New Perspectives on the Future of Healthy Light and Lighting in Daily Life features best Lighting Design Practice, Lighting Research and Related Aspects, as well as potential issues related to Medical Science and Lighting in human and natural settings. This publication includes contributions and research originally presented at the 5th Light Symposium Wismar 2016 (LSW 2016) held on October 12-14, 2016 in Wismar, Germany at the Hochschule Wismar, University of Applied Sciences: Technology, Business and Design. It is a vital reference source for students, researchers, academics, the lighting industry, lighting planners, and policy makers.

"I was really delighted to be a part of the much acclaimed Light Symposium series at Hochschule Wismar in 2016, which once again successfully brought together an amazing array of experts from all around the world to discuss the positive benefits of both light and darkness on human health and well-being. Excellent!"
Mark Major, Founder and Principal of Speirs + Major, United Kingdom
LSW 2016 Keynote Speaker

"LED is rapidly changing the world of lighting and lighting design. The dynamics of the technology ask for masters to control light for the best use in our habitat. Therefore, education in the form of the Light Symposium and interdisciplinary collaboration of industry and lighting designers is the basis for all future developments. For us it is important to make a significant contribution to this advancement."
Dr. Michael Kramer, CEO LED Linear, Germany
LSW 2016 Diamond Sponsor

"The Light Symposium is the perfect environment to learn, discuss and connect with friends and colleagues. This year's selection of lectures and speakers was not only interesting for the lighting industry but also for the general public. It's an honour and privilege for us to sponsor the LSPC16."
Orlando Marques, Editor L+D Magazine, Brazil
LSW 2016 Media Partner, LSPC16 Award Sponsor

"I had been curious about Light Symposium Wismar due to its content and the difficulty finding useful information on the presented aspects. I was very much impressed with the presentations and the quality of the speakers, and congratulate the organizers for this wonderful opportunity to gain knowledge."
Birgit Walter, Founder and Creative Director of BMLD, co-founder of APDI, Spain
LSW 2016 Participant

HOCHSCHULE WISMAR UNIVERSITY OF APPLIED SCIENCES TECHNOLOGY, BUSINESS AND DESIGN

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978-3-940677-61-7
9 783940 677617

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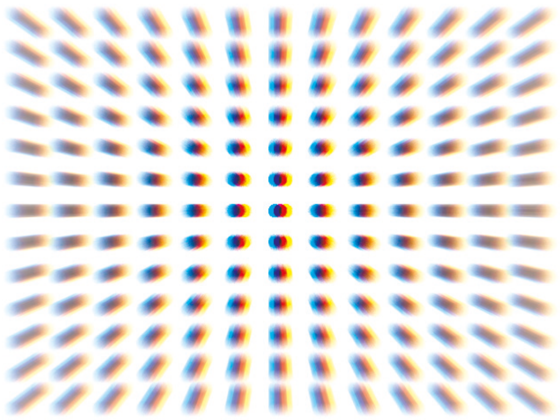

LIGHTSYMPOSIUM
WISMAR 2016

Edited by Karolina M. Zielinska-Dabkowska and Michael F. Rohde

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Wismar 2017

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Edited by:
Karolina M. Zielinska-Dabkowska and Michael F. Rohde
Hochschule Wismar Faculty of Architecture and Design

Proofreading:
Gisela Çakir

Cover, text and composition design:
Karolina M. Zielinska-Dabkowska, Mirko Dahms

Publisher:
callidus. Verlag wissenschaftlicher Publikationen
Technologie- und Forschungszentrum - Ost
Alter Holzhafen 19
23966 Wismar

Printed in Germany
ISBN: 978-3-940677-61-7

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PART IV MISCELLANEOUS

INTRODUCTION AND ACKNOWLEDGEMENTS

Thanks to state-of-the-art medical and environmental research, what we know about the impact of light and lighting is increasingly being questioned by experts. Rapidly evolving lighting technologies are opening up new design possibilities but, at the same time, they pose new challenges to planners and the general public if used lightheartedly. We no longer spend time in the outdoor environment and are often completely disconnected from nature and natural light, spending most of our time under artificial skies. There is already a growing awareness that light is not purely required for vision and that there is more to it. To answer the need for cross-disciplinary talks and bridge the knowledge gaps in the field of architectural lighting design, the idea of the Light Symposium emerged in 2007 at the Professional Lighting Designers Convention (PLDC) in London. It was introduced a year later for the 100th anniversary of the Hochschule Wismar (HSW), University of Applied Sciences, Technology, Business and Design.

This publication includes contributions and research originally presented at the 5th Light Symposium Wismar 2016 (LSW 2016) held on October 12-14, 2016 in Wismar, Germany at the HSW. This three-day international forum brought together new insights into the effects of healthy light and lighting in daily life with respect to research, theory, technologies, design, and applications. Following the popular symposia in 2008, 2010, 2012 and 2015 in Wismar and Stockholm, this edition aimed to deliver a state-of-the-art outline of how natural and artificial light affect human beings' physical and mental health, and performance. The symposium offered an outstanding opportunity for researchers, students, and practitioners to keep up-to-date with recent findings.

The main theme was the Future of Healthy Light and Lighting in Daily Life. The organizers chose this topic due to the fact that modern lighting technologies and design should address and, if possible, be based on the evidence revealed by scientific studies. The use of new technologies such as LEDs is already changing the future of lighting design and will continue to do so.
The title of the LSW 2016 event was a clear pointer to a world that is changing dramatically, with human health and well-being the area most affected. The impact of this, and the opportunities it offers, are hard to define right now, which is why they were the subject of the debate.

Furthermore, today and in the future, architectural lighting design needs to better acknowledge the need for interdisciplinary collaboration between scientists, medical researchers, the lighting industry, and lighting designers. Therefore, education and continuing education in the form of such an event is, and will remain, the basis for all developments in the field of lighting design as a discipline and a profession. The interdisciplinary structure of LSW 2016 promoted future-oriented discussion on the importance of light and the lighting design profession. Thirteen renowned speakers from lighting design, art, environmental science and medical science from Germany, the US, Canada, Switzerland, Norway and the UK presented their talks in three different tracks: Lighting Design Practice, Lighting Research and Related Aspects, Medical Science and Lighting. LSW 2016 was attended by more than 250 participants from several European nations as well as from overseas.

LSW 2016 also hosted the final of the students' and young designers' speaker competition: The Light Symposium Paper Competition (LSPC16) is included in this book. Four young talents competed for the first prize on 13th and 14th October in the final stage. Within the framework of the final, the speakers were judged on the quality of the content of their papers and the professional quality of the presentation itself. The jury, supported by independent experts, decided on two winners: Catherine Perez Vega, who will have the opportunity to present her paper at the 8th edition of LEDforum in São Paulo, Brazil in 2017, and Monika Vega, who received a free ticket to the PLDC 2017 in Paris, France.
We hope that by bringing together a cross-section of current findings in the field of light and lighting, this publication will contribute to the international debate on human health. This is seen as a necessary step to ensure that public policy frameworks, incentives and initiatives undergo a phase of change and review.

We thank the members of the Scientific and Organizing Committees of LSW 2016 for the hard work that they put into making it such a successful event. We also thank the staff and students of Wismar University, Faculty of Architecture and Design for their effort and support both before and during the event. We are most grateful to our 27 Lighting Industry Sponsors for their generous financial contributions towards the realization of the Symposium. Last but certainly not least, we would like to thank all the LSW 2016 speakers. The symposia could not continue to flourish without their high quality input.

Dr. Karolina M. Zielinska-Dabkowska,
Professor Michael F. Rohde

Hochschule Wismar
University of Applied Sciences
Technology, Business and Design
Faculty of Architecture and Design

PART I
LIGHTING DESIGN PRACTICE

THE QUALITIES OF THE NIGHT – WHY WE NEED LIGHT AFTER DARK

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Mark Major is a lighting designer and founding partner of the multi-award winning international design practice Speirs + Major.

Mark originally trained and practiced as an architect prior to focusing on the unique relationship between light and the built environment. He has worked on a wide range of award-winning lighting projects and is considered a specialist in the field of urban lighting. He was named as being a key city advisor by Monocle magazine in 2013. He also acted as the Lighting Design Advisor to the Olympic Delivery Authority for London's Olympic and Paralympic Games in 2012.

With an active interest in architectural and lighting education Mark lectures all over the world. He spoke at TEDx at the Sydney Opera House, Australia in 2014.

Mark is a corporate member of the Royal Institute of British Architects and the International Association of Lighting Designers. He is also a Fellow of the Royal Incorporation of Architects in Scotland. He was created a Royal Designer for Industry in 2012.

"If light is scarce then light is scarce; we will immerse ourselves in the darkness and there discover its own particular beauty."
- Jun'ichirō Tanizaki [1]

This paper examines the role that light plays after dark in our cities and towns, and how we can begin to get the balance right between our need for illumination and our wish to retain darkness in our lives – particularly with respect to well-being. It will consider the qualities of the night and ask: How lighting designers can help society become more aware of the challenges that lie ahead with the growing use of artificial light?

Fig.1: Light is critical to human health in the way it informs our circadian rhythms.

"If humans were truly at home under the light of the moon and stars, we would go into the darkness happily, the midnight world as visible to us as it is to the vast number of nocturnal species on this planet. Instead we are diurnal creatures, with eyes adapted to the sun's light. This is a basic evolutionary fact... (It's the only way to explain what we have done to the night. We've engineered it to receive us by filling it with light. This kind of engineering is no different from damming a river. Its benefits come with consequences...)"
- Verlyn Kinkenborg [2]

I. Introduction...

As Kinkenborg explains - people needartificial light. Unlike most other species we do not see well in the dark. Human beings have evolved with diurnal vision and, whilst we have some ability to adapt to low levels of illumination, our wish to extend the day and to embrace the night has required us to develop technologies that enable us to function between sunset and sunrise.

II. Our passion for light...

For many centuries lighting largely revolved around the individual and collective use of crude devices that openly burned fuels such as oil, tallow and wax. The limitations of such technology meant the world largely remained in relative darkness after the sun had set. By the nineteenth century we introduced more widely distributed and controllable networks of industrialised artificial light powered by gas and electricity that began to light up the environmenton a scale not previously experienced. Today, developed countries now enjoy the ability to provide seemingly unlimited amounts of illumination 'on demand' through a wide array of solid state devices.
As a result of the increasing desire for illumination we have flooded our world with light. In many cases this has been in an attempt to help support increased productivity, leisure or lifestyle choices. In others it has been in response to overcoming our fear of crime. We also increasingly employ artificial lighting

Fig. 2:
We often use more light than we need to
Over-illumination is a major issue.

Fig. 3:
We fill our cities with light to support social and economic activities.

to help strengthen our visual environment, support the night-time economy or for cultural reasons such as art and events. All of this results in a significant impact; as images from satellites and the International Space Station illustrate mankind's footprint on the earth is most visible at night.

The writer Paul Bogarde comments on this impact:
"We are losing dark skies all over the globe, but nowhere more than in western Europe and North America. Astronomers say that because of light pollution, fully eighty percent of the people living in those areas no longer experience 'real night,' that is, real darkness." [3]

III. Consequences, consequences...

As the consequences of our use of artificial light become much clearer–energy use, light pollution and the adverse effects on humans and flora and fauna – society, and the lighting community in particular, has begun to challenge just how much light we need. This has resulted in our re-considering the role that darkness plays: Sometimes the deliberate absence of light is an intuitive response, by example in areas of natural wilderness or rural zones. In other cases, such as within the urban realm, we now find ourselves deliberately reducing the amount of light to try and do more for less. Certainly, the benefits of such an approach are clear in terms of the natural world as Catherine Rich and Travis Longcore assert:
"Our diurnal basis has allowed us to ignore the obvious, that the world is different at night and that natural patterns of darkness are as important as the light of the day to the functioning of ecosystems." [4]
It has, however, become apparent that promoting darkness in the early 21st century is sometimes done from a position of privilege. As Eric Rondolat observes:
"We live in a world where 1.1 billion people – more than one in seven – still do not have access to electric light. The lack of this most fundamental service puts a stranglehold on human development. Without artificial light, life as we know it grinds to a halt at sunset. Communal life stops, children are unable to study, and businesses are forced to close. Deprived of electric light, people resort to candles, kerosene lamps and fires to counter darkness – all too often with devastating consequences. These primitive light sources claim the lives of 1.5 million people every year through fires and respiratory illnesses – the same number killed annually by HIV related illnesses. Light poverty and the millions of associated deaths are avoidable – the technology to balance this inequality is all around us and taken for granted across most of the world. In those countries blighted by light poverty, the difficulty lies in administering the cure, not in creating it." [5]

So part of the dilemma in tackling light pollution and over-illumination and their potential impacts on the environment is that developing countries must be left open to making the same

Fig. 4: A sensitive approach to light and darkness was taken in lighting this new square in King's Cross, London.

choices as the first world to increase their access to artificial light. In many regions communities that associate the presence of light with personal security demand more illumination. We understand that it is often only the wealthy areas of cities and towns that can enjoy the benefits that darkness can bring.

IV. It's for our own good...

Beyond the visual, economic, social, and ecological considerations we may also ask: How is light impacting on our well-being? Research shows that this is in two ways: Firstly, the potential physical and biological impacts of over-illumination are well documented, with issues related to disturbed sleep patterns, disruption of circadian rhythms and over-exposure all being viewed as potentially harmful. As the Lighting Research Centre at Rensselaer Polytechnic Institute asserts:
"All living organisms on Earth exhibit circadian rhythms which are biological cycles that repeat themselves on a daily basis and are regulated or entrained by environmental signals, the most important one being the natural, 24-hour, light-dark cycle. In humans and the vast majority of animals, patterns of light and dark reaching the back of the eyes are converted to neural signals that promote synchronization of the body's "biological clock" with the local time on Earth. Without this synchronization, research has shown that we may experience long-term decrements in physiological function, neurobehavioral performance and sleep, and are put at a higher risk for cardiovascular disease, diabetes and certain forms of cancer." [6]

Secondly, there are the cultural and psychological issues: A reduced view of the stars disconnects us from understanding that we live on a planet and divorces us from our true nature. Mankind has not evolved to only live by day but also to be a creature of the night. The more we banish the natural darkness around us the more artificial our world becomes. Darkness not only brings the potential for sleep but also privacy, visual silence and aesthetic appreciation. The absence of light has its own beauty that we can appreciate.

V. Where next?...

So where do we go from here? The first step must be to agree that darkness is important, not only in respect of the natural environment but also human health. If we begin to treat light as a precious commodity we will be well on our way to realising many of the benefits of the night. If in turn we treat darkness as being essential we can quickly help redress the balance.

The next step is to help educate people that lighting, like so many facets of our culture, is something that should be 'designed' by those who properly understand it. This helps reinforce the importance of the development of lighting education and the lighting profession.
Finally, it may be the case that we need to legislate. Many developed countries have guidance and standards that endeavour to control the worst excesses of pollution and obtrusive light, and whilst some might be indirectly enforced through legal planning frameworks, the true impact of new developments is rarely properly explored after dark. To that end it may no longer be enough to expect 'good practice' but there may be the need to find ways to reinforce it. Whilst rules and regulations rarely lead to the most creative and sensitive responses culturally it may be the only way in the short to medium term to effectively limit the continuing detrimental encroachment of illumination in our world and positively discriminate in favour of the dark.

"What's a dark-sky ordinance? The answer is easy enough – laws regulating the use of artificial lighting – and difficult enough that I am soon stumbling, wanting to say, Dad, it's about holiness and beauty, shouldn't that be enough?" [7]

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Fig. 5 (top): The courtyard at the New Student Centre at Oxford Brookes uses a balance of light and shade to create a convivial ambience.

Fig. 6 (bottom): Darkness in the city has become a privilege of the wealthy.

THE EDGES OF LIGHTING DESIGN. RESEARCH AND PRACTICE ON THE FRINGES

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Malcolm Innes is an artist by training and has extensive experience of architectural lighting design and light art from over 20 years working on international projects. Having worked for Kevan Shaw Lighting Design and then Speirs and Major before setting up his own practice, Malcolm's portfolio includes two IALD Radiance awards and nine IIDA awards.

After 7 years of part - time involvement in higher education, Malcolm is now a full-time senior lecturer and reader in Design at Edinburgh Napier University. He specialises in research and teaching in architectural lighting, light art, projection and interactive digital arts. Malcolm's book, "Lighting for Interior Design" (2012) by Laurence King Publishing, has been published in English, Spanish, Portuguese and Chinese.

Malcolm's experience of the boundaries of lighting design is born out of his experience of museum conservation lighting, light art and architectural lighting which has extended over the last two decades and continues through live research projects today.

If architectural lighting design is contained within a defined area, then the edges are, at the very least, quite blurred. All kinds of other lighting practice straddle the boundaries: theatre, live event, film, light art, lighting for health ... All these areas of practice have influenced architectural lighting over many years and sometimes the distinctions between lighting disciplines is difficult to identify. However, it is on the boundaries that much of the most interesting and innovative work happens.

I. Art, Science or Craft

Art and Science are often seen as two distinct areas of intellect and activity, with a continuous line between the two extremes that can map the location of other disciplines, such as design, that include various proportions of art and science [1].

In this linear representation the extremes represent what may be described as a Pure Art, an area concerned only with aesthetics, and a Pure Science, an area that eschews the aesthetic and concentrates on analysis and rational thought to produce an artless science.

However, whilst many areas of knowledge and practice, such as design or engineering, appear to fit neatly onto a line between art and science, there are exceptions that suggest that this model is incomplete. The examples of polymaths such as Leonardo Da Vinci (artist, inventor, engineer, scientist, mathematician and anatomist) seem to defy a single location on a linear scale. Leonardo was, at the same time, excelling at Renaissance art and science. The example of Leonardo appears to contort the linear art-science model such that the two extremes meet, not in the middle, but at the ends. Leonardo fuses high art and high science, skillfully using each one to advance the other. It is as if Leonardo managed to warp the line into a circle where high art and high science can exist in the same place.

"Artistic activity is a form of reasoning, in which perceiving and thinking are indivisibly intertwined." Rudolf Arnheim [2]

Table 1: Science, Art and Craft. Adapted from Gram (2010) [3].

	Science	Art	Craft
Foundation	Logic	Imagination	Experience
Relies on	Scientific Fact	Creative Insight	Practical Experience
Raison d'étre	Replicability	Novelty	Utility
Decision Making	Deductive	Inductive	Iterative
Primary Strategy	Planning	Visioning	Try Something
Contribution	Science as systematic analysis, in the form of inputs and measurement	Art as comprehensive synthesis, in the form of insights and visions	Craft as dynamic learning in the form of actions, tests, trial and error

Gram [3] sees the linear continuum between Art and Science as a flawed model. He references management theorist Henry Mintzberg to create a modified version of a Mintzberg model that includes Craft (or experience) as a third position in the model. Table 1 records Gram's definitions of the three loci.

Gram also adapted a diagram by Mintzberg which mapped these three points as a triangle (Fig. 1).

This tripartite model may also manage to include another common linear continuum, the one between aesthetic and functional. For, if we see Art as being the loci of aesthetics, then the pinnacle of Craft can be defined as the point of total functionalism. Rather

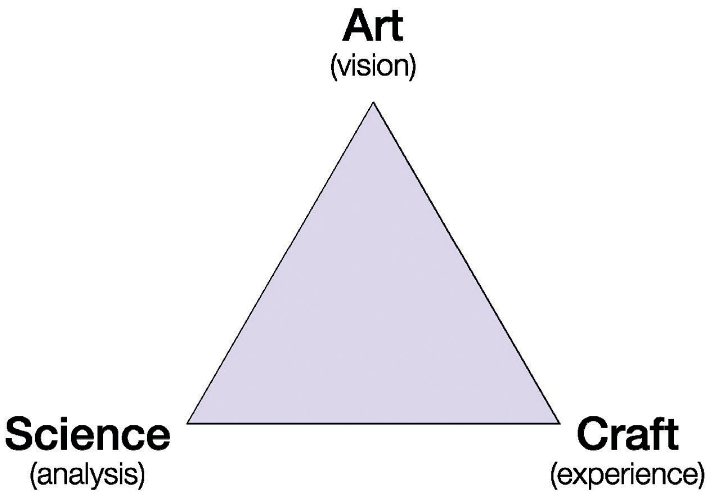

Fig. 1: Map of Science, Art, and Craft space. Adapted from Gram (2010) [3].

than a typical dictionary definition of Craft as a description of small scale and hands-on activity, in this model, Craft should be seen as a broader term that encompasses many experience-based fields. After all, if Craft is defined as a "profession that requires particular skills and knowledge", [4] then that would encompass (to greater or lesser degrees) diverse areas such as: construction, engineering or nursing.

If we now reapply this tripartite model to Leonardo da Vinci, we see that all his many activity areas can be encompassed within this model. Nevertheless, the breadth of his interests and skills suggest that Leonardo cannot exist as a single point on this chart, but instead occupies an area, a non-geometric shape that covers the science, art and craft of his broad portfolio of work.

If we then begin to think of where Lighting Design may exist within this model, we begin to see that, like Leonardo, a single point cannot describe all of Lighting Design. Lighting practice extends from the almost purely aesthetic light art, to the more experience based craft of theatrical lighting and numerically based illumination engineering. In amongst this there are also areas with a strong scientific or analytical underpinning, such as light for health or conservation lighting in museums.

II. Living on the edge

For me, some of the most interesting, exciting and inspiring aspects of lighting design exist on the margins, the extreme boundaries of what we might define as design. As I have not had any formal education in lighting design myself, a lot of my own lighting design practice has been built on a foundation of learning by emulating others, learning by doing and building up a store of experience - the Craft of Lighting. However, even when I was studying as an artist at Edinburgh College of Art, I was never satisfied with simply accepting received wisdom, I was always inquisitive enough to want to know not just that something was

Fig. 2: Studies of the foetus in the womb. Leonardo Da Vinci. Circa 1510-13.

Fig. 4: Botanic Lights, Royal Botanic Gardens Edinburgh. Light Art by M. Innes and E. Winton.

true, but why that was true. I found my own work to be stronger with this theoretical underpinning. This quest for deeper knowledge and deeper meaning is something that I believe is common to many established lighting designers that I know. Colin Ball of BDP in London talks often about lighting design through the lens of philosophers or psychologists such as Carl Jung [5]; Italian designer Francesco Iannone has created unique lighting schemes for Renaissance paintings by applying ideas of neuroaesthetics to his practice [6]. Emrah Baki Ulas of Steensen Varming has talked about ideas as diverse as lighting design's role in economics and consumerism [7], and esoteric ideas such as how light allows us to "taste with our eyes" [8].

The more I have learned about light, the more I have come to believe that good lighting design is good psychology. This is an important factor in lighting design because the empirical metrics that we have to work with (from the lumen to colour metrics) often fail to adequately describe the complex and contradictory nature of the human visual experience of light and colour. In this sense, human centric lighting design, as opposed to illumination engineering, is a form of applied or practical psychology. As designers, the oddity here is that to fully satisfy the human response to light, we need to fall back upon our experience (Craft) and our aesthetic feelings (Art) for light because the pure science does not always apply.

An example of this is an experimental study that I set up to empirically explore a visual effect that I had experienced in lighting conservation displays in museums (Fig.3). I had seen in practice that adjacent museum displays lit to the same illuminance level can appear to have different apparent brightness depending on the colour temperature of the illuminant [9]. Whilst I am not a scientist, this study used scientific methodologies to explore a feature of light that I had experienced on site (Craft). Whilst on site, I saw that there was a clear discrepancy between the existing theory (that the illuminance measurements accurately represent

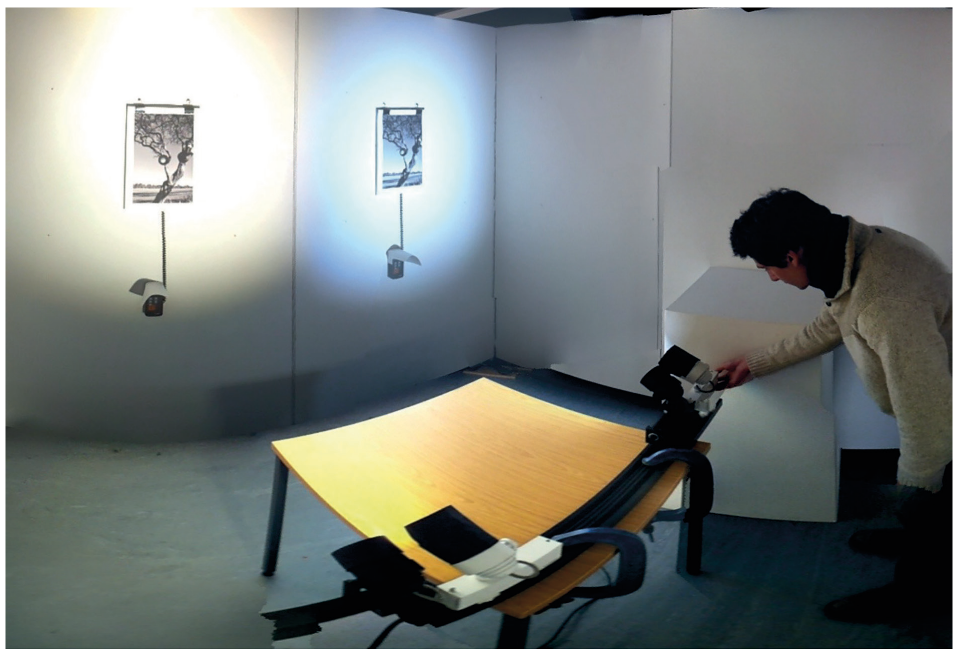

Fig. 3: Perception of brightness experiments at Edinburgh Napier University.

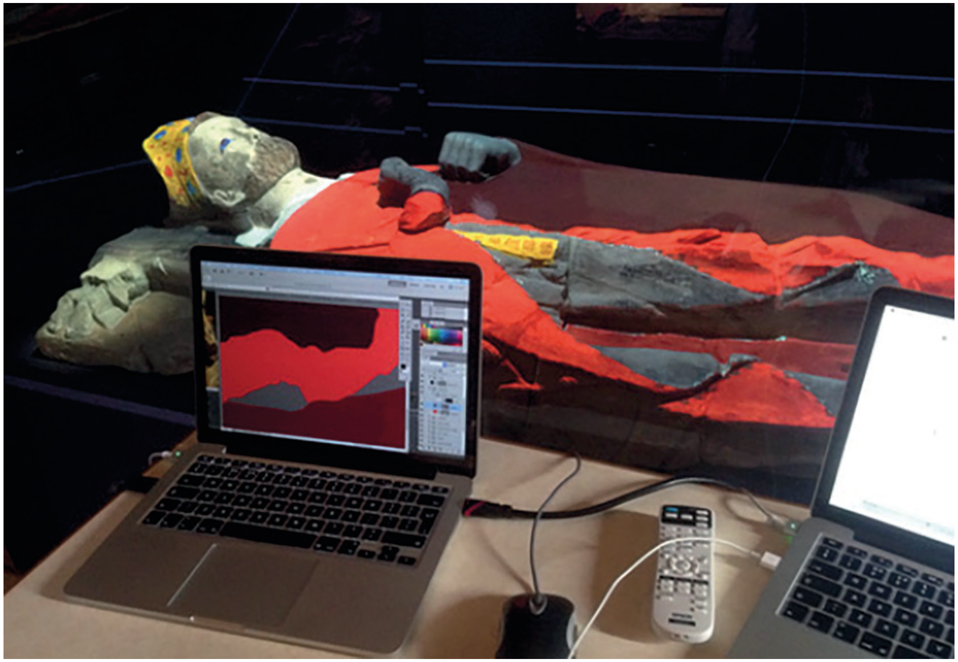

Fig. 5: Programming for lighting of the Bishop Archibald display at Elgin Cathedral.

human perception of light) and observable fact.

I was expecting that my experiments may show either a very small effect of brightness perception being influenced by colour temperature, or possibly no effect because I had imagined the whole thing. However, I was surprised that the effect was very clear amongst the test subjects and was much larger than I had expected. This foray into using scientific methods to explore aspects of light, colour and perception has led me to look at other features of light that I have experienced through my Craft. This has enriched my design work and has made me realise how valuable targeted experimental work can be to support the more intuitive aspects of lighting design.

Having originally trained as an artist before discovering lighting design, light art plays an important role in my own work (fig. 4). The majority of my work is design, but it is very difficult to identify where the boundary between my own art and design actually lies. My light art projects are always undertaken with a designer's approach to problem solving, my design work is equally informed by an artist's vision of the desired outcome and a strong rationale or narrative for the project. For me, the two disciplines are complementary and strengthen each other.

A recently completed project at Elgin Cathedral combined aspects of Art, Craft and Science to illuminate a life size 13th century carved stone funeral effigy of Bishop Archibald. The effigy was originally brightly painted, but the subsequent 700 years have not been kind to the effigy and almost all of the paint finish has been lost. This research led project set out to virtually restore the lost colour to the object, using light.

The project did call on existing skills in museum and gallery lighting, projection skills from light art projects and elements of scientific understanding to determine how the exhibit would respond to projected colour.

This kind of creative use of projection equipment raises important questions for designers. Firstly, is projection lighting design? Is a projector just another light source that we can work with? Should lighting designers be actively working with projection or should they leave projection to others? As projection systems continue to become smaller and more reliable, these questions are going to become harder to ignore. It is, therefore, important that we are asking these questions of ourselves now and that we begin to take charge of the illuminated future, before other specialists do.

Designers often suffer from an inability to explain what we do. As Steve Jobs, co-founder of Apple said, “When you ask creative people how they did something, they feel a little guilty because they didn't really do it, they just saw something” [10]. But designers should not be so coy about the intuitive skills they possess, or believe that, in some way, they are inferior to scientific intelligence. After all, Albert Einstein himself was a great admirer of creativity and intuitive thought:

"I believe in intuition and inspiration. Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research." Albert Einstein [11]

It is possible that recognising effective lighting design as a creative combination of Art, Science and Craft could help us to get over the embarrassment of being designers. Embracing life at the boundaries of lighting design can open our minds to new opportunities and strengthen and extend our core practice. It has enriched my work and I would recommend everyone to be more inquisitive and question the norms of lighting practice. After all, some of them are built on vary shaky scientific foundations.

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DAYLIGHT IN URBAN PLANNING

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Aicha Diakite studied Electrical Engineering at the (TU Berlin) Germany and Poznan University of Technology, Poland. She went on to study Architecture and Industrial Design at the National Autonomous University of Mexico, where she received a Postgraduate Architectural Lighting Design Diploma in 2011. In 2013 she finished her master's studies in the Department of Lighting Technology at the Technical University of Berlin. Aicha's thesis was awarded the H.-J. Hellwig Prize 2014 by the German Lighting Technology Association, the Hans-Peter Willumeit Award by the Foundation Committee of the Center of Human-Machine Systems (ZMMS) and the Clara von Simson Prize honoring women in Science and Technology by the Technische Universität Berlin.
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This paper presents a novel approach to describe sky models, based on spatially resolved spectral information. Currently, in the daylight planning solely luminance distribution and an approximate CCT of 6500K are taken into consideration. The additional information on temporal and spatial distribution of the sky color enables the inclusion of non-visual effect in daylight planning without increasing the energy consumption. This paper introduces a novel model to predict CCT potentials in the urban structure in function of: existing daylight conditions (season, sun position, location, and dominant sky types) and obstruction proprieties (orientation, obstruction level, reflectance from the built environment).

I. Introduction

Built spaces have a profound impact on public-health [1]. For many years scientists were studying the correlation between spaces, human perception and the resulting well-being qualitatively. The discovery of the intrinsically photosensitive retinal ganglion cells (ipRGCs) has allowed us to add quantitative cognitive information into the urban planning process, which enables a more precise description on how built environments affect people's mental well-being. These in turn allows designers and decision makers to anticipate cognitive value and adjust the planning decisions accordingly. Yet, most of the existing framework models to design or redesign the urban structures with daylight are primarily focused on energy optimization and rarely represent user-and-site-specific aspects. Currently, in the daylight planning solely luminance distribution and an approximate of CCT 6500 K are taken into consideration. However previous research has shown that in order to enable the inclusion of non-visual effect in daylight planning, without increasing the energy consumption, additional information on temporal and spatial distribution of the sky color is required [2]. This novel approach of collecting spatially resolved spectral information enables the inclusion of non-visual effects in the urban planning process and may also provoke a new idea of how to modify physiological responses or response patterns. The real-time data combined with human response models supports a data-driven management. Including the non-visual aspects in the debate on daylight planning allows us to shift the focus to a more human-oriented design process and provokes a multi-criteria assessment approach in order to realize healthy and truly sustainable urban environments.

Additionally today's cities are subject to dynamic spatial and social change, which cause new spatial and social framework conditions for urban planning [3]. In present times of progressive urbanization and increasing population, daylight plays an essential role in the urban structure. The subsequent correction of the daylight openings in buildings is not only difficult, but also very expensive. Therefore user-and-site specific daylighting plans should be implemented in the early stage of design. Daylighting masterplans provide an opportunity to tackle the lack of urban space with sophisticated architectural concepts based on in-context and human-centered solutions. This method offers a large-scale approach to coordinate the design and/or retrofit for multiple buildings simultaneously.

II. Methodology

The work is divided into three parts: the development of spectral sky models, the creation of orientation dependent CCT potential diagrams in function of: existing daylight conditions (season, sun position, location, and dominant sky types) and obstruction proprieties (orientation, obstruction level, reflectance from the built environment), and a proposal for a computer-based urban parametric tool [4].

In order to meet the need to evaluate and link the impact assessment of each individual criteria for multiple buildings simultaneously, a computer based parametric tool is being developed. This planning tool allows a better impact assessment of designing urban spaces with daylight by outlining the spectral dynamic range for non-visual effects of daylight based on spectral sky models. For this purpose, spectral sky models are being developed analogically to the CIE illuminance sky models [5,6]. The tool builds up on the spectral data measurements carried out by the Department of Lighting Technology at the Technical University of Berlin (Fig. 1).

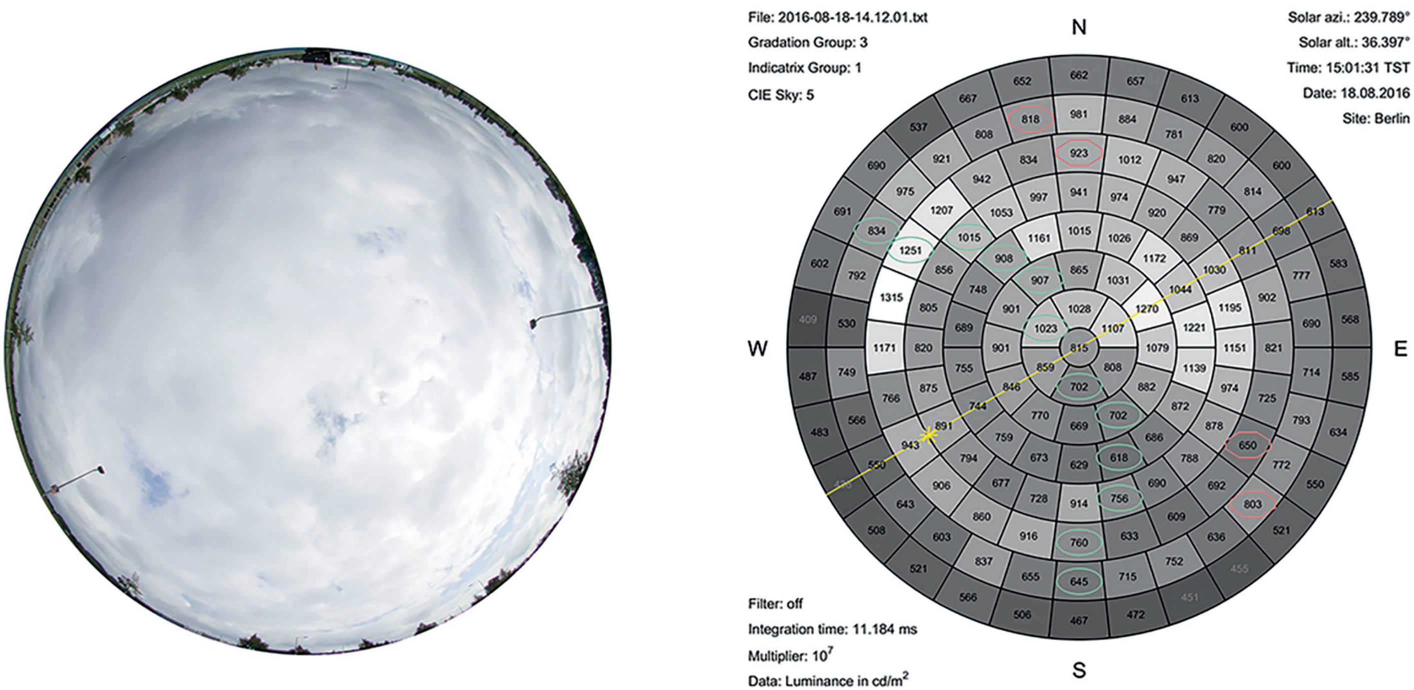
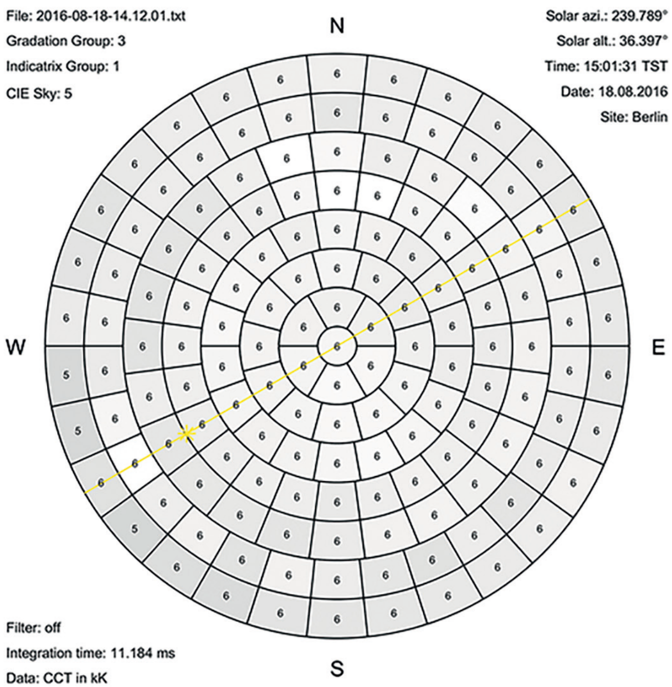


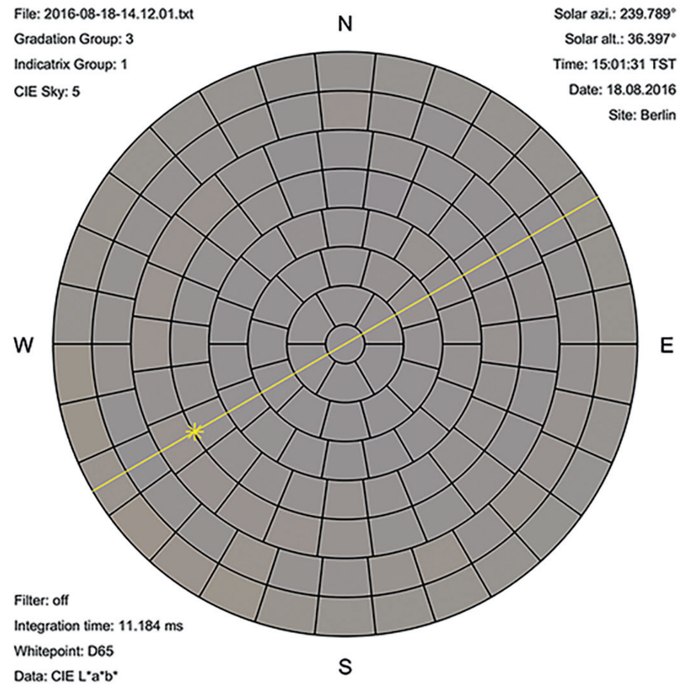
Fig. 1: Measured luminance distribution and CCT distribution for CIE Standard Sky 5 (Berlin).

III. Results

The work provides an overview of current developments in the research regarding measuring, modelling and practical applicability of color distribution of sky radiation in order to define the orientation dependent CCT on the facades and thereby enable the inclusion of non-visual aspects in the urban planning process. This work examines additionally the influence of individual sky patches in order to predict the daylight potentials on the facades in function of existing daylight conditions and built environment.

The parametric study showed that obstruction coupled with reflectance and orientation has a significant impact on the spectral daylight potential on the facade. Moreover, the results confirm that daylight conditions influence the spectral characteristics on the facade significantly [7]. Therefore it is recommended to individualize the planning process by using the local information on daylight conditions and build environment.





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DAYLIGHT: LIGHTING A SUSTAINABLE FUTURE

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Arfon Davies is a lighting designer and Director within the lighting studio of Arup. He is one of the three founding members at Arup Lighting, which has grown to consist of more than thirty-five designers in the UK and over hundred worldwide, making the studio one of the largest independent lighting design practices. He has particular expertise and passion for daylight design and collaborating with architects to ensure daylight is considered at the very beginning of the design process.

Arfon contributes extensively to the lighting industry and the formulation of lighting standards and guidance, recently authoring the daylight section of the British Council for Offices Guide to Lighting, and co-authoring the Society of Light and Lighting Daylighting Guide.

Daylighting has long been driven by three prevailing objectives: energy savings, health and well-being, and aesthetic appeal. Throughout history, the weighting of these objectives has varied depending on the sociopolitical climate, as well as individual project needs. Development and adoption of LED lighting has improved energy efficiency significantly, the outcome being that the energy case for daylighting has become more challenging. As lighting designers, we should shift our focus from energy to people – their wellbeing and creating exiting, delightful, and engaging visual environments – and the primary source of light to achieve this should be daylight!

Daylight is fundamental to life. We have evolved in daylight for millions of years, only recently entering a phase that is dominated by indoor working and electric lighting. In evolution terms, this phase equates to a miniscule 0.000075% of the time we have spent evolving from our primate ancestors. This emergence of electric lighting has transformed our lives, both at home and at work. Advancements in light source, luminaire and control technology has allowed us to work longer, play longer, all the time distancing us from our natural daylit habitat. The more recent development and adoption of LED lighting has improved energy efficiency significantly, dramatically reducing energy consumption from electric lighting is all sectors and project types. This is turn is making the energy case for daylighting much more challenging. This could be viewed as an unfortunate side effect of an otherwise positive industry trend, or an opportunity to refocus daylighting priorities.

Increasing focus and interest in the field of wellbeing also presents an opportunity for lighting designers to rethink how we approach lighting design for projects. Conversation on topics such as human centric lighting, circadian lighting and personalisation are however being dominated by electric lighting technology and controls. Instead, as a collective of practitioners and designers, we should focus on progressing our understanding and application of the „intangible" benefits of daylighting: the physiological effects of spectrum and time appropriate lighting for stimulating healthy circadian rhythms, the emotional benefit of maintaining a connection to the outside, the pleasantness of a beautiful daylit space, and how daylight can define our experience of a project and a place. Regardless of energy savings, daylight can have a significant effect on the wellbeing of occupants of our built environment.

Beyond the physiological and wellbeing benefits, daylight has the ability to create atmosphere and texture, visual environments that provide delight and intrigue for people that cannot be achieved with electric lighting. Daylight is an unparalleled as a source of light, and has the unique ability to create dramatic visual experiences that are ever changing with the time of year and season. Intensity, colour and distribution are a function of time and place that make daylight dynamic and unique for every place. These are qualities particular to daylighting design that are embedded in our visual memory of place. Daylight variability also feeds our innate desire for variety and change: the use of daylight in buildings improves peoples' mood and sense of well-being. This variability is also aligned with our circadian rhythm, and as such provides the perfect source of circadian light, with spectrum, intensity, duration and timing in tune with our human needs.

A sustainable future is not just a future where energy consumption is reduced and carbon neutrality are commonplace - these outcomes are often thought of being the only ingredients of a sustainable future. Energy and carbon consumption are an important ingredient in the sustainability story, but another key ingredient that is often forgotten about is people, the occupants of the buildings and projects that we design. A sustainable future is therefore one that puts people at the heart of what we do, where people and occupants are the focus of our design thinking and effort from the outset of a project. It also means we should consider daylight from the earliest possible moment in a project, before we consider electric lighting. We should use daylight as a source of light to create delight for people, to shift the focus away from the energy-cost paradigm, and toward a lighting approach centered on daylight to achieve occupant comfort, experience, and wellbeing.

PART II
LIGHTING RESEARCH AND RELATED ASPECTS

DIRECT AND INDIRECT MEASUREMENT OF THE MENTAL STATE OF HUMANS EXPOSED TO DIFFERENT SOURCES OF LIGHTING

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Dr. Uwe Geier received his Ph.D. degree in agricultural science from the University of Bonn in 2000. Since 2007 he has been head of quality development and on the board of Forschungsring e.V.
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Dr. Geier is also a member of the FQH-International Research Network for Food Quality and Health and, since 2016, manager of the WirkSensorik GmbH (www.wirksensorik.de).

In the sensory analysis of food, humans become a measuring apparatus. A new element of sensorial analysis is the measurement of food-evoked emotions. Early studies show the effect of light treatment on both sensorial perceptions and induced emotions of food.

I. Human-based methods to measure food quality

In sensory analysis of food, humans become a measuring apparatus. The examination of the organoleptic attributes of a product is carried out by the sense organs [1], namely the senses of touch, smell, taste and the visual sense. In food examination, sensory analysis is equivalent to analytical methods; several ISO standards describe this method. Sensory analysis distinguishes between untrained consumers [2] and trained assessors [3].

The measurement of food-induced emotions is an extension of sensory analysis. In recent years, numerous studies have investigated food-induced emotions, leading to the development and application of different questionnaires that focus on emotional perceptions of food [4], [5]. Standards for the measurement of food-evoked emotions have not been developed up to now.

A new element of measuring food-induced emotions is the distinction between trained and untrained observers [6]. Another new approach is the use of preparatory settings, analogous to an element of Kabat-Zinn's concept of mindfulness-based stress reduction [7], in order to improve the attention of the observers [8].

II. Impact of lighting on food quality

Even though sunlight is the main light source in agricultural primary production, there are certain areas in food production where artificial light plays an important role. Artificial light is important in greenhouse production, especially for seedling cultivation and the production of ornamental plants, vegetables and fruits. The diverse possibilities of using LED lights in greenhouses is currently a strongly discussed topic. Light is also of great importance for food traders in the context of the optimal presentation of food to the customers. However, little awareness exists of the influence of light in the context of food processing.

Some food producers have started to discuss how LED lights influence the quality of food. Samples of honey, apples and carrots exposed to LED and halogen lighting for three days for 15 hours each day were tested, commissioned by one German retailer. The light treatment had to reproduce the conditions in a shop. The questionnaire EmpaticFoodTest (EFT) [8] was used by a panel of nine trained persons to measure food-evoked emotions. (Fig.1) The EFT includes 12 polar questions on the physical and mental state.

Significant differences occurred between light treatment and control. The control was evaluated as more positive for all three products. This outcome corresponds with the results of Martin et al. (2016) [9] who analyzed the influence of light treatments on the fat content, age and microbiological content of milk. Milk treated with LED light resulted in a broad negative reaction from consumers with regard to sensorial perception. In the above mentioned experiment, differences were also found between the LED and halogen light sources. The evaluation of food-induced emotions was more

Fig. 1: Calming down of panel before observing emotional response to food.

Table 1: Measurement of the emotional and bodily perceptions caused by different sources of light. Free description of 11 trained observers.

LED	Halogen
slightly light/light (2)	emotion of wideness/open for surrounding world (7)
stiff/crystalline/mineralized (6)	warm (6)
boundary/closure to surrounding world (6)	come to rest/calming (5)
pressure on the head (4)	coating (4)
pressing/presses me down (3)	open (4)
nervous/restless (3)	moving/movable (3)
cold/slightly cold (3)	centered (3)
contracting/retracting (2)	light (2)
fragmented/scattered (2)	good standing (2)
pressure in stomach/throat (2)	pleasant (2)
heavy breath/ breathlessness (2)	awake/alert (2)
narrowness (2)	happy (2)
	more community experiencing (2)
	something flows (2)
	slightly pressing (2)
	fluctuating stand to the front and back (2)

negative towards honey and carrots treated with LED light compared to halogen light. No differences were found for the apple sample.

III. Direct measurement of light induced emotions: First results

The outcomes described above lead to the question of whether it is possible for observers to describe the mental state affected by different light sources directly. A preliminary test based on the questionnaire EFT [8] was carried out. Eleven panelists trained in introspection were exposed for 10 minutes to two light sources, namely halogen (150W) and LED (35W) in a classroom situation. The EFT questionnaire revealed significant differences. The free description of the observed emotional and bodily perceptions also indicate deviating effects of LED and halogen (Table 1). The validation of the method is still pending.

The numbers mentioning an attribute are in parentheses.
Colors:
green = rather positive connotation,
red = rather negative connotation.

Fig. 2 (top): Potato and carrot samples for investigation.

Fig. 3 (bottom): Sugar samples for investigation.

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LANGUAGE: A KEY ELEMENT IN LIGHTING DESIGN EDUCATION

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Dwayne Waggoner completed his Bachelor of Science degree in Engineering Technology at California Polytechnic State University, San Luis Obispo, USA in 2008.
After that, he moved to Germany where, in 2013, he completed his master's studies in Architectural Lighting Design at Hochschule Wismar, Germany.
Dwayne's interest in language as an important element in lighting design has led him to present at multiple conferences on the topic, as well as teach part-time on the subject at Hochschule Wismar. At the last Light Symposium in Stockholm in 2015, Dwayne presented his master's thesis entitled "Conveying Light: An Analysis of the Language of Lighting Design" and was the winner of the Light Symposium Paper Competition (LSPC).
After graduating from Hochschule Wismar, Dwayne worked as a lighting designer at Lichtvision in Berlin. Dwayne has now recently joined the Key International Accounts Team at XAL in Graz, Austria, where he is working as the department head of lighting design.

Since architectural lighting design began as a practice, a new language for light has slowly emerged. Much of this new language is aimed at better categorizing and systematizing our perception of the illuminated world. For the past year, students of the master's degree program in Architectural Lighting Design at Hochschule Wismar have investigated the nature and development of the language of lighting design. By having the students look at architectural lighting design through a window framed by language and culture, a better awareness of the quality of illuminated spaces can be achieved.

I. Exploring the language of lighting design

In follow up to the master's thesis and paper presentation entitled Conveying Light: An Analysis of the Language of Lighting Design, the faculty of Hochschule Wismar's master's degree program in Architectural Lighting Design chose to incorporate the topic of language and lighting design as an elective class module. The use of language as a scholastic framework creates the opportunity for architectural lighting design students to have an additional parameter by which they may gain insight into the qualities of illuminated spaces, as well as discover areas in practice that deserve closer attention. The paper presentation is aimed at informing the lighting design community about the students' coursework in order to further the dialogue of the theoretical approach.

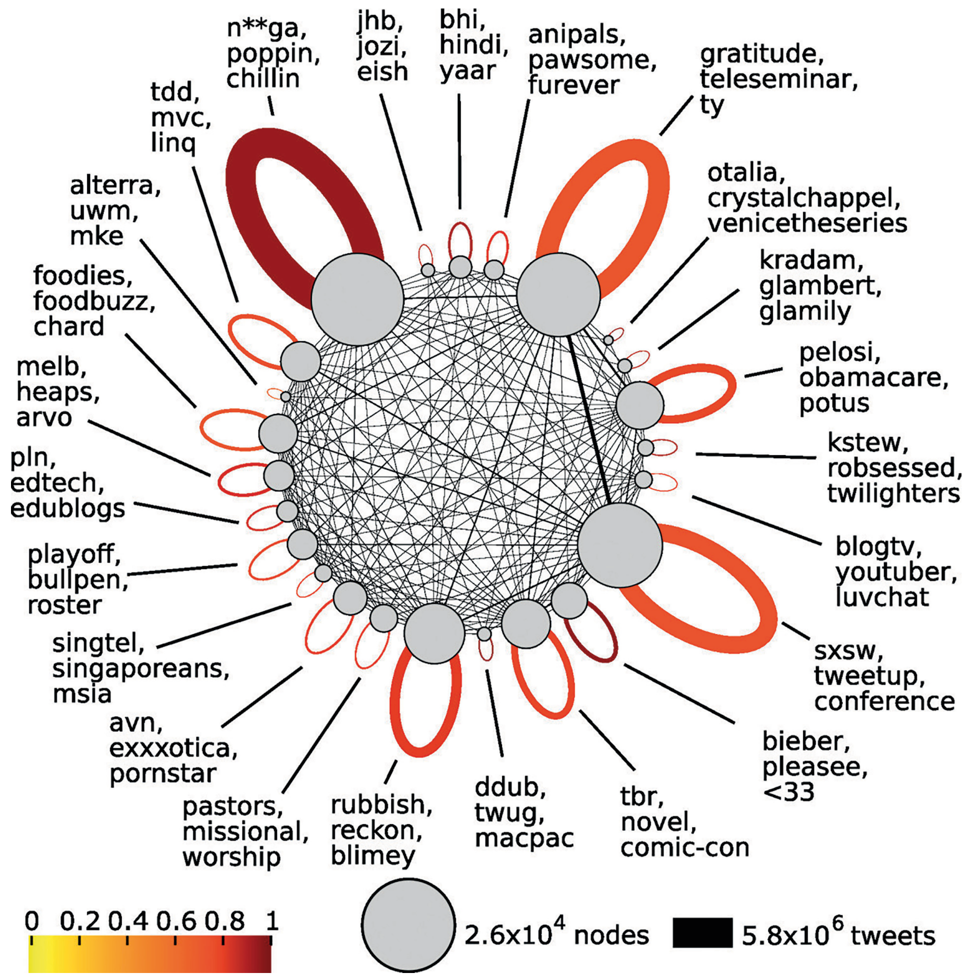

Fig. 1: Linguists Bryan, Funk and Jansen found that specific words could characterize certain communities according to the terminology used in their tweets. Communities were analyzed and the words they used were ranked to determine which words best identified that particular community.

II. Class coursework

The Hochschule Wismar course, Conveying Light: Exploring the Language of Lighting Design, was aimed towards new students with limited architectural lighting design experience. The coursework consisted of both individual and group assignments that were designed to invoke critical thinking about the state of the practice, technological and internet applications to communicate lighting, as well as cultural interpretations of light through language.

II.1 Analysis of Richard Kelly's terminologies

The article, Lighting as an Integral Part of Architecture, written by Richard Kelly, is arguably one of the most famous articles for architectural lighting design in the 20th century. The article is the first published source of his three terms: focal glow, ambient luminescence and play of brilliants [1]. These three terms were coined as a means of establishing verbal tools for the basic building blocks of good lighting design. The students were asked to explore the appropriate analogies of these terms within their own native language. The discrepancies in the results from students of the same nationality or language can imply the developmental stage of the lighting design industry within that country.

II.2 Communicating light in the internet age

The practice of architectural lighting design is emerging amidst a technological revolution, which is changing the ways in which we communicate. The question arises whether or not these new technologies are helping or hindering the development of a cohesive language for lighting design. Linguistic evidence now shows that internet communities can be characterized by their most often used words, and the words used by a user can predict the community of which that user is a member [2]. Through the use of analytic software, this study can be applied to the language of the lighting design community within social networking tools such as Twitter.

II.3 Exploring other languages

Many languages have unique words to describe lighting conditions that do not exist in other languages. Students of different nationalities and native languages were paired together to learn how other cultures and languages might shape and highlight particular lighting qualities. With English being the predominant language for the international community of architectural lighting designers, the students were then asked to translate these words into English. The translated words were then analyzed using Google nGram Viewer software to determine the usage of the word or phrase throughout recent history [3].

II.4 Neologisms

As the practice of architectural lighting design develops, new terminologies, or neologisms, will be coined to communicate important visual elements or occurrences within the illuminated environment. The students on the course were required to individually think of lighting situations or effects that might be important to a community of people working with light. By analyzing and comparing the created terms, valuable lighting situations arose which are currently unnamed and are deserving of a verbal vehicle.

Fig. 2: Eugen Wüster, whose research on international technical communication led to the International Organization of Standardization creating the Technical Committee for Terminology Standardization in 1936. Wüster also played a major role in the first edition of the International Electrotechnical Vocabulary, London 1938.

II.5 Language as a design tool

After investigating several aspects of the terminology of lighting design, the architectural lighting design students in the class were encouraged to create an architectural lighting installation or a design object that used language as the basis for their design. The framework of language allowed for unique expressions and creativity, providing the student a richer awareness of their illuminated space and their abilities to verbally express their illuminated works.

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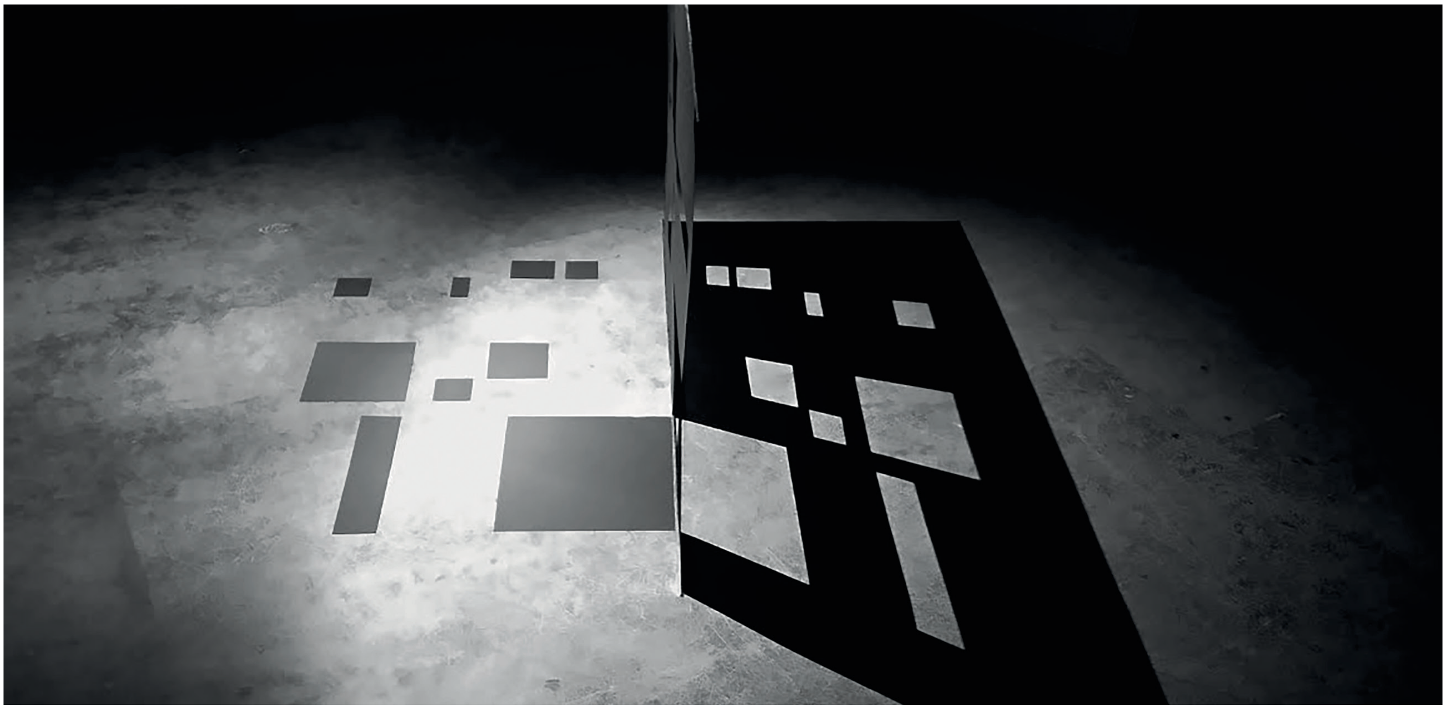

Fig. 3: Architectural lighting design student, used language as the tool when exploring the relationship between light and shadow as applied in architecture. In her original art piece, the viewer questions the importance or value of illuminated objects and unilluminated objects in contrast to one another. She defined the term “Framed Light” to better express the illuminated situation.

IMAGE OF THE CITY AND LIGHT POLLUTION

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Monica Vega obtained a bachelor's degree in Architecture from the Centro de Estudios Superiores de Diseño de Monterrey (CEDIM, Monterrey, Mexico) in 2008. She has worked with the private sector as creative project manager for several interior design agencies in Monterrey and as a sales representative consultant for a lighting company in Mexico City (Birot). Currently, she is studying Architectural Lighting Design at Universidad Autónoma de México (UNAM, Mexico City).
In 2015, Monica founded her own design firm LumLum Iluminación where she has designed and managed projects for commercial areas (primarily hospitality projects).
Monica's research interest is focused on coexistence in urban environments and the way each individual collaborates with others to shape their public space and city.

Although billboards are a source of street lighting that can have an impact on a city's inhabitants, they are not considered as part of the public lighting system and, therefore, are exempt from the norms that should regulate them.
Lighting designers should be more involved in policy-making and in raising awareness about the effects of the indiscriminate use of lighting and technology. Mexico City can be used as an example to show how negligent behavior with regard to these activities can become harmful.

I. A new system for the city

On August 20th, 2010, Mexico City Outdoor Advertising Law was published for the first time. The legislation was created to help improve the city's image, and to recover its urban landscape through the elimination of visual pollution. For this purpose, Mexico City's government decided to rearrange the existing billboards through a system of nodes and advertising corridors. The main goal of a node is to accommodate billboards on public property such as subway and bus stations, vehicular and pedestrian bridges, etc. Meanwhile, corridors, which are primary routes, can have them on private property.
Between the years 2010 and 2015, the number of nodes increased from 3 to 158, and advertising corridors also showed an increase, rising from 3 to 18 [1-6] (Fig. 1-3). Located on primary routes, corridors can have an extension up to 30 km; the rapid increase in the allocation of advertisements makes the attempt to improve the city's image questionable.
The most recent reform made to Mexico City's Outdoor Advertising Law on the matter of illuminated signage established that:

- the maximum level of direct lighting that the signage is allowed to emit is 600 lux - this, whenever the light reflected on motorists and pedestrians does not exceed 50 lux between 18:00 hours and 06:00 hours the following day the brightness of the electronic screens (LED) directed towards motorists and pedestrians may not exceed 325 nit (cd/m^2).
- in the case of advertising fences, the brightness of the screens may not exceed 325 nits; it must also have an automatic adjustment system that reduces the brightness according to the allowed limits [7].

However, it does not regulate the following:

- quantity of illuminated billboards on nodes or corridors
- electrical power consumption per billboard
- lighting technologies - although it does suggest the use of LED
- direction of light
- distances between roads and illuminated billboards
- distances between residential buildings and illuminated billboards
- light trespass limits

The above are left open to interpretation by the advertising industry and bureaucrats. While streetlights are regulated, there are various sources of light that are not although they do contribute to levels of street brightness and its average contrast.
While Mexico City's Law of Outdoor Advertising allows a maximum luminance level of 325 cd/m^2 at street level, the Official Norm of Mexico NOM-013-ENER-2013 Energy efficiency for street lighting systems establishes a minimum luminance level of 1 cd/m2 and a contrast ratio of 0.3 to 1 on primary routes. This suggests that it is likely that areas with a contrast ratio of 325 to 1 can be found on advertising corridors and nodes.

II. A new landscape model

Node 009 was the first approved project under these guidelines and was pitched as a new landmark for the city which would be a tourist attraction similar to Times Square. It is located on a roundabout at the intersection of two primary routes that host a subway and a metrobus station. The project consists of 2 cylindrical LED screens, located on the North and South exits (Fig. 4), each one facing the traffic.
Authorities claimed that the project featured "energy-saving LED screens, which will provide better lighting to public space." [8]. However, we know that a LED light by itself does not mean energy saving or good lighting, nor does a LED screen mean a tourist attraction. Node 009 project scheme is intended to be replicated in similar locations, and the Law for Outdoor Advertising is likely to be applied to other

Fig.1 Mexico City 2010, 17 nodes and 31 corridors were approved for the relocation of existing billboards.

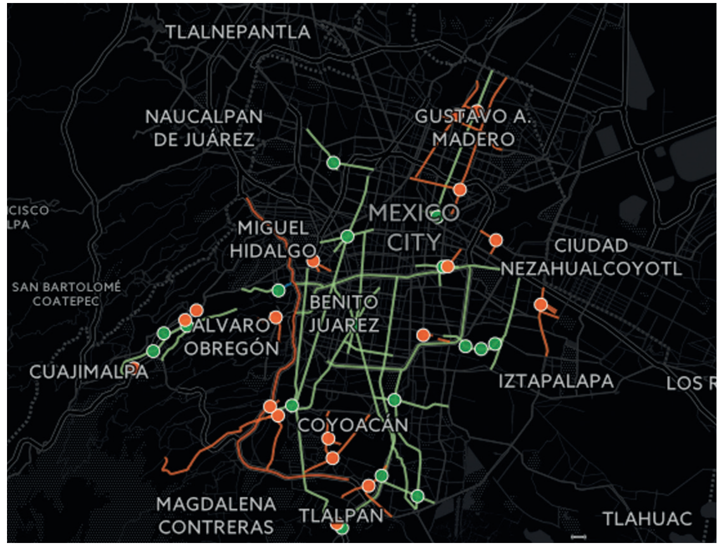

Fig. 2: Mexico City 2011, 18 nodes and 38 corridors were approved.

Fig. 3: Mexico City 2012, 125 nodes and 0 corridors were approved.

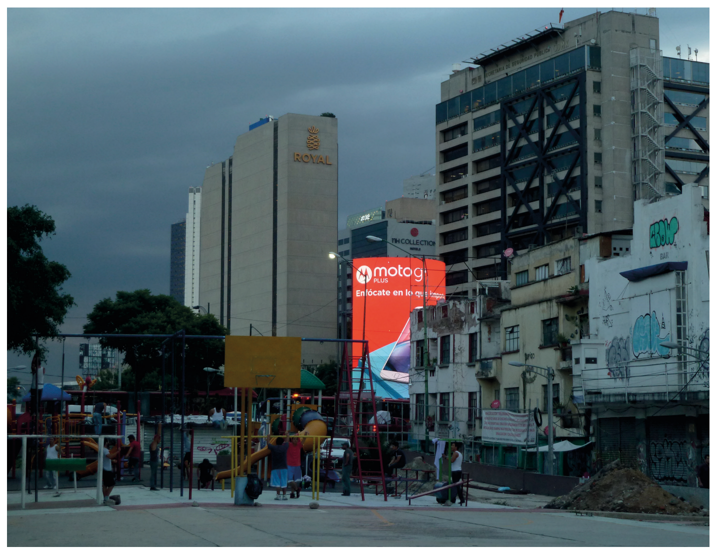

Fig. 4: Node 009 developed under current law, North exit LED screen.

parts of the country.
Researchers found (a) driver distraction on the road, (b) alteration of sleep cycles, (c) power energy waste, (d) lighting pollution, and (e) loss of the night sky to be consequences of outdoor advertising [9], [10]. Little has been said about how citizens perceive the the nocturnal image of the city and its night sky. Light trespass has become a common area of dispute among neighbors, rather than an environmental issue. The city's inhabitants have accepted that gazing at the stars is no longer possible. We should go a step further and think of every source of light as part of a whole system.

Table 1: Minimum luminance levels and contrast ratio according to IESNA and NOM for primary routes. Minimum levels of luminance according to IESNA and NOM, areas with digital billboards are likely to have greater luminance levels and contrast ratio.

	Min. luminance	Contrast ratio
IESNA	1 cd/m^2	1 to 40
NOM-013-ENER-2013	1 cd/m^2	0.3 to 1

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NON-VISUAL EFFECTS: MYTH OR TRUTH?

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Professor Stephan Völker studied Electrical Engineering at Ilmenau University of Technology, Germany. After graduating, he worked there as a researcher carrying out research into innovative high temperature plasma applications. In 1999 he obtained his Ph.D. degree from the Department of Lighting Technology.
Thereafter, he worked as a senior engineer and senior researcher at Hella KGaA Hueck & Co.
In 2002 he started work as a junior research professor for Lighting Technology in Paderborn, Germany, where he led his own research group. Additionally, he worked as a guest lecturer at University College of London.
Since 2008 Professor Völker has been a full professor and head of the Department of Lighting Technology at the Technische Universität Berlin, Germany. He is chair of CIE TC 4-33, member of CIE TC 4-54 & 4-52, board member of the German Lighting Society (LiTG), member of the advisory board of FNL & DIN and member of the TWA.

Non-Visual Effects: Myth or Truth?

Non-visual effects – is it a nice fairy story for sale of high price products or can we control our body completely through light? This contribution will give an overview about the different aspects from the scientific point of view. The presentation will pick up the ATKearney study (for the ZVEI), the KAN paper (August 2015) and the CIE Position Statement on Non-Visual Effects of light. These three papers show the wide bandwidth on positions if non visual effects are discussed. But one statement is the same in every paper: We need more research! And so the next question follows: Why do we need more research, while so many research studies were done?

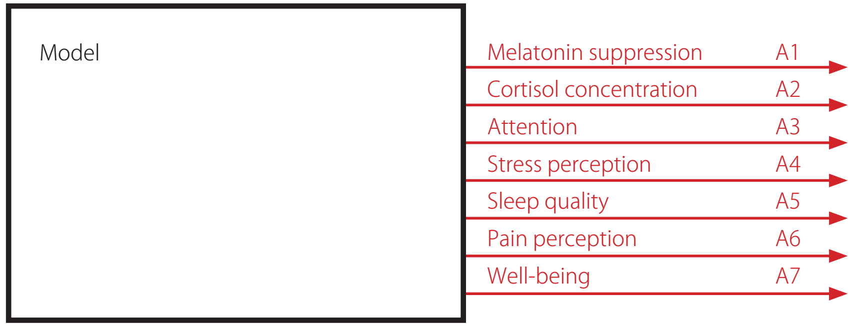

Fig. 1: Non-visual effects.

I. Non-visual effects – what are they?

If we speak about non-visual effects, first we have to define the item Non-visual-effects. It is true, that alot of body functions are synchronized by light. That needs body clock, melatonin suppression, cortisol concentration, Sleep-wake-cycle, sleep quality, immune response, pain perception, appetite, mood, alertness, stress perception, attention and well-being. Fig. 1 shows some of them. It is a myth, that light is the only timer. Also meals are responsible for the internal time. If light is an important timer for the non-visual effects, a receptor is necessary. It is true that the s-, m- and l-cones alone can't explain reaction of body functions according different spectra. The ipRGCs (Intrinsically photosensitive retinal ganglion cells) with their specific sensitivity play an important roll for understanding of non-visual effects. For the description of sensitivity of ipRGCs the $S_{mel}(\lambda)$ – function is used currently. But it is a myth, that the ipRGCs have no interaction with other receptors. Lucas [1] has shown, that the ipRGCs interact with cones and rods. It is not enough to consider the spectral sensitivity of ipRGCs separately.

II. Quality figures for non-visual effects

As quality figure for the non-visual effects of a lighting system is used the a_{cv}. It is true, that the forecast of melatonin suppression at evening is possible (Fig. 3). But the transfer on other non-visual effects is not proved (Fig. 4).
The knowledge about the ipRGCs have been won in lot of experiments in the night and most of them were done with monochromatic radiation. Schierz [2] remarked that a simple transfer of sources with polychromatic radiation is not allowed. For practical using of all this knowledge it is important to know the interaction of radiation, the spectral distribution, spatial distribution, time of exposition, dynamic of light (Fig. 5). And here we are on a main problem with the interpretation of the results in the literature. The input variables are very often not verified; therefore, the results are not comparable. Additionally, the output variables are used in the same sense, but this is not scientifically based.
The Most of the physiological variables show large scattering. To identify further influence factors covariates should be used (Fig. 6). They will help us to understand the different effects for different people.
Like the Fig. 3 shows, the a_{cv} is a good predictor for the forecast of melatonin suppression. If you want to make an effective lighting design, you need much more knowledge as the factor a_{cv}. Currently the research project 'NiViL' supported by BMBF collect all data and try to find models for a description of the different non-visual effects under different photometric parameters and for different covariates.

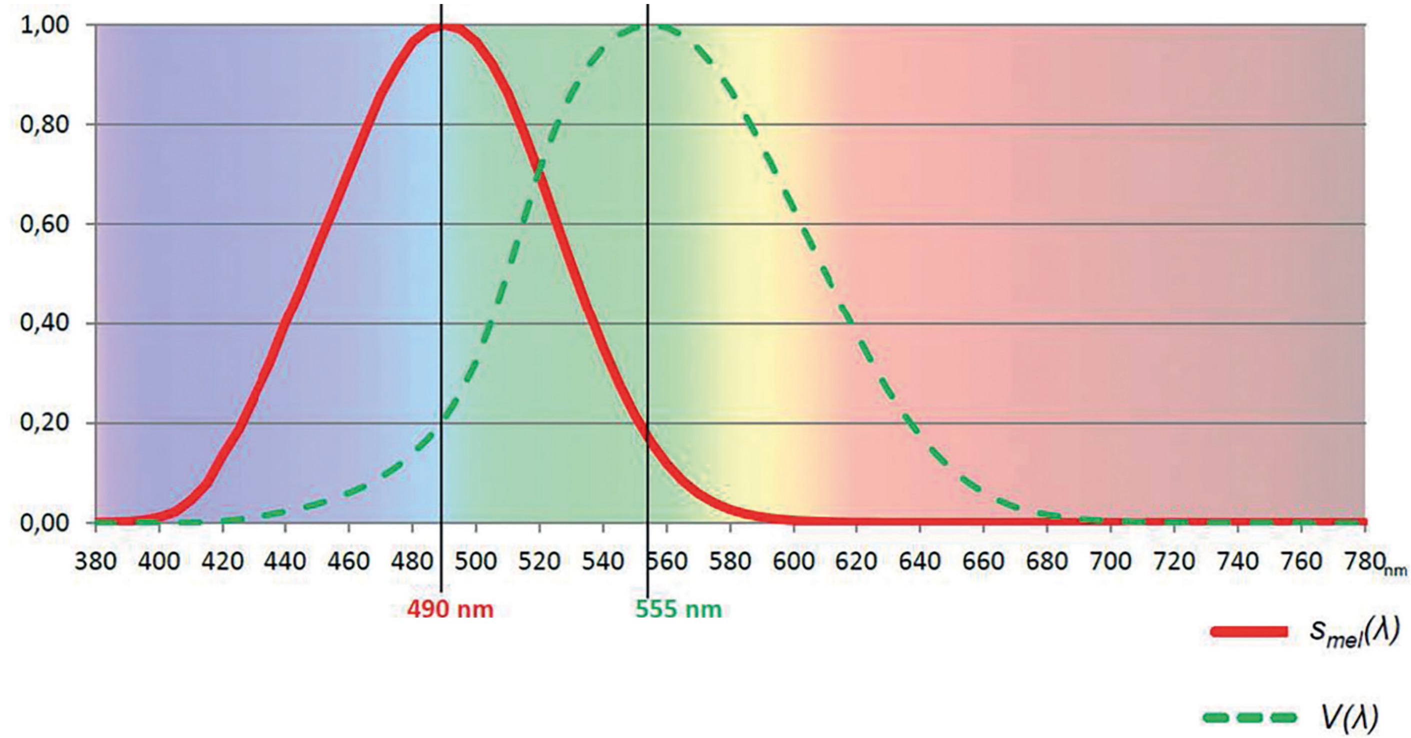

Fig. 2: $S_{mel}(\lambda)$: action spectrum for melanopic effects of light at night, weighted with the transmission of lens of a 32 years old person.

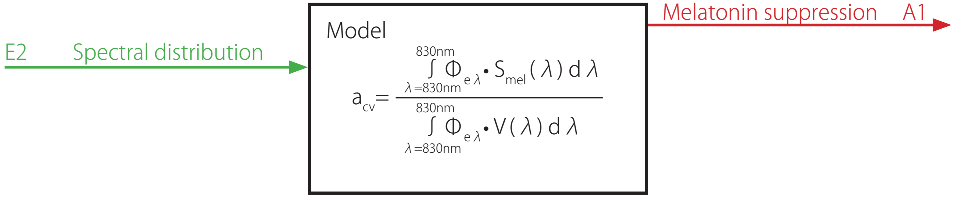

Fig. 3: Description of Melatonin suppression as function of the spectral distribution.

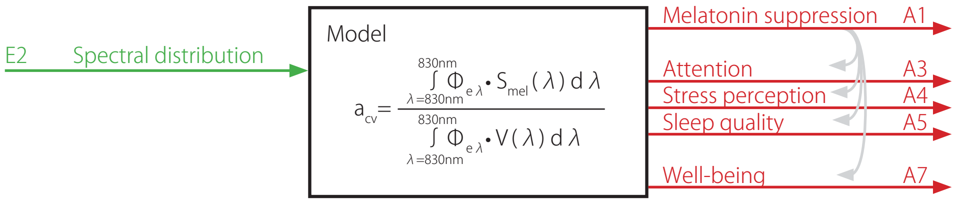

Fig. 4: Transfer of the effect of melatonin suppression on other non-visual effects.

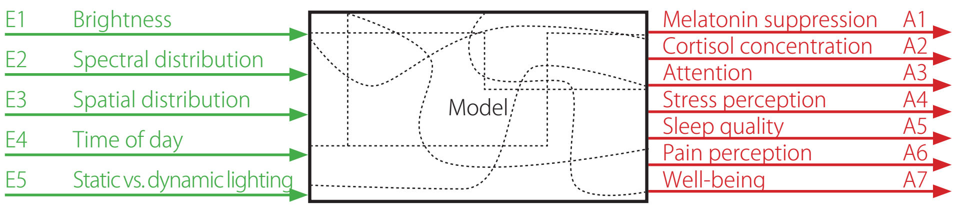

Fig. 5: Non-visual effects depending on different photometric conditions.

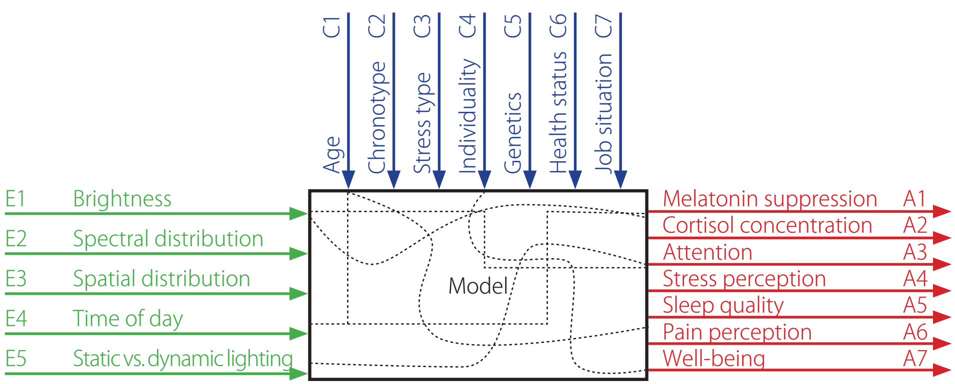

Fig. 6: Non-visual effects depending on different photometric conditions with covariates.

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QUALITY OF LIGHT – QUALITY OF LIFE

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Dr. Falkenberg trained and practiced as an optometrist in both Norway and the UK. After her Ph.D. at Glasgow Caledonian University, she did a post-doc in vision rehabilitation at UCL, London. She has worked in Norway since 2007.
Helle K. Falkenberg is the president elect for the Norwegian association of optometrists, and a member of the UK College of optometrists.

The growing ageing population emphasises the importance of healthy ageing. Good vision is essential for quality of life and ageing healthy at home. Normal age-changes lead to reduced vision and demand more light. However, improved lighting to compensate this age loss receives little attention. This paper presents an intervention study investigating the effect of lighting levels on health and activities of daily living. Although participants were happy and healthy living in very low levels of indoor lighting, increasing the lighting levels showed a significant improvement. This indicates that quality of light influences quality of life.

I. Introduction

Increased life expectancy and improved living conditions in combination with an escalating older population with health-care needs will lead to great challenges in both Norway and other European countries. Arranging for people to remain living at home as long as possible may result in both improved quality of life, health and significant social economic effects. To enable living at home and performing everyday tasks, it is important to have good vision. Due to normal age-related vision loss, older people need correct glasses and more light to safely perform daily activities. Reduced vision negatively effects general health and both basic activities of daily living (ADLs) (dressing, transferring) and instrumental activities of daily living (IADLs) (food preparation, reading [1]). Poor vision also increases risks of falls, depression and anxiety. Poor lighting exacerbates these problems. Lighting is thus a significant environmental attribute promoting visual, physical and mental health [2]. However, increased indoor home lighting to promote healthy ageing has received little attention.

The aims of this intervention study were to measure lighting levels in the homes of healthy 75-year olds and how they, in respect to the indoor lighting, assess their vision and general health, ADLs and IADLs, and well-being. Further, to investigate how improved lighting effected abilities to perform IADLs and health related quality of life in older people living at home.

II. Methods

The intervention consisted of two parts: the baseline study and the intervention study. The baseline study is described in details elsewhere [3].

II.1 Participants & procedures

In the baseline study 114 75-year olds living at home, without receiving any home-based care and Snellen visual acuity >0.7, participated with informed consent. Indoor lighting levels were measured in several rooms. Self-reported visual and general health and ability to perform ADLs and IADLs in regards to ambient lighting levels were recorded using a questionnaire using visual analog scales and SF-36. A subsample of 20 participated in qualitative interviews.

Based on the measured lighting levels in the baseline study, 60 participants were stratified to the intervention group (IG=30) or control group (CG=30) in the four-month intervention. The intervention optimized lighting levels in the living room by providing lamps and a control system with preset levels. Participants adjusted the light levels and kept a diary. Self-reported visual and general health and ability to perform ADLs and IADLs in regards to lighting before and after the intervention period were measured with the baseline questionnaire in both groups. The IG additionally answered eight questions about the intervention.

II.2 Light measurements

In the baseline study, light levels were measured in six rooms and compared to recommended standards [4, 5]. The intervention took place in the living room where the lighting was optimized by supplementing existing lamps if necessary to achieve recommended lighting levels, and installing a basic control system with three preset levels (normal (200 lx); medium (100 lx); low (50 lx)). Qualified lighting designers performed all light measurements using a calibrated lux meter according to international standard procedures. Both the baseline and intervention study took part during the dark winter months.

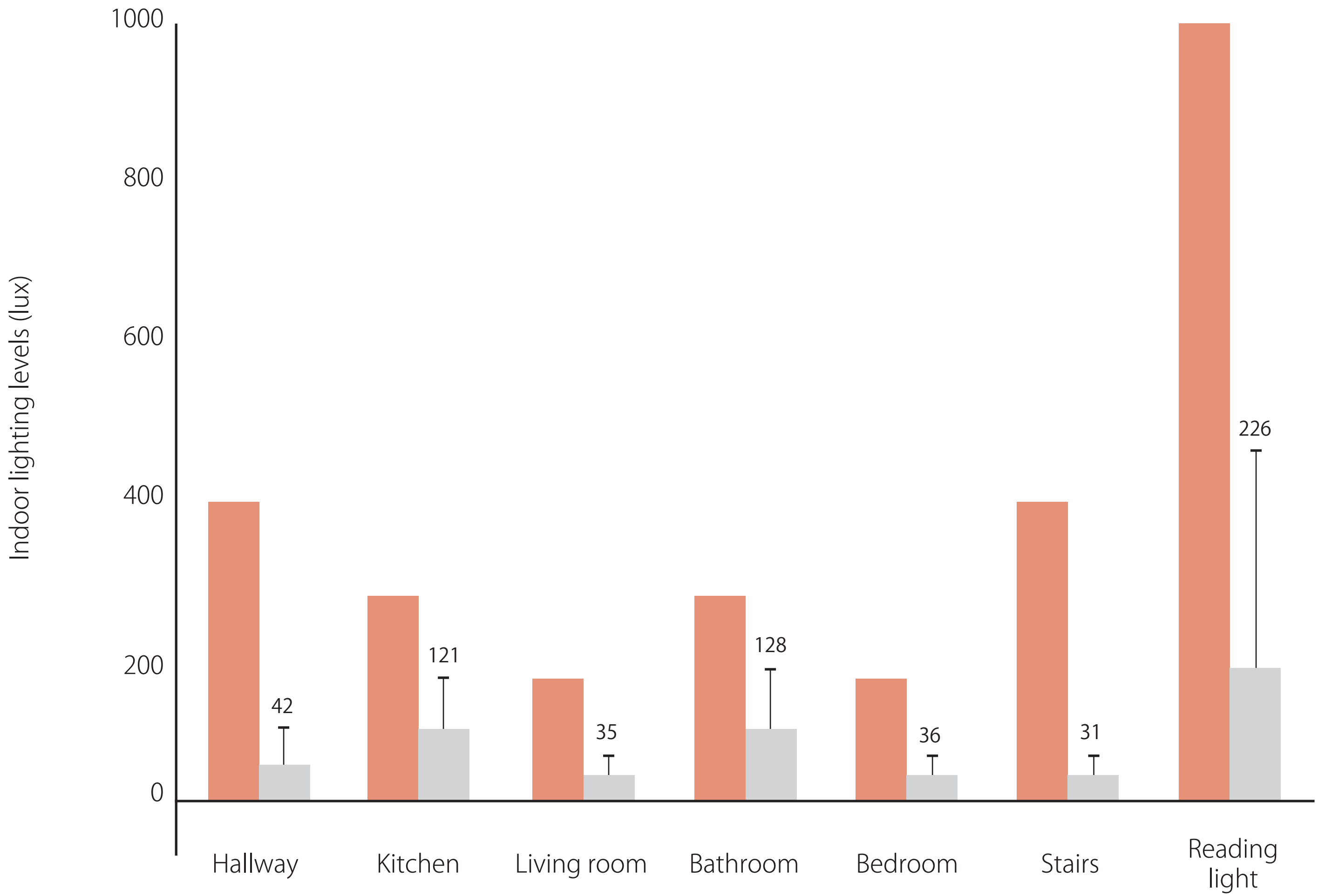

Fig. 1: The grey bars are mean indoor lighting levels (lux) according to each room for the 114 homes in the study. Numbers are the mean lux values; vertical lines represent two standard deviations. The red bars are the Norwegian recommended lighting levels for senior living.

III. Results

The baseline study revealed that lighting levels overall were very poor (Fig. 1). Despite living in darkness, significantly below recommended levels, participants perceived their visual and general health to be good, were happy, and unaware of any problems related to lighting and everyday tasks. This corresponded well with the interviews. However, when reflecting upon the ability to perform certain tasks, interviews uncovered that they had adjusted their behaviour and no longer performed certain visually demanding tasks in the evening.

The intervention revealed that participants were even happier with the improved lighting and reported improved quality of life. They used higher light levels, which increased comfort and wellbeing. Now they were able to perform visually demanding tasks even in the evening, and acknowledged that avoiding these tasks were mainly due to poor lighting. They loved the lighting control system because it was easy to use with the preset levels and included their own lamps, and emphasized that such systems are universally designed.

IV. Conclusion

Good vision is essential to maintain good quality of life and facilitate healthy ageing at home. This requires adequate lighting. However, the knowledge of lighting as a key factor to compensate age-related vision loss is limited. The intervention shows that improved lighting can easily be achieved with a basic lighting control system. This suggests that improved quality of light could improve quality of life.

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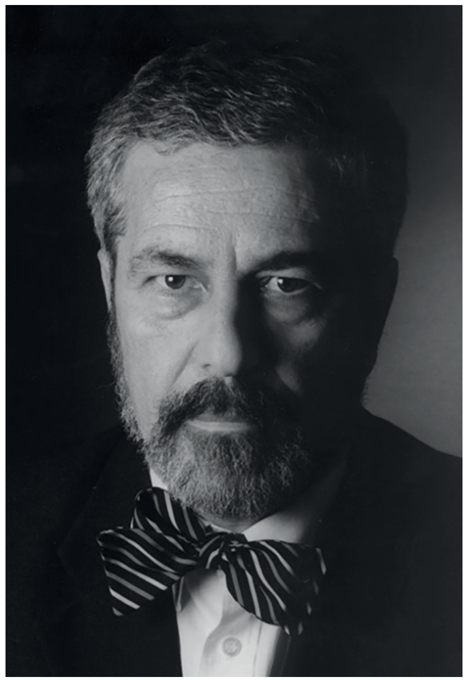
USER EXPERIENCE AS THE LEADING CONCEPT FOR LIGHTING DESIGN



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Since 1980 he has been the scientific manager of the ERGONOMIC Institute for Social and Occupational Sciences in Berlin. He is a fellow of the Ergonomic Society and editor-in-chief of the scientific journal Behaviour & Information Technology. Dr. Çakir is chair of the international committee ISO/TC159/SC4/WG3 responsible for the standardization of workspace and the work environment, and of the national German committee NAErg/NIA: Ergonomics for Information Processing Systems.

Light impacts human health and performance by enabling performance of visual tasks, controlling the body's circadian system, affecting mood and perception, and by enabling critical chemical reactions in the body. This paper introduces User Experience (UX) as a new concept for lighting design (Fig. 1). It is based on three qualities of Vitruvius (firmitas, utilitas and venustas) which are now being used also outside the architecture domain.

I. On the concept User Experience (UX)

The word lighting is being used in different meanings, and the goals lighting planners follow are not the same across the area. No wonder that all stakeholders miss a clear concept, and the users may suffer from this situation severely. This paper outlines a successful concept, User Experience (UX), with a long history in architecture and a comparably short, but not less successful history, in product and software design.

The objective of bringing light into built space was originally accomplished by the architect as part of the building design, and lighting was used in the sense of artificial lighting. Even today, architects use a different word to characterize the light level in a space than lighting engineers do. This is true even after the 1950s when artificial lighting began determining the structure of buildings instead of offering a service of secondary importance to the design.

The main objective of lighting for workplaces was – and still is – making the work objects visible. In many respects, this can be done better by artificial lighting than by natural lighting. However, people working in windowless spaces never did feel well, and lighting focusing on work objects never did meet the requirements of users. Today, non-visual effects of lighting – or so-called "health effects" – form the focus of many conferences and meetings related to lighting. Healthy lighting is more than a mere slogan.

User Experience is attributed to the Roman architect Vitruvius (Fig. 2) who introduced a principle with three concepts or qualities: firmitas (quality, stability), utilitas (utility, usefulness) and venustas (beauty, elegance) to be balanced while creating an entity, in Vitruvius' time a building or a space. In modern use, UX refers to a person's emotions and attitudes about using a particular product, system or service (Fig. 1).

II. Applying User Experience on lighting in buildings

According to my opinion, at least utilitas and venustas were relevant for creating built space including daylight even before the days of Vitruvius. What made people sick was putting the main (or even only) focus on utility, namely on visual performance, which is a remarkably ill-defined concept: "Performance of the visual system as measured for instance by the speed and accuracy with which visual tasks are performed" (International Electrotechnical Vocabulary, term 845-09-04). Besides the vague definition, people are reluctant to state that visual performance is not related to color vision. From the four features that help characterize a visible object, shape, brightness, color, and gloss, lighting engineering considers just the first and ignores color almost completely.

In one of the oldest standards on lighting, DIN 5035 of the year 1935, the fathers of that document stated that lighting serves health and beauty and should be useful and economical. This is not extremely different from Vitruvius' original concept. In addition, that standard included quality criteria to which the creator of space and lighting may assign different weights depending on the purpose of the entity under consideration. Thus, you may focus on firmitas and utilitas, e.g. if you plan underwater spotlights for sewage basins, but put great emphasis on venustas while designing a concert hall without violating the standard.

A violation of the standard is a given if you ignore the two others while focusing on one. This violation took place perfectly when the lighting of workspaces was defined considering only utility in later versions of the standard. In addition, the definition of utility, visual performance, is vague and ignores the most important characteristic of the visual space, color and color vision.

Applying the concept of UX on lighting design will help overcome the apparent shortcomings of the current understanding(s) of lighting built space. It may also help bridge the gap between architecture and lighting engineering which has existed since the days when artificial light started to dominate architecture, at least to a certain degree, in the 1920s.

III. What's new?

Even while defining health to which lighting should serve, people were thinking of protection against health hazards rather than promoting health. Although the health effects of light were well known and utilized in ancient times – solarium was the Roman name for sanatoria -, the main purpose of lighting remained making objects and environments visible.

In the late 1940s, the German ophthalmologist Hollwich demonstrated experimentally that various vital functions of the human body were affected by light. His claims that the lighting of workplaces would affect human health were contradicted by lighting engineers. The related German technical society commissioned white papers claiming to have refuted Hollwich's findings and claims. In 1990, Çakir [1] published a research report according to which 57 % of office workers considered the lighting of their workspace as a stressor. The report showed that the natural lighting of work environments would trigger positive health effects. The interpretation of the results was that the potential stressor, artificial light and lighting, acted by affecting the circadian rhythms as once claimed by Hollwich. After it was demonstrated in 1984 that artificial light changed the circadian rhythms [2] and following the discovery of the third receptor in the eye, an unprecedented wave of research work on the health effects of lighting commenced.

Today and for the future, lighting design has a new objective: promoting health. Why not apply also a new approach, Vitruvius' qualities to achieve better user experiences?

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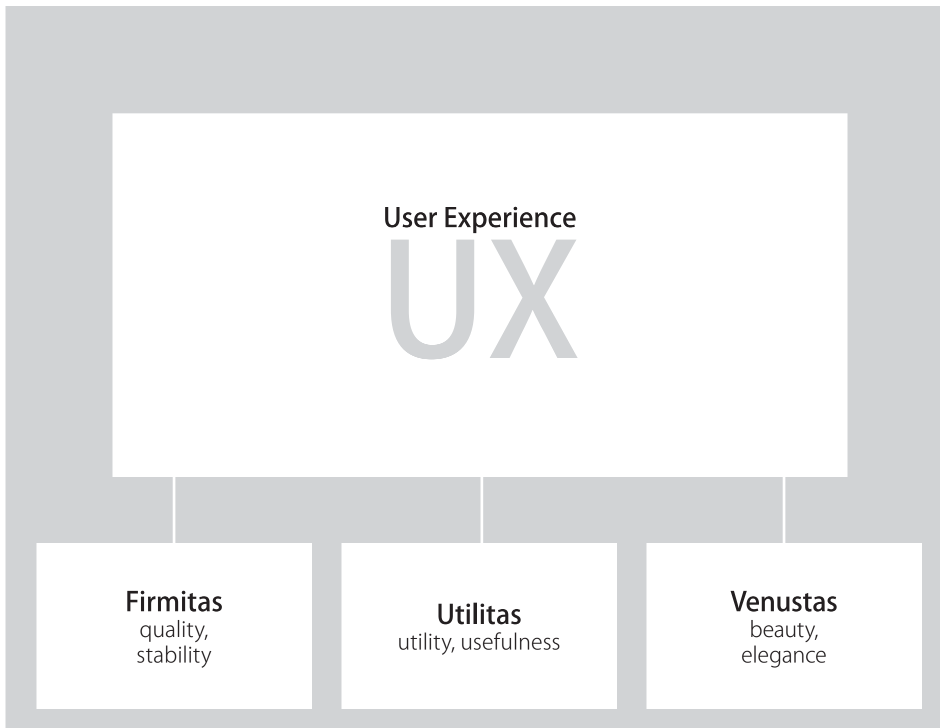

Fig. 1: User Experience(UX) as a new concept for lighting design, based on three qualities of Vitruvius.

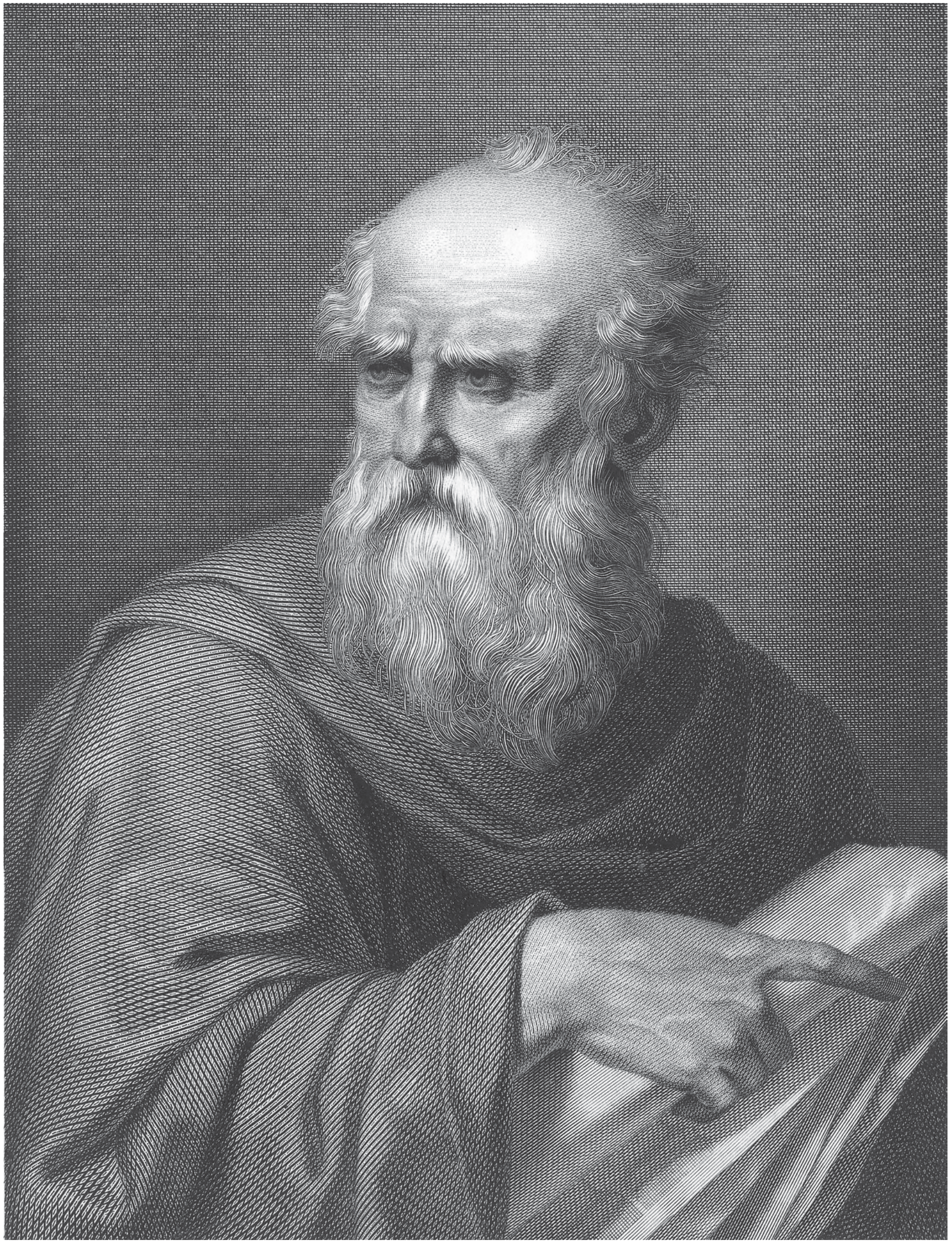

Fig. 2: Marcus Vitruvius Pollio (born c. 80–70 BC, died after c. 15 BC), commonly known as Vitruvius, was a Roman author, architect, civil engineer and military engineer.

PART III

MEDICAL SCIENCE AND LIGHTING

PHOTOENDOCRINOLOGY: HOW NATURAL AND ARTIFICIAL LIGHT IS IMPACTING ON THE HUMAN ENDOCRINE SYSTEM AND HORMONES

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Alexander Wunsch is a physician, researcher and lecturer in light medicine and photobiology with particular interest in the effects of light and the beneficial/adverse health impacts of solar radiation and artificial light sources on endocrine and cellular levels in humans.

He conducts studies on the photobiological effects of optical (UV, VIS and IR) radiation. In his private medical practice in Heidelberg he uses therapeutic light spectra in combination with other biophysically based treatments, and develops lighting equipment for medical and cosmetic purposes.

He is associate lecturer at the Wismar University of Applied Sciences and mentors students writing their master's theses on light- and health-related topics. Alexander Wunsch presents at international conferences and operates as a consultant for federal authorities, media, and industry.

Alexander Wunsch is a member of the German Lighting Society (LiTG) and former president of the International Light Association (ILA).

Humans vitally depend on environmental light conditions. Light intensity, spectral composition and timing influence literally every function in the organism, regardless if of conscious or autonomous nature. Adaptation to the outer world is crucial for survival, and survival is fundamentally provided by vegetative adaptation. Mediators and directors of these autonomous functions such as circulatory, metabolic and water balance are hormones and neurotransmitters. Photoendocrinology describes how the environmental light conditions, the "natural chronology of the cosmos" (Hufeland), translate into the rhythmical vital functions providing diurnal activity and stress in alternation with nocturnal restoration and regeneration.

I. Introduction

The 19th century marked the dawn of photochemistry, which represents the scientific base of photobiology. Every photobiological process starts with a primal photochemical reaction, followed by a chain of consecutive responses. Photoendocrinological reactions can be found in all kinds of living multicellular organisms and are not exclusively reserved to humans. Many hormones involved in photobiological reactions were developed in an early stage of evolution and have been preserved ever since [1].

Hormones involved in photobiological reactions are small molecules responsible for chemical signal transduction and unfold their biological activity either via the bloodstream (endocrine) or in the direct vicinity of their formation (paracrine). Hormones usually act in very low concentrations by initiating preprogrammed cellular processes which are triggered when the hormone molecule binds to its specific receptor. Three major classes of hormones exist: eicosanoids, amino acid derivatives, and steroids. The latter are cholesterol derivatives and play a paramount role in many photoendocrinological processes. Aromatic amino acids are the precursors of many important signaling molecules involved in photobiological reaction chains [2].

II. Natural and artificial light and its effects

Natural and artificial light sources differ significantly with regard to intensity, spectral distribution, electromagnetic properties and timing. Human metabolism and autonomous functions are complexly adjusted to the environmental light conditions with the principal purpose of ensuring survival. Human skin is – in contrast to the majority of other mammals – unprotected by fur, which is remarkable, especially if humans originated from the equatorial regions of Africa with high solar irradiation levels [3,4]. This has far-reaching consequences for local and systemic photoadaptation processes, which are mainly, but not exclusively, regulated by ocular light perception. The skin contributes to photoendocrine reactions, e. g. via nitric oxide [5] and vitamin D photosynthesis [6].

Photoadaptation processes involve skin protection, water balance, acid-base regulation, energy metabolism, thermoregulation, reproductive functions, immune system responsiveness and motor activity, to name only the most important [7]. Besides these predominantly autonomous regulations, photoadaptation in a highly complex manner involves also psychological and cognitive aspects [5].

When exposed to the natural light source with the highest impact, the sun, all these photoadaptation mechanisms (Fig. 1) are executed in a meaningful manner, comparable to the coordinated interplay of musicians in a philharmonic orchestra, which is directed by the conductor. While sunlight with its broad spectrum, high intensity, and complex variance and timing is the true maestro, artificial light sources are just surrogates of a higher principle which is untouchable even by contemporary high tech.

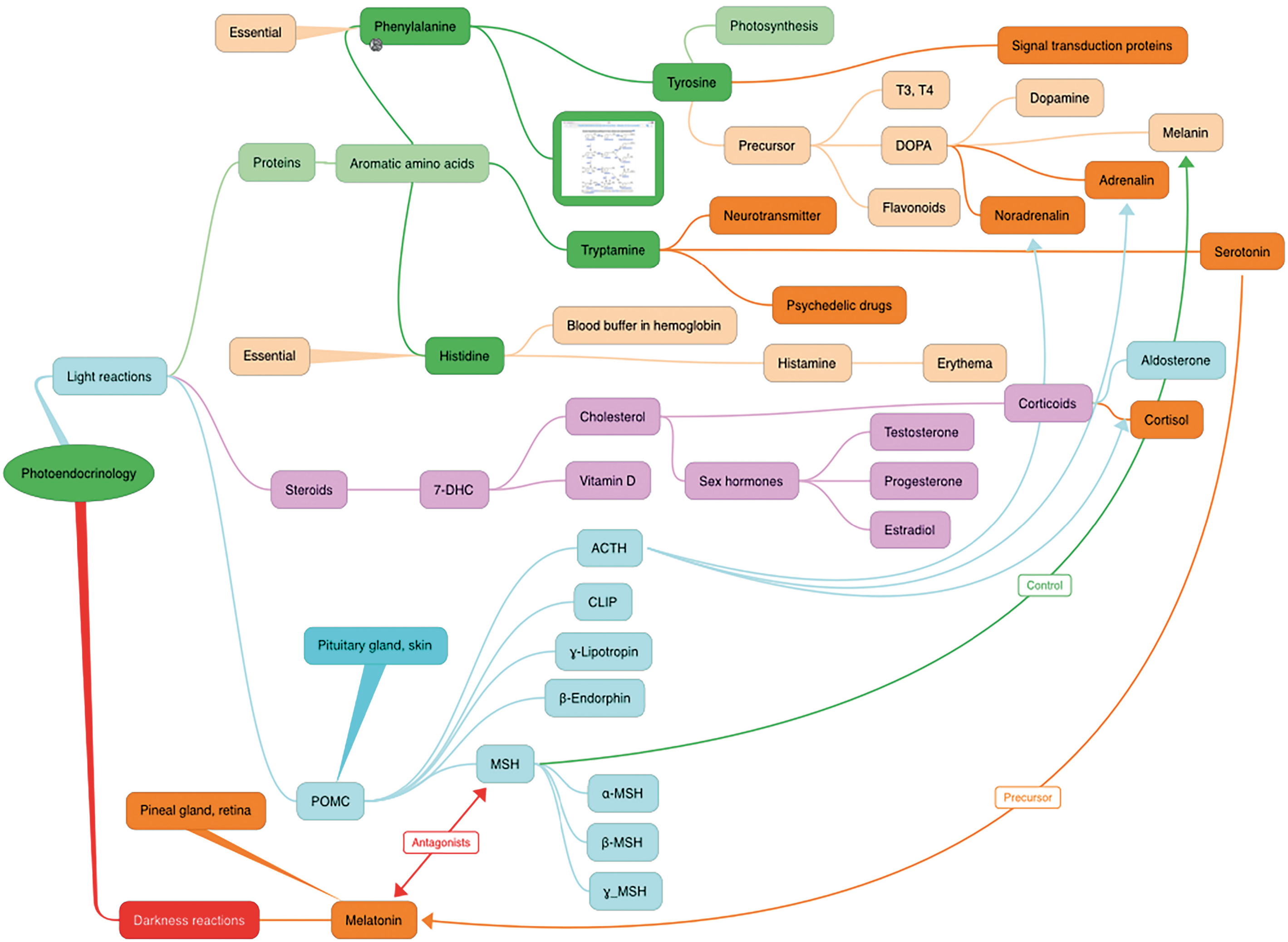

Fig. 1: Photoendocrinological pathways, hormones and signal transducers.

III. Conclusion

Many lighting professionals seem to be fascinated by the possibilities of digital lighting technologies, which provide high energy efficiency, all rainbow colors and color temperatures, ruggedness and versatility. But – with regard to biocompatible lighting - true mastership becomes evident if not every available possibility is used: Biologically effective artificial lighting is controversial [9, 10, 11] and authentic human centric lighting is much more than suppressing melatonin and collectively manipulating workers with photons.

Truly understanding the complex human photobiology should rather lead to deep respect for the inner harmony of the individual human and to the industry´s quest for biologically neutral artificial lighting.

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Alexander Wunsch

SKIN AND BEAUTY

Light is an indispensable tool for beauticians and anti-aging experts. Shortly after the development of the incandescent lamp, electrical light baths became available for addressing intended uses in the realm of wellness, beauty and restoration. In the middle of the 20th century, the sale of cosmetic and therapeutic heat lamps turned into a mainstream business. Three decades later, soft lasers and LEDs for Low Level Light Therapy (LLLT) and photobiomodulation (PBM) entered the stage. Today, various light sources and technologies are available for wound healing, tissue regeneration and photorejuvenation of the skin.

I. Introduction

Could it be valuable for a lighting professional, regardless if designer or engineer, to occupy his mind with pondering over the results and effects of light applications in the field of beauty and anti-aging treatments? Definitely, yes! Even if light for vision purposes is produced exclusively for the eye, it will, as a side effect, also illuminate skin areas which are not covered by garments. Skin and eyes have some properties in common, both are light perception organs [1]. What light can do to the skin on the cellular level it can also do to the eye and vice versa. If the beautician uses blue light for damaging germs in the skin via the induction of reactive oxygen species (ROS), the lighting professional should know about this capability: HEV (high energy visible = short wavelength) light can damage both skin and eye via an identical process [2]. Light with long wavelengths is able to help the skin to regenerate and it fosters repair and wound healing [3]. This should be taken into account in the risk assessment of non-thermal light sources with regard to ocular health, because they exhibit a lack of these beneficial red and near-infrared wavelengths. Cosmetic and therapeutic light applications can elucidate the potential of light to influence biological functions of skin and eye.

II. Light for skin rejuvenation

Photon emitters, such as lasers or LEDs, have proven to be effective light sources for PBM during recent decades, thereby demonstrating that it is not the technical type of light source but the treatment parameters such as wavelength, irradiance, and fluence that are likely to be accountable for the effects. However, laser and LED light sources may offer some disadvantages because of their punctiform emission characteristics and narrow spectral bandwidths. Because the action spectra for tissue regeneration and repair consists of more than one single wavelength, it might be favorable to apply a polychromatic spectrum covering a broader spectral region for skin rejuvenation and skin repair. We investigated the safety and efficacy of two different novel non-thermal, non-ablative, atraumatic, polychromatic low-level light treatment modalities with a focus on pleasant skin feeling, improved skin appearance, intradermal collagen increase, and the visible reduction of fine lines and wrinkles in a prospective, randomized, controlled trial that consisted of 136 volunteers [4].

III. Results and conclusions

The treated subjects experienced significantly improved skin complexion and skin feeling, profilometrically assessed skin roughness, and ultrasonographically measured collagen density. The blinded clinical evaluation of photographs confirmed significant improvement in the intervention groups compared with the control. Efficacy could be demonstrated for both polychromatic light sources with differing spectra. Both novel light sources that have not been previously used for PBM demonstrated efficacy and safety for skin rejuvenation and intradermal collagen increase when compared with controls. Low level red and near infrared radiation can contribute to positive effects in human skin in vivo and, therefore, should be implemented in the assessment of light-tissue interactions, not only in the cosmetic and medical field, but also in the field of general lighting applications due to the significantly longer exposure times.

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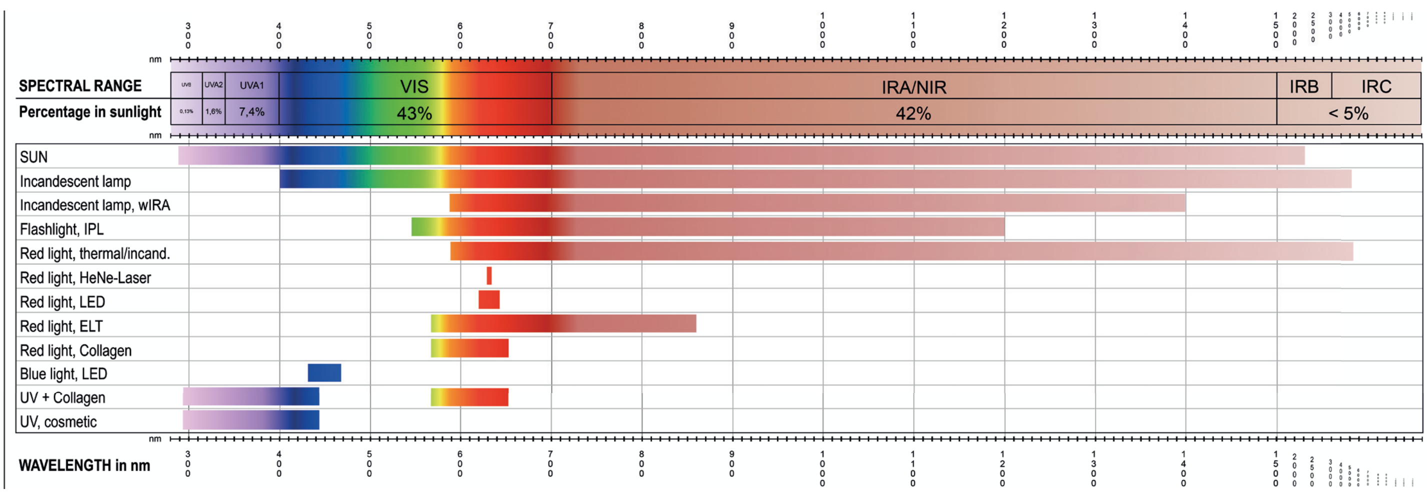

Fig. 1: The chart illustrates the areas of the optical spectrum which are relevant for medical and cosmetic light-based applications.
The percentages refer to the proportion of the respective spectral range in sunlight. The bandwidth of different light sources is represented by appropriate colored bars, whereby the limit wavelengths may deviate slightly depending on the specific design of a device.

Charlotte Remé

HOW OUR RETINA WORKS: THE BRIGHT AND THE DARK SIDES OF LIGHT

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Professor Charlotte Remé is a professor emeritus of the University of Zürich, Switzerland. After Medical School and residencies she took up postdoctoral training with Richard W. Young at the University of Southern California in Los Angeles, working on the renewal mechanisms of retinal photoreceptors. This research led to the discovery of autophagy, a cellular mode of removing or recycling cytoplasmic constituents.
Upon her return to Zürich, in 1980 she founded the laboratory of retinal cell biology within the setting of the University Eye Clinic, Zürich and she began pioneering work on retinal circadian rhythms together with her colleagues Anna Wirz-Justice and Michael Terman. Later, her studies focused on the deleterious effects of bright light on the retina. This work led to the discovery that light can induce gene-regulated cell death by apoptosis. She and her team elucidated molecular mechanisms of retinal apoptosis and discovered the first gene directly involved in retinal apoptosis.

How Our Retina Works: the Bright and the Dark Sides of Light

The vertebrate retina is exquisitely equipped for receiving and processing light signals from our external world. Nevertheless, an overdose of light can damage the light receptors and their supporting tissue: rods and cones, and the retinal pigment epithelium. Therefore, adequate protection against harmful light is essential. Apart from the image forming light receptors, the visual cells (rods and cones), there are circadian light receptors which transmit the daily light signal to specific neurons in the central nervous system (CNS). The non image-forming system consists of intrinsically photosensitive retinal ganglion cells (ipRGCs) which are essential for the regulation of circadian rhythmicity (Fig. 1).

I. Rod and cone function

Cones operate at high light levels with high resolution and enable us to see colors, contrasts and motions with fast responses and low sensitivity. Rods, by contrast, operate at low light levels and high sensitivity with slow responses and low resolution. Most vertebrate species and humans possess both types of visual cells in different proportions, making them „nocturnal" (mainly rods), „diurnal" (mainly cones) and duplex (both receptors, e.g. human), respectively (Table 1).

Table 1: Functional range of rods and cones.

Cones: fast responses, saturation only at high intensity	**Rods:** slow responses, saturation at low intensity
Bright light	Dim light
colour vision high resolution low sensitivity	low resolution high sensitivity no colour vision

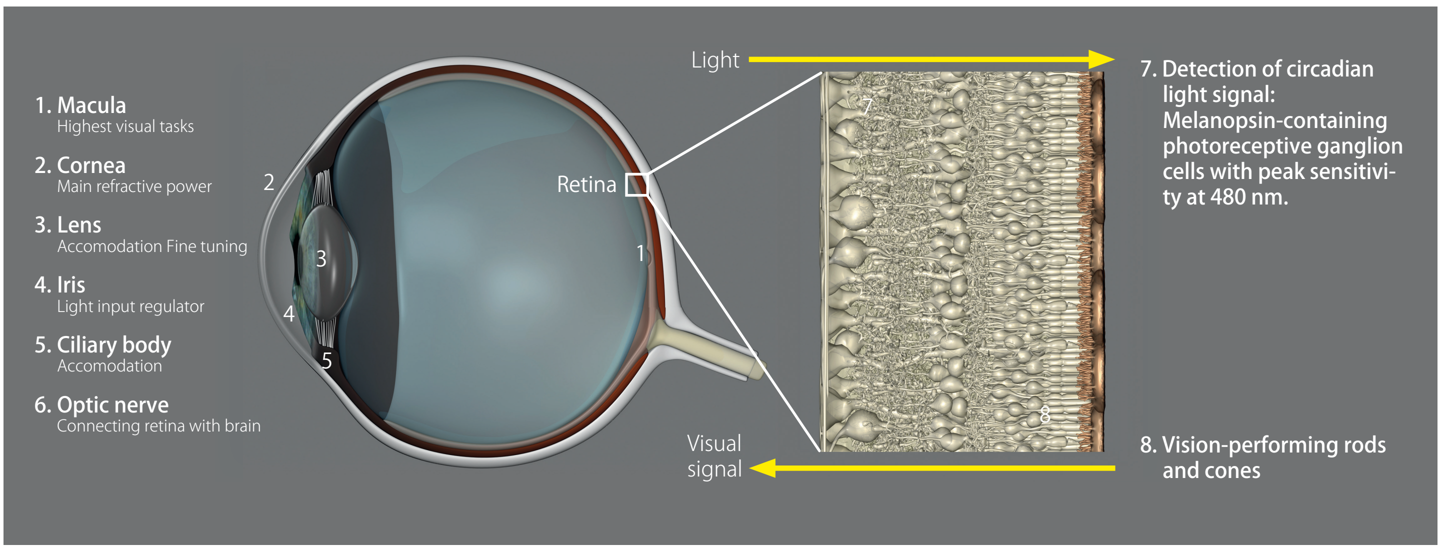


Fig 1: Major functions of ocular structures.

II. Phototransduction

Image-forming light reception comprises the capture of photons by visual pigments followed by phototransduction in several amplification steps within photoreceptors, the transduction and diversification of this signal by specialized neurons within retinal layers, and finally the transmission to the visual cortex of the brain. Rod and cone visual pigments are located in outer segments where transduction and amplification occur. Likewise, the shut off of the activated transduction cascade involves complex mechanisms leading to a replenishment of light sensitive visual pigments [1]. Inner retinal neurons form a highly specialized network for „computational analysis" of the incoming signal, enabling the retina to function over a wide range of light intensities. The human visual system operates over a range of 10-11 logarithmic units of illuminance levels. The visual cortex of the brain interacts with other cortical areas to further differentiate and analyze the incoming signal. About 40 % of the primate cortex of the brain subserves various visual functions. We experience a sharp, colored, three-dimensional, constant and erect image of the world around us, which represents a rather remarkable retinal and cerebral performance (Fig. 2, 3).
In addition to our image-forming visual system there is the non image-forming photoreceptive system in the retina and the brain. The intrinsically photosensitive retinal ganglion cells (ipRGCs) contain the photopigment melanopsin with a sensitivity peak measured in

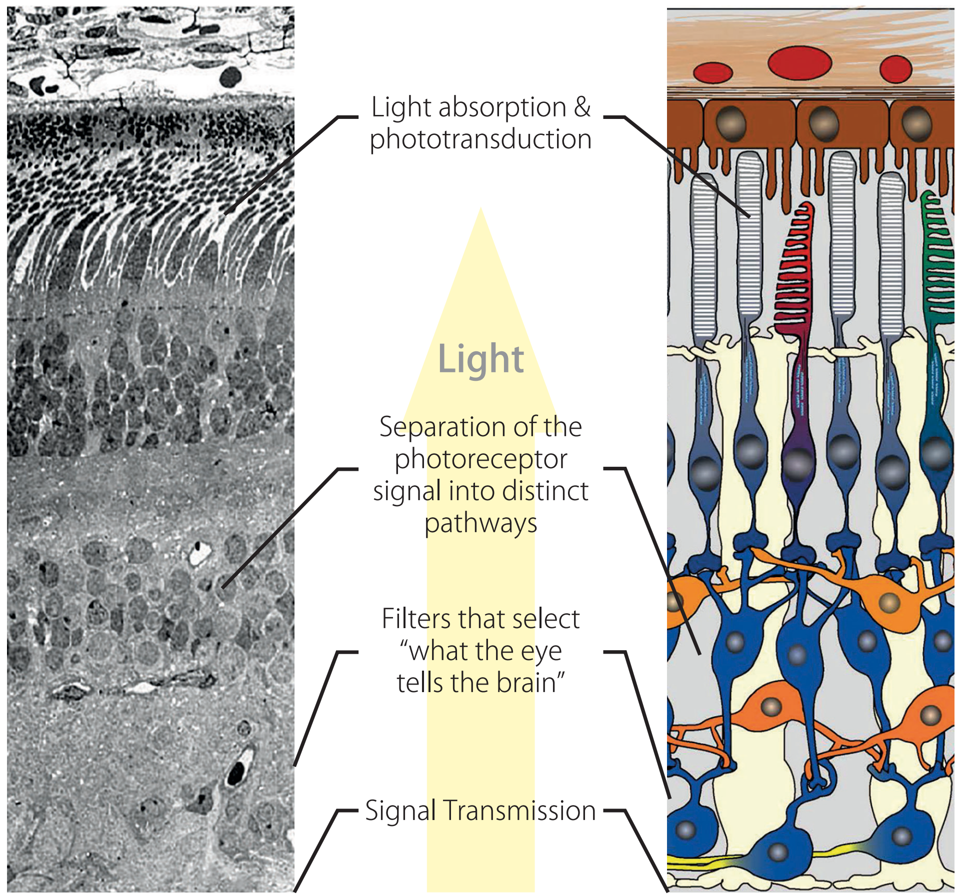


Fig 2: Retinal layers and their specific tasks.

humans and various animal species at 480 nm [2]. These cells convey signals via specific neuronal pathways to the circadian master clock in the suprachiasmatic nucleus of the central nervous system (CNS). Signaling to the pineal gland results in light and dark signals respectively. This signaling is an essential component for the regulation of circadian rhythms. The morning light signal is crucial for the suppression of melatonin and with that for the regulation of rhythmic daytime metabolic activities. A sufficient light dose over the entire day is equally significant for our wellbeing. In the evening, during dusk, the pineal synthesis of the dark hormone melatonin begins to rise due to a reduced light signal from the eyes. If this signaling is suppressed (e.g. due to light exposure during nightly computer work with high blue emitting screens, tablets, cell phones, or other bright artificial light sources), severe sleep disturbances and other disruptions of our circadian rhythms ensue [3]. Thus, for lighting designers it is essential to keep in mind the light - as well as the dark - needs for the appropriate regulation of human circadian systems.

As well as this physiological world of light perception there exists, however, our psychophysical or subjective visual world, which we experience emotionally and analyze with a preconceived world view. „Light“, therefore, may encompass very different meanings for ophthalmologists and neuroscientists on the one hand and artists, architects and lighting designers on the other.

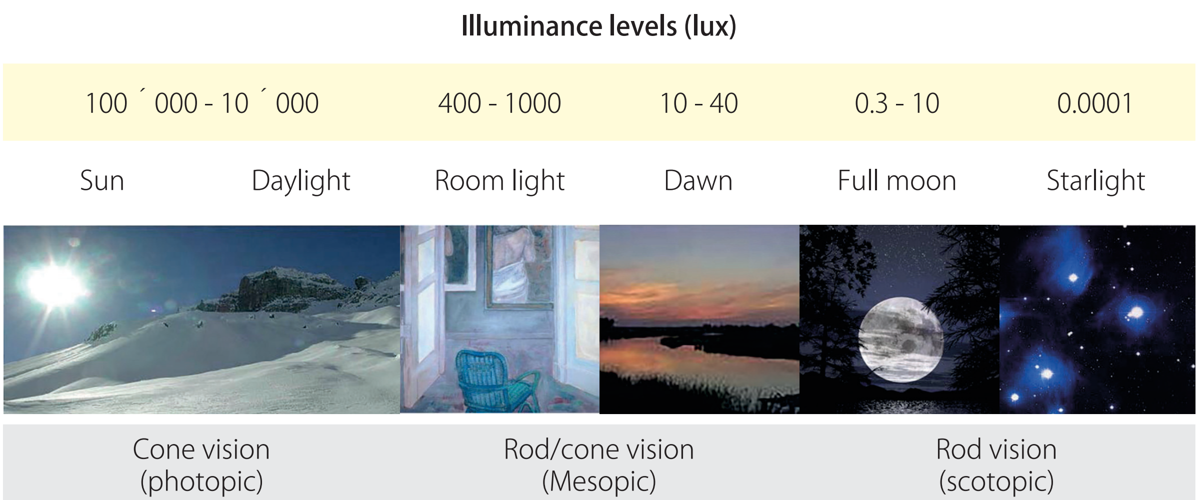
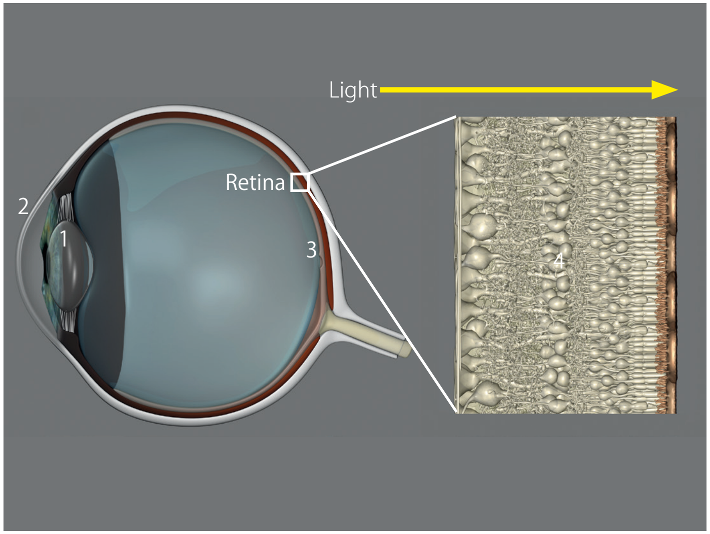


Fig 3: Functional range of the human visual system.



1. **Lens:** UVB and A (300-400 nm)
2. **Cornea:** UVB (280-315 nm)
3. **Retina /Macula:** visible violet-blue
4. **Visual cells:** visible violet-blue (400-460 nm)

Fig.4: Susceptibility to damage by ultraviolet and visible light of major ocular structures.

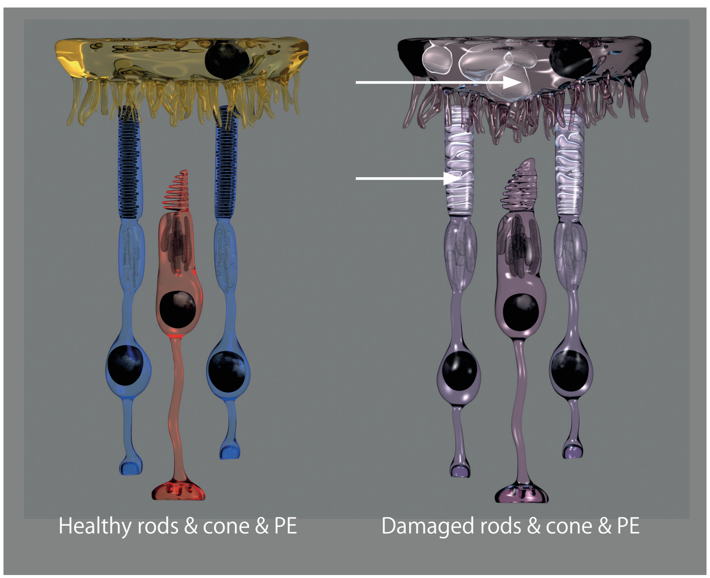


Fig.5: Light damage in visual cells and pigment epithelium.

III. Light damage

It may appear contradictory that the retina, which is highly specialized to receive and process light, can also be damaged by light. The same structures which receive the primary signal, the image forming visual cells, are the ones to be damaged by an overdose of light. Visual cells die by a „death program" which is termed apoptosis. The process of apoptosis is complex and multifaceted, regulated by gene expression and/or its inhibition [4,5].

The retinal pigment epithelium embodies the supporting tissue for visual cells. It performs essential functions by supplying precursor molecules for visual pigment synthesis, regeneration of visual pigments which are bleached by light exposure, removing surplus water from the retina, transporting oxygen to the visual cells, and by absorbing stray light [6]. Throughout our life, the pigment epithelium accumulates waste materials from retinal metabolism. These pose an inherent danger because they contain several light absorbing molecules, so-called chromophores, assembled in the age-pigment lipofuscin (Fig. 5, 6).

IV. Chromophores and wavelengths

Apart from visual pigments and their metabolites, those chromophores can mediate light damage to both retina and pigment epithelium [7]. Most of those chromophores absorb in the short wavelength range, from ultraviolet to violet and blue up to about 460 nm. With decreasing wavelength the photon energy increases, thus facilitating injury (Fig. 7). For this reason ophthalmologists and biologists are warning against high fractions of violet and blue in artificial lighting such as fluorescent tubes, halogen- or certain LED sources [8]. The crystalline lens of our eyes absorbs UV light and, with increasing age, also fractions of violet and blue, thus protecting the retina. However, infant and young eyes transmit nearly 100% of violet and blue and a narrow range of ultraviolet A; therefore, young eyes are at danger of suffering from an overdose of light, which may lead to retinal degeneration in later life (Fig. 8). It is important to note that there are some gene mutations within the wide range of retinal degenerations which render patients' eyes particularly light sensitive [9].

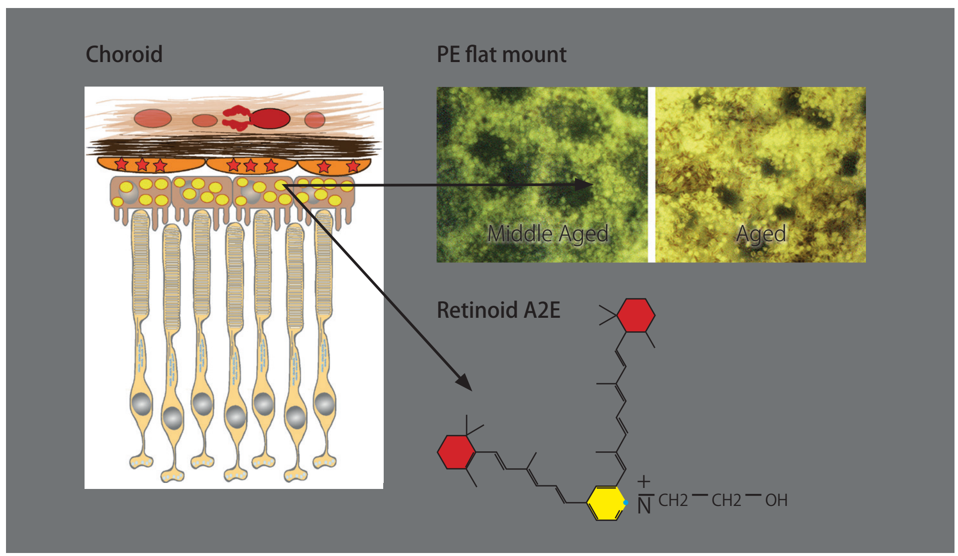


Fig.6: Pigment epithelium showing autofluorescence of blue light absorbing lipofuscin.

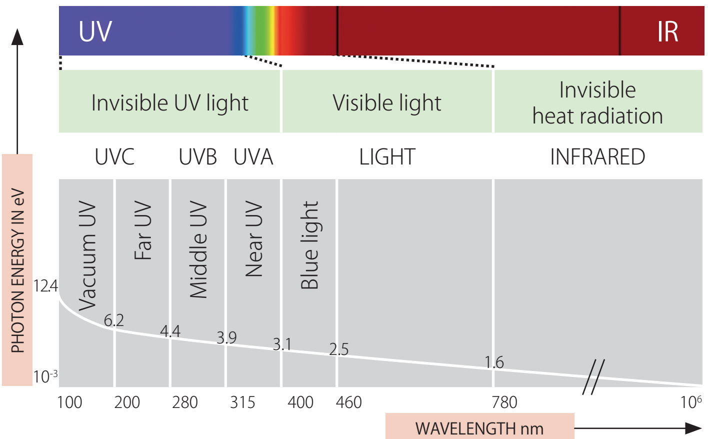


Fig.7: Increasing photon energy with decreasing wavelengths.

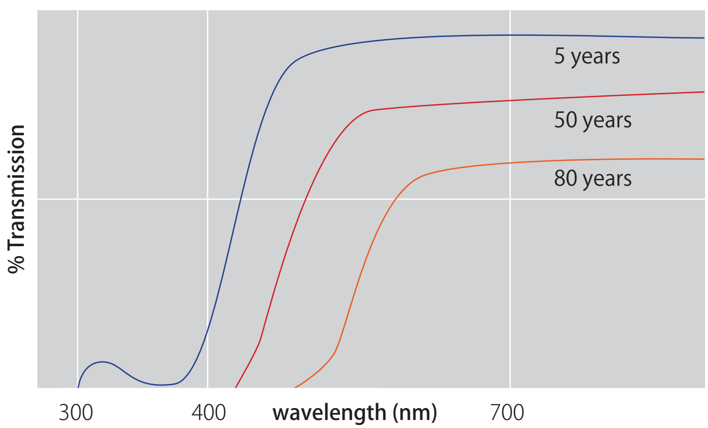


Fig.8: Average light transmission of ocular structures at different ages.

V. Conclusion and practical considerations

1. The retina can be damaged by an overdose of light of the shorter wavelength range. Thus, blue and violet light should be reduced but not omitted from artificial light sources.

2. Young eyes have a significantly higher light transmission than older eyes.

3. The light need increases with increasing age (Fig. 9).

4. Appropriate work place or home illumination should avoid stray light, too dim lighting, glare, abrupt transitions from dark to bright, and provide sufficient contrast, larger illuminated areas, indirect light from above or the side, and additional light sources for precision work.

5. The regulation of circadian rhythms crucially depends on sufficient daily light levels received and transmitted by non-image forming melanopsin containing ipRGCs. Furthermore, the dark signaling by the neurohormone melatonin during dusk and night time is equally essential [10].

6. Finally, our subjective experience of the „enlightened" world depends on comfortable, appealing and emotive lighting conditions. Thus, a reasonable synthesis among different requirements is of vital importance.

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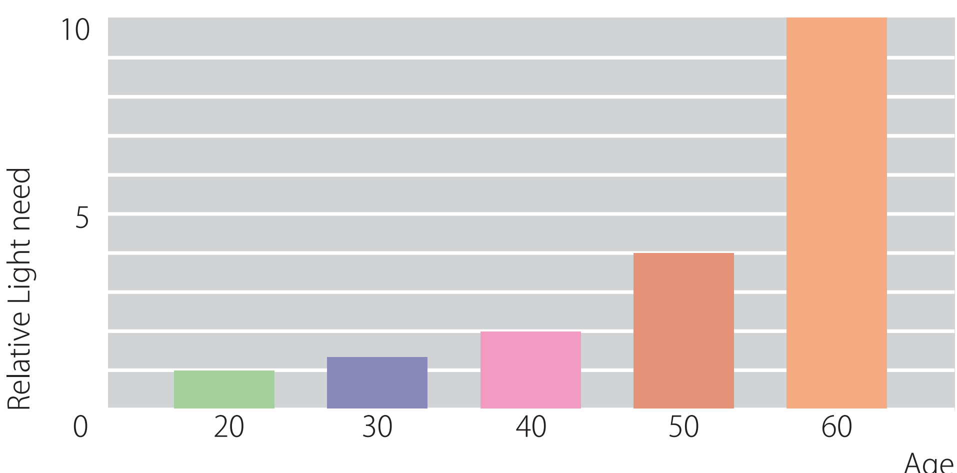

Fig. 9: Increase in relative light need as a function of age.

THE ENVIRONMENTAL INFLUENCE OF LIGHTING DESIGN ON FLORA AND FAUNA

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Catherine grew up in Panama City, Panama. Between 2009 and 2011 she studied French at the University of Montreal, Canada. After that, she moved to Europe and from 2011 to 2014 she studied Product Design at L'École Supérieure de Design, Troyes, France, obtaining her bachelor's degree in 2015.
After this, a professional opportunity took her to Paris where she worked for Carré Basset as an Assistant to the Artistic Director and Beau et Bien Lighting Sculptor as Assistant Lighting Designer. These experiences allowed her to discover the world of lighting design.
Today, she is a student on the master's program in Architectural Lighting Design at Hochschule Wismar, University of Applied Sciences: Technology, Business and Design in Wismar, Germany, where she has been experiencing the multidisciplinary and poetic sensibility of Lighting Design. She expects to graduate in 2017.

The city turns bright as the night slowly comes. A glowing skyline turns the natural nocturnal sky opaque, with artificial lighting transforming the night into day. It is a sleepless city where light is a symbol of success, prosperity and celebration. This phenomenon is known as light pollution [1]. Before urban development, the skies above us showed the billions of stars, comets and galaxies. Today, human interference in the sky during the night creates an overflow of floodlight that forges an unnatural brightness which alters the behavior and survival of wildlife and plants [2]. The main purpose of this paper is to present the consequences and overall impact of improper lighting design on the environment. Scientific environmental research on how light is affecting flora and fauna has not been conveyed due to a lack of communication between environmental specialists and lighting designers. In order to raise awareness of how lighting design influences the environment, it is important to know the nature of artificial lighting. Additionally, an interdisciplinary relationship between educators, astronomers, environmental specialists and lighting designers will unify a strong educational focus on communicating and spreading the word about the need to commit to reducing unwanted glare.

I. Introduction: the evolution of animals and plants

The biological rhythm of organisms is related to the process by which they develop. Animals evolved with an internal bone skeleton which allowed them to rule over their environment. This migration from one place to another is linked to their internal compass for orientation [3] [4]. Scientific evidence shows that most vertebrates depend on the position of the stars during the night and the visibility of the sun during the day to locate their way back home [5]. Numerous plants grow and develop depending on the light quality, the intensity of the light, and the number of nocturnal hours. The evolution of animals and plants depends on the bright hours during the day and the dark hours during the night which allow a process of activation and regeneration in organisms. Somehow, we became a society ruled by big cities that are visual pollutants. We are diurnal creatures suited to a nocturnal life engineered by the use of artificial lighting. It is in the interest of the professional field of lighting designers to communicate with environmental specialists in order to question how lighting is being designed and how it is affecting the environment. The meaningful relationship with the dark sky is currently being replaced by an artificially highlighted landscape.

II. Light and birds

The sun rises and the natural environment shifts from its natural darkness to a pale blue sky. The first indicator of this change is the bird vocalization and melodies that resonate. Birds use melodic responses for mating and for communication. In 2015, early vocalizations of bird songs were registered during winter and spring due to the early start of dawn and dusk created by light pollution [6]. Birds use vocalization as a major reference of communication. It allows them to protect themselves from predators, to attract mates, and to defend their territory [7]. Further investigations were conducted regarding light and how it affects the common European blackbird [8]. Calculations regarding illuminance levels (lux) from the frequencies during the night and also the amount of darkness birds encountered revealed that even low light intensities of 0.3 lux lead to premature growth and influence birds' reproductive systems [9].

A number of publications suggest that the average required illuminance ranges for street lighting should be between 2 lux to 15 lux based on uniformity and adequate glare for the benefit of a human being [10] [11]. Most birds are nocturnal migratory species that use the light from the moon and the stars in a cloudless sky to migrate [12]. Attracted to colored light, some birds are tetrachromats, which means that they have the advantage of having different photopigments with four peak wavelengths, such as red, green, blue and ultraviolet [13]. It has been recorded that long wavelength characteristics found in red, yellow and white light have a negative impact on the magnetic orientation of birds, altering their nocturnal hours [14]. However, experiments have shown that birds require blue-green light from the spectrum for magnetic compass orientation [15] [16]. Light pollution has become a big contributor to bird collisions and modifies birds' daily behavior, (Fig.1) which changes their seasonal activity pattern and early mating habits. Research has revealed that other colored light, such as magenta, blue and indigo, is less likely to disturb birds during nighttime.

III. Light and bats

Smuggled under the shadows, bats are commonly found hanging in caves, roosting under bridges, in the depths of the forest or in the attic of an abandoned house avoiding light [17]. Over the years, the bat population has been affected by the improper use of artificial lighting. Numerous species of bats feed on insects, flowers, leaves and pollen. Most insects are attracted to the light that comes from lamps close to their habitat. This phenomenon has affected the bat's access to insects. Insects are attracted to light that contains short wavelengths, such as ultraviolet and blue light, where the light spill in the environment delays and disturbs the bat's feeding behavior [18]. The continuous use of improper external lighting creates a barrier between bats and their prey, preventing them from feeding. Bats are the only mammals that can fly. They extend their wings and orient through the use of echolocation, which allows them to catch prey. In order to improve their chances of survival, it is important to integrate a sustainable lighting approach where further research will allow an understanding of new emerging technologies [19].

Fig. 1. Light pollution has become a big contributor to bird collisions.

IV. Light and fish

The synchronized movement of a shoal of fish can be seen due to the natural light from the sun refracted on the water. Fish gather, shift, turn, and school along coasts, migrating from one ocean to another [20] [21]. Numerous studies concerning artificial light and its impact on fish are relevant to fish visual sensitivity [22]. Even a slight change in light intensity has an impact on the overall behavior of fish, influencing their growth, breeding and migration process. (Fig. 2.) It has been recorded that the light from the moon, equivalent to 0.05 to 0.1 lux, and the light from starlight, 0.0005 to 0.0001 lux, can affect the behavior of fish close to the surface of water [23]. Fish that swim closer to the surface of water tend to be more sensitive to shorter wavelength ranges such as red and orange

Fig. 2. Even a slight change in light intensity has an impact on the overall behavior of fish, influencing their growth, breeding and migration process.

light [24]. Shorter wavelengths can't reach or penetrate into the depths of the ocean as far as longer wavelengths can. Once a deeper environment is reached, creatures such as deep-sea fish have retinal sensitivity to blue and green light. In general, fish eyes contain rods and cones, which allow them to perceive low light and colors. However, fish don't have eyelids to protect them from the brightness of light. This can trigger changes in migratory paths and increased stress levels [25].

V. Light and turtles

Marine turtles are terrestrial and aquatic creatures that learn to live in between environments. A journey submerged underwater allows turtles to migrate following currents where they adapt their vision. This allows them to feed, to locate future mates, and to avoid predators. Female turtles approach the shoreline during nesting season and crawl to lay eggs on land. Once the turtle eggs are hatched on land, a change in temperature indicates nighttime and the female turtles crawl back to the sea guided by the moonlight reflected on the water [26]. Today, artificial lighting near coastlines and beaches interrupts this egg laying behavior and turtles' orientation back to the sea [27]. Now, improper light conditions direct turtles towards light sources, making them visible to predators. It has been recorded in recent years that the use of white light containing short and long wavelengths affects sea turtles [28]. It is important to take into consideration the fact that any use of high intensity light sources such as fluorescent lamps should be avoided.

VI. Light and frogs

Under the glare of artificial light frogs refrain from singing and trying to coordinate their acoustics, which would normally announce the start of a breeding ritual. Moonlight is suppressed by the excessive use of artificial lighting in urban areas and this disrupts the nocturnal croaking of frogs. The fragmentation of the environment has affected frogs' process of foraging, visual sensitivity, their growth and reproductive behavior [29]. A significant number of experiments have been done under twilight and nocturnal conditions revealing frog's sensitivity and responses to indirect artificial lighting [30]. However, no evidence has been recorded concerning frogs' sensitivity and response to direct artificial lighting. These nocturnal species wander from terrestrial to aquatic urbanized environments in search of the perfect moisture conditions where acoustics, brightness and light spectrum play an important role [31]. Amphibians are nocturnal species that are attracted to light as it offers them a visible easy meal, such as insects, flies, mosquitoes, moths, and dragonflies that are also attracted by light. It becomes a chaotic chain of attraction that will pull frogs from their natural habitat and concentrate their density and population around improper artificial lighting [32]. During the full moon, a frog's urban habitat can reach illuminations as high as 1 lux [33]. For some frogs the brightness of the moonlight, equivalent to 0.003 lux, can even disrupt the breeding process [34]. A cloudy night where the moonlight is dimmed down is the perfect environment for choruses to attract female frogs, allowing other male frogs to synchronize their singing in order to stand out from the crowd [35].

VII. Light and insects

Insects have compound eyes with a body of sensitive units known as Ommatidia. These units carry two or more photoreceptors that are sensitive to ultraviolet, blue, green or red wavelengths [36]. Insects such as ladybugs, mosquitoes and moths fly during nocturnal hours without knowing that their next stop will be an artificial light source. (Fig. 3) It is very common to see phototactic organisms gathering around artificial light that has been mistaken for natural light from the moon or stars [37]. Light sources in the ultraviolet spectrum and short wavelengths, such as violet and blue, should be avoided due to the fact that they are more likely to trap migratory insects like moths [38]. Most insects are sensitive to shorter wavelengths due to the fact that ultraviolet vision plays an important part in the detection of nectar patterns on flora [39]. It is recommended to avoid light sources high in ultraviolet radiation, such as mercury vapor lamps [40] [41]. Nowadays, high quality LED's that produce a small amount of ultraviolet emission are preferable for outdoor areas in order to prevent insects being attracted away from their natural habitats by urban outdoor illuminations [42].

VIII. Light and plants

Nature has thrived and bloomed proving that the wilderness can be found anywhere. Nevertheless, urbanization has disrupted the nocturnal sky with light pollution, affecting plants' behavior and growth. The extension of the day by improper artificial light affects the dormancy, growth and blooming state in plants, thus altering their development. (Fig. 4) Photoreceptors in plants detect and respond to light quality, intensity and duration [43]. Nocturnal pollinators such as moths

Fig. 3. It is very common to see phototactic organisms gathering around artificial light that has been mistaken for natural light from the moon or stars.

and bats are important for the process of reproduction in plants. During the night, the interruption of dark hours diverts pollinators from flowers and plants to nearby improper artificial light sources [44]. Some plants can only handle a certain amount of brightness while others have a higher tolerance to light. Overexposure to light can damage and modify the physiology of a plant, for example its color and size [45]. The leaf's epidermis is the first element that comes into contact with the brightness. It is an organ that is sensitive to light and has adapted to the brightness of the moon and the sun. A red to infrared range of the spectrum should be avoided due to the fact that it affects most plants.

Fig. 4. The extension of the day by improper artificial light affects the dormancy, growth and blooming state in plants, thus altering their development.

IX. Conclusion

A chaotic nocturnal environment overpowered by nocturnal artificial light is responsible for the disorientation of birds during flight, starvation of bats, blindness of fish, disorientation of turtles, delay in the breeding process of frogs, overpopulation of insects and changes in the growth of plants. In conclusion, it is vital that lighting designers understand the evolution of animals and plants as birds, fish, frogs, insects and plants are just some of the victims of the improper use of lighting. It is essential to communicate with and educate the lighting community in order to minimize the dangerous consequences that light pollution has created in recent years.

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EFFECTS OF BLUE LIGHT ON RETINAL PHOTORECEPTORS

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He has published more than 220 papers in reputed journals and serves as an editorial board member.

Characteristic features of the mammalian retina make it vulnerable to short wavelengths of light in particular. Our recent studies have demonstrated that molecules of the respiratory chain are present in the photoreceptor outer segment. Thus, the outer segments are significant sources of reactive oxygen species (ROS) after blue light stress. It is now possible to understand many unique features of the photoreceptors, for example excessive oxygen consumption. Also, the therapeutic use of red and near infrared light can be set anew. The above mentioned findings are very important for a new interpretation of retinal neurodegenerative diseases like age-related macular disease (AMD).

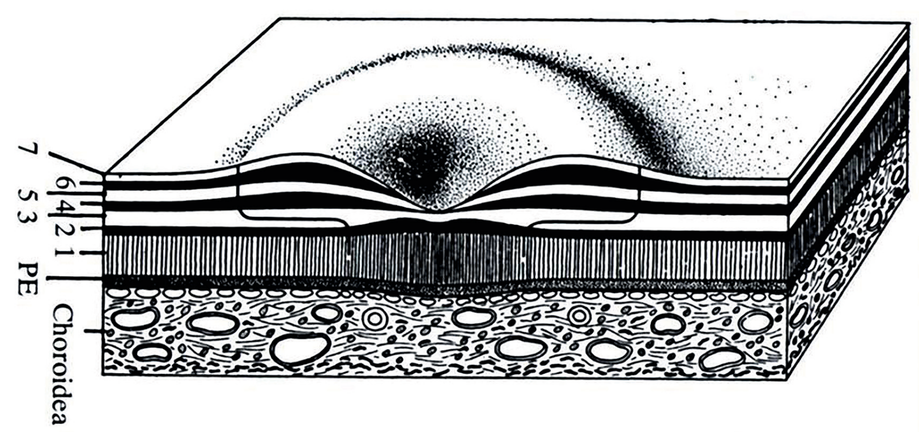


Fig. 1: Schematic drawing of a human fovea centralis (nearly the same area of the so-called macula lutea with the yellowish antioxidant pigments). Note that the inner layers of the retina (2–7 in figure) are pushed aside from the central part. Thus, the light can hit the photoreceptors more directly. These are slightly slimmer and more densely packed. Here, recently photoreceptors for white light were detected besides the commonly known red, green and blue receptors. PE: pigment epithelium is situated underneath the Bruch´s membrane and the choroid (Choroidea).

I. Functional anatomy of retina and photoreceptors

The mammalian retina is generally an inversed retina. This means that the photoreceptors look outward in the direction of the choroid. This is, however, unfavorable for an optimal resolution of the depicted image. On the other hand, direct contact with the very well perfused choroid is a guarantee for good oxygenation of the maximally consuming photoreceptor discs harboring the light transduction chain (see below). A new finding is that the Müller glial cells act like light guides leading the light more precisely from the inner retina to the photoreceptor outer segments. Furthermore, in higher mammals and some birds the inner retina is shifted away in a zone called fovea, forming physiologically a spot of optimal sight (Fig. 1, 2).

The photoreceptors in the human retina are specialized nerve cells possessing two completely different cell compartments: the inner (neural) part (ellipsoid, perikaryon and axon with the synapses) and the outer part (outer segment). Within the outer segments, membrane discs harbor the visual pigments. During photo-transduction radicals are formed; radicals originating in the rhodopsin cycle transform all-trans-retinal into di-retinoid-pyridinium-ethanolamine (A2E). This metabolite then accumulates as the most dangerous component of lipofuscin in the retinal pigment epithelium (RPE) and blocks cytochrome c oxidase in the mitochondria. Thus, the radical product A2E itself blocks the respiratory chain and leads to new ROS. This renders the outer segment discs susceptible to ROS damage, partly circumvented by a regeneration of the outer segments by steady renewal and shedding of discs. About 10 of the average 700 discs in the outer segments are shed per day. Then, they are phagocytized by the RPE, which can also be a victim of the oxidized by products.

The high pO2 coming from the choroid decreases almost linearly to the inner portion of the photoreceptors" [3], because the photoreceptors are probably the cells with the highest oxygen consumption of all cells in the human body [4]. Moreover, mitochondria are especially susceptible to oxidative stress [5] as they harbor the enzymes of the respiratory chain which handle electrons (Fig. 3).

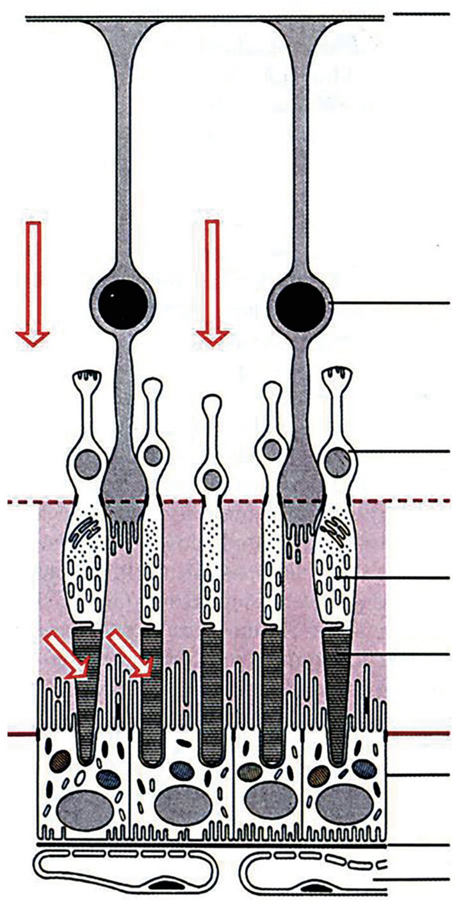
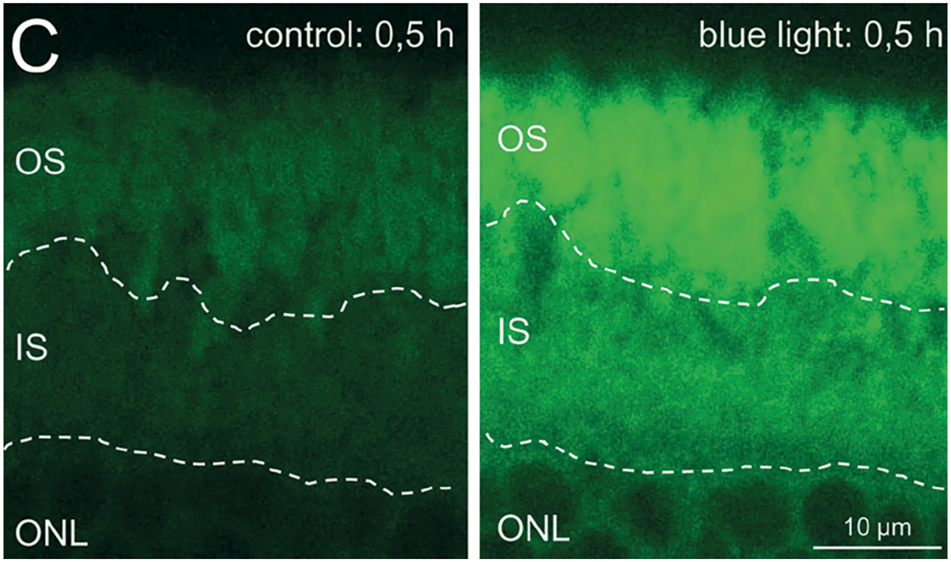


Fig. 2: Schematic drawing of the path of light (arrows). Light is coming from the vitreal body into the inner retina and is guided by the Müller glial cells. These cells end at the inner segment of the rod and cone photoreceptors near the outer limiting membrane.

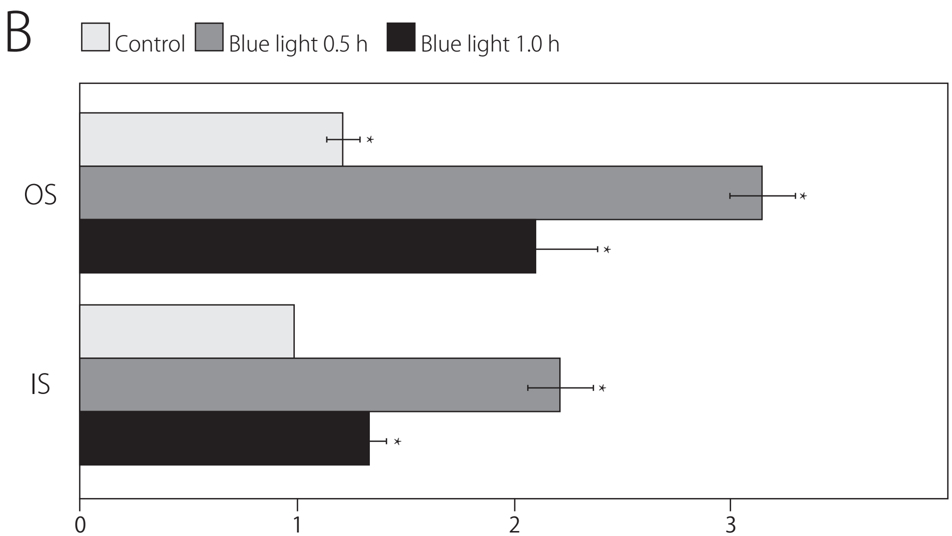
We also found that enzymes of the respiratory chain are located in the membranes of the photoreceptor outer segments [6]. In isolated outer segments, we showed that a proton potential difference exists across the disc membranes - formed as double membranes like the double membranes of the mitochondria. This fact contributes to the high oxygen demand, too.

II. Effect of blue light on retinal cells

The effect of short wavelength light on the metabolism of the mitochondria has been an important topic of experimental in vitro and in vivo studies. Indeed, these studies could show that blue light impact leads to an enhanced production of radicals in mitochondria [7]. Enzymes of the respiratory chain like flavins and cytochrome oxidases can absorb at wavelengths of 440 – 450 nm and they can cause the production of ROS and oxidative stress. Thus, after blue light exposure, more electrons deviate from the respiratory chain in the mitochondria, resulting in further damage. Furthermore, the high content of polyunsaturated fatty acids renders the outer segment discs susceptible to ROS. Thus, the first signs of the most devastating neurodegenerative retinal disease – age-related macular disease (AMD) - can be explained (Fig. 4).



Increased ROS production in photoreceptors
method: vital staining+fixation; H_2DCFDA



Fluorescence intensity (treated/untreated)
*$p < 0.05$; *shows significance compared to control IS.

Fig. 3: Vital staining fluorescence picture of radical oxygen species (ROS) in photoreceptor inner- (IS) and outer segments (OS). Note the increased ROS production after irradiation with blue light, not only in the mitochondria of IS but also within the OS.
The quantitative diagram of the fluorescence measurements shows a peak of ROS production after 0.5 hours and a decrease (probably due to exhaustion) after 1 hour.

III. Red light in therapy?

Quite opposite to the action of blue light, red or infrared light can have positive (protective) effects on different tissues and organs – a fact which is described in an increasing number of recent studies.

Several studies have also shown the positive effects of red or infrared light on regeneration processes in the retina. Here also, the mitochondrion and the respiratory chain within the mitochondria seem to play a major role [17]. As one causal explanation, recent studies have revealed that red and NIR light is absorbed by the heme structures and copper centers of the cytochrome c oxidase. Here, absorption maxima exist in the range of 760 – 900 nm with peaks at 767, 791 and 880 nm [11]. A dimeric copper complex with four ligands absorbs in the 810 – 820 nm range. Copper atoms in the redox active centers in the Cco show absorption peaks at 620, 680, 760 and 820 nm and have a maximum of biological activity at an absorption wavelength of 670 and 830 nm with a nadir in both spectra of around 728 nm [11].

In the light of the newly found analogy between photoreceptors and mitochondria, it is possible that the positive protective effects found by Tang et al. [17]; Begum et al. and Albarracin et al. [13] are also due to amelioration of the metabolic situation within the outer segment and not only to an enhancement of the respiratory chain in photoreceptor mitochondria – a fact, which we also found in recent studies (Fig. 4).

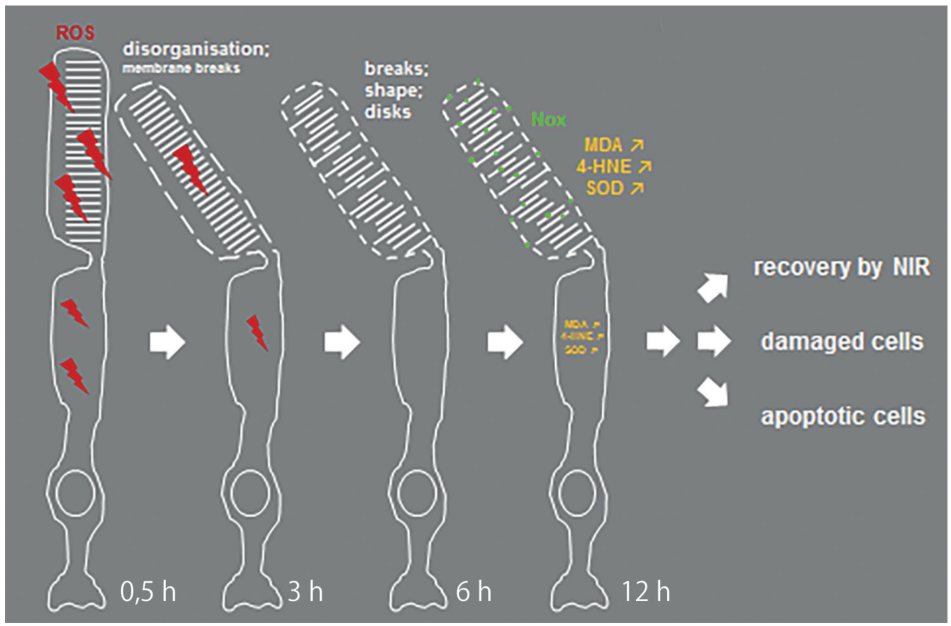


Fig. 4: Event diagram of our blue light and red light experiments in mice: after 0.5 hours maximum of ROS production, 3 hours: disorganisation of the photoreceptors, 6 hours: breaks within the shape and outer segment discs, 12 hours: compensatory upregulation of antioxidative enzymes and further fate decision in the direction of damaged cells or cell death (apoptosis). After red or infrared irradiation a recovery is significantly more probable via reduced production of superoxides, reduced production of free radicals and a positive effect on electron transport chain activity.

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Sergei Gepshtein

WALKING THROUGH STRUCTURED LIGHT

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As a founding member of the 5D|World Building Institute and as an inaugural recipient of the Harold Hay Award from the Academy of Neuroscience for Architecture, he is increasingly involved in research on built environments and the design of immersive media.

Moving through any complex environment presents the sighted individual with a sequence of visual experiences. Visual objects move in and out of the observer's awareness because of the changes in occlusion, but also because vision is not equally sensitive to the objects that appear in plain sight. To capture this dynamics we introduce the concept of "solid field of visibility" and the attendant quantitative model of spatial organization of experience. The model describes visibility of every part of the environment as a continuous function of observer location. Having the model built into drafting software will allow designers to predict which parts of an environment can be experienced at every location and where multiple parts can be experienced concurrently. The designer will be able to discover how the experience would change under different intensities and directions of lighting, static or dynamic.

I. The problem

The emphasis of physical sciences on objective theories of space and time left us poorly prepared to predict the experience of a person freely moving in her environment. New technologies for lighting and visualization make this deficit felt acutely within many professions concerned with spatial experience, from city planners and architects to lighting designers and makers of immersive narratives. Indeed, the new technologies allow one to simulate environments of breathtaking complexity and realism, and also augment physical reality by rich digital content. Yet our ability to apply these advances effectively is stymied by the lack of understanding how humans experience space.

II. A solution

I propose that a systematic account of spatial visual experience should begin with a systematic account of how we access visual information. Indeed, parts of any environment can be seen from some locations and not from others, for several reasons. Some reasons are self-evident, such as whether or not the line of sight to the object of interest is interrupted, producing the phenomena of occlusion and transparency. [1-3]. Other reasons are more delicate but nevertheless pervasive, concerning the visual experience of objects that stand in plain sight. Such objects can be visible or not because visual systems are highly selective, making some optical patterns readily visible over a wide range of conditions, while other patterns can hardly be seen even in the most favorable conditions.

In the laboratory studies of visual perception, this visual selectivity is described in terms of visual sensitivity functions, including sensitivity to chromatic and achromatic patterns, stereoscopic displays, displays that involve motion, etc. Of particular note is the basic fact that visual sensitivity to chromatic and achromatic optical patterns is determined by the amount of spatial detail in the pattern. This fact has been used extensively to characterize visual performance in clinical studies [4], to discover mechanisms of visual perception [5-6], and also to optimize visual technologies [7-8].

Since the amount of detail projected into the eye depends on the viewing distance, we can make quantitative predictions of the distances at which a pattern will be visible, for static patterns and for patterns that moves relative to the observer (whether the patterns or the observer move). Generally, patterns are not visible from very long and very short distances, which means that the visual experience of every pattern is confined to a solid region (a three-dimensional pocket) of the environment. As a method for visualizing experience, our approach is reminiscent of the approach by the Gestalt psychologist Rudolf Arnheim and the architect Paolo Portoghesi [9] who proposed to describe the experience of built environments in terms of "perceptual fields," illustrated in (Fig. 1) In the figure, the range of distances over which objects exert their graded perceptual effects are represented by concentric circles. Our approach allows one to derive the solid regions from which specific pattern can be seen in different conditions of lighting. Thus, if the pattern is painted or projected on a small object, such as a vertical cylinder unobstructed from every direction, its solid region of visibility will form a solid ring with the cylinder at the center. When a part of the pattern is illuminated (e.g., using a point light source), the solid region of visibility will shrink to a solid sector of the ring.

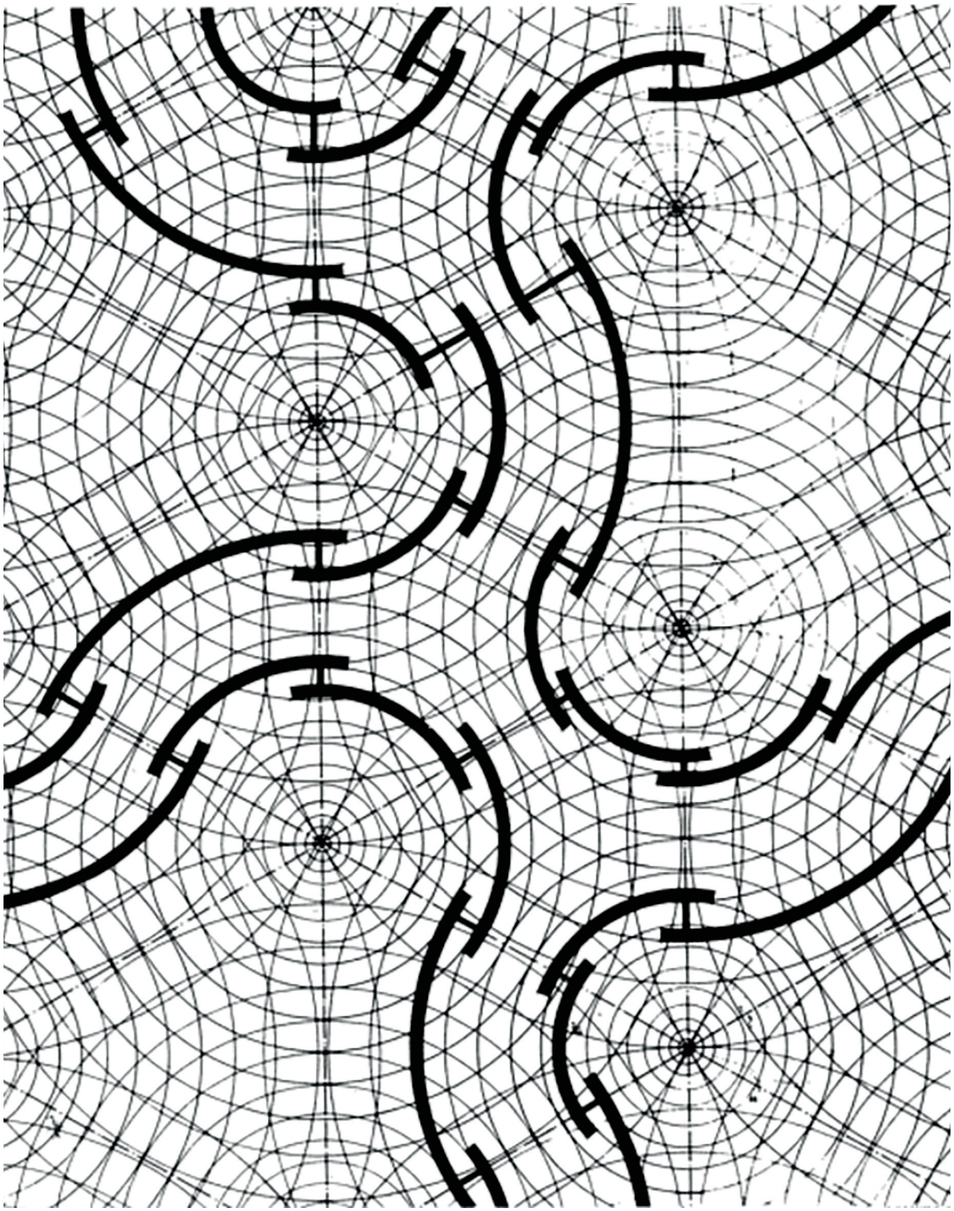

Fig. 1: The plan view of a hypothetical "perceptual field" generated by an arrangement of curved walls. This drawing by Paolo Portoghesi is reproduced from Rudolf Arnheim's The Dynamics of Architectural Form, p. 30 [9].

III. Solid field of visibility

As mentioned above, the totality of locations in the solid space from which an object is visible constitutes its solid region of visibility. Every object that populates the environment has a corresponding solid region of visibility. The multiple solid regions can overlap or nest in one another. Together, these regions make up a continuous solid field, which we call the SOLID FIELD OF VISIBILITY of the environment. Such a solid field of any immersive environment – physical, virtual, or mixed – provides an inclusive description of all the potential experiences that the environment can afford. The model specifies which features of the environment are visible and to what degree from every location, and also where multiple objects can be seen simultaneously.

Basic studies of visual perception produced a number of models of visibility for static and dynamic optical patterns [5-8]. But these models were derived and tested using flat screens and viewed from fixed distances by stationary observers. Do such models generalize to the immersive conditions where observers view objects from multiple distances while the objects or the observers (or both) can move?

IV. A first model and test

A model of solid field of visibility was recently tested using a well-established characteristic of human vision called spatiotemporal contrast sensitivity function [5-6]. This characteristic captures how visibility of an optical pattern depends on the amount of spatial detail in the pattern and on whether the pattern moves or flickers. This model allows one to predict where any pattern is visible and how salient it is relative to other patterns, for every location in an environment that contains complex arrangements of static and dynamic objects, each with a different amount of detail.

Predictions of this model were tested by the author in collaboration with the architect Greg Lynn (University of California at Los Angeles; UCLA) and the narrative designer Alex McDowell (University of Southern California) at the IDEAS Robotics Laboratory at the Department of Architecture and Urban Design (UCLA). Static and dynamic luminance patterns were projected on screens propelled through space by large-scale robotics. Observers reported their ongoing experiences by periodically responding to standard visual tasks, such as direction discrimination and direct report. The results confirmed predictions of the model in several respects, including locations of the boundaries between solid regions of visibility, the steepness of such boundaries, and the notion that these locations depend on the presence of motion within the pattern [10].

V. Applications

The conception and model of solid field of visibility has multiple applications for predicting experience in built environments and immersive narratives in the process of their design. For example, standard software packages for computer-aided design can be equipped with the capability to render predictions of the model of solid fields of visibility, allowing the designer to anticipate visual experience at every location in the environment.

The designer would freely select certain parts of the environment and have their solid regions of visibility visualized by color or brightness, represented as a flat or solid map, indicating where in the environment users would see the desired features and where multiple features could be seen concurrently. This way, the designer could explore how the experience would change as users move, or parts of the environment move, under different conditions of illumination, including changes in direction and color of lighting.

This research was supported in part by the inaugural award from the Harold Hay Research Program of the Academy of Neuroscience for Architecture.

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Magda Havas, Sheena Symington

DIRTY ELECTRICITY, RADIOFREQUENCY RADIATION, FLICKER, AND SPECTRAL QUALITY GENERATED BY DIFFERENT TYPES OF ENERGY EFFICIENT LIGHTING

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In our move for greater energy efficiency, various types of energy efficient lighting have replaced the simple incandescent light sources. Some of these light sources are making people sick, especially those who already suffer from electro hypersensitivity (EHS). Symptoms of EHS include a combination of chronic pain, chronic fatigue, difficulty sleeping, mood disorders like anxiety and depression, cognitive disorders associated with poor short-term memory and difficulty concentrating, heart palpitations, tinnitus, dizziness, nausea, and skin irritations. These symptoms are becoming increasingly prevalent in industrialized populations. The purpose of this study was to determine how light sources differ with respect to electromagnetic emissions. Thirty-eight light sources – mostly light emitting diodes (LEDs) but also incandescent, halogen and compact fluorescent (CFL) lamps – were measured for electromagnetic emissions consisting of low frequency electric and magnetic fields, intermediate frequencies referred to as dirty electricity, radiofrequency and microwave radiation, light flicker, and spectral distribution. Apart from spectral distribution, these measurements constitute electrosmog, an undesired form of electromagnetic pollution at different frequencies. Incandescent and halogen lamps generated the least amount of electrosmog, and CFLs and LEDs the most. Almost all of the LEDs generated visual flicker and most produced dirty electricity. Three LED lamps, which were designed to communicate with cell phones, also emitted microwave radiation when plugged in and turned on in "standby" mode. The major difference between warm and cool LEDs was the proportion of blue light, which has been implicated in melatonin disruption and impaired sleep. We believe some combination of these electrosmog frequencies is responsible for the symptoms of EHS mentioned above. It is critical for lighting engineers to design energy efficient lamps that promote rather than disrupt human health and well–being. Energy efficiency at the expense of health is an unsatisfactory option that constitutes flawed design.

I. Introduction

Incandescent light sources generate heat as well as light and are energy inefficient. They have been replaced with light source that consume much less power using either fluorescence or light emitting diode (LED) technology. However, the response to lighting has been mixed and many people claim that energy efficient light sources make them ill [1–5]. To examine this problem, we measured electromagnetic emissions from 38 light sources that include incandescent, halogen, compact fluorescent, and both cool and warm LEDs.

II. Methods

People were invited to participate in an internet survey and to provide information on their response to different types of lighting. They were also asked to assess their electrical sensitivity (EHS). While this was a random survey, it is likely that more people who were aware of EHS responded and as such is not representative of the population at large. Rather it provides information on self-perceived EHS and a subjective response to lighting.

In order to determine what characteristics of lighting people were responding to, we measured light sources at a distance of 20 cm for various electromagnetic (EM) frequencies with the meters indicated below. Experiments were conducted in an electromagnetically clean environment and the baseline readings are provided as "background" values. All lamps are coded as to the type (CFL, HAL, etc.) and numbered in increasing order of combined electrosmog emissions.

1. ELF electric and magnetic fields: GigaHertz Solutions NFA 1000 (5 Hz–1000 kHz);
2. Dirty Electricity: Graham Stetzer Microsurge Meter (4 to 150 kHz);
3. Radiofrequency and microwave radiation: Electrosmog Meter (10 MHz – 8 GHz);
4. Flicker: Medical Electronics Light Noise Detector LND 709 (370 – 900 nm);
5. Light Spectrum: UPRtek Spectral Analyzer MK350S (IR to UV);

Table 1: Percentage of respondents within each self-proclaimed electrical sensitivity category who experience symptoms when exposed to different types of lighting. (Note: LED = Light Emitting Diodes; CFL = compact fluorescent lamp, and fluorescent = linear (tube) fluorescent lamp).

n	ELECTRICAL SENSITIVITY ↓	TYPE OF LIGHTING Incandescent	LED	halogen	CFL	fluorescent
		headache				
65	not at all	3%	2%	2%	2%	15%
132	a little	8%	11%	17%	17%	55%
150	moderately	17%	15%	28%	37%	63%
83	very	24%	20%	44%	59%	75%
		body pain				
	not at all	0%	0%	0%	0%	0%
	a little	0%	0%	1%	0%	1%
	moderately	1%	1%	3%	3%	8%
	very	5%	4%	9%	21%	28%
		confusion				
	not at all	0%	0%	2%	0%	2%
	a little	1%	2%	4%	4%	9%
	moderately	3%	5%	7%	11%	26%
	very	4%	8%	13%	28%	35%
		fatigue				
	not at all	0%	0%	0%	0%	5%
	a little	1%	0%	2%	6%	19%
	moderately	5%	4%	9%	19%	34%
	very	12%	14%	22%	46%	56%
		dizziness				
	not at all	0%	0%	0%	2%	0%
	a little	0%	2%	2%	2%	11%
	moderately	4%	3%	4%	13%	25%
	very	8%	11%	20%	29%	38%
		nausea				
	not at all	2%	0%	0%	0%	5%
	a little	1%	2%	4%	3%	14%
	moderately	7%	8%	9%	14%	33%
	very	8%	9%	16%	24%	39%
		eye problem				
	not at all	3%	2%	3%	0%	11%
	a little	4%	6%	8%	7%	27%
	moderately	13%	14%	17%	25%	44%
	very	16%	24%	31%	47%	61%
		irritability				
	not at all	3%	2%	2%	0%	5%
	a little	2%	3%	6%	7%	26%
	moderately	5%	4%	7%	18%	37%
	very	12%	14%	29%	41%	56%
		depression				
	not at all	0%	0%	0%	0%	2%
	a little	0%	0%	0%	3%	5%
	moderately	1%	3%	2%	5%	13%
	very	6%	5%	6%	18%	19%

% of responses within each sensitivity category

0%	< 10%	10-24%	25-49%	≥ 50%

ELECTRICAL SENSITIVITY ↓	TYPE OF LIGHTING Incandescent	LED	halogen	CFL	fluorescent
	migraine				
not at all	0%	2%	2%	2%	9%
a little	8%	7%	18%	10%	42%
moderately	14%	15%	23%	23%	56%
very	14%	19%	27%	35%	60%
	numbness				
not at all	0%	0%	0%	0%	0%
a little	0%	0%	0%	1%	1%
moderately	1%	1%	1%	1%	5%
very	5%	4%	7%	16%	21%
	memory problem				
not at all	0%	0%	0%	0%	0%
a little	0%	0%	0%	4%	6%
moderately	2%	2%	5%	11%	21%
very	6%	5%	14%	28%	38%
	poor sleep				
not at all	0%	0%	0%	2%	2%
a little	1%	1%	2%	3%	8%
moderately	3%	5%	5%	9%	17%
very	9%	5%	15%	29%	45%
	hearing problem				
not at all	0%	0%	0%	0%	0%
a little	0%	0%	0%	0%	3%
moderately	1%	1%	1%	3%	9%
very	2%	4%	5%	19%	20%
	feeling unwell				
not at all	0%	0%	0%	0%	6%
a little	1%	1%	4%	6%	23%
moderately	6%	11%	16%	23%	47%
very	15%	12%	28%	38%	61%
	skin problem				
not at all	0%	0%	0%	0%	0%
a little	0%	0%	0%	0%	2%
moderately	1%	1%	1%	4%	4%
very	6%	5%	11%	16%	19%
	anxiety				
not at all	0%	0%	2%	0%	2%
a little	2%	2%	4%	3%	8%
moderately	3%	3%	6%	13%	20%
very	7%	9%	16%	27%	36%
	heart arrhythmia				
not at all	0%	0%	0%	0%	0%
a little	0%	0%	0%	0%	1%
moderately	1%	1%	1%	4%	7%
very	2%	2%	5%	16%	15%

Table 2: Electromagnetic emissions generated by light sources.

Fluorescent lighting (CFL or linear) appeared to cause the most health problems for those with EHS. However, the survey was conducted before LEDs became widely available, hence the response to current LEDs may differ.

For this type of monitoring, it is essential that the background levels in the environment be as low as possible for all of the parameters monitored. BG1 refers to the unplugged light and BG2 to the light plugged into an electric outlet but not turned on. The only real change is an increase in the electric field. Incandescent and halogen lamps, apart from some flicker, generate the least amount of electrosmog. Compact fluorescent lamps and the LEDs that were designed to communicate through microwaves with cell phones (RF LEDs) are the worst in terms of eletromagnetic pollution. Among the warm and cool LEDs, there is considerable variation, although most generate flicker and dirty electricity. The electric field is also elevated for many of these light sources, although this would decrease considerably with increasing distance. The flicker does not decrease with distance and is visible even from reflected surfaces.

	Radio Frequency ($\mu W/m^2$) 1 minute max	Dirty Electricity (GS units) Intermediate Frequencies	ELF Magnetic Field (mG)	ELF Electric Field (V/m)	Light Noise Detector Loudness (-dB)
Background					
BG1	0.2	nd	0.35	17.4	-78.2
BG2	0.2	37	0.34	25.0	-78.5
Incandescent					
INC1	0.2	38	0.31	39.3	-21.2
INC2	0.2	38	0.30	45.2	-19.2
INC3	0.2	40	0.33	73.7	-29.9
Halogen					
HAL1	0.1	38	0.32	32.4	-19.2
Compact Fluorescent					
CFL1	0.1	98	0.60	92.1	-39
CFL2	0.2	1642	0.50	81.6	-24.4
RF LEDs					
LEDr1	646	177	0.50	50.6	-18.8
LEDr2	1,165	171	0.50	61.5	-19.2
LEDr3	16,870	487	0.26	58	-57.7
Cool LEDs					
LEDc1	0.2	40	0.30	47.1	-52.5
LEDc2	0.1	114	0.36	41.5	-53
LEDc3	0.2	364	0.7	61	-60.1
LEDc4	0.2	40	0.36	56.2	-18.4
LEDc5	0.2	362	1.06	55.6	-19.7
LEDc6	0.2	1281	0.77	47.7	-20.7
LEDc7	0.2	1182	1.28	60.7	-19.2
LEDc8	0.1	1371	0.36	69.8	-17.7
LEDc9	0.1	1433	0.36	63.8	-21.3
LEDc10	0.1	2001	0.39	48.1	-17.8
LEDc11	0.2	2001	0.51	53.2	-19.3
LEDc12	0.2	2001	0.40	53.5	-19.4
LEDc13	0.2	2001	0.34	60.6	-20.6

	Radio Frequency ($\mu W/m^2$) max – 1 minute	Dirty Electricity (GS units) Intermediate Frequencies	ELF Magnetic Field (mG)	ELF Electric Field (V/m)	Light Noise Detector Loudness (-dB)
Warm LEDs					
LEDw1	0.2	39	0.39	39.3	-19.7
LEDw2	0.1	39	0.33	35.4	-24.7
LEDw3	0.1	37	0.36	67.1	-20.4
LEDw4	0.1	40	0.34	56.7	-18.8
LEDw5	0.2	44	0.36	59.3	-36.1
LEDw6	0.2	88	0.31	35.2	-32.6
LEDw7	0.2	134	0.47	47.8	-18.4
LEDw8	0.1	399	0.48	55.0	-19.1
LEDw9	0.1	330	0.97	55.2	-19.3
LEDw10	0.2	2001	0.45	47.9	-19.6
LEDw11	0.2	1262	0.74	48.7	-21.4
LEDw12	0.2	1287	0.37	56.6	-26.1
LEDw13	0.2	1946	0.30	54.1	-19.3
LEDw14	0.1	1985	0.37	68.1	-31.6
LEDw15	0.2	2001	0.52	58.6	-18.2
LEDw16	0.1	1050	1.43	63.0	-18.6

legend	units	low	intermediate	high
RFR	$\mu W/m^2$	< 0.50	0.5 to 50	> 50
DE	GS units	< 40	41 to 400	> 400
ELF MG	mG	< 0.50	0.51 to 1.0	> 1.0
ELF EF	V/m	< 10	11 to 50	> 50
Flicker Noise	-dB	< -75	-74 to -40	< 40

III. Results

Subject assessment of lighting and self-perceived EHS: A total of 432 people responded to the Internet questionnaire (117 males and 315 females), ranging in age from 20 to 79. 32% of males and 9% of females stated that they were not at all sensitive to electromagnetic fields, while 42% males and 59% females claimed to be moderately to very sensitive. The remainder had little sensitivity. Their response to lighting is summarized in Table 1.

People with EHS stated that they responded adversely within 10 minutes of being in the same room with certain types of light sources and that symptoms lasted from minutes to days following exposure.

Electrosmog emissions by different light sources: The results for each light source are provided in Table 2, which indicates light sources with desirable (light boxes) and undesirable (dark boxes) qualities based on their electrosmog emissions.

Typical visible spectral distribution is provided in Fig. 1 for the various types of light sources tested and is compared with sky radiation measured perpendicular to the ground, at noon on a sunny October day 2016 in Peterborough, Canada.

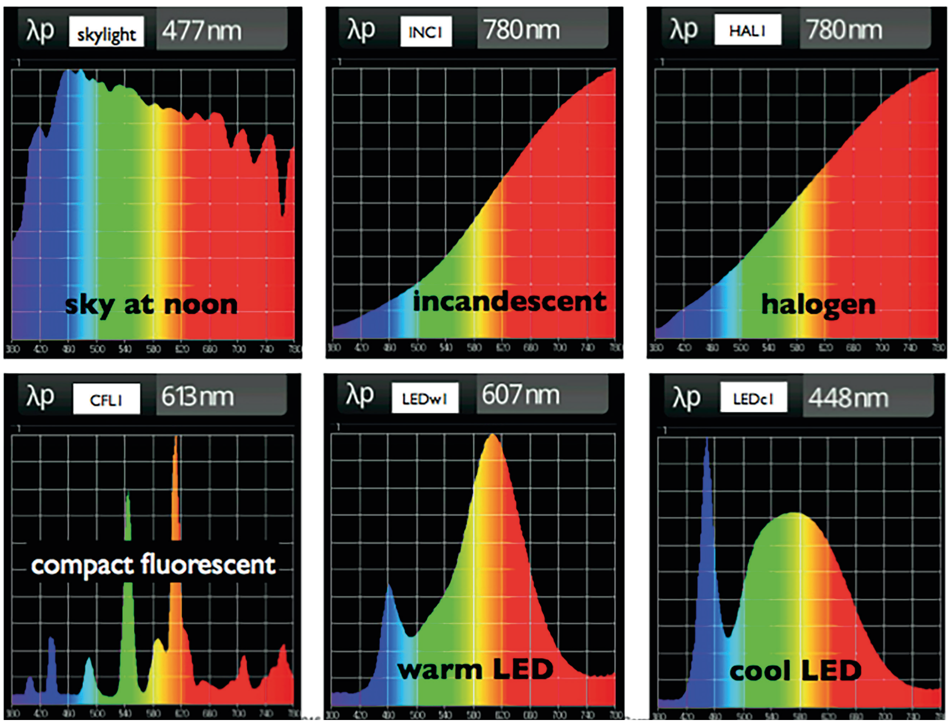

Fig. 1: Spectral distribution of various sources of light.
Often lighting manufacturers attempt to provide broad spectrum lighting as demonstrated by natural sky light. Incandescent and halogen light sources are similar in that they generate less blue and green light than sky light. LED lampss generate much less at red and infrared wavelengths than incandescent and halogen lamps and are thus more energy efficient. The major difference between warm and cool LED is the amount of blue light and the ratio of blue to red light. CFLs generate the most irregular light.

IV. Discussion

Governments around the world are banning the manufacture of incandescent lights sources because they generate heat and are deemed to be energy inefficient [6–8]. However, the lights that have replaced incandescent light sources may be far worse. They require more electronics and hence consume more materials and cost more in terms of energy for manufacturing. Some (fluorescent lamps) also contain mercury, a neurotoxin, that is released into the environment during manufacturing and when these lamps break [9]. And finally, fluorescent lighting and many light emitting diodes (LED) are making people ill with symptoms that include headaches, migraines, fatigue, heart palpitations, mood disorders, cognitive dysfunction and seizures [1–5].

Many of these lamps generate dirty electricity, which has been associated with cancers [10], increased blood sugar among diabetics [11], symptoms of multiple sclerosis [12] and various

EHS symptoms including asthma in students [13].

Flicker is also undesirable as visible flicker has been linked to seizures and invisible flicker (i.e. not perceived by the human eye) can contribute to headaches, migraines, impaired motor control of the eye and impaired visual performance [14]. Clearly this type of lighting should not be used in schools, hospitals, occupational settings or homes.

Light sources that can be controlled by a cell phone emit microwave radiation even in standby mode and contribute to electromagnetic pollution. This is a frivolous use of wireless technology that reduces energy efficiency and increases RF exposure. RF lighting technology is analogous to using x-rays in shoe stores to fit children's shoes and should be banned for normal use.

Our research is a call to lighting engineers to design light sources that are both energy efficient and health promoting and for governments to relax their ban on incandescent lamps until improved lighting becomes available and affordable. The ideal light source from a health and an electromagnetic perspective is one that produces broad–spectrum lighting mimicking solar radiation; has minimal flicker; and does not produce an elevated magnetic field, electric field, dirty electricity, or radio frequency radiation.

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TCM IN LIGHTING DESIGN: AN INTEGRATIVE MEDICAL METHODOLOGY IN LIGHT RESEARCH

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Yike Pan has a bachelor's degree in Illumination Engineering from Shanghai Fudan University, China (2008), a master's degree in Architectural Lighting Design from the Hochschule Wismar, Germany (2015), and is currently working on his PhD at the Technical University of Eindhoven, the Netherlands.

Yike has worked as research assistant, lighting designer and project manager in Shanghai, China (2008 - 2012), New York City, USA (2013 - 2014) and Bonn, Germany (2014 - 2015). He perceives light as a medium of energy and information, harmonizing the human body with its surrounding environment. By adopting the holistic and preventative medical approach of traditional Chinese medicine (TCM), he uses mathematical and physical methods to quantify the impact of light on human health, thus benefiting the work of architectural lighting design. Yike also works in a start-up "aralys", Adaptive Lighting Solutions, researching and developing a biologically and socially smart adaptive lighting system.

The advancement of artificial lighting technology has enabled a lifestyle free from the restriction of natural daylight. However, scientists have discovered that light, assisting the cardiovascular system and synchronizing the biological clock, is a vital form of energy and information to sustain human health [1] [2].
Traditional Chinese Medicine (TCM) considers human beings undividable from its surrounding nature environment. When interpreted into the languages of physics and mathematics, the integrative oriental medical approach helps to understand the chronic impact of light to human health in a holistic point of view.

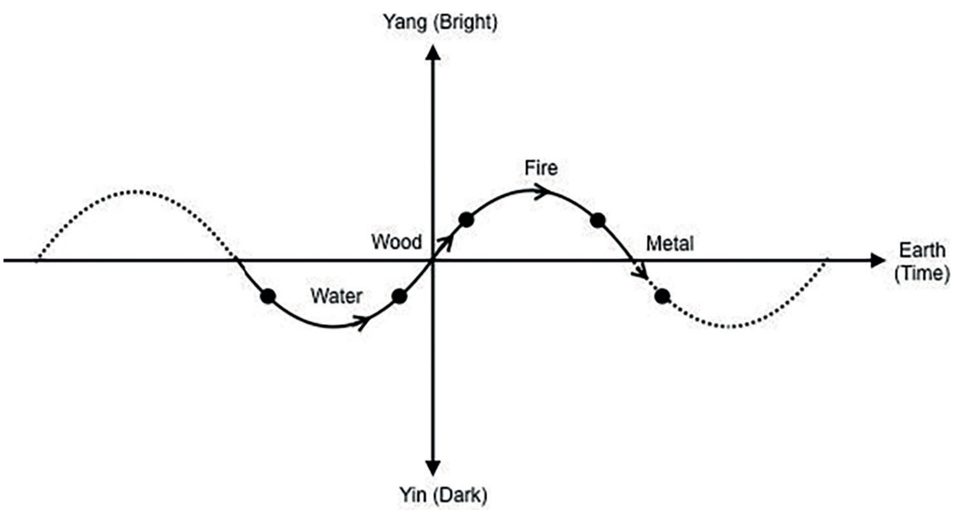

Fig. 1: Five Phases in Sine Function.

I. East and west, telescope and microscope

I.1 Modern Western Medicine (MWM)

Rooted in Hebrew and Greek civilizations, modern western medicine (MWM) is fundamentally analytical and reductive. Because of its success of handling infectious diseases, acute symptoms and emergencies, MWM has become the predominant medical system worldwide since 20th century [3].
According to the doctrine of western medicine, if each organ component functions properly, the whole body is healthy, among which, the subjective human role is missing during the diagnosis process. The challenge arises with increasing clinical complaints such as depression, "burn-out" and sleeping disorders. The health issues of modern urban residents have partially shifted from curing acute diseases to maintaining chronic wellbeing.

I.2 Traditional Chinese Medicine (TCM)

Once treated as the dominant medicine in China, TCM serves as a complementary and alternative medicine nowadays. It comes from a holistic medical perspective and has been developed through thousands years of empirical observations and clinical practice.
Instead of focusing on diseases, TCM is more dedicated to maintaining the "health", a state of equilibrium, balance and harmony of mind-body and human-environment. The systemic and preventative medical methodology includes one perfect harmonious status: Taiji; two fundamental attributes: Yin and Yang; five biological phases: metal, wood, water, fire and earth. By Fourier Analysis, all periodical movements (including bio-electromagnetic waves) can be decomposed into a superposition of a series of sine functions. Therefore, a mathematical interpretation of bio-dynamics could be illustrated as (Fig. 1).
When each living cell is a source of bio-electromagnetic radiation, "Five Phases" describes the living dynamics of human internal interference pattern: "meridian" [4], a synthesized network of fundamental energy and biological information, which partially locates within the frequency scope of visible light [5].

I.3 Comparisons and synthesis

As shown in Table 1, it is necessary to involve both eastern and western methodologies as the combined utilization of microscope and telescope, to qualify and quantify the impact of environmental light to human biological health.

Table 1: The comparisons of MWM and TCM.

Modern Western Medicine (MWM)	Traditional Chinese Medicine (TCM)
Symptoms relief	Root causes of the symptoms
Acute disease and reacts quickly	Chronic cases and takes slow effects
Reductive and analytical method	Inductive and synthetic method
Standardized	Individualized
Evidence based	Experience based
Relies on medication and procedures	Emphasizes the role of the body in healing
Uses pure chemical compounds	Uses herbs and natural agents
Analyze the structure and function of the parts	Consider the behavior of the system as a whole
Manages disease	Maintain health

II. Light, Human and the Universe

Quantum Mechanics has terminated the effort of mankind to search for the “elementary particle”. It implies that the very nature of the universe is “vacuum fluctuation” [6]. Light penetrates everything as photons and exists everywhere as electromagnetic standing waves.

II.1 Light, the ultimate messenger

There are mainly three types of bio-communication within our bodies: biochemical reactions, neurotic impulses and bio-radio modulations [7]. The first two systems transfer biochemical materials and bioelectrical signals while the third system modulates the extremely complex metabolism and mind-body mechanism in the speed of light.

II.2 Light, the link of human and nature

With a bandwidth 10,000 times wider than Wi-Fi waves [8], visible light contains and transfers huge amount of biological identified information in an analogue way. The photonic information of light prompts human body to response to the change of natural environment as reflected in the subtle change of Yin-Yang and described in “Five Phases” theory.

III. Light and harmony

If we compare human biological system to a complete set of orchestra, wel-being the symphony, which requires not only mechanical function of each instrument (focus of MWM), but also the harmony and coherence among all instruments (scope of TCM). Light, as the only capable biological “conductor”, modulates human body to function properly.

III.1 Light, the modulator of biological harmony

Light is able to modulate the degree of coherence, which is a key barometer to tune bio-harmony status. The mathematic models of the statistical distributions are as the followings:

- Absolutely relaxing: Gaussian distribution.
- Extremely stressing: Delta distribution.
- Ideally coherent: Log-normal distribution [9].

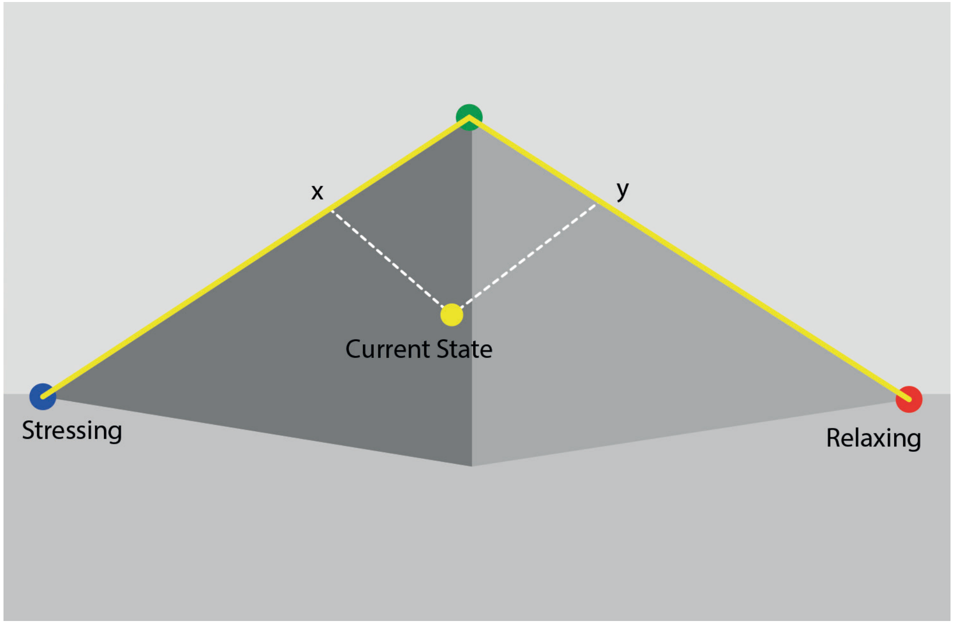

Fig. 2: An illustration of the "coherent pyramid" Concept: Zhang, Changlin.

III.2 TCM in Architectural Lighting Design

Light has the power to heal or harm. To harness the advantage of light with a natural and holistic medical approach, architectural lighting professionals should consider the art and science of lighting design systemically, to design a dynamic lighting scheme based not only on neural science, but also on human nature in general. The mathematic distributions help evaluate the current mind-body status and design the dynamic spectral power distribution (SPD) accordingly [Fig.2].

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PART IV
MISCELLANEOUS

LSW 2016 SCIENTIFIC COMMITTEE

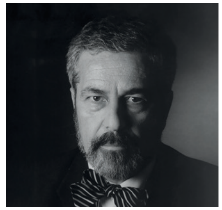

Fig. 1

Ahmet Çakir

Dr. Ahmet Çakir is director of the ERGONOMIC Institute, Berlin. He studied telecommunication technology at the Technical University of Berlin. After receiving his doctor's degree in lighting technology, he became a research fellow with the Institute of Ergonomics where he conducted an investigation of VDT utilization in German industries, sponsored by the Federal Ministry of Labour and Social Affairs. The scientific outcome of this study forms the main basis for German standards governing computerized workplaces.
Since 1980 he has been the scientific manager of the ERGONOMIC Institute for Social and Occupational Sciences in Berlin. He is a fellow of the Ergonomic Society and editor-in-chief of the scientific journal Behaviour & Information Technology. Dr. Çakir is chair of the international committee ISO/TC159/SC4/WG3 responsible for the standardization of workspace and the work environment, and of the national German committee NAErg/NIA: Ergonomics for Information Processing Systems.

Fig. 2

Gisela Çakir

Gisela Çakir finished her studies of telecommunication technology at the Technical University of Berlin in 1972. Upon graduating, she worked as a computer specialist for Siemens until 1979. After that, to 2005, she was the Managing Director of the ERGONOMIC Institute for Social and Occupational Sciences in Berlin, where she was also a scientific assistant. Today she works as a consultant in ergonomics, light and lighting. Gisela Çakir has been a member of several DIN standard committees for artificial lighting. Since 2000 she has been a member of the board of FitLicht e.V.

Fig. 3

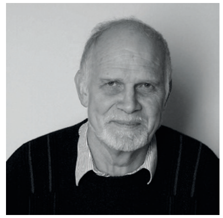

Fig. 4

Alexander Wunsch

Alexander Wunsch is a physician, researcher and lecturer in light medicine and photobiology with particular interest in the effects of light and the beneficial/adverse health impacts of solar radiation and artificial light sources on endocrine and cellular levels in humans. He conducts studies on the photobiological effects of optical (UV, VIS and IR) radiation.

In his private medical practice in Heidelberg he uses therapeutic light spectra in combination with other biophysically based treatments, and develops lighting equipment for medical and cosmetic purposes.

He is associate lecturer at the Wismar University of Applied Sciences and mentors students writing their master's theses on light- and health-related topics. Alexander Wunsch presents at international conferences and operates as a consultant for federal authorities, media, and industry.

Alexander Wunsch is a member of the German Lighting Society (LiTG) and former president of the International Light Association (ILA).

Heinrich Kramer

Professor Heinrich Kramer has been working with lighting design for more than 30 years. Since graduating in Electrical Engineering from RWTH Aachen, Germany in 1965 and obtaining his Ph.D. degree from the Ruhr-Universität Bochum, Germany, he has devoted his efforts exclusively to lighting design.

From 1971 to 1980, he was head of the Marketing, Research and Development Department of a luminaire design manufacturer.

In 1980, together with H. T. von Malotki, he founded the LICHTDESIGN studio in Cologne, Germany and in 1990 he became the general manager of the company. During this time he designed artificial and natural lighting for projects with many famous architects such as: Hollein, Foster, Meier, Nouvel, Pei and Ungers.

Professor Krammer also owns several patents on luminaire design.

He was a founding member of the European Lighting Designers' Association (ELDA+) and was made a fellow member of the PLDA after a period of four years as its president (1995-1999).

Since 1988 he has been lecturing at the Faculty of Architecture of RWTH Aachen University. In 2000 he became an honorary professor at the same faculty, and since 2006 he has held the title of Professor Emeritus.

He is a member of several national and international committees responsible for the standardization of light and lighting (DIN, LiTG, CIE).

Since 2014 Professor Kramer has been a founding member of the Federation of International Lighting Designers (FILD).

Fig. 5

Michael F. Rohde

Professor Michael F. Rohde completed his studies of architecture at Karlsruhe University. After three years of practice as an architect, he obtained a Master of Science degree in Light and Lighting from the Bartlett School of Architecture at UCL in London.
In 1998 he founded L-Plan Lighting Design, an independent lighting design practice in Berlin. He has wide experience of lighting in all areas of artificial and day lighting design.
Since September 2006, Michael Rohde has been teaching as a Professor of Architectural Lighting Design and Architecture at the Hochschule Wismar, University of Technology, Business and Design Wismar, Germany.
Professor Rohde currently works primarily as an independent lighting designer and as an educator.

Fig. 6

Karolina M. Zielinska-Dabkowska

Dr. Karolina M. Zielinska-Dabkowska completed her studies of Architecture and Urban Planning at Gdansk University of Technology (GUT), Poland and Architectural Engineering at University of Applied Sciences and Arts (HAWK), Hildesheim/Holzminden/Goettingen Germany.
As a trained architect, she pursued a career in lighting by working for several world-renowned lighting design firms in Berlin, London, New York, and Zürich. She has 10+ years of international experience in the completion of medium and large scale interior and exterior design projects and in project management for clients from corporate, institutional, retail, hospitality, and transportation sectors.
In 2013 she obtained her Ph.D. from Gdansk University of Technology, Poland, where she translated her practice-based knowledge in architectural lighting into theoretical guidelines for architects, for which she was recognized with the 2014 Polish Prime Minister's Research Award. In 2015 she was awarded the Professional Lighting Design Recognition Award 2015 in the category "Research" for her work and research on the non-visual effects of light for humans, flora and fauna.
In 2013 Dr. Zielinska-Dabkowska co-founded the firm designs-4-people [d4p], where she currently practises as a lighting designer, educator, and researcher.
She has participated in a number of international conferences, and has written articles for national and international publications.
She is also a professional member of the Royal Institute of British Architects (RIBA) and the International Association of Lighting Designers (IALD).

Fig. 7

Oliver Greve

Oliver Greve successfully finished his studies as a Certified Business Economist (BA) at the Flensburg University of Applied Sciences in Germany in 1995.
For many years he has worked in management positions in both industrial and service companies, where he has developed quality management systems and defined and implemented new processes in purchasing, human resource development and order processing.
In his current position as Managing Director of Forschungs-GmbH Wismar (FGW) and as a transfer representative at Hochschule Wismar, University of Applied Sciences: Technology, Business and Design, he has been able to combine a high standard of quality with a high level of service for almost 15 years.
With his company, he has been responsible for the planning, organization and accounts of the Light Symposium Wismar for the last 12 years, making a significant contribution to the event's success.

LSW 2016 ORGANIZING COMMITTEE

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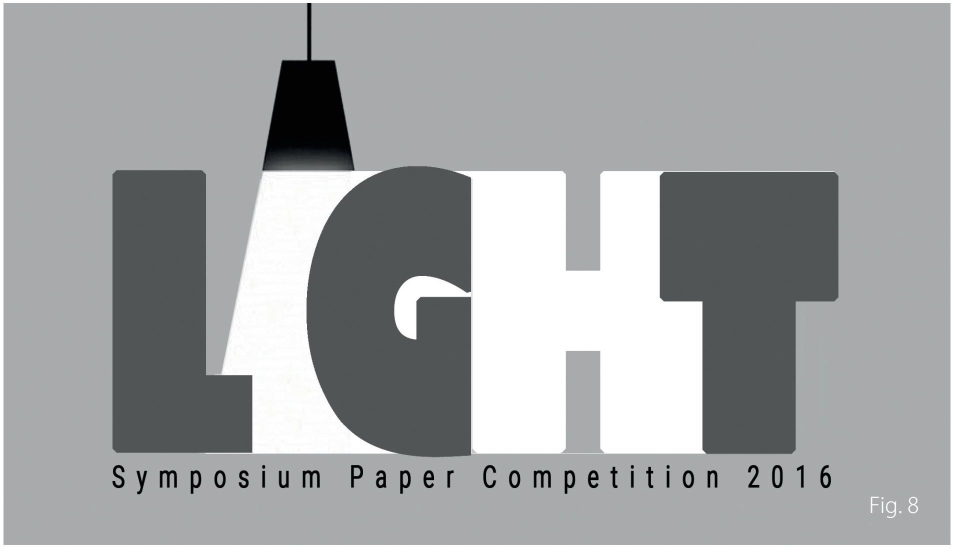

Fig. 8

- Future of Light and Lighting in Architecture (2012) University of Technology, Business and Design in Wismar
- Lighting for future healthy architecture (2015), during the International Year of Light 2015, KTH Lighting Laboratory Stockholm
- The theme of the forthcoming 5th Symposium in 2016 is: Future of Healthy Light and Lighting in Daily Life - a wide-ranging perspective on lighting design practice, lighting science and medical science related issues shall be discussed.

Introduction

The Light Symposium Paper Copetition (LSPC16) is an opportunity for students, designers and professionals with fewer than 5 years of professional experience in the field of lighting design and who are under 35 years of age to present a paper to an audience during the Light Symposium 2016 in Wismar, Germany (LSW16). We are searching for young professionals who have innovative ideas and/or have worked on projects in the field of Lighting Design. LSW16 offers the opportunity to present findings, observations, and research to a specialist audience alongside experienced professional speakers. It is an excellent chance to share and exchange ideas with peers and visionaries.
LSPC16 will be held during the Light Symposium conference in Wismar, Germany on 13th and 14th October 2016.

Event description

The first Light Symposium took place in 2008 at the Faculty of Architecture and Design of the University of Technology, Business and Design in Wismar, Germany.
The event, entitled The Future of Light and Lighting, had as its main objective the interdisciplinary gathering of professions involved with light, and offered a great opportunity to forge links between international researchers and scientists who support the creation and development of existing networks. Since then, the Symposium has been hosted biannually in Germany and Sweden at University of Technology, Business and Design in Wismar and KTH Lighting Laboratory:

- Natural Light - Daylight and artificial lighting for mankind (2010) KTH Lighting Laboratory Stockholm

Paper topics

FUNDAMENTALS:
refers to basic knowledge of the relationship between the human being and light and lighting. How lighting factors such as intensity, colour and distribution affect human perception visually, emotionally and/or physically.

ARCHITECTURE:
refers to the interaction between light and lighting and the physical environment, related to material, space, colour, form, size and proportion.

HEALTH:
refers to a structured principal application of how basic health knowledge related to lighting can be implemented in our daily lives and environments, affecting our comfort, functionality and wellbeing.

DESIGN:
refers to the professional lighting design approach. How can the development of professional theory, concept and methodology be carried out in order to optimize the quality of our future lighting installations. Practical examples and solutions can be presented.

Entry requirements

- Applicants should be students, designers and professionals with fewer than 5 years of professional experience in the field of lighting design. Applicants should be under 35 years of age on 1st of May 2016.
- Applicants can be students of Lighting Design, Architecture or related disciplines, Master's and PhD students, independent practitioners or young educators in the field of Lighting Design, Architecture or related field.
- The papers should take approximately 20 minutes each to present, 5 minutes will be added for questions.
- The conference language is English.

Submission

PAPER DESCRIPTION / ABSTRACT:
Please give the exact title of the paper and include an abstract of 400 (minimum) to 500 (maximum) words. The general format of the abstract is free; however, try to address the following questions: WHY? WHAT? HOW?
(in English / pdf format).

PRESENTATION STRUCTURE:
Please submit a storyboard in a maximum of 7 slides (in English / pdf format). This format will help us assess your capacity to structure and visualize the key concepts of your presentation.

The submitted papers should:

- Relate to at least one of the four main tracks as stated above (significance of work)
- Contribute new content and an original approach in the field of Lighting Design to issues which are particularly timely
- Be relevant to the field of Architectural Lighting Design (useful to practitioners or researchers)
- Advocate special interests and motivation for design goals, research or investigation
- Communicate the content in a coherent and professional manner (conclusions are valid, properly supported, paper is complete (no major "loose ends"), research methods are appropriate, data valid, use of professional language etc.)

The Jury

- Renowned members of the professional lighting community:
  Professor Heinrich Kramer,
  Dr. Ahmet Çakır
- Representatives from Wismar University:
  Professor Michael F. Rohde,
  Dr. Karolina M. Zielinska-Dabkowska
- Representative from KTH University:
  Federico Favero
- Renowned member of the professional medical community:
  Alexander Wunsch
- Representative of the sponsors:
  Joachim Ritter, Orlando Marques

Once shortlisted, each of the four finalists will give their 30 minute presentation to a full audience at LSW16 on 13th or 14th October 2016. The selected speakers will be notified on Wednesday 1st July 2016 and receive a financial contribution to travel and accommodation expenses up to 700 Euro per paper. A two-day free pass to the Light Symposium 2016, including lunches and participation in the buffet dinner on Friday 14th October, will also be provided.

The jury, supported by independent experts, will decide on an overall winner who will be given a free ticket to the PLDC in Paris, France and the opportunity to present her/his paper at the 8th edition of LEDforum in São Paulo/BR in 2017! The winner will be announced on Friday 14th October during the LSPC16 Awards Ceremony.

The winners of the Light Symposium Paper Competition 2016 (LSPC16) were Catherine Pérez Vega for her presentation titled: „The Environmental Influence of Lighting Design on Flora and Fauna“ and Monica Vega for her presentation: „Image of the City and Light Pollution.“


Fig. 9


Fig. 10


Fig. 11


Fig. 12


Fig. 13


Fig. 14


Fig. 15

Impressions of the LSW 2016

Fig. 16


Fig. 17


Fig. 18


Fig. 19


Fig. 20


Fig. 21


Fig. 22


Fig. 23

THE HOCHSCHULE WISMAR (HSW)

The Hochschule Wismar, University of Applied Sciences Technology, Business and Design (or in its short form: the University of Wismar), is the third-biggest and third-oldest public university in Mecklenburg-Vorpommern, Germany. The university is situated on the Baltic coast in the very north of Germany with its campus only 500 meters away from the harbor. The university was founded in 1908 as an engineering academy and has become an important part of the city's cultural life. Since 2007 the university has been restructured and now has 3 faculties reflecting the three subjects in its name: technology, business and design:

- The Faculty of Engineering (Mechanical, Process and Environmental Engineering, Civil Engineering, Electronics and Multimedia Engineering, Maritime Studies).

- The Faculty of Business (Business Administration, Business Law, Business Informatics) also called Wismar Business School.

- The Faculty of Architecture and Design (Design, Architecture, Interior Architecture, Communication Design, Architectural Lighting Design).

www.hs-wismar.de/en/homepage/

FORSCHUNGS-GmbH WISMAR (FGW)

Forschungs-GmbH Wismar (FGW) is a modern, innovative and independent research and development service company.
It was founded in 2002 as a 100% subsidiary of Hochschule Wismar, University of Applied Sciences, Technology, Business and Design. FGW offers services in the areas of project management, support, marketing, service and information.

www.forschung-wismar.de/

DECLARATION OF WISMAR

Architectural Lighting Design is the art of shaping light that forms life. Light can do much more than serve only vision; it goes far beyond design-only issues, it creates more than just emotions giving atmosphere to space.

Light maintains human health; it heals wounds and cures diseases!
Light and health – a new approach to improve the quality of life!

The University of Wismar has come of age, leading the way in this innovative field, promoting health and well-being in the 21st century. In the age of the photon, light will be an engine for growth and innovation and one of the strongest pillars of the health economy.

The spirit of the Hanseatic region resurges anew, offering their tradition of peace and health, and radiating out to the world.


Fig. 24


Fig. 25


Fig. 26


Fig. 27

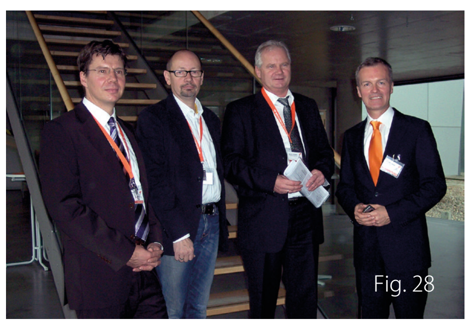
Fig. 28


Fig. 29

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PART II LIGHTING RESEARCH AND RELATED ASPECTS

PART III MEDICAL SCIENCE AND LIGHTING

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BACK COVER

Logo: HSW
Logo: FGW