Smarter lighting for life

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Inaugural lecture
Prof. Evert van Loenen
April 13, 2012

/ Department of the Built Environment

Technische Universiteit
Eindhoven
University of Technology

Smarter lighting for life

Where innovation starts

Inaugural lecture prof. Evert van Loenen

Smarter lighting for life

Presented on April 13, 2012
at Eindhoven University of Technology

Introduction

As a title for this lecture I have chosen 'Smarter lighting for life'.
'Smarter **lighting for life**': because I will focus on the impact of natural and virtual daylight on health and comfort. Natural daylight: because it is an essential ingredient for life on earth. In humans, it affects our physical and mental health and synchronizes our biological clock. And virtual daylight: because natural daylight is not always available in the amounts and at the locations where we need it, particularly inside buildings where we nowadays spend more than 90% of our time. Here, I use the phrase 'for life' also in its meaning of 'for ever', to indicate that the challenge is to find solutions that are not only healthy, but also sustainable.
And '**Smarter** lighting for life' because I will discuss how intelligent system methods and techniques can be applied to find solutions, that can adapt environmental conditions to the health and comfort needs of people, while simultaneously reducing energy consumption.

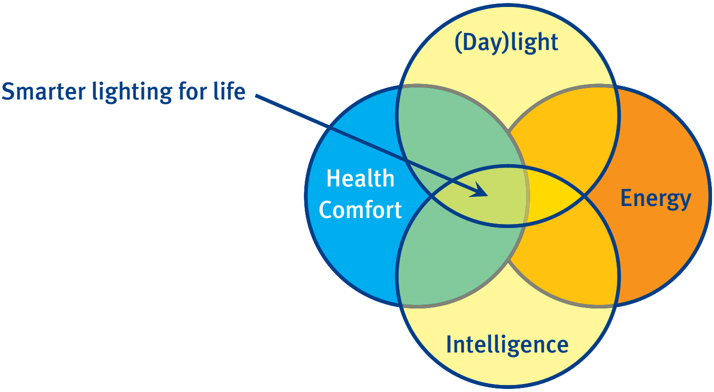

Figure 1

Scope of the lecture and chair

Intelligence

To explain what I mean by intelligent system methods and techniques in this context, I will use the definitions as originally described in the Ambient Intelligence vision of the future, published in 2001 (Aarts et al., 2001). Ambient Intelligence refers to digital environments that are sensitive and responsive to the presence of people. This vision built on the Ubiquitous Computing vision of Mark Weiser (Weiser, 1991), who predicted a world where we would be surrounded by large numbers of devices, such as sensors and processors, embedded in our environment. These devices would be communicating to each other and form a smart environment. The Ambient Intelligence vision added a focus on the user aspects of such a future: how could such environments become truly helpful to people, how could we interact with them in an easy and natural way, and how would the intelligence in such context aware environments evolve. It describes an evolution in three stages, starting with personalised systems, tailored to individual needs, followed by adaptive systems, that can change in response to you and your environment. The final stage consists of systems that anticipate your desires without conscious mediation. This is the most complex and most debated stage. It comprises of systems that learn from the behaviour of their users so they can anticipate the next activity or state. When applied to lighting, one typically refers to smart lighting or intelligent lighting.

To illustrate this with a simple example, let's take a hotel. Today, lights in the corridors tend to be constantly on, while in the rooms they are, by default, off. When you open the door to your room, you look into a dark room, until you insert your keycard in a slot and some lights are switched on. A personalized room would know your preferences and set the atmosphere accordingly. Hotels are increasingly installing adaptive corridor lighting to save energy: when no movement is detected, the lights in the corridor switch off. As soon as you enter the corridor from the elevator or from your room, the lights switch on again. These solutions are quite effective in saving electrical energy for lighting. However, the user experience is far from optimal: every time you open the door to step out of your room, you first look into an unpleasantly dark corridor, before the lights switch on. An anticipatory system would be smart enough to learn what kind of behaviour leads to exiting the room, and would already switch on the hallway lights before you open the door. For the user it now is as if the lights are always on in the corridor, whereas in reality the lights are off most of the time. Realizing such solutions is quite complex, because latencies in sensing and uncertainties in positioning and reasoning can lead to undesirable system behaviour.

Smart environment examples

To show what this could mean in practise, and where I come from, I would like to share with you some examples of adaptive system concepts we studied at Philips Research.

Figure 2

Intelligent shop window (© Philips Research)

Fig. 2 shows a prototype intelligent shop window, capable of sensing the proximity, speed and direction of multiple passers by (van Loenen, Lashina et al., 2006). When no one is nearby, it uses the entire glass store front to display transparent visuals expressing the brand and style of the store. When people pass by, it gently attracts attention. When they stop, it tries to understand which product they are interested in by detecting and analysing their gaze or pointing direction. Once determined, it highlights that product by changing the color of a light tile behind it, and offers relevant information in the glass. This example illustrates that a range of advanced technologies is available to realise system awareness of users and their context (Kessels et al., 2009).

Figure 3

Adaptive atmosphere system (© Philips Research)

The second example is an adaptive atmosphere system. Through observation studies in hotels, Jon Mason learned that lobbies are used for many different activities: some people sit there briefly waiting for a taxi, others relax reading newspapers, drink coffee with friends or have business meetings. Yet the lighting conditions are the same for everyone: simply static and always on. For this case a sensing method was developed, capable of identifying the posture of people sitting on the chairs. Smart algorithms then classify the results in terms of likely activities, such as working at a laptop on the table, reading or relaxing, or being in conversation with someone in the next chair. When no one is sitting on the chairs, nearby light levels are dimmed, except for an electric candle on the table. This is inviting, and saves electrical energy at the same time. As soon as someone sits on the chair in a relaxing posture, a nearby lamp gradually increases intensity for comfortable reading. When that person uses the table, for example to work on a laptop, a spot lights up to illuminate the table. And when a situation is detected where two people are interacting with each other, light is provided between the chairs so that the faces of the two people are not in the shadow.
This example illustrates how adaptive indoor lighting can increase comfort and support interaction, while reducing electrical energy consumption at the same time.

One of the key challenges in the development of successful smart lighting solutions is understanding user behavior, and finding the correct balance between system initiative and user control. To explore this, we undertook a study in which we designed and built a hotel room in Philips' ExperienceLab. The range of intelligent solution concepts included a door that automatically opens when you approach carrying suitcases, a desk lamp and reading lights by the bed that turn on when you sit down to work or read and an ambient light system that uses your heart rate to automatically create an atmosphere which best suits the state you are in.

Figure 4

Experience study intelligent hotelroom (© Philips Research)

To analyze the impact of these concepts on hotel guests' first impression of a hotel room, 20 participants were invited to experience this room. For the test group it was set to full intelligent mode, and for the reference group to full manual control. Guo Yang analysed participant reactions by remotely observing them through cameras, and conducting a structured interview after each session. To eliminate the influence of system performance, an ideal tracking solution was emulated by using the experimenter behind the observation cameras as smart sensor (fig. 4). We found a consistent, high acceptance of the smart desk- and reading lights, whereas opinions varied widely on the automatic atmosphere rendering. This example illustrates another crucial element in the development of successful smart lighting solutions. Namely that it is very important to understand the users' latent needs, expectations, privacy concerns and behavior.

Trends in sensor infrastructures

A wide range of sensors can be applied to realize context awareness in smart environments. You can think of RF identification, ultrasound, infrared, or ultra wide band positioning, vision, audio fingerprinting and sensor based activity detection, speech, gaze and gesture recognition, as well as wired and contact-free monitoring of vital signs and other indicators of personal state.
In practice, one of the key barriers to a widespread use of smart environment solutions are the installation and maintenance costs of the required sensor infrastructure. Owners and users of buildings are hesitant to invest in such an infrastructure until an application or set of applications is available that has proven to be of sufficiently high value.

There are two recent developments that I expect will significantly lower this barrier, and thus accelerate the introduction of smart lighting solutions.

First, ubiquitous sensor infrastructures are emerging autonomously. You probably carry part of it in your pocket or purse: a smart phone. When you buy a mobile phone, what you get is a device that has GPS and WiFi positioning, so it knows where it is and therefore where you are. It also contains orientation sensors, so it knows the orientation in which it is being held, and therefore in what direction you are pointing. And its camera lets it know what you are looking at. Point it at any building in your environment, and the Layar app looks up which building it is and displays its name (Layar, 2009).

An interesting example of how this may impact future outdoor applications is the automatic pothole detector system that the city of Boston is developing through crowd sourcing. Potholes in roads are a great nuisance, both for car drivers and for cities responsible for repairing them. Finding where they are is labor intensive and time consuming. Smart phones form a free, mobile sensor infrastructure. Citizens are invited to install a free app (StreetBump), that uses the acceleration sensors of the smart phone to detect when its owner is driving through a pothole, and its GPS to record the location. By combining the readings from all participants, the city expects to obtain an automatic mapping of potholes throughout the city (City of Boston, 2011).

A second important trend that will impact the emergence of smart lighting solutions is the rapid development of LED lighting. Whereas traditional lighting technologies such as incandescent and fluorescent lighting have evolved gradually over many decades, LED lighting is developing at unprecedented rates. And with its high efficacy, long lifetime and high application flexibility, LED lighting is expected to replace traditional lighting technologies and to enable new embedded applications.

LEDs (light emitting diodes) are semiconductor devices, operating at low voltages. This opens possibilities to combine or integrate them with other semiconductor devices such as processors and sensors. In the future, every LED source could then carry its own intelligence at little extra cost.
Intelligent systems, and more specifically smart lighting, may have a significant impact when applied to the area of health. To see how, let us explore what we can learn from nature, that is from natural daylight.

Daylight and health

The ancient Greeks and Egyptians already found out that sunlight exposure is healthy. Around 400 BC, Hippocrates prescribed heliotherapy (sunbathing) for both medical and psychological purposes. He noticed that depression was more common in the winter months in Greece when there was less sunlight (Hockberger, 2002). But by the time of the Renaissance (14th - 16th century), a white skin had become the norm for the aristocracy and sunlight was mostly avoided. As a consequence, they suffered from a broad range of health problems, including rickets.

The rediscovery of the importance of daylight for health and healing is mostly attributed to Florence Nightingale, the pioneer of modern nursing. In her 'Notes on Hospitals' of 1859 she writes: "Direct sunlight, not only daylight, is necessary for speedy recovery, except, perhaps, in certain ophthalmic and a small number of other cases. Instances could be given, almost endless, where, in dark wards or in wards with a northern aspect, even when thoroughly warmed, or in wards with borrowed light, even when thoroughly ventilated, the sick could not by any means be made speedily to recover... All hospital buildings in this climate should be erected so that as great a surface as possible should receive direct sunlight - a rule which has been observed in several of our best hospitals, but, I am sorry to say, passed over in some of those most recently constructed" (Hobday, 2007).

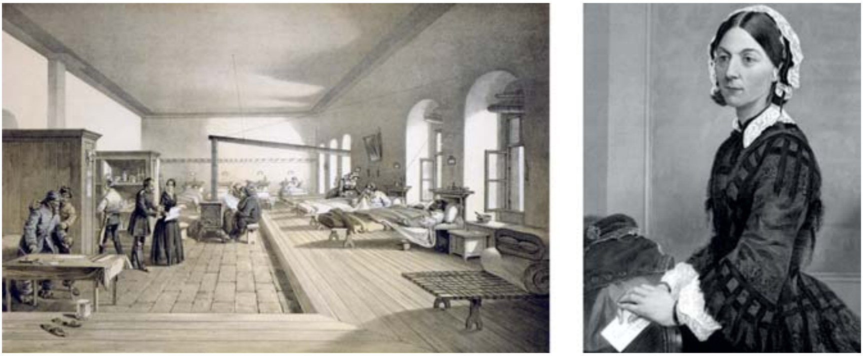

Figure 5

Florence Nightingale (right) and the ward in Scutari where she worked in 1854
(Source: Wikipedia)

In recent decades, the impact of sunlight on mental and physical health has been studied systematically. These studies have proven that Florence Nightingale's insights were correct. I will discuss the most important health effects in more detail.

Sleep

Good sleep is essential for a fast recovery (Ulrich, 2008), but while being hospitalized, patients in general suffer from disturbed circadian rhythms and poor sleep instead (Southwell and Wistow, 1995). Exposure to sufficient light in the morning helps to activate patients during the day and let them sleep better during the night (Giméneza et al., 2011).

The mechanism behind this beneficial effect of daylight is the fact that the blue wavelengths that are present in the daylight spectrum activate the melanopsin receptors in the eye, which are sensitive to a narrow band of wavelengths around 480 nm. These melanopsin receptors are not involved in image formation, but project directly to the suprachiasmatic nucleus (SCN) in the brain, our biological clock (Berson et al., 2002). The SCN is involved in the regulation of sleep-wake rhythms and the production of various hormones, such as melatonin (the "sleep hormone") and cortisol (often referred to as the "stress hormone") (Dacey et al., 2005). When blue light hits the melanopsin receptor, the production of melatonin becomes suppressed. At sunset, when daylight contains little blue light but is orange/red instead, melatonin production is activated and one starts to feel sleepy. At night, it reaches a maximum, decreases toward daybreak and remains almost completely suppressed during daylight hours (Cagnacci 1996; Crowley et al. 2007). In this way, humans and other diurnal mammals regulate their circadian rhythm. As a consequence, insufficient daylight exposure for a longer time can disrupt the circadian rhythm, and by presenting sufficient daylight in the morning and at noon, patients sleep better at night and become more alert during the day.

Depression

Daylight exposure has been shown to have a significant impact on the length of stay of patients with severe depression in hospitals. Beauchemin and Hayes (1996) found a shorter stay by 2.6 days, while Benedetti et al (2001) showed a shorter stay by 3.7 days for patients assigned to sunny rooms compared to those assigned to rooms that were more shaded.

Length-of-stay

Also for other medical conditions, studies have shown a significantly reduced length of stay for patients in sunny rooms (Beauchemin and Hayes, 1998; Lee and Song, 2007), and even a lower morbidity.

Pain and stress

In 2005, Walch et al. found that patients staying in dim rooms after surgery needed significantly more pain medication (28.3%) than patients staying in bright rooms. Also, patients on the brightly lit side reported a significantly greater decrease in stress compared to patients on the dimly lit side.

It should be noted that the dimly lit rooms in this study were facing a brick wall, whereas the bright rooms had an open view. Literature shows that views also have an effect on stress and recovery, with significant differences between nature views and urban views (Velarde et al., 2007).

Ulrich (1984) studied the effect of views on length of stay, pain medication and complaints of surgical patients. He concluded that the patients in the rooms with a nature view spent significantly less time in the hospital and had had fewer complaints according to nurses notes.

Staff performance

Exposure to daylight not only has a positive effect on patients, but also on the staff. Nurses can better adjust to night shifts when exposed to sufficient light. Furthermore, studies have shown that staff working in hospitals with a lot of incoming daylight are more satisfied with work life (Mrockzek et al., 2005), which is a potentially important factor to reduce staff turnover.

In conclusion, we see that the effects of daylight on patients are strong, especially on length of stay, sleep, depression, stress and pain. Finally, daylight is also important for the staff, especially in terms of job satisfaction and adjusting to night shifts.

We experience daylight in buildings as light and views through windows or skylights. Knowing how important these elements are for health and comfort, two basic questions should be addressed. The first is: how to design buildings in such a way that optimal access to daylight and views is provided, without introducing discomfort from glare and high heating and cooling loads. The second concerns how to bring the health and comfort benefits of windows or skylights to spaces with insufficient or no real daylight.

Natural daylight in the built environment

Many architects have recognized the importance of daylight. In the words of Le Corbusier in 1989: “Architecture is the masterly, correct and magnificent play of volumes brought together in light”. “The history of architecture is the history of the struggle for light. The struggle for the window”.

An example of recent designs are the ‘Kubus’ by architect Rem Koolhaas, which originally included a huge curved light tunnel through the building to bring the daylight inside. Another example is the daring design by Sejima and Nishizawa for the Rolex Learning Center of EPFL in Lausanne. This remarkable building is one continuous 20000 m² undulating space, with high access to daylight and views in all directions (fig. 6).

Figure 6

Inside Rolex Learning Center at EPFL, Lausanne (source: private collection)

So what is the problem with windows? One problem is that windows cost energy. The other problem is that they can transmit too much light, which we experience as glare.

Carlos Ochoa in our Building Lighting group performed a simulation study to find optimal window sizes for a standard office in the Dutch climate (Ochoa et al., 2011, 2012). For a range of window-to-wall ratios he calculated heating, cooling and electrical energy loads, as well as comfort parameters such as illuminance levels, contrasts and glare indices. His results show, that electrical energy consumption for artificial light decreases with increasing window size, but that heating and cooling loads are dominant and increase with increasing window size. The optimum in terms of energy consumption would be window-to-wall ratios around a rather unattractive 20-30%, whereas health and comfort considerations would favour large window-to-wall ratios.

But a more fundamental problem is that bright daylight is not always available, for example with overcast skies, that high illuminance levels are only available close to a window, and that daylight is not available at all in interior spaces of a building.

Virtual natural light solutions

Wouldn't it be great if we could provide natural light, in the form of virtual windows or skylights that have the characteristics and behavior of real windows or skylights?

Using computational methods, Rizki Mangkuto is studying what the impact and commercial value of such future Virtual Natural Lighting Solutions (VNLS) would be, and what performance indicators can be defined to steer their development and integration in the built environment (Mangkuto et al., 2011). Note that a VNLS should be smart enough to either maintain a balance with available real daylight and view, or compensate for bad or non-existent daylight and view, depending on its location and context of use.

The value of virtual windows or skylights lies in the fact that interior spaces of buildings could be used for high end tasks, for example office work, and that spaces with insufficient daylight could be upgraded to spaces with sufficient daylight and views, for example intensive care units and patient rooms.

We can also ask ourselves the inverse question: if we would have VNLS of sufficient performance, how would that impact the design of future buildings? Today, building topologies typically have forms consisting of elongated sub-units, since the outer surface area has to be maximized in order to maximize the number of rooms with windows. This is costly as it requires a large space, and the distances thus created lead to logistics issues. VNLS solutions would allow significantly more compact designs. Given the urbanization trend, this is likely to become increasingly important. One hundred years ago, two in every ten people lived in an urban area. Today, more than half of the population lives in an urban area. By 2030, the percentage of urban dwellers will be 60% and by 2030 this number will rise to 70% (WHO, 2012).

Disruptive developments in architecture may also impact the need for VNLS. Such as the concept of earthscrapers: inverted skyscrapers. Architects at BNKR have designed a 65-story ‘earth-scraper’ which plunges 300 meters below ground. The upside down pyramid in the middle of Mexico City is designed to get around height limits on new buildings in the capital. The subterranean building will have 10 stories each for homes, shops and a museum, as well as 35 stories for offices. A glass floor covers the massive 240 m x 240 m hole in the city’s main square to filter in natural light. The advantage of the unusual structure is that it creates open space in the center of the densely populated city, while still enabling more people to live and work there. (Daily Mail, 2011)
The realization of such structures will require many issues to be solved, one of which will undoubtedly be bringing sufficient daylight into the homes and offices in deeper lying levels.

Future VNLS will typically consist of a combination of lighting and display technologies, at luminance levels and view qualities comparable to those of real windows or skylights. Rizki will develop models of such virtual windows, and use simulations to estimate their light distributions and impact on building energy consumption.

But in order to be able to do so, we need to better understand the characteristics of real windows and skylights. Important characteristics, besides light intensities, color temperature or spectrum and directionality, are dynamics and view. Increasing knowledge is available about the impact of light intensity, color temperature and 24 hour dynamics on people, but much less is known about the impact of directionality and shadow contrasts, views, and the fast dynamics caused by moving clouds.

So what is the state-of-the-art when it comes to existing virtual windows or skylights? Various concepts have been published, but they either only simulate the lighting characteristics of a window or skylight, or only the view. Fig. 7 shows an example of the first category: a virtual window concept developed by Philips, which can be mounted in a wall and can generate a range of daylight effects.
A recent example in the view category, is the virtual sky by Fraunhofer IAO, which uses a large array of LEDs to create moving cloud patterns (Fraunhofer, 2012).
A common disadvantage of display-type skylight solutions is, that special

measures need to be taken to provide some depth perception (van Loenen, 2006, IJsselsteijn, 2008), and that they illuminate the space with the color of the image. When displaying a blue sky for example, people and objects will appear blue.

Figure 7

Virtual light window (© Philips Research)

Combining both light and view characteristics in one solution is very challenging. But recently, in the Artificial Daylight Sources project team headed by Pieter Seuntiens at Philips Research, we invented a solution: an artificial skylight that is capable of casting bright, white light, but when you look at it, it is as if you look at a blue sky at infinite distance.

Smart lighting for health

As I discussed earlier in my talk, light, and in particular the blue part of the spectrum, plays an important role in the synchronization of our biological clock. Viola et al. (2008) have shown, that artificial blue-enriched white light in the workplace also improves self-reported alertness and performance. These insights are applied in novel dynamic lighting systems for schools and hospital patient rooms (Giméneza et al, 2011).

Would it be possible to further increase the beneficial effects of such solutions by including the view aspect, and adding intelligence? At Philips Research, we are exploring this question in the Adaptive Healing Rooms project for Philips Ambient

Experience business, with a concept in which the total environment adapts to the needs and condition of individual patients. I like to share this case with you, to show what such solutions could look like, and to illustrate the importance of studying trends in green building design at the same time.
To identify the needs of patients and staff, we started with extensive contextual inquiry studies in hospitals, consisting of 24 hour observations of spaces, shadowing of patients and staff, many interviews and feedback sessions. We learned that exposure to natural light varies significantly between beds close to and further away from the window. Moreover, natural light is typically absent in the staff spaces, and sometimes even in patient rooms. Patient groups like neurology patients and patients in intensive care units often have disorientation problems, whereby they loose track of time and location. We focussed our research on stroke (CVA) patients. These patients stay relatively long in the hospital. Directly after the stroke event, they often suffer from over-stimulation due to extreme sensitivity to light and noise, while at the end of their stay they suffer from under-stimulation and boredom. Neither of these conditions is beneficial for the recovery process (Flinsenberg et al., 2011).

Figure 8

Adaptive patientroom in activating mode (left), and preparing for sleep mode (right)
(© Philips Research)

To help such patients, as well as the hospital staff, we have developed a prototype smart room solution which is aware of patient and staff location, and combines real and virtual daylight with real and virtual views to provide a clear daily rhythm adjusted to the condition of the patient. Clinical trials are planned to test whether such a solution indeed has the beneficial effects expected.

The adaptivity of smart lighting solutions like this one makes it possible to apply them in virtually all sectors, including hospitals, rehabilitation centers, mental health care facilities and elderly care facilities. Besides understanding users and technology, it is important to understand trends in architecture and building physics. Green hospital design requirements may, for example, have a significant impact on ceiling construction decisions. Taking future natural and virtual daylighting possibilities into account early in the design process is important to optimize benefits and minimize total cost.

Smart lighting for comfort and energy

Today, Smart Lighting is mainly associated with reducing energy consumption. In the US, 41% of all energy is consumed in buildings, of which 16.9% for lighting. The two main approaches to realize reduction of energy consumption are to replace traditional lighting systems with more efficient LED solutions, and to apply intelligent systems. Here we will focus on the latter.

By sensing the presence of users, reasoning about the context of use, and dimming lights when they are not needed, significant savings on lighting energy can be achieved, ranging from 30% - 92% depending on location and specific context (Shen and Hong, 2009). Through simulation studies, Shen and Hong (2009) show that further reduction of energy consumption may be reached, by considering total heating, cooling en electrical energy and applying integrated control of lighting, blinds and HVAC.

In practice however, energy savings are often less than predicted, because user behaviour can not yet be adequately modelled. For example, users tend to override the automatic control of blinds systems. Bernt Meerbeek is studying this phenomenon, as a basis for the design of a novel interface.
To find out under what conditions people accept or override a smart blinds system, he selected a building at the High Tech Campus in Eindhoven, and installed a camera that can monitor the external blind positions and the manually controlled internal blind positions of all windows simultaneously. At the same time outside conditions were recorded, and questionnaires developed for participants in order to be able to correlate their use of the system to the environmental conditions.

Fig. 9 shows an example of one day, the moments just before and after the automated system has decided to lower the blinds. For a large fraction of all rooms the blinds stay up, indicating that the users have switched to manual mode. In order to understand why and under what conditions this occurs, Bernt teamed up with one of our Master students, Marije te Kulve, for a user study with a selection of these users. One of the things they learned was that the reason most often cited for keeping the blinds permanently open, is to maintain the view.

Figure 9

Office building before and after the automatic lowering of blinds (© Philips Research)

The view is an important aspect of satisfaction with the indoor climate, and people are even prepared to accept some visual discomfort for it if needed.

New switchable glass materials are being developed that may reduce glare without blocking the view. An interesting example is Smart Energy Glass by Peer+ (www.peerplus.nl). Smart Energy Glass can switch between a bright, a darkened and a diffuse state to improve visual comfort and can simultaneously generate electrical energy.

Figure 10

Test set-up for the visual comfort study with varying glass transmissions
(source: Chraibi, 2011)

Since the experience of switchable glazing is very different from that of blinds, new research questions have to be answered. A study by Sanae Chraibi has investigated the optimal light transmittance for visual comfort in an experiment set up in the laboratory of the Building Physics and Services unit. Five similar full-scale test rooms were built with a west-facing window, four of which were laminated with films of different light transmittances. Test subjects were asked to perform an office task in the test spaces for 10 minutes, followed by a questionnaire about visual comfort, over three periods: summer, autumn and winter. Significant differences were found between the different conditions. Test spaces with total light transmittances of 52% and 70% were most preferred when there was no direct sunlight whereas, in the summer period and on sunny autumn days, there was a clear preference for transmittances of 25% and 52%. During cloudy autumn and winter days a desire is evident for the highest light transmission, while direct sunlight on the façade revealed a preference for a transmittance of 25%. Smart switching in an appropriate range would have seen these users satisfied with daylighting at least 71% of the time, up to 89% of the time (Aarts et al, 2011).

Outlook: towards smart lighting for life

What we can learn from all this, is that smart lighting is a powerful option to reduce electrical energy consumption. Even higher gains can be reached through the integral optimization of daylighting (blinds), lighting and HVAC to reduce total heating, cooling and electrical energy.

But the biggest opportunity lies in using smart lighting to influence health and comfort. Looking at the total costs of a commercial building over its lifetime, we find that by far the largest component is the cost of the people using the building (Romm and Browning, 1994; Rowbottom, 2009). This means, that solutions which can realize as little as 1% improvement in effectiveness, through reducing sick leave and errors, or improving staff retention, safety, performance, creativity, patient safety and recovery, would have an impact comparable to the total cost of energy, and would easily justify extra investments in a building and its technology.

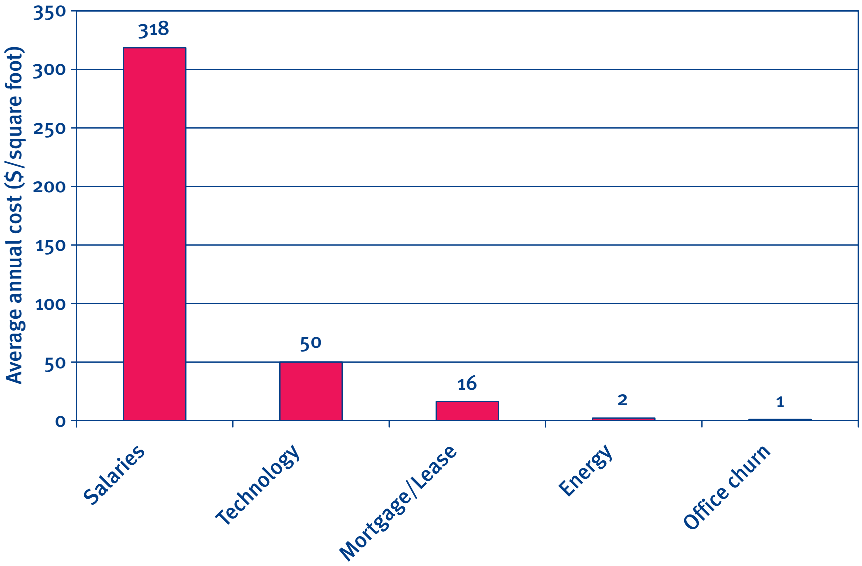

Figure 11

Distribution of total cost of an office building over its lifetime in dollars/square foot/year (data: Rowbottom, 2009)

Through this chair, I hope to contribute to improving our fundamental understanding of daylight, and the impact of all its characteristics on our health, comfort and effectiveness, and with that to the development of smart real and virtual lighting solutions. The application domains cover virtually all segments, including hospitals, rehabilitation centers, mental healthcare facilities, elderly care facilities, offices, production facilities, schools, shops, hotels and homes.

By studying the impact of user behavior on building performance, and of building behavior on user performance, we will be able to develop better user models that can be integrated into building simulation tools to improve their predictive value. Particularly interesting challenges are to understand the separate and combined impacts of light and views, and of slow and fast dynamics.

Developing timely smart lighting solutions requires teamwork across a range of disciplines, and between academia and industry. I look forward to joining forces with the departments involved in the Intelligent Lighting Institute, and to strengthening its interaction with industry. I hope it has become clear that the department of the Built Environment has very relevant expertise in this area. By developing methods to predict the impact of new and future smart (day)lighting technologies on building performance, architects, consultants and engineers can take such options into account early in the design process when the impact can still be maximized. And I look forward to working with you, students of this department. You are the decision makers of tomorrow. Together we have great opportunities to contribute to a smarter and brighter future.

Acknowledgements

That brings me to the end of my lecture. I would like to thank all those I have had and have the pleasure of working together with, and all of you for being here to share this special occasion with me. I thank prof. Jan Hensen, head of the Building Physics and Services unit, dr. Paul Scholte, managing director, prof. Elphi Nelissen, dean of the department of the Built Environment, prof. Hans van Duijn, rector of Eindhoven University of Technology, and my colleagues in the unit and Building Lighting group for their confidence and for making me feel welcome here.

I would like to thank Philips Research management, in particular Carel-Jan van Driel, for their support to build up this new chair. And all of my colleagues at Philips who were instrumental in realizing the systems I presented, for the great teamwork over the years and for enabling me to share these examples today.

I want to mention two people in particular, who have had a significant impact on my career. The first is prof. Frans Saris, my promotor and director of AMOLF (the FOM institute for Atomic and Molecular Physics) when I did my PhD there, and later director at ECN and dean at Leiden University. His energy to promote the institute and physics in general, made it an honor to work at AMOLF. The other is prof. Emile Aarts, who has been a tremendous source of inspiration during crucial moments in the later part of my career. He inspired me to move into interesting new fields, and I highly value our regular discussions.

I would like to thank especially the speakers in this afternoons' symposium, for responding so enthusiastically to my invitations and giving such great presentations. I met prof. Russell Foster at the VELUX Daylight Symposium in Lausanne last year. Instantly I knew that this was a man I would like all of you to meet, and I am very honored you are here today. I did not have to think long about the names for the other speakers either: Gaby Meekes to link the fundamental research on light and health to real products, and prof. Wim Sinke, with whom I worked together at AMOLF, to show the power of sunlight as one of our most sustainable sources of energy.

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Finally, where I hope this chair will lead is seeing smart lighting for life solutions emerge, based on knowledge and technology which originated in this smartest region of the world!

Ik heb gezegd.

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Curriculum vitae

Evert van Loenen was appointed part-time professor of Smart Lighting in the department of the Built Environment at Eindhoven University of Technology (TU/e) on June 1, 2010.

Evert van Loenen (1956) graduated in Applied Physics at the University of Groningen. He did his PhD research at the FOM Institute AMOLF in Amsterdam, obtaining his degree from the Utrecht University in 1985. He was visiting scientist at IBM in Yorktown Heights before returning to the Netherlands in 1986 to join Philips Research. From 1986 to 1998 he was research scientist in surface science, senior scientist in mechatronic miniaturization and head of the professional imaging department. In 1999 he was appointed principal scientist in the emerging field of Ambient Intelligence. He led the European AMBIENCE project, which was awarded the 2003 ITEA Achievement Award. His research in this field started in the Consumer Lifestyle domain, expanded to Smart Lighting concepts for retail and hospitality, and currently focuses on Healing Environments in Healthcare, exploring how environmental parameters such as real and artificial daylight can improve patient recovery. He holds 6 patents, and is co-author of more than 90 scientific papers.

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