expectations are likely to change over time. There is no reason why lighting should be exempt from such shifting expectations. The problem comes about because different people, in the same or different cultures, have different experiences and hence different expectations.

Veitch and Newsham²⁵ found that the effect of expectations is evident in an attempt to get lighting designers worldwide to rate the quality of lighting in a series of offices furnished with the cubicle systems common in North America. Separating the reactions of designers working in North America, who had

experienced similar installations to those presented, from the non-North America designers who had no such experience, could only produce agreement? Visual discomfort is dependent on context and the determinants of visual discomfort cover the whole visual field. It separates visual discomfort from visual performance.

The general causes of visual discomfort are:

- Visual task difficulty: Any visual task, which has visual stimuli close to threshold, contains information, which is difficult to extract. This in itself leads to headaches and fatigue.
- Under- and over-stimulating: Discomfort occurs either when there is no or little information to be extracted or when there is an excessive amount of repetitive information.
- Distraction: The human visual system has a large peripheral field, which detects the presence of objects that are then examined using the small, high-resolution fovea. For these systems to work, objects in the peripheral field, which are bright, moving, or flickering, have to be easily detected. If, upon examination, these bright, moving, or flickering objects prove to be of little interest, they become sources of distraction because their attention gathering power is not diminished after one examination. Ignoring objects, which automatically attract attention, is stressful and can lead to symptoms of visual discomfort.
- Perceptual confusion: The visual environment consist of a pattern of luminance's, developed from the differences in reflectance of the surface in the field of view and the distribution of illuminance on those surfaces. Perceptual confusion can occur when there is a pattern of luminance's present, which is solely related to the illuminance distribution and conflicts with pattern of luminance associated with the reflectance of the surface.

Specific causes of visual discomfort:

- Uniformity:

- Glare: suggested eight different forms of glare: “Flash blindness”, “Paralyzing glare”, exposure to light bright enough to cause retinal damage, “Distracting glare” produced by bright, flashing lights in the peripheral visual field. “Dazzle or saturation glare” when a large part of the visual field is bright. “Adaptation glare”, “Disability glare” when a range of luminance’s simultaneously present in the visual field. “Discomfort glare” when a range of luminance’s simultaneously present in the visual field. “Veiling reflections”, “Shadows” and “Flicker”

The visual system

The visual system consist 2 parts. An “optical system” that produces an image on the retina of the eye, and an “image processing” system that extracts different aspects of that image at various stages of its progress up the optic nerve to the visual cortex, while preserving the location where the information came from.

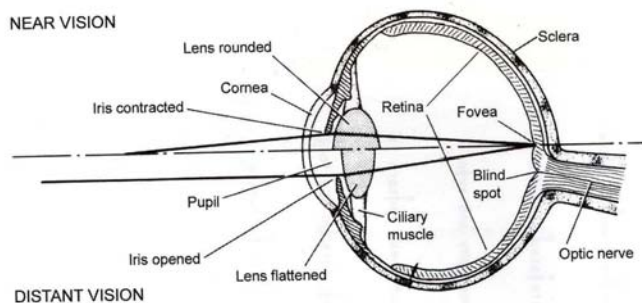


Figure 8: A section through the eye adjusted for near and distant vision (Boyce, P. page 48)

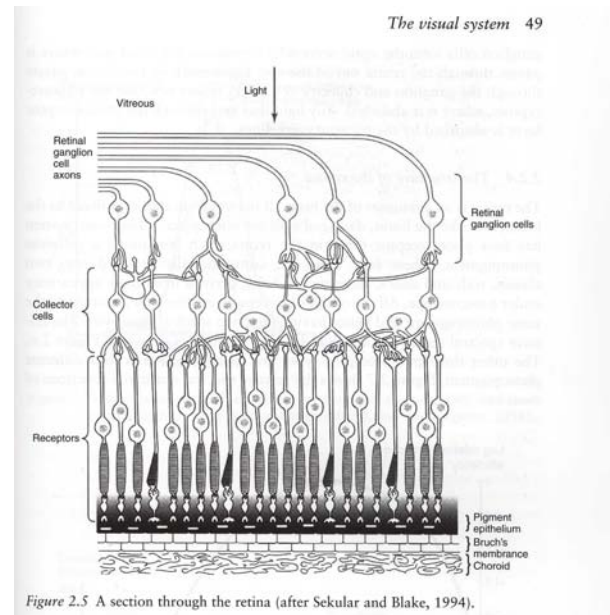


Figure 9: A section through the retina (after Sekular and Blake, 1994) Boyce, P page 49

The visual system can operate over a wide range of luminance’s, from sunlight to moonlight and starlight. The amount of light from daylight to darkness, takes the visual system through three operating stages: The “photopic” (fine discrimination of size and colour can be made), the “mesopic” (The ability to make these discriminations deteriorates so that the time the scotopic is reached), and the “scotopic” (colour can no longer be seen, details are impossible to discriminate and the fovea is blind).

The visual system devotes most of its resources to analyzing the central area of the retina, particularly the fovea. This implies that peripheral vision is mainly devoted to identifying something that should be examined in detail by turning the head and eyes so the image of whatever it is falls on the fovea.

That lighting conditions can affect work is not necessarily the same as the way it affect the visual performance. Task performance is the performance of the complete task. Visual performance is the performance of the visual component of the task. The effect of lighting on the performance of a specific task depends on the structure of the task and specifically the place of the visual component relative to the cognitive and motor components.

Most visual task has three components:

- Visual component: The process of extracting information relevant to performance of the task using the sense of sight.
- Cognitive component: Process by which sensory stimuli are interpreted and the appropriate action determined.
- Motor component: process by which the stimuli are manipulated to extract information and/or the actions decided upon are carried out.

The three components interact to produce a complex pattern between stimulus and response. Every task is unique in its balance between visual, cognitive and motor components and hence in the effect lighting conditions have on task performance.

The perceptual system.

The thresholds define the limits of the capabilities of the human visual system, but we spend the most of our life looking at things that are well above threshold and hence clearly visible. The topic is how we perceive these myriads of stimuli.

The perception of the visual world is not solely determined by the physical stimuli presented to the visual system as the retinal image, or by the characteristics of the visual system described above.

Ex: the footprints upside down... we are used to look at things, where the shadow appears from the light above.

The perceptual constancies in light are the four fundamental attributes of an object, which are maintained constant over a wide range of lighting conditions. They are:

- Lightness: Related to a physical quantity, reflectance. It is often possible to distinguish between the illuminance on a surface and its reflectance. To perceive the difference between a low-reflectance surface receiving a high illuminance etc.... It is this ability to perceptually separate the luminance of the retinal image into its components of illuminance and reflectance which ensures that a piece

of coal placed near a window is always seen as black while a piece of paper far from the window is always seen as white, even when the luminance of the coal is higher than the luminance of a paper.

- Color: Physically, the stimulus a surface presents to the visual system depends on the spectral content of the light illuminating the surface and the spectral reflectance of the surface. Two factors need to be separate: the spectral distribution of the incident light and the spectral reflectance of the surface.
- Size: As an object gets further away, the size of its retinal image gets smaller but the object itself is not seen as getting smaller. This is because by using clues such as texture and masking, it is usually possible to estimate the distance and then to compensate unconsciously for the increase in distance.
- Shape: As an object changes its orientation in space, its retinal image changes. In most lighting conditions the distribution of light and shade across the object makes it possible to determine its orientation in space.

There are four modes of appearance. While lighting has an important role in preserving or eliminating constancy, it also has a role in determining the perceived visual attributes of objects. Boyce²⁶

- Aperture mode: This occurs when an object or surface has no definite location in space, as occurs when a surface is viewed through an aperture
- Illuminant mode: This occurs when an object or surface is seen to be emitting light
- Object mode: Volume. This occurs when a three-dimensional object has a definite location in a space with defined boundaries.
- Object mode: Surface. This occurs when a two-dimensional object has a definite location in space with defined boundaries.

There is much about the visual system that remains a mystery. But it is clear that it involves both eye and brain working together. Given lighting conditions that provide enough light with a wide spectral distribution in such a way that how the space is lit can be easily understood, the lightness, colour, size, and shape of objects in the space remain constant no matter how they are viewed. It is only when the information about the space and the way it is lit is restricted or misleading, that these perceptual constancies will break down. Lighting can be used to reinforce or to undermine the perceptual constancies.

The route through perceptual system is through the perceptual system. The perceptual system takes over once the retinal image has been processed by the visual system. The simplest outcome of the perceptual system is a sense of visual discomfort, which may change the observer's mood and motivation, particularly if the work is prolonged. Perception is much more sophisticated than just producing a feeling of discomfort. In a sense, every lighting installation sends a "message" about the people who designed it, who bought it, who work under it, who maintain it, and about the place it is located. Observers interpret the "message" according to the context in which it occurs and their own culture and expectations. Unfortunately, the effect of lighting on human performance mediated through the perceptual system has rarely been studied. Studying the effects of lighting with a wider definition of human performance might be fruitful to the understanding the economic impact of lighting.

Veitch 2001²⁷ pointed that Flynn as pioneer in the field of lighting and behaviour; He argued that the emphasis on lighting and performance is too mechanistic. Flynn used semantic differentials (bipolar adjectives) to study subjective responses to the clutter, uniformity of lighting, and various other qualities of environments. Specifically, what levels of light do individuals prefer?

Veitch critics of work of Flynn's are that it is not clear whether the participants were judging the appearance of the lighting or the appearance of the room. Any confusing about the instructions would add to the random variation in the responses. And his work has never been independently replicated and his sample size was invariably too small for a robust factor analytic solution.

The circadian system:

Circadian rhythms are a basic part of life and can be found in all plants and animals, including humans. The role of the circadian system is to establish and in internal replication of external night and day.

This internal representation is not just a passive response to external conditions but rather prediction of external conditions to come.

The circadian system has lately been a focus for lighting research. It has a major impact on human performance Veitch²⁸, Lockley, Steven²⁹, Logadottir, A & Christophersen, J.³⁰

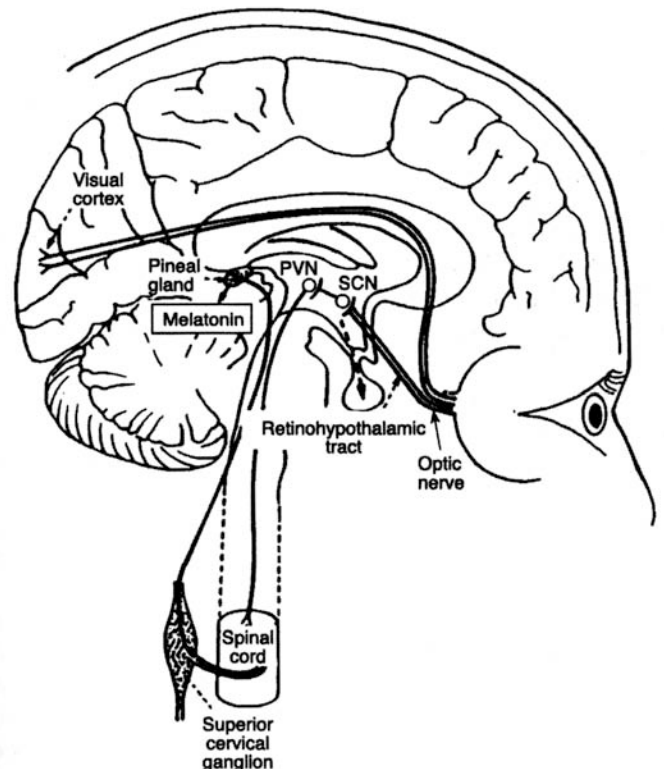


Figure 10: A simplified illustration of the RHP axis (from IESNA, 2000a) Boyce, P page 97

Another route where lighting conditions can affect work is through the circadian system (The sleep - wake cycle). Beneath the surface of the sleep-wake cycle, there is a variation of many different hormonal rhythms over a 24 hour period. Our knowledge of how lighting conditions might affect human performance through the circadian system has grown rapidly in recent years. There are two distinct effects:

- A shifting effect in which the phase of the circadian rhythms can be advanced or delayed by exposure to bright light at specific times.
- An acute effect related to the suppression of the hormone melatonin at night. Both these effects can be expected to enhance human performance in the right circumstances.

Perceived control can moderate stress reactions. Barnes argued that choices about physical environmental conditions could prevent detrimental effects such as feelings of powerlessness and hopelessness. "Veitch, J.A." 2001³¹

Individual lighting controls are, of course, a practical way to accommodate changing task demands, variations in daylight availability, and individual preferences. However, the evidence does not support the notion that perceived control over lighting is inherently beneficial for human wellbeing or performance, in space that have good-quality lighting design.

Butler, Darrell L. 1987³² says that a typically study of illumination have emphasized its effects on performance of specific tasks. Their study examined preference for lighting levels. Among the reasons for investigating preferences is that preference measures theoretically include a variety of human reactions to lighting, including comfort, aesthetics, and performance. The purposes of the experiment were to obtain preferences for lighting levels, judgments of the importance of lighting levels, and judgments about the desirability of controlling lighting level for behaviour settings. Results indicated large differences in the variety of lighting preferred

for various behaviours and settings. Judgments of importance of lighting level had a quadratic relationship to preferred illumination, that is, importance was greater for behaviour settings preferred either dark or bright. Importance and control were strongly linearly related.

Newsham, et al³³ is testing the impact of scales of attraction, non- uniformity scales and brightness scales. They discovered that the relationship was significant with a positive coefficient, the more non-uniform the image, the more attractive it was rated". The research is a part of a larger study sponsored by the Light Right Consortium; temporary office workers spent a day in an office working under one of four different lighting installations. Two of them the workers had the freedom to adjust the lighting of the cubicles they occupied. This paper examines the illuminances chosen under these two conditions, compares the result with those found in other field and laboratory studies, and addresses pertinent questions about the behaviour of office workers when they have the freedom to adjust the lighting of their workspace.

Rowland 2008³⁴ found that the overall message is that people make an environment. The attitude, competence and helpfulness of the staff create the atmosphere of the ward regardless of layout, furnishings, equipment and décor. Patients did feel that the environment had an effect on their mood and wellbeing and discussed the factors that influenced them positively. They wanted small friendly wards where they could interact with others in a light, airy, clean environment and have a view outside or at the very least pictures of natural scenes. These findings concur with earlier studies.

The users of the ward are central in a light evaluation or lighting design. The environmental appraisal is important for the relaxation and recovery process. The users experience and expectations with the light is individual, there are different types of users and our perceptual, circadian and visual system is important to know.



Figure 11: The patient is using the ward in many ways. It is the place they eat, sleep, having visitors and the place where they are talking to the staff.

User types

The users of the ward can be divided into different groups with different purposes, expectations, and functions. The three main groups are the patients (even more accurately separated into two groups: adult and children), the staff (doctors, nurses, cleaning staff), and the visitors (family, friends).

Patients

Glind, I. (2007)³⁵ pointed out that the patients' experience of hospital stay is obviously important. A hospitalization contains some fear and uncertainty about the future. The patients have different expectations and needs. The stay should facilitate the patients' feeling of relaxation, comfort and safety. They should feel that they are visible, and the physical effect of the surroundings is important for the patients' recovery process. Privacy is important.

Simpson³⁶ For patients trying to sleep, night ward lighting should be chosen so as not to suppress melatonin production (it should have a low blue content and low light level). Switching on the general ward lighting during times of sleep may shift the body clock.

During the day, patient alertness will be influenced by the presence of cool light at a higher level. This may be provided by daylight, or where there is a small daylight component, supplemented by artificial lighting during winter months.

The transition between night and day can be made less stressful for the patient by suppressing melatonin production before actual waking occurs. This is related to being woken up by the natural change in lighting at dawn, but which may be missed in a ward or during the winter.

The overall approach is to make the artificial light act in the same way as daylight, in the areas where normal daylight levels will not be reached.

Rowland³⁷ found out that the patients felt that the care environment had an effect on their mood. The view of outside, cleanliness, light and airy is important within the environment: The patients felt that the ward should be

friendly and conducive to interaction and mutual support.

In an interview with Toks Ajeniji³⁸, chief executive of lighting manufacturer Ardent Products, he explains how to use the latest Mood Lighting to create an optimum healing and working environment.

He tells that improving the environment in a hospital ward can cut the recovery time for non-operative patients by 14-21%. According to NHS statistics, mental health patients vacate their beds on average 2.6 days earlier if they occupy sunny rooms. NHS figures also reveal 24% fewer outburst and incidents of threatening behaviour in new wards with more uplifting, less oppressive interior design.

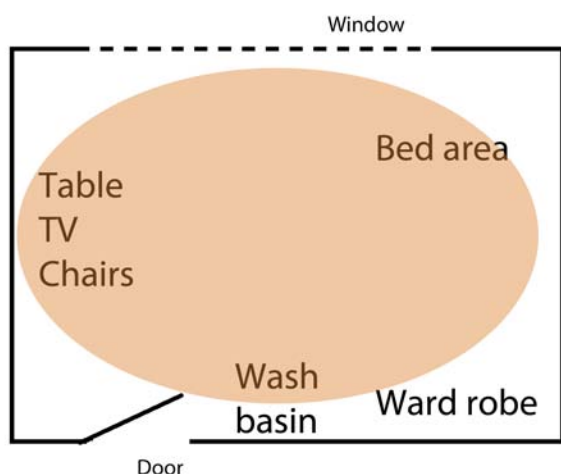


Figure 12: The patients are mainly using this zone in the wards.

Staff

Alongside the patient we need to think about the needs of the staff. For staff, the hospital is their workplace and the light should contribute to creating a pleasant, stress-free environment. The Staff could be divided in sub groups as: Nurses, doctors, cleaning staff, porter or technical staff. For this group there are standards for the light installations to comply.

Simpson³⁹ Hospitals are a 24-hour working environment, with staff constantly changing shift patterns. Where long-term shift working is in place, the biological effects of light can be used to shift the bodyclock of staff.



Figure 13: The staff is using the ward when they are seeing the patient, bringing the food, giving medicine, cleaning the room, changing the installations, and bringing the food or transportation the patients. The Staff could be divided in different sub groups.

For short-term shifts changes or occasional night shifts, phase changes would course problems in re-adjusting to day shift pattern. The staff environment must support professional examination, dialogue and communication with the patients. Their needs are easy workflow and space to do their job. If there is a space for them the will patient also benefits.

The staff's task lighting and how the lighting designer can avoid glare from luminaries so the light would not disturb the patients, and the distribution of luminance at the ward is described.

"Patients have few visual tasks, but need lighting design that makes pleasing surroundings as possible. The staff must have adequate lighting to perform their visually demanding work ". DS 703⁴⁰

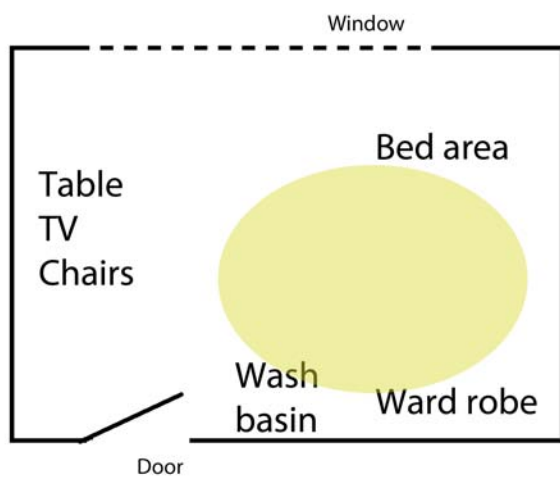


Figure 14: The Staff (nurses and doctors) are mainly using this zone in the wards. Cleaning staff and technical staff are using all area.

Visitors

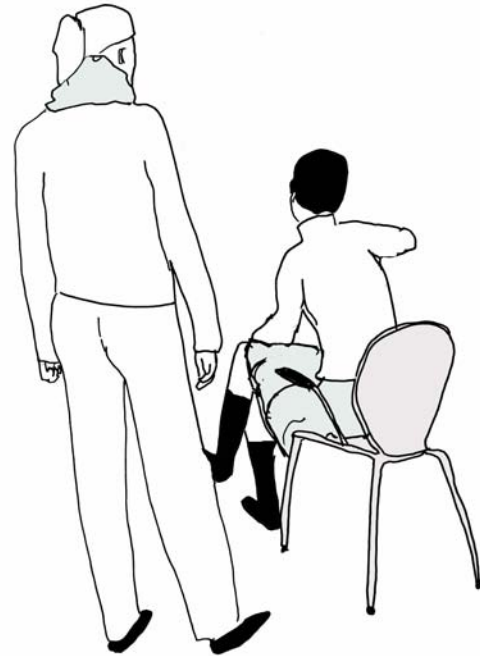


Figure 15: The visitor's appraisals of being with the patients are important factor, also for the patient's experience of a hospitalization.

The visitors should also feel comfortable about being with the patient. Different cultures use the wards in different ways. Some have many visitors at the same time, some few. Knez (1998)⁴¹ study present an investigation of the effects of the recommended office lighting on subjects' mood and cognitive performance on the physical setting of an office. In addition, a gender effect on the performance in the appraisal task was examined, both as a between- and within-subject factor.

Implications of these findings for the mood effects of indoor lighting and the gender effect in work-related judgment are discussed. The genders role for light perceiving is different. Knez found that light was considered more glaring, more intense, less dim, and less soft by females than it was by males. Consistent with some previous results in emotional psychology these data indicate that females are more expressive (in general terms) toward the indoor lighting (an affective source) than are males.

Butler and Biner (1987)⁴² studied preferred light levels for tasks within settings and found that when participants believed the lighting conditions to be important to a situation, they wanted to be able to control the lighting. Similarly, Veitch (1996)⁴³ predict that beliefs about the effect of lighting would correlate with the desire to control features, including lighting. The theory supports the theses of the unconsciousness and consciousness judgment of lighting design. The belief of the expectations plays an important role for judgment of light quality.

Veitch and Newsham⁴⁴ proposed a behaviourally based model for lighting quality research, in which individually based processes mediate the relationships between luminous condition and such behavioural outcomes as task performance, mood, social behaviour, aesthetic judgments and satisfaction. The paper summarizes the state of knowledge concerning mediate psychological processes: perceived control, attention, environmental appraisal, and affect. Mediate psychological processes as perceived control, attention, environmental appraisal and affect were selected because of their relevance to the explanations often given for lighting design choices.

The result of Kaplan's, R⁴⁵ study suggests that nature elements must not be considered as amenities but as basic to satisfaction and wellbeing. The view from the window can provide long-term contact with the natural environment. Perhaps such an enduring connection is particularly useful for sustaining restoration. Given the multitude of culture and commercial forces that reduce the likelihood of many people's connection with the natural environment, cultivating the window view as a source of pleasure and restoration is worth both further study and appropriate action

Simpson, M⁴⁶ The whole approach to how a hospital building works, and is used, is changing the whole demographics of healthcare shifts. Value for money has become as important as the treatment itself, so as the population ages, the emphasis will be on providing better quality treatment more

effectively over a shorter time. Lighting is a part of this equation. Fulfilling basic standards will always be a requirement, but the new approach discussed above offer real benefits to patients, staff and managers alike. Dynamic lighting that changes to suit the patients mood can reduce stress, whether in a individual ward or treatment room- and reduce stress improve the effectiveness of any treatment.

Future thinking will incorporate areas for the family to stay with the patient, in an environment more comparable to at hotel room. No longer will the visitor have to rely on a bedside chair for a few hours. They are already encouraged to stay with the patient for longer periods and sometimes overnight. This makes the patient feel more relaxed and secure, but has the added benefit of providing better surveillance of the patient than a visiting nurse will ever be able to give.

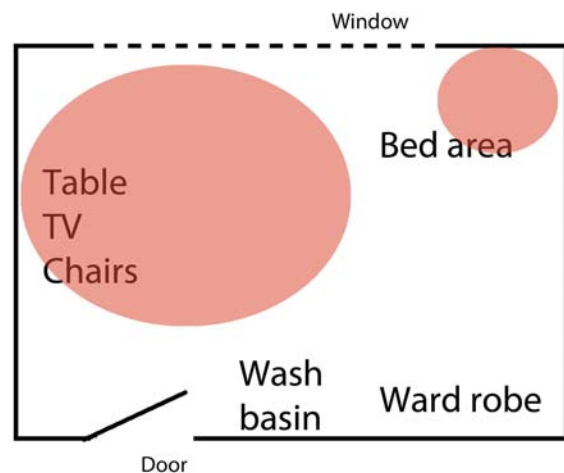


Figure 16: The visitors are mainly using this zone in the wards.

The different user needs is important to take into consideration when new hospitals are designed. The patients should be in focus of lighting research in the field of hospital wards. The patient's behaviour in the ward, the way they "normally" use light in homes could be an inspiration for lighting design at wards.

The lighting design in wards has for the patients view influence over a long period,

but in a short while for the staff. It is the staffs a working area.

Some patients collect all family members during the hospitalization. Some want the spouse to reside with the patient during the hospital stay. There can be a desire to have meals together in the rooms, etc. All this makes the ward a multifunctional room, and the interior design must be flexible to support the different ways of using it. The ward should be designed in relation to social relations the patients included in and the lighting design should support it.

[Ward Environment]

Because of the wards complexity, it is an interesting architectural space to design. It has a range of functions to facilitate. There are many users with different needs. The ward is the patients home, the place they have dinner, they sleep, the relatives visit, and at last it is the office where the doctor do the ward rounds. It's a public domain with a lot of references to the design for the private sphere as a home and the idea of wellbeing, and a sense of safety.

The ward accommodate different people's expectations and experiences of space, the materials and spatial composition should be in focus and a lighting design can support with the individual preferences and produce different moods, even in more or less uniform spaces.

The ward is the place where the patient uses a lot of time alone. Doctors and other staff spend only some minutes at a time, so the time where others can influence the experience of the room is short, and the space influence the experience of the hospital stay all day long.

Altimier (2004)⁴⁷ pointed out that the views of nature, natural light, soothing colours, therapeutic sounds, and the interaction of family members can enhance healing. These elements must be balanced with the staff needs when designing critical care environments. It is important to take all factors into consideration when the wards are planned.

On entering a space we use all our senses at the same time. We are trying to connect the data from the senses, separate and create a line of sensory information. The body does not only rely on the senses, but also attempts to form links between them - a sensory integration. Consciously or unconsciously, we decide whether we like being in a room and thus relax, or whether the body must use energy adapting to the surroundings.

The spatial composition, indoor air quality, the connections between the materials, acoustics and the thermal environment are all important for the perception of space and the experience of atmosphere. Rice, C.⁴⁸, Rowland, J.⁴⁹

Boyce, P⁵⁰ described material is an important factor because it reflects the light, and therefore has an influence on sensory perception.

- Brightness (based on the extent to which an object is judged to be emitting more or less light).
- Lightness (based on the extent to which an object is judged to be reflecting a greater or lesser fraction of the incident light).
- Hue (based on the classification of a colour as reddish, yellowish, greenish, bluish, or their intermediaries or as having no colour).
- Saturation (based on the extent to which a colour is different from no colour of the same brightness or lightness).
- Transparency (based on the extent to which colours are seen behind or within an object)
- Glossiness (based on the extent to which a surface is different from a matte surface with the same lightness, hue, saturation and transparency)

Van de Glind et al⁵¹ has focused on the outcomes concerning patients during hospitalization to be able to conduct a manageable review. Following chosen measures to be meaningful for purpose of policymaking and designing of wards:

- Privacy and dignity of patients
- Noise and quality of sleep
- Patient satisfaction with care
- Hospital infection rates of MRSA
- Patient safety: fall accidents, medication errors
- Patient recovery rates, complications and length of stay

Glind refer to research project where it is found that patients in single rooms were significantly more satisfied with care than patients in multi-bed-rooms. Accordingly to a comparison-study of satisfaction rates

hospitals with more single rooms had higher patients satisfaction rating. In the articles that have been studied no negative effects of single rooms were reported. A negative effect could have been feelings of loneliness among patients and between patients and staff a decrease of patient safety could occur. Finally patients may experience passive feelings through missing activation and positive stimuli in their room (direct opposite to the cancer patients research).

Glind also found that single rooms have a moderate effect on patient satisfaction with care, noise and quality of sleep, and the experience of privacy and dignity. Conflicting results have been found on hospital infection rates. Some studies did not show significant differences, while others concluded that single rooms decrease the risk of hospital infection rates. Some studies did not show significant differences, while others concluded that single rooms decrease the risk of hospital infections. Evidence on recovery rates and patient safety was lacking.

Single rooms are interesting for the healthcare management because of the effects of single rooms in terms of length of stay, the risk of cross-contamination of hospital infections and patients satisfaction with care. They want to develop a more customer-oriented management approach and design issues have been applied in order to be responsive to consumers.

The location of daylight is an important factor when the light setting is qualified. Geographically and culturally we have different experiences and expectations for the daylight qualities. The hypotheses are that there is coherence between our daylight experience and the way we lit our homes. How the daylight is distributed, the appearance of light, and unconsciously we use this socio cultural experience in the way we lit our homes. In Denmark we talk about "Nordic light" as a special light quality we have here in the north. We are having a long tradition focusing light as a design object, light as a tool to create "Hygge" (a cosy atmosphere) and light as an essential part of our conversation between people. The question is what defines the Nordic Light and

what Nordic Light contains. Mathiesen, N.⁵² just began her PhD study in the field of Nordic light.

The ward's orientation has a role in qualifying the daylight scene. A room facing north has an indirect skylight and no direct sunlight access. Light rays from direct sunlight have access to a room facing south.

"The luminous environment is transformed into the retinal image which is the stimulus for the visual process that provides information to enable the perceptual process to recognize objects and surfaces which form the visual basis for the perceived environment." Cuttle⁵³

The ward has an impact on the overall experience of a hospital stay. The quantity of objects, the size of the room, and spatial composition, etc. affect how light is experienced in space.

When we evaluate the lighting design, we evaluate the light, but as much the surface the light is reflected from. Therefore, the surface texture and material quality is an important factor. Its evaluation of light will always be an interaction between human - light - object - space.

The surface has an influence on sensory perception of the space.

A variation in texture will stimulate the sensory quality and how the space appearance is attractive and interesting.

In hospitals the use of materials has a lot of hygienic conditions to consider and restrictions to respect. It's a standard to use glossy finish because of its often easy to clean. If we made a registration and drew a parallel of materials in a home, I see the matte finish is the prominent surface in most homes.

We have a variation in texture and surface finish and use a lot more organic materials than in a ward. I think it has an impact on the sensory indications that affect our judgment of the environmental appearance and the atmosphere.

Reflectivity is a directional property, it should be noted that most surfaces could be divided into specular reflection and diffuse reflection.

For specular surfaces, such as glass or polished metal, reflectivity will be nearly zero at all

angles except at the appropriate reflected angle.

For diffuse surfaces, such as matte white paint, reflectivity is uniform; radiation is reflected in all angles equally or near-equally. Such surfaces are said to be Lambertian. Most real objects have some mixture of diffuse and specular reflective properties.

The surface character of objects and the room is important for qualifying the experience of light in a space. The reflection of light dividing the light we see, and the colour, texture etc has an impact on the impression of the space.

[Light]

The light source can be divided into main groups: the natural daylight from the sun, the skylight and the reflected light from the surroundings and the artificial electrical lighting. The artificial light is the substitute for daylight. The effect of light can be divided into different categories: The functional, aesthetic, and symbolic effect. Boyce, Peter. R.⁵⁴; Butler, Darrell. L.⁵⁵

There has been research done clarifying ways of qualifying lighting design. Veitch, J.A.⁵⁶ describes the development and validation of a questionnaire to assess beliefs about the effect of common types of interior lighting on human health, work performance, mood, and social behaviour. The questionnaires explore the users responses to interior lighting and to discover what beliefs end users hold. This information will assist in allaying unwarranted fears and concerns about new lighting technologies.

The physical environment, the organizational structure and the organizational culture can influence affect. Lighting is clearly part of the physical environment and lighting conditions such as the illuminance and the correlated colour temperature of the lighting have been shown to change mood and to change behaviour in a way consistent with positive affect. McClughan, C. L. B.⁵⁷

By upgrading the quality of lighting design and promote the sensory similarity, the users mood can change. The ward atmosphere can be changed in relation to users perception and thus provide the user with opportunity to control the surroundings and be "masters in their own house" Hawkes, J.R.⁵⁸; Boyce, P.⁵⁹.

Lighting condition that makes important information we need difficult to recognize, will be likely to generate fatigue and negative affects. Conversely, lighting which ensures good visibility of the task and is perceived to be much more attractive than is usual might produce positive affect. Boyce, P.⁶⁰. He refers to different definitions of lighting quality:

- Single-number photometric indices calibrated by subjective response
- Holistic design process based on lighting patterns Loe, D.L.⁶¹
- The lighting conditions with desirable impacts on task performance, health and behaviour Veitch, J.A.⁶²
- Lighting which enhances the ability to discriminate detail, colour, form, texture, and surface finishes without discomfort

There has been research done clarifying ways of qualifying lighting design. Veitch et al.⁶³ describes the development and validation of a questionnaire to assess beliefs about the effect of common types of interior lighting on human health, work performance, mood, and social behaviour. The questionnaires explore users responses to interior lighting and to discover what beliefs end users hold. This information will assist in allaying unwarranted fears and concerns about new lighting technologies.

Veitch and Newsham⁶⁴ presented a model with a summary of relevant research results, organized by theoretical psychological processes thought to mediate lighting-behaviour relationships.

Veitch; J.A.⁶⁵ pointed out Flynn as a pioneer in the field of lighting and behaviour, He argued that the emphasis on lighting and performance is too mechanistic. Flynn used semantic differentials (bipolar adjectives) to study subjective responses to the clutter, uniformity of lighting, and various other qualities of environments. Specifically, what levels of light do individuals prefer? His work was innovative and creative; he was among the first to apply sophisticated psychological techniques and multivariate statistics to lighting research.

Birgit Cold Kristensen, L.⁶⁶ presented six perspectives in quality:

- Naturalistic perspective (universal of comparison and dimension of comparison)
- Technological perspective (product requirement and product performance)

- The place/role perspective (people's perception, expectations, actions and the physical environment (people's daily interactions with his surroundings which motivates him))
- The aesthetic/contextual perspective (the question here is whether the quality is appropriate in relation to the context "the language games". different perspectives on the nature of beauty in art.
- The art perspective
- The metaphysical perspective (short term value judgment and long term value judgment)

Majoros, A.⁶⁷, Wetton, E.⁶⁸ pointed out the important quantitative and qualitative factors of lighting:

- The important quantitative factors of lighting: The amount of light there is available for the patient, staff and the visitors to achieve a pleasurable light atmosphere at the wards. And take the heat transfer into consideration.
- The important qualitative factors of lighting: It is desirable to optimize the design of the building so that the majority of the occupants like it. The Ambience, orientation, and the contact with outside are important factors and it is difficult to quantify these factors.

For the written standards the control of glare, luminance distribution, the geometry of the light, light colour, flicker and illumination refers to the reference in paragraph 4 DS700⁶⁹ The special glare conditions should benefit the patient's needs and the light source should have an appropriate cover and be placed in the right positions. Lighting to be used in rooms where precise colour assessment is needed - for example, intensive section should have a light colour and a index $R_a > 90$ and a colour temperature on approx. 4000 K. DS 703⁷⁰ For the rest of illumination chosen for patients need is an attractive in-house lighting, which in most cases will mean colour temperatures are not higher than 3000 K and a fairly good light colour with $R_a > 80$ ' "Illumination designed to search as follows, that the foregoing illumination gives a pleasing impression of space.

The physical environment, the organizational structure and the organizational culture can influence affect. Lighting is clearly part of the physical environment and lighting conditions such as the illuminance and the correlated colour temperature of the lighting have been shown to change mood and to change behaviour in a way consistent with positive affect

This suggests that lighting can produce mood changes. Lighting conditions, which make what needs to be seen difficult to see, will likely generate fatigue and negative affect. Conversely, lighting which ensures good visibility of the task and is perceived to be much more attractive than is usual might produce positive affect. (McCloughan et al.⁷¹)

Demonstrations of affect theory require information about lighting preferences and their effects on performance and other behaviours. There are many attempts to determine which luminous conditions people prefer. Although it appears that people prefer bright vertical surfaces and luminous conditions that are sufficiently non-uniform to be characterized as "interesting". There is no consensus on the luminance values or distributions that are preferred. Predictive models for discomfort associated with glare exist, but there is little guidance for the degree of luminance contrast that might be positively desired as contributing to interest. Indirect and direct/indirect lighting systems appear to be preferable to direct-only systems, but not conclusively so. Boyce⁷²

The light is able to influence a feeling like joy at sunrise, the romantic at sunset, the cosy twilight, where confidentiality thrives. It is a different experience of a view set in a clear cool daylight full activity or a sad cloudy and overcast day. Henrik Clausen⁷³ categorizes light moods in 6 different types:

- The private light: The type of light which leads us to feel at home, confident and comfortable = low horizontal light and low colour temperature. It could be an intimate confidential or romantic mood, a sunset or candles or the light that brings a cosy atmosphere. Poul Henningsen work-

ed on getting people to look beautiful. He designed his first lamp to make his vain mother look pretty. Poul Henningsen called his pendent shaped lamps for "dialogue lamps" which supports the confidentiality and intimacy. He formed the basis of Danish lighting culture exactly because he remained critical of the way we were use to look at light the way we traditionally illuminated our surroundings. He was capable to design the light there directly addresses our most positive feelings.

- The party lighting: Celebration and joy associated with light. The festive light is the sharp contrast to the cloudy and overcast atmosphere. Lights, which sparkles, shines, glitter and glares. The light from the thousand prisms of chandelier or from the myriad of point-shaped light sources in the ceiling. It is a high luminance, small spatial extent of the light source. The magnificent and lavish atmosphere where there is not spared anything. The light we want to produce when we want to support party, life and happiness between people.
- The solemn light: When you enter a church, a chapel, and a hall of the palace or the old town hall. The kind of silent places where you lower your voice when you enter the room. Here is the solemn light mood. The light distribution is without confusing shadow drawings and gives a quiet atmosphere. The inter-reflected diffuse daylight coming through very conscious placed windows and the light creates this very special solemn mood. The peaceful atmosphere is underlined by an almost shadow resolved light that characterizes indirect lighting. The solemn light brings great feelings in people.
- The professional light: The professional light stimulates concentration and provides a framework for a pleasant workplace.
- The industrial light: Here is a certain mood in the industry. Time is short, there is activity and there is much practical work to be done, items to be processed and items to be moved. The industrial

light should create a security feeling for the workers. It must be geared to the specific job and can't be standardized. Lighting style is often located symmetrically fittings with a uniform light, which govern quite frequently general lighting. The industrial lighting creates a safe and efficient workplace.

- The spineless light: The atmosphere produced by a boring, flat and without shadows. Fittings located symmetrically, with no signs of the approach to lighting. There is often a grinding silence in these spaces. Orientation solved light with high illumination. The spineless light creates distance and isolation between people.

Lighting quality

Analyses model in practice:

- The functional effect: lighting changes on task visibility, glare
- The aesthetic effect: appearance of the space
- The symbolic effect: The effect on attitudes.

The most generally applicable is that lighting quality is given by the extent to which the installation meets the objectives and contains set by the client and the designer. Depending on the context, the objectives can include facilitating desirable outcomes, such as enhancing the performance of relevant tasks, creating specific impressions, and generating a desired pattern of behaviour, as well as ensuring visual comfort. Boyce⁷⁴ separate quality lighting in three categories:

- Bad quality lighting: The type of lighting, which does not allow you to see what, you need to see, quickly and easily and/or causes visual discomfort.
- Indifferent quality of lighting: The type of lighting which does allow you to see what you need to see quickly and easily and does not cause visual discomfort but does nothing to lift the spirit.
- Good quality lighting: The kind of lighting that allow you to see what you need to see quickly and easily and does not cause visual discomfort, but does raise the human spirit.

Where lighting is intended to facilitate the extraction of information from the visual environment, there are four situations in which visual discomfort is likely to occur:

- Visual task difficulty, in which the lighting makes the required information difficult to extract:
- Under- or over-stimulation, in which the visual environment is such that it presents too little or too much information
- Distraction, in which the observer's attention is drawn to objects that do not contain the information being sought:
- Perceptual confusion, in which the pattern of illuminance can be confused with the pattern of reflectance in the visual environment.

Dalke et al⁷⁵ was required by NHS Estates to write a report on lighting and colour design schemes, accessible to non-professionals with responsibility for refurbishment strategies. The made an investigation on 20 hospitals to establish a picture of current practice and to identify key issues where colour design could broadly enhance the environment for patients, staff and visitors. Critical areas were outlined in this report, where colour design can be utilized and applied, for the benefit for all users, from ambience to essential legal requirements such as colour contrast for the visually impaired.

Having considered how light can be measured, the physical principles and properties of natural and artificial light sources are considered. Natural light is characterized by its variability in both quantity and spectral emission. Artificial light sources are more stable but differ considerably in their properties, particularly spectral content and the efficiency with which they convert electricity to light. Boyce⁷⁶

Light in architecture can be divided in 2 categories; "Daylight" and "artificial light". In hospital wards daylight access the room from outside. Artificial light will mostly come from the ceiling, and the light source is located closer to us. The artificial light is a replacement for daylight and is more controllable than daylight. Both daylight and

artificial light play a role together to the ward appearance and atmosphere, and it is not always possible to experience the two types separately. It should be seen as a whole lighting design. The two categories of light has different qualities, differently purposes. If the purpose for a better light atmosphere is to create a more natural artificial light setting, it is important to rethink the use of artificial light and work with the placements of the light fittings and the way the light creates shadows.

Daylight



Figure 17: Hospital sink in daylight

Daylight has an ability to bring life to the environment, because the light is constantly changing intensity and direction. This variation affects the way shadows fall on the floor, the room's materials appear differently, and the experience of objects changes through the day over the year.

Veitch, J.⁷⁷ Demonstrates in her research that people who rated the lighting as of higher quality (regardless of the type of lighting they experienced) considered the space to be more

attractive, were happier, and had better health and well-being on the form of less discomfort and greater satisfaction with their environment and their work. People generally prefer to be in a space with windows rather than one without windows. This preference implies that daylight creates an interior which is more pleasant and satisfying than one illuminated only by electric light.

Wetton⁷⁸ refers to a study to compare the incidence of post-operative delirium in two samples of surgical patients in Arkansas and 50 patients in each sample. One sample was nursed in an intensive care unit without windows and the other sample in an intensive care unit with windows. Further, there was an increased incidence of post-surgical depression in those patients in the windowless ward who did not develop post-operative delirium. The study concluded that it is highly desirable to have windows in an intensive care unit to prevent sensory deprivation.

The contact with the outside is also particularly important in the Cardiac care unit. Designing a new unit it is necessary to provide each patient bed area with a window to give a sense of orientation and wellbeing. When the day lighting refer to the use of the light and the manipulation of the visible light from the sun and sky. This light is made up a band of colours, the spectrum, extending over one octave from violet (380 nm) to red (760nm). But the sun radiates energy in addition to visible light-cosmic rays, gamma rays, infrared rays, and ultraviolet rays. Ultraviolet radiation can affect our health. Too much UV can cause skin cancer. On the other hand, UV can produce desirable effect in our bodies. Ex. it helps synthesize the production of vitamin D3, the vitamin that helps to make strong bones.

Wetton refers to the impressive study into the most effective window shapes and sizes for hospital wards carried out by Hopkinson about 50 years ago, when his was at the Building Research Station in England. Hopkinson investigated the relationship among window size, visual comfort, and daylight factor. He concluded the daylight

factor at the back of the wards should not fall below one percent for the brightness distribution to be pleasant. A minimum daylight factor of one percent was accepted as a design criterion by the (British) Department of Health and Social Security. Windows in an intensive care unit can help prevent sensory deprivation, which can contribute, to depression and delirium.

Artificial light



Figure 18: Hospital sink in artificial light.

A space can be experienced in a varied and intense daylight, where rays from the sun are streaming in through the windows. At night the experience of the space will be different. Its dark outside and the window surfaces appear dark. At the hospital, a uniform artificial light often illuminates the space and the spaces appear without the light variation. By lighting design, we have the opportunity to create harmony or disharmony in the room. We can create a focus on places. With light we can emphasize environmental information or we can hide the information in the dark. The total spatial composition can be

supported with light and give an extra dimension and something more to the experience of the environment. Artificial light allows you to add space value, since the light can affect sensory perceptions like or catch the attention etc.

When the artificial light brought into play, it is often uniform in terms of direction and intensity. Space objects have the same form over time, the same form as last time the light was turned on, no variations. Those factors are very important for our perception of well being in space and the analysis of light quality.

The Danish Standards for lighting design in hospital environments DS 703⁷⁹ shows how a good artificial lighting achieved and most information is described based physical quantities of light. Light features contrast is also described well, but it is hard seeing how the light atmosphere and the characteristic of the light can be achieved and get a status and standard description, where the more sensory qualities and the softer values in lighting design can be assessed. These qualities are more open to discussion and maybe more individual in preferences. The experience, the aesthetics, the atmospheres of light is not well described, but it is an important factor for good lighting design and as important as the measured light. The specification of the necessary lighting for the users at the wards is not well described.

Further it describes clearly the circumstances and significance for the direct task light: the needs for the central vision. It describes the light necessary for the staff work and patient's personal light by the beds. This information is relevant and important for light atmosphere. To reach an "attractive lighting of domestic nature" requires a focus on the general appearance of spaces and the light we perceive in the peripheral vision.

Bartlett Research group found that non-uniform luminance distributions were preferred over more uniform ones. Hawkes et al.⁸⁰ found that 8 configurations with diffuse light source were all rated as uninteresting: 10

configurations with one or more focused source were on the interesting side of neutral

Preferences for scenes generally increase as these qualities increase: However, high levels of one quality can reduce levels of another.

Lighting researchers have not systematically tested the application of this theory to the lit environment; it has parallels with well-known lighting research, which is not surprising given that light provides the stimulus for all visual appraisals of environment. As with attention theory, the majority of relevant research concerns the luminous environment expressed in terms of luminance distributions across space. Veitch, J.A.⁸¹

Light Culture

When leaving our home and traditions to other countries, or settle down in other cultures, we are heavily influenced by our experiences with the daylight.

The culture of artificial light follows. Just by observing a block from outside, it is quite obvious to see different ways of lit our homes. Our familiar understanding of light conditions and our culture of using the artificial light affect our assessment of the surroundings. To achieve attractive surroundings we should obtain consistency between our expectations and our experience. One should experience the connection between self-perception and the situation you actual experience. If we do not recognize ourselves, it leads to uncertainty, insecurity and it effects the perceived situation.

Our light culture is incorporated and adapts the understanding of ourselves in the surroundings. Our body, skin, hair and eye colour adapts to the amount of light we are expecting in the place we live.

Our ancestors have lived in the same latitudes in thousands of years, and instinctively, we have a common reference and feel the same lighting moods. Henrik Clausen⁸²

According to James Turrell 1992⁸³ our brain will seek order and meaning and it begins to interpret and sort things out, and seek for meaning if there is no accordance between our ideas and expectations of the light (the

"inner" light) and the observed and experienced light (the "external" light), we will be aware of the light. "It is from the inner vision of light that we see the light in a room. While creating the inner vision of the light of what we are experiencing "The way you look (seeing, sensing, experiencing) daylight in a room. It is an interaction between the "external" and "inner" lights, where the "internal "light (the expectation, idea, dream, etc) and the "external "(radiation stimuli, etc) are two sides of same coin, the same whole, the same light, including daylight"

In the concept of lighting Danish homes it seems like a tendency making it possible to vary the light in the room. The homes have many sources of light placed - they are distributed irregular and located where the user needed light zones or placed exactly where you want to have a light zone. The light can be varied, so I lit up the room with an equal light distribution in the space – perfect light for cleaning. But it can also be varied, as there is a light zone around the dining table and small bright spots around the room placed at a low level for an ambient light setting, with table lamps, candles, floor lamps, etc.

[Time]

The time has an influence on the access of daylight at the ward. The time of the day, the time of the year has an impact on the needs for lighting, and for the way daylight influences the experience of atmosphere at the ward.

Light has the opportunity to influence the way we experience and are sensing an environment, in this case the ward. It also has an effect on human performance and the locomotion in a environment.

Dynamic lighting that changes to suit the patients mood can reduce stress, whether in an individual ward or treatment room- and reduce stress improve the effectiveness of any treatment. Simpson, M.⁸⁴

The appearance of an environment is different in daylight and artificial light. It chance over a year, the altitude of the sun, and the daylight variation can be used as inspiration for the design of artificial lighting. Millions of people spend a significant part of their lives working. Electric lighting is provided at their workplaces to ensure that they can see to do their work quickly, accurately, safely, and easily.

The different seasons of the year at different geographical areas, has different needs for artificial light. In the northern part of the globe, we have the long summer days, with a lot of daylight. A variable light conditions in the autumn. A long dark winter almost with the absence of daylight, and the springtime where the long awaited daylight is bringing new life to our surroundings.

It is important to have the time we stay in the room in mind, the angel we experience the environment have a meaning for the lighting design solution. Moving from one room to another, or from a dark spot in a room to the lightest spot, the adaption to light is an important factor. Backlight, light level, and light distribution influences the adaption to the light in the ward.

The relation between the human movements, the light distribution, and the distance to the light source has an impact on the experience of a space.

Boyce refer to report from Heerwagen and Heerwagen (1986) a longitudinal laboratory study investigating possible subjects experiencing Seasonal Affective Disorder (SAD) and matched control group. Specifically concerned with assessing preferences of sunlight as apposed to artificial light in various household rooms at various time of the day.

Logadottir, A.⁸⁵ observes individual preferences for dynamic lighting, individual control and possibly achieve energy savings in a day lit space. A case study of subjects performing office work for one day in a simulated office environment shows a difference in choice of light intensity in working area through the day

Carlo Volf, Abildgaard⁸⁶ made a new lighting project at Rigs Hospitalet, Copenhagen (DK). He demonstrates a dynamic light setting in a basement corridor, with no access of direct daylight. The aim of the project was to design a daylight atmosphere increasing the workflow and restoration. The Lighting design at Rigs hospitalet, Volf, implemented a lighting design where he used a system controlled by computer and a daylight sensor, which were coordinated to create changes during the day and the year.

In many workplaces only small amounts of daylight enter. This can be especially true for hospitals, where a lack of daylight in corridors may affect both patients and staff members. At the same time, this "dynamic lighting" helps saving energy, which makes it a win for the hospitals, their staff and patients. In the first experiment Volf designed a light with more variation and hence more contrast in the room. The light was placed in clusters, with a purpose making the experience more interesting.

In the second trial was set a daylight control, so the artificial light was referring to the outdoor light. Day and night a computer controlled the artificial light, so that gave a more bluish appearing light. He designed a lighting that supported the production of the sleeping hormones to benefit the sleeping rhythm of the nightshifts.

By controlling the illumination the Rigs Hospital also achieved electricity saving of 53% compared to the same lighting without dynamic management.

The project conclusion:

- A clear improvement of using T5 (HE) light sources rather than T8 (TLD)
- By putting multiple T5 tubes in clusters achieved significantly greater satisfaction with the light distribution. The idea of light distribution was more varied and therefore perceived as less dark
- By mixing light sources with two different colour temperatures (3,000 K and 6.500K) in same luminaries cluster improves light colours. A finding documented of measurements performed by DTU (The Danish Technical University) Photonics.

Dynamic control of the light and daylight management by means of a sensor provides improvements over a uniform and static lighting – even though less significant improvements.

Computer daylight management provides a significant saving in energy consumption. The energy consumption is a relevant factor for choice of lighting design. Electric lighting consumes 30-40 % of the electricity consumed in commercial buildings. Det CO2 Neutralt Hospital)⁸⁷

[Perspectives]

The quality of hospital, ward and lighting design, can be discussed in many different ways and with different focuses. This report and the state of the art are showing some of the perspectives I find interesting to clarify.

The aim of this report is to provide the basic knowledge and be the framework for ideas of future lighting designs in hospital wards. Focusing on at the experienced light, the preferences for atmosphere, the sensory qualities in dynamic lighting, and present a new approach for evaluating light atmosphere on wards focusing on dynamic lighting qualities.

The main issue is the question is what is quality? Up to now I find the measurable parameters most investigated and many of the sensory qualities and the experience and aesthetic qualities of lighting design more equivocal and undocumented and in need for further research. It will clarify the aesthetic dimension in lighting design clarifying the sensuous qualities and provide lighting design leads to more tangible tools and arguments when the illumination of the future hospital is to be designed. In addition, this clarification of the sensory qualities of lighting design should support designers in creating a better hospital environment for patients, visitors and staff.

Glind, I.⁸⁸ Future research should build the body of knowledge in single-bedded rooms to explore their impact on wellbeing and healing on both patients and staff. Also consequences of single rooms and management of care should be explored. Research should support policy making by exploring, indicating and initiating improvements in-patient housing and quality of care.

We know that light affects the experience of space and that it can be used in creating a certain atmosphere. The way of testing and researching on the affect of lighting design in hospital wards is also an issue. Dalke used pictures to evaluate colour scenes for hospital design. Aalborg University (SBI) used a 1:4

model testing daylight glare. The best way of testing lighting atmosphere has to be in a mock-up at a real hospital ward. Using a 1:1 room must be the best way to make a sensory experience of a ward.

Another aim of this report is:

- To summarise state of the art and provide evidence-based design results of research on dynamic lighting design with a focus on the quality of dynamic light rhythms and the sensory factors of lighting design.
- To pin out dynamic light qualities relevant to the experience of a pleasurable light atmosphere.
- To discover what the natural connection between daylight and artificial lighting and what is beneficial for the recovery of the patient?
- To be an interesting inspiration for lighting design.

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