Intelligent Lighting Institute | Edition 16, May 2022

ILIMAGAZINE

PHOTO: NORBERT VAN ONNA

> **NIRVANA MERATNIA** PERVASIVE COMPUTING RESEARCH

> **INTEGRATIVE LIGHTING ILLUMINATED**

> **DELVING INTO DYNAMIC LIGHT**

> **MEET THE H&T LABS SUPPORT TEAM**

TU/e

EINDHOVEN
UNIVERSITY OF
TECHNOLOGY

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Enjoy our new ILI magazine!
Harold Weffers
Operational manager

ILI
INTELLIGENT LIGHTING INSTITUTE
TU/e

HAROLD WEFFERS | OPERATIONAL MANAGER

Welcome

I am very pleased to be able to present to you the 16th edition of our ILI Magazine. Since the previous edition in November 2021 much has happened and I hope that after reading the various contributions in this magazine you will once again agree with me that many exciting and promising developments have been happening.

Amongst others you will be informed about (the outcome of) recently completed and on-going projects in our R&D programs and our R&D facilities and infrastructures annex Living Labs, which form the basis for our new scientific discoveries & (technological) innovations related to Light and Lighting for various application domains. We also provide you with an in-depth perspective on the role of pervasive computing for our work. Next to this, we also provide a 'recap' on our contributions to the GLOW 2021 light festival and a 'recap' on our ILIAD 2021 public outreach event.

Pleasant reading!

MAY 2022-NOVEMBER 2022

Calendar

1-3 June 17 th International Symposium on the Science and Technology of Lighting. EEDAL-LS-2022: International Conference on Energy Efficiency in Domestic & Light Sources. Toulouse (France)

12-16 September European Optical Society Annual Meeting Porto, Portugal

November ILIAD outreach event Eindhoven

12-19 November GLOW City center Eindhoven

ILI PhD thesis

Delving into Dynamic Light: Uncovering visual experiences and neurobehavioral responses to light transition. Maaike Kompier, April 2022, Advisors: prof.dr.ir. Yvonne de Kort and dr.ir. Karin Smolders. This dissertation was received with honors ('cum laude')

ILI PDEng thesis

Shared control in office lighting systems. Tatiana Lashina: May 13, 2022. Advisor: prof. dr. ir. Evert van Loenen and dr. Juliëtte van Duijnhoven

INGRID HEYNDERICKX | SCIENTIFIC DIRECTOR

Scientists of ILI have convincingly shown the potential benefits of intelligent lighting for humans. Optimized lighting enables enhancing performance and cognition, regulating sleep and alertness, creating atmospheres in rooms, providing safety in cities, and saving energy through smart designs and controls of the light.

ILI wants to create impact

Also in this ILI Magazine, we report new research insights on an integrative way of creating optimal lighting in an office, on the visual experiences and neurobehavioral responses to dynamic light patterns in offices, and on creating smart light solutions for cities. Translating these innovative research findings to real-world practice, however, is a huge endeavor, and surely something that ILI cannot do on its own, despite its good network with companies and governments.

Therefore, ILI is looking for more options to create impact with its research. One option with already promising results is through student projects. To ensure that multidisciplinary teams of students translate ILI's findings into demonstrators of intelligent lighting systems, we collaborate closely with TU/e innovation Space – an environment in which students work on real-life challenges as part of their curriculum. By setting students from different educational programs together, we ensure that these teams take a system's approach in designing intelligent lighting solutions and building prototypes for real-world industrial or governmental challenges. In this way, we do not only visualize our findings, but also develop students in the direction of a smart lighting engineer. To bring this further we aim to strengthen the ecosystem with partners in the field to jointly accelerate the development and adoption of smart lighting solutions.

If you want to be actively involved in use cases, solutions, demonstrators, or new challenges, let us know.

PHOTOS: BART VAN OVERBEEKE

ZOE KARAMANIDE | SUPPORT TECHNICIAN H&T LABS SUPPORT TEAM

Meet the H&T Labs support team

THE TEAM IN A NUTSHELL

If you visit the south side of the 9th floor of the Atlas building, you will come across the Humans and Technology Labs (H&T Labs) support team: an autonomous group within the Faculty of IE&IS which has recently expanded and welcomed three new members. The group was created with the vision of acquiring the human resources and expertise required to support the expansion of the services offered to various parties within TU/e. Currently, the H&T Labs support team consists of 4 employees and is in charge of the smooth operation, maintenance and development of 8 labs and 2 living labs.

THE H&T LABS

The 8 labs managed by the team span almost half of the 9th floor of the Atlas building and include, amongst others, a Social Robotics, a Virtual Reality and a Lighting lab. The Lighting Lab is equipped with controllable lighting facilities that can be used for researching the effect of varying lighting conditions on the participants. An example of such device is the ColorBox, which can be used to stimulate participants with light of variable spectral composition. The 2 living labs falling under the group's responsibilities are the Atlas and Markthal living labs. All H&T labs are open for use by members of IE&IS but it is worth nothing that the living labs are open to the entire TU/e research community. For the interested reader, more details about the infrastructure, the equipment found within the H&T labs and the related user costs can be found at https://htilabs.ieis.tue.nl/laboratories.html.

THE TEAM MEMBERS

Nasir Abed was appointed as the head of the H&T Labs support team and his goal is to ensure the continuous improvement of the group's services, the formation of new partnerships and the efficient use of the financial resources available to the group. As a software engineer, he is also responsible for the development and administration of two online experiment and participant management systems used within the Faculty of IE&IS – the Archie and the JFS Participant database.

Nikolina Molnar is contributing a lot of technical expertise to the team with her background in Electronics Engineering. She has assumed the role of the coordinator of the Atlas Living Labs and the manager of the HTI Lighting lab. Her technical duties concern the development of hardware and software for prototypes used by students and researchers working with light technology such as the Colorbox, LED-based devices and light sensors.

Vadym Markelov has joined the team to bring in Full-Stack and DevOps software engineering experience from the modern industry. As a senior research software engineer, his focus is currently the GameBus project - a platform that rewards team for playing while collecting valuable data - he is maturing application code and architecture to facilitate the requirements of the researchers.

Zoe Karamanide has joined the H&T Labs support team as a support technician. Her main responsibilities surround the management, maintenance and smooth operation of the group's labs and equipment. She should be contacted for matters related to lab usage and availability and reservations of equipment. ■

ANNELOES DE LANGE | MASTER STUDENT BUILDING PHYSICS & SERVICES |
SUPERVISORS | **JULIËTTE VAN DUIJNHOVEN (BE)** AND **RIANNE VALKENBURG (IE&IS)**

Public space accessible to everyone through good lighting design

THE CHALLENGE

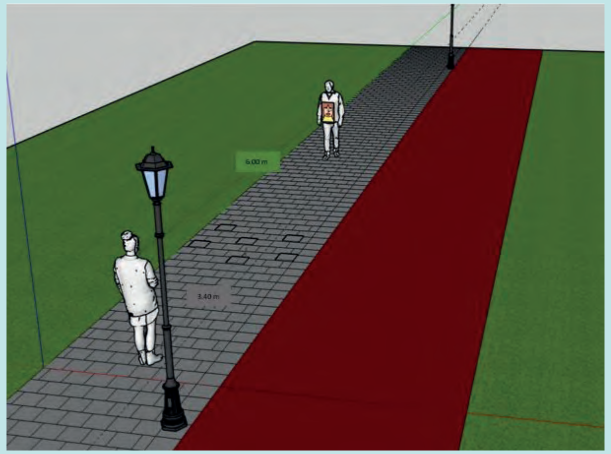
Public space should be accessible to everyone and night view is a significant part of this. However, professional lighting design in public spaces is still in its infancy. Street lighting is often mainly designed for car drivers, ignoring the needs of pedestrians. LED lighting has many advantages, but often causes an increased level of glare which might result in stress, discomfort, and feelings of unsafety for pedestrians. Different luminaires perform differently. Since especially the visual performance of people with visual impairments decreases significantly under poor lighting conditions, we want to gain insights on which lamps illuminate well, without causing any nuisance.

THE PROJECT

CROW has been committed to developing guidelines for public lighting that better facilitate elderly people and people with visual impairments for years. Currently, scientific knowledge from literature is available, but practical knowledge is still lacking. Therefore, in her master thesis research, Anneloes de Lange investigates the visual performance for different target groups: young people, elderly people, and people with visual impairments. The visual performance is predicted by the visual extent (how far a person can see) and the scanning ability (whether all objects in the near environment can be seen). These two parameters can be studied by performing an obstacle detection task. Several studies have already investigated the difference in obstacle detection under different light conditions and for various age levels; however, studies were limited to laboratory settings and do not include the variability that characterizes the outdoor environment. The aim of this

"Within ILI, TU/e has brought together a fairly unique collection of competencies around the theme of light. This project shows that building on the available knowledge and experience and making use of the technical facilities of the TU/e, a worldwide unique experiment can be set up (again) in a short time."

Maurice Donders, Signify



***(1)** Field study design: a participant is asked to recognize a face at a distance of 6 meters, while at 3.4 meters there is a varying number and pattern of obstacles in the road surface.*

***(2)** With a hydraulic system it is possible to move different paving stones up and down (obstacles) to simulate unevenness in the footpath*

"Through the collaboration between TU/e and OVLNL, we bring the world of science and practice together, learn from each other and both benefit from this in achieving our objectives."

Arthur Klink, Municipality of Utrecht & OVLNL

***(3 and 4)** Participants (seen here from the back) are asked what emotion they recognize in the face that the researcher is holding up, while – at the same time - a number of obstacles are present in the footpath, from 2 different positions between the lampposts (front and back),*

research is to design a method to investigate obstacle detection under different street luminaires in a field study. The location where we tested this method in the field was the Carnegiedreef in Utrecht where seven different LED luminaires are positioned in pairs.

THE RESEARCH

Anneloes developed a field study in which participants had three tasks. First, participants were asked to identify a facial expression. At the same time, a (varying) number and pattern of obstacles was created in the road surface in front of them. People were asked if and where they had seen obstacles. This was repeated on two different positions and multiple times per luminaire type (with different settings of the obstacles). Third, in an environmental perception task, people were asked how comfortable and safe they perceived the situation under the conditions of each luminaire.

Next to the experiment, the vision (i.e., the visual acuity and contrast sensitivity) of the participants was measured and luminance pictures of the situations were taken.

"TU/e managed to switch extremely quickly between research design, wishes and actual realization. In just a few months, this enormous research was carefully and meticulously designed and actually realized." -

Bart Melis-Dankers, Royal Visio, Center of expertise for visually impaired and blind people

THE RESULTS

The experiment lasted for 5 evenings and this resulted in a large dataset. In total 32 participants did 6 trials per luminaire under different conditions, resulting in 42*32 trials in total. The next step is to analyze the data and investigate the lighting needs of the different target groups.

Hopefully, these insights will lead to better lighting and public space standards for everyone. Considering the ageing population and the recognition of the rights of people with (visual) disabilities, this is highly desirable. The research contributes in any case to existing literature by developing and evaluating a method to investigate obstacle detection for different target groups in a real context. ■

"With the results from this unique practical study, we can continue to work on the quality of public lighting. TU/e has helped enormously in that regard: it turns out to be a unique place where a lot of knowledge about light and lighting is available."

Richard Boerop, project manager Clafis (on behalf of CROW, the technology platform for transport, infrastructure and public space)

ILI New employees

SIMON BELGERS
PhD Human Technology Interaction (IE&IS) | AI Twighlight project

I obtained my Applied Physics bachelor's degree at Fontys university of Applied Sciences in Eindhoven and received my master's at the Human-Technology Interaction program. The graduation project from my Physics degree was on improving the design of a small spectrometer and going from design to prototype. During my master's I took some distance from light-related projects; I did my thesis on what comfortable crossing interactions between humans and robots would look like.

After this, I applied for a PhD position within the same department, Human-Technology interaction, once again focusing on light. My research is part of a European consortium that is a model to creating digital twins of LED's to predict the change in spectral power distribution of LED's over time. My role within this consortium is to provide a more human-centered view to these digital twins: What is the effect of the changing spectral power distribution on humans, and what characteristics can we determine to gain more insight in those effects?

EMMA VISSER
PhD Human Technology Interaction group (IE&IS) | Bioclock project

I have completed a Bachelor's degree in 'Health and Lifesciences' at the Vrije Universiteit Amsterdam, where I majored in 'Clinical Sciences'. Fascinated by the complexity of the brain, I decided to pursue a Master's degree in 'Neuroscience & Cognition' at Utrecht University. During this program, I combined my passion for neuro-biology with my goal to improve clinical care, by examining the effectiveness of non-pharmacological interventions for psychiatric disorders such as depression, schizophrenia and delirium. In February 2022, I accepted a PhD position at the Human Technology Interaction group of the TU/e. I am involved in a multidisciplinary consortium, BioClock, in which researchers and societal partners from across the Netherlands will join forces to restore and preserve the health of the biological clock in humans as well as in the natural environment. In my project, we will be working closely together with partners from Leiden University and the Institute of Mental Health Care Eindhoven and the Kempen (GGzE) to examine the working mechanisms of morning bright light therapy for patients with depression.

SIETSE DE VRIES
PDEng Building Lighting group (BE) | IntelLight+ project

I've been a member of the TU/e community for quite some time, having obtained my Bachelor's and Master's degrees at the department of the Built Environment. During my studies, I mainly focused on the effects of building lighting on its users. For my thesis, I investigated the influence of behavior of office workers on their ocular light exposure. The results from this research were used to identify the constraints necessary for simulation protocols of non-image forming effects of lighting in offices. Besides academics, I've been working on projects for various international light festivals such as GLOW Eindhoven.

I'm keen on further developing myself in the field of human-centric building lighting and bridging the gap between research and real-life applications. In March of this year, I started as a PDEng trainee at the Building Lighting group to work on a project in collaboration with Signify. My project investigates the simulation and implementation of spatial and temporal lighting schemes, to optimize (non-) image forming light parameters and energy efficiency.

The Eye of Atlas

The Ballroom

Cycle of light

Growth

Sketch Your Light

LiDAR

GEM-stage

GLOW 2021 at TU/e recap

It was wonderful to see the 8 innovative light artworks for Glow on TU/e campus that our students had worked so hard on. Under the guide and support of Philip Ross as artistic and project leader, over 260 talented students produced a fantastic result.

It was a great edition of GLOW, the event was well attended, with 300,000 visitors in total on the TU/e Campus.
Two teams were rewarded with the Crowe Talent Award: team Wayfinding and Storytelling was the winner of the Jury prize. They received a cash prize and the opportunity to further develop and realize the project for the next GLOW Event. Winner of the public jury prize was The Ballroom. We hope to see both teams back at GLOW 2022.

We invite you to look at the aftermovie and the 1-minute videos that House of Yellow created of all the teams and their installations at www.tue.nl/glow

PHD RESEARCH | SAMANTHA PEETERS – HUMAN TECHNOLOGY INTERACTION (IE&IS)
SUPERVISORS: **YVONNE DE KORT** AND **KARIN SMOLDERS**

Integrative Lighting Illuminated

Reconsidering manipulations, measurements, and quantification of light

A lot of our time we reside inside buildings, it is even estimated that in the Western world we spend about 90% of our time inside. It is therefore important that while being inside these buildings we are supported optimally and of course an important factor in this regard is the light.

Through potential non-visual pathways light can transiently affect our alertness, vitality, performance and sleep. At the same time it can also have an effect via potential visual pathways influencing our mood, motivation and wellbeing via comfort, pleasantness and brightness perception. In my thesis I aimed to take both the visual and non-visual responses to light into account in order to optimally support occupants in an office and provide potential input for intelligent lighting systems. The work described here was successfully defended on October 20th 2021.

The combination of visual and non-visual effects is something we explored both in the laboratory and, more importantly, in the field. In my first empirical chapter a laboratory based study is described, where the aim was to explore a daytime dose-response curve for various indicators of alertness. And even though we did not find a clear relationship, this study did raise questions about employing longer and repeated exposures to higher illuminances in the field. The other chapters report on two field studies we performed to explore daytime effects of light in a longitudinal fashion. Both lasted three weeks and were performed both in late spring and winter. During these field studies we investigated several important aspects. First, we looked at whether and how a light manipulation in the office translated to employees' individual light exposure. Conclusions here were that large differences occur between and withing persons in the same office, leading to varying light exposure patterns as can be seen in *Figure 1*.

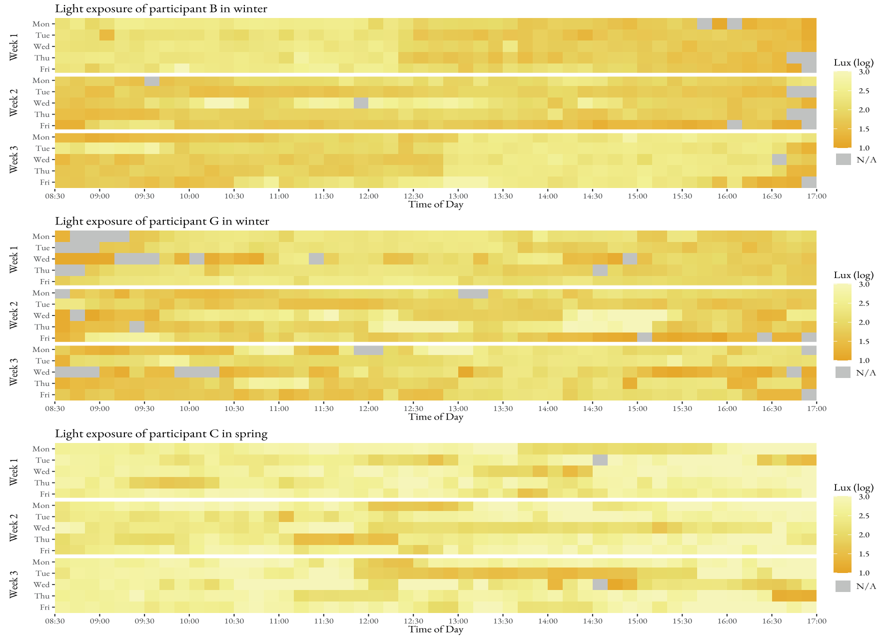


Figure 1 *Light measurements obtained between workdays from 08:30 – 17:00 for three different participants throughout the sampling period. The horizontal axis represents local clock time and the vertical axis represents the day in the experimental period. One square represents the average of log transformed illuminance over each 10-minute bin. E.g. the square left of the 16:00 tick mark represents the average log-transformed illuminance from 15:50 – 16:00. No presence filter was applied.*

In our next steps we investigated the effects of the light manipulation on alertness, sleep and appraisals. Here we found no robust non-visual effects, but substantial visual effects. These analyses plus the translation of a light manipulation to a person also led to questions on how we actually should quantify light in field studies, which is challenging given the highly dynamic nature of exposure. Last, we explored to what extent it is possible to predict experienced pleasantness with light parameters obtained from unobtrusive measurements using a ceiling-based camera.

This work led to several relevant insights for future research in light. First of all, intelligent lighting systems require person-based input, not generalized room-based input. Second, in research we must reconsider how we quantify light: the traditional ways of doing so often do not capture the dynamics of daily life, nor that of perceptual and physiological processes. Third, as integrative light pertains to both visual and non-visual pathways, light researchers and light system developers should aim to include both non-visual effect-based and visual effect-based metrics. Last, we must accept that effects in the field, especially non-visual ones, are likely modest at best.

For employing intelligent lighting systems in practice this has several implications. Intelligent systems need to be able to deal with the input from rich and noisy datasets, and to be able to use person-based input in order to make sure that every person gets their needed share of light. This also requires us to understand the relationships better. Additionally, it is good to be aware of the fact that we cannot control light 24/7, and that we should not only focus on what we can achieve acutely, but also how our light settings might have an influence on us once we have left the office: we must also take a time-integrative perspective. ■

Jesper Kapteijns, new team leader IGNITE

Student Team Ignite has a new team leader. Jesper is a third year Industrial Design student with a passion for light. For years, he has been a loyal fan of the GLOW festival and last year he finally experienced it from behind the scenes while working as an intern for lighting designer Philip Ross. Last December, Jesper took over from Tim de Jong as team lead of Team IGNITE, and he is thrilled to guide the team towards the realization of new lighting installations.

With a brand new team that is slowly growing, he is currently working with his team on two projects. First, they are working on a new concept for GLOW and second on a permanent lighting installation for a creative melting pot in Utrecht.

Apart from that, he is excited about the collaboration between the team and ILI in the creation of a broader light community where ideas, knowledge and experiences can be shared. Recently, they organized an inspiring light night together. Jesper is looking forward to future collaborations!

PHD RESEARCH | **MAAIKE KOMPIER** - HUMAN TECHNOLOGY INTERACTION (IE&IS)
SUPERVISORS | **YVONNE DE KORT** AND **KARIN SMOLDERS**

Delving into dynamic light

Uncovering visual experiences and neurobehavioral responses to light transitions.

In most office environments, the light is turned on when the first person enters the office and the light is kept at this same setting throughout the entire day. With the advent of LED lighting, dynamic lighting with changes in brightness or color can easily be created. How dynamic lighting affects us, however, was largely unknown as most research in this field examined the effects of static light conditions. With a literature review, multiple laboratory studies and a field study, we systematically investigated the temporal development in visual experiences and neuro-behavioral responses to various dynamic light patterns. This was all performed within the context of the DYNKA project (www.dynka.nl) in which the main aim was to investigate and develop dynamic indoor temperature and lighting profiles with the goal to ensure a healthy and productive office environment, while simultaneously realizing energy savings.

The literature review demonstrated that dynamic electric lighting has often been introduced due to its analogy to daylight. The dynamics in daylight, especially the 24-hr dynamics with dark nights and bright days, are crucially important for our biological clock. Additionally, (the variability in) daylight is generally experienced positively.

Moreover, dynamic lighting may be motivated by the ambition to tune light settings to specific mental states, tasks or activities that a person encounters throughout a day (e.g., to provide an energizing stimulus when persons feel fatigued, or to create the optimal atmosphere for a group discussion). These different rationales for dynamic lighting already illustrate the many relevant outcome parameters that come into play in this research – varying from comfort to mental states (e.g., alertness, mood), performance, physiology and sleep.

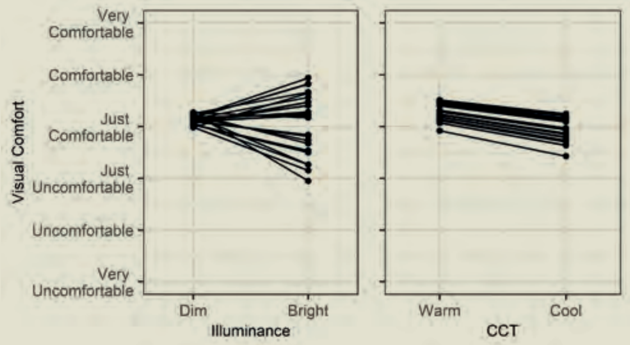
From the laboratory studies, we concluded that each parameter shows a unique response trajectory to light transitions. Task performance and the included physiological parameters (heart rate, skin conductance & skin temperature) did not respond to an abrupt change in the light setting. The subjective markers that did respond were all affected immediately. Visual sensation was impacted persistently, whereas moderations in feelings of alertness, vitality and visual discomfort slightly dissipated in 45 minutes after the abrupt transition. Feelings of calmness and happiness also showed immediate responses, but these dissipated quickly within 15 minutes. These different response trajectories indicate that the dichotomous categorization of responses to light as either visual or non-visual responses is a dangerous oversimplification of reality, because this crude categorization suggests that results for one of these (non-) visual responses can be blindly transferred to the others in the same category, whereas clearly that is not the case. For many of the responses generally categorized as non-visual (alertness, task performance, productivity), additional research is required to understand the processes underlying these responses and identify the required lighting to positively stimulate them.

Furthermore, we found that significant interindividual variability in responses exists for several parameters. For example, bright light was rated more comfortable than dim light by some participants, but as less comfortable by others. These differences between people need to be taken into account when implementing dynamic light scenarios as one specific scenario is likely not to have the desired effect for each individual.

Our field study, during which 30 participants were repeatedly exposed to different dynamic scenarios, largely confirmed our laboratory findings and the findings in the literature review. We reconfirmed the important role of lighting for sleep, but we could not confirm clear and consistent beneficial effects of the employed dynamic scenarios on alertness and task performance. Additionally, the dynamic scenarios were evaluated more negatively than the static one. Overall, we advise to take great care when implementing dynamic light scenarios as comfort is often compromised by using large and fast fluctuations.

Moreover, we conclude that although LED lighting provides ample possibilities to create dynamic lighting, yet the many different responses that light has – and the variability in their response trajectories – require additional research in order to implement such scenarios in operational office environments. ■

'Bright light was rated more comfortable than dim light by some participants, but as less comfortable by others.'



Individual difference in the comfort evaluation. Each line in the graph represents one person. CCT = Correlated colour temperature

ILI SHORT

ELKE DEN OUDEN | AMBASSADOR OF TU/E INNOVATION SPACE

Building a lighting community

The number of students working on lighting related projects is growing. Both in lighting related challenges we offer in our courses in the bachelor and master programmes, as well as in the different initiatives that students are taking up outside the curriculum. GLOW 2021 was the highlight of last semester. The efforts of students and student teams cumulated into a fantastic light festival on the TU/e campus. Over 80 students from 8 different departments, plus another 71 students in GLOW-related courses, 87 students from student associations and 15 students of Fontys were involved in the creation of no less than 10 light artworks. The GLOW Academy events brought together students and professionals for very inspiring exchanges of thoughts. This has led to new ideas to further extend activities where students can meet each other and professionals in the field.

Together with Team IGNITE LightNights are organized for and with students working on lighting projects for GLOW or other occasions. The first LightNight was held the 9th of March. Six projects pitched their plans and exchanged experiences, shared ideas, and asked questions. It resulted in a lively discussion, also providing new ideas for future challenges in TU/e innovation Space.

To further enrich the collaboration, we are exploring opportunities to intensify working with companies and professionals in the field and create a lively ecosystem, where students and professionals mingle, and where students can work with state-of-the-art material and support from companies. We aim to accelerate the development and adoption of smart lighting solutions by bringing together our talented students and seasoned professionals.

If you are interested to be active part of this ecosystem, please let us know!

ILI SHORT

New set of recommendations for healthy lighting within indoor spaces

Our light exposure across daytime and nighttime has important influences on our physiology and behavior. It regulates our circadian rhythms and affects our mood, daytime functioning and nighttime sleep. However, the ubiquitous availability of electric light enables us to spend large parts of our day indoors, in spaces with limited, or sometimes even without, any natural daylight. Simultaneously, we extensively use electric light during the evening and at nighttime. Hence, we typically experience dimmer days, brighter nights and different spectral compositions as compared to the natural light-dark cycle outdoors, with negative consequences for our daily mood and functioning, as well as for our sleep, health, and well-being.

A recent publication in PLOS Biology provides recommendations for healthy lighting based on the scientific consensus from an international expert workshop on circadian and neurophysiological photometry, chaired by Profs. Brown and Wright. The recommendations use a recently-developed metric, melanopic equivalent daylight illuminance, to provide specifications of bright days and dim nights to best support human physiology, sleep, and wakefulness in day-active people within indoor settings. The recommendations provide highly needed further guidance towards truly integrative lighting solutions but are not meant to supersede existing guidelines and regulations relating to for instance visual function, comfort and energy consumption.

Brown, T. M., G. C. Brainard, C. Cajochen, C. A. Czeisler, J. P. Hanifin, S. W. Lockley, R. J. Lucas, M. Münch, J. B. O'Hagan, S. N. Peirson, L. L. A. Price, T. Roenneberg, L. J. M. Schlangen, D. J. Skene, M. Spitschan, C. Vetter, P. C. Zee and K. P. Wright, Jr. (2022). "Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults." PLOS Biology 20(3): e3001571. https://doi.org/10.1371/journal.pbio.3001571
https://doi.org/10.1371/journal.pbio.3001571

ILIAD recap

For the 2021 edition of ILIAD, our annual public outreach event, many ILI relations were welcomed in De Blauwe Zaal at the TU/e Campus.

We were happy to meet our audience and speakers in person again. The audience, consisting of people from academia, industry, and (regional) government was presented with a full day of presentations. Theme of the day was: the effect of light and lighting on plants, animals and people.

We teamed up speakers from academia and industry on the subjects. Professor Leo Marcelis (Wageningen University & Research) and dr. Esther de Beer (Signify) talked about the effect of light and lighting on plants, Dr. Marc de Samber (Signify and representing the Functilight consortium) and Dr. Aaron Stephan (ONCE Animal Lighting) on the effect of light and lighting on animals, and Professor Roelof Hut (University of Groningen) and PhD candidate Ellen van Lieshout (GGzE) on the effect of light and lighting on people. After the presentations, there were interactive sessions, facilitated by Elke den Ouden and Rianne Valkenburg of TU/e LightHouse and Chantal Brans from TU/e innovation Space, to discuss opportunities for collaboration in R&D and technical innovations on the subjects presented. This gave ILI insight into possible new research projects and partnerships.

We hope to see you again at ILIAD 2022!

‘We aim to design intelligent sensor systems that deliver guaranteed Quality of Service‘

THE PERVASIVE COMPUTING RESEARCH OF ILI CORE TEAM MEMBER **NIRVANA MERATNIA**
INTERVIEW BY MICHIEL DE BOER OF MOESASJI

“We are surrounded by data generating systems, objects, and people. My research mainly focuses on making sense of this data in presence of resource and data constrains. It is my ambition to do research that benefits society and stimulates scientific and technological advancement.” Get to know a little bit about Nirvana Meratnia, TU/e professor in the Department of Mathematics & Computer Science and connected to ILI as the Head of IRIS (Interconnected Resource-aware Intelligent Systems).

Both at University of Twente and at TU/e, the research of Nirvana has been centered around pervasive computing. Pervasive or ubiquitous computing aims at enabling distributed intelligence and making computation indispensable part of everyday objects and systems. It is closely linked with sensing and (wireless) communication to collectively create intelligent networked (embedded) sensor systems.

Nirvana: “These networked systems usually contain a large number of different devices, from little sensors and nodes that gather data, up to powerful computing devices and infrastructures that take care of analysis of that data, and everything in between. The approach of pervasive computing is to have computation done throughout the network and as close as possible to the devices that generate the data. My research is application agnostic as it focuses on the enabling technology used in a wide range of applications. I have worked in many different projects and applications such as logistics, predictive maintenance, smart cities, health & wellbeing, agriculture & animals. In my opinion pervasive computing can help deliver Quality of Service required in all these areas.”

PERVASIVE VS CENTRALIZED

The benefits of pervasive computing are widely recognized. There are various reasons to choose for pervasive over centralized computing. First is energy consumption. Data communication uses a lot of energy, a hurdle for small and resource-constrained (usually battery-powered) devices.

The second reason is privacy. Techniques that do not require data exchange and allow processing and usage of local (on-device) data are much more privacy preserving. And a third reason is latency. For time critical applications it is essential the computation is done where data is generated. Take for example driver support systems in modern cars.

THE AIM AND THE CHALLENGE

“Pervasive computing is beneficial to the performance of the system in terms of situational/context awareness and adaptation for example. A challenge in pervasive computing however, is heterogeneity. Designing a system that is able to ‘talk’ to many different types of devices/systems/users, ‘handles’ different types of data and data quality, and ‘satisfies’ different (sometimes conflicting) requirements, is complex. And it really becomes challenging - and interesting - if we bring learning capabilities to the system. In my research on pervasive computing and edge-AI, we aim to bring a comparable level of intelligence as exhibited in centralized approaches down to smaller platforms and resource constrained systems.”

SMART HOME

A good example on a small scale is the control of intelligent lighting in a Smart Home. In this home you have different rooms, users and activities/context. Each situation demands a certain setting for the perfect lighting scenario. The system must be able to recognize the context: What is happening? Who is using the system? What are the needs and preferences of this user at that time? Nirvana: "The lighting system will contain different types of sensors that produce different kinds of data which must be processed and interpreted in isolation or collectively. Moreover, you don't want to share that data with a centralized service outside your home. The intelligence should be present safely in your home enabling your lighting control system to learn about the different users and their preferences. The learning model should also be generic, it must be able to process various input/sensor modalities and data quality, deals with lack of labeled data and should be able to function well in any Smart Home environment. Once you've got that running successfully, you can scale up to a public and semi-public spaces such as hospitals or universities."

LEARNING AUTONOMOUSLY

"We design AI and machine learning solutions that are resource- and data- efficient. Systems can usually learn well on huge volume of labeled data, the so called 'supervised learning' approach. Downside of this approach is that what data represents should be known beforehand. This knowledge is usually acquired through a labor-intensive process, during which data is tagged with known labels. This is a time-consuming and error-prone task. So, our ultimate goal - and we are moving in this direction – is to design systems that learn fully autonomously, are generic enough, and can efficiently deal with heterogeneity, uncertainty, lack of sufficient (labeled) data, resource constraints, and conflicting requirements."

CONNECTION TO ILI

"As a core team member of ILI, I take part in the discussions about the Bright Environments program, the vision, research agenda, challenges, links and connections with national and European research agendas and global network. The challenges of Bright Environments are comparable to those of pervasive computing, which are creating intelligent systems that can cope well with different demands, technologies, constraints, heterogeneity, concerns, and yet are self-learning to a level where they can operate autonomously, with minimum interactions and errors causing discomfort for users. Our common goal is to come up with approaches that deliver maximum Quality of Service."

RADIO SENSING

Linked to the ILI program 'Bright Environments', Nirvana is currently working on domain adaptation in the area of unobtrusive sensing. Nirvana: "We are researching the use of radio-signals such as WiFi CSI, millimeter wave, for sensing and context recognition. Patterns of radio signals change depending on what's happening in a certain space. If a person enters an empty room, for example, the pattern of radio waves will be slightly different. We design AI techniques that analyze these changed patterns and can sufficiently learn from them, intendent of external factors influencing the signal to accurately reason about the phenomena, events and context, allowing a new form of situational awareness. The research is challenging however, because many factors influence the data: temperature, sun/light intensity, direction of the antenna's, characteristics of the object/person, type of activity, etc."

LIMITLESS

"ILI is of course focused on lighting (solutions). We see a wide array of other sensors being used and becoming important in such settings. Moreover, there are interesting emerging areas around lighting: sustainability for instance. I believe intelligent lighting systems cannot be designed in isolation but can benefit from collaboration between various fields of science and technology. This is happening within ILI. Collaboration makes the possibilities limitless." ■

When Human Centric Lighting gets personal: p-HCL

In LED professional Review nr. 89 of Jan/Feb 2022, ILI Thought leader Jean-Paul Linnartz and Post Doc researcher Chara Papatsimpa introduced the term personal-Human Centric Lighting. In fact, it was triggered as a follow-up of the article published earlier in ILI Magazine (edition 14, May 2021) in which they reflect on the insights generated in the NWO Optilight project, that had a successful final review on November 30, 2021.

In ILI Magazine Jean-Paul Linnartz stated that two important lessons were learned:

1. Human Centric Lighting preferably is personalized. By taking specific preferences and chronobiological parameters of the individual into account light recipes become significantly more effective. But as the impact of light exposure is a slow and subtle processes, the effects on the specific users are preferably tracked over longer periods.

2. Research designs in human interaction and psychological research can be quantified such that they more easily allow for the subsequent development of mathematical abstractions and in control algorithms.

In the LED professional review article, Linnartz and Papatsimpa state that the use of mathematical models to understand and to predict the effects of light on this complex physiological system is becoming increasingly accepted in scientific literature. That raises the question of when and how these insights in human aspects of light find their way into lighting control algorithms.

For personalized HCL, Optilight extended the digital twin concept into an approach that evaluates multiple noisy variants in parallel and regularly pick the most likely variant. This concept is known in the field of statistical signal processing as a particle filter.

This digital twin of one's biological clock extended with a particle filter to allow for uncertainty and for imperfect observations was used to predict and to anticipate the impact of various light recipes. Read the whole article and see how these concepts can be used to create a smart office with a personalized bio-adaptive office lighting system, controlled to emit a lighting recipe tailored to the individual employee.

Linnartz, Jean-Paul M., Papatsimpa C. "When Human Centric Lighting Gets Personal: p-HCL". 2022 Luger Research e.U | LED professional Review (LpR) | Lighting Technologies & Design | Issue 89 Jan-Feb 2022

KARIN SMOLDERS | TU/E HUMAN TECHNOLOGY INTERACTION,
GERRIEKE DRUIJFF-VAN DE WOESTIJNE & KIM MEIJER | NEUROCAST[1)]

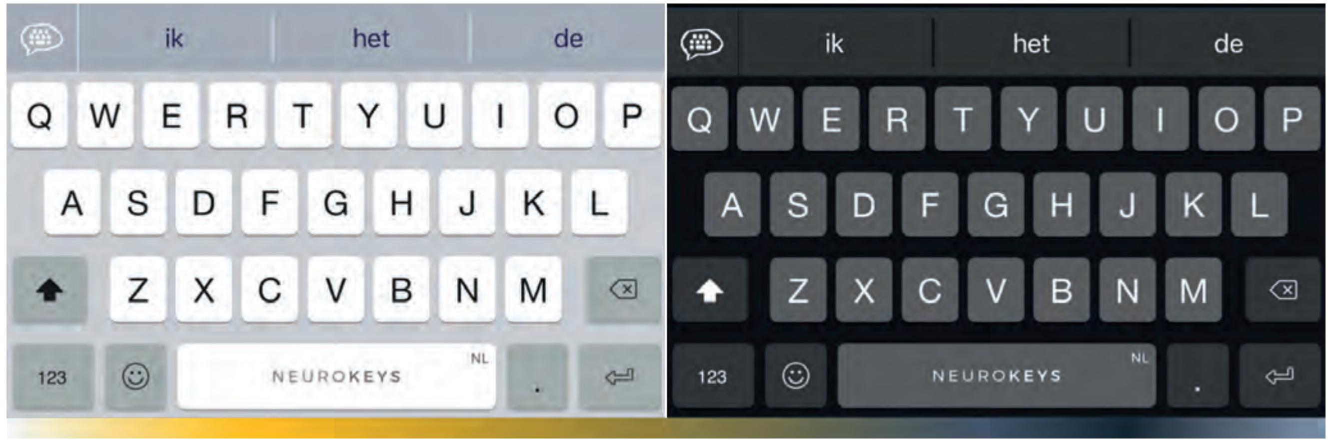
Smartphone keyboard interaction monitoring as an unobtrusive method to approximate rest-activity patterns

Sleep is an important determinant of our health and behavior during the wake phase, and disturbances in sleep constitute a major societal health issue. Sleep disturbances are prevalent in both clinical and non-clinical populations and have likely been increased due to the COVID-19 pandemic. Yet, obtaining intensive longitudinal data of rest-activity patterns to better understand the implications and development of perturbations in sleep across large samples remains challenging, and requires novel, unobtrusive, and user-friendly tracking methods.

Smartphones have been fused into our daily routines, and many persons use their smartphones in the period surrounding sleep. This ubiquity of smartphones offers new avenues to detect rest-activity patterns in everyday-life situations non-invasively, inexpensive and on a large scale. Together with the company Neurocast we investigated the potential of smartphone interactions monitoring as a novel, passive tracking method to approximate rest-activity patterns throughout the 24-h day.

We performed two field studies among students to validate keyboard interaction monitoring as a behavioral proxy for the rest and active period onsets.
In both studies (Study 1[2)]: N = 51 and 293 nights; Study 2: N = 157 and 977 nights), we obtained time series of keystroke events using the Neurokeys App, developed by Neurocast, and collected sleep diary data. The Neurokeys app replaced the native keyboard with an intelligent keyboard that registered keyboard interactions in users' daily routines without information about specific letters or numbers typed (to guarantee privacy).

Both studies revealed that the timing of the last keystroke and the first keystroke surrounding the nocturnal prolonged keyboard inactivity period can serve as good predictors for the self-reported timing of the rest and active period onsets. On average, the time differences between the keyboard-derived and self-reported estimates were small (<.5 h). Yet, we saw discrepancies between the two assessment modalities for quite some nights, suggesting that these methods may give rather distinct – and informative - approximations when inspecting rest-activity patterns on a day-to-day basis within persons. In



fact, there were also several occasions where keyboard interactions occurred after self-reported sleep onset and before self-reported sleep offset, which questions the accuracy of these self-reported estimates.

It is important to mention that the use of screen technology (including smartphones) in the late evening has been linked to disturbances in sleep. Therefore, we may not want to strive to minimize deviations as smartphone usage may hinder a good night of sleep. While we only looked at rest-activity patterns in our studies, smartphone-interaction monitoring would also allow for fine-grained assessment of the use of digital media surrounding sleep. In fact, insights in the interference of smartphone usage with sleep and rest-activity patterns might inform the development of person-tuned strategies to promote healthy sleep hygiene.

Complementary to earlier investigations, our studies suggest that we can leverage the ubiquitous smartphone use surrounding sleep to approximate rest-activity patterns. Large-scale and prolonged monitoring of trajectories in natural rest-activity patterns in real life utilizing the biomarkers obtained with smartphone keyboard interactions could facilitate the use of advanced (time series) data analytic approaches and mathematical modelling. Together this will advance our knowledge on (ir)regularities in rest-activity patterns across days, weeks or years, potentially elucidating the effects of sleep-promoting interventions (like bright light therapy). These insights can, in turn, inform the design of adaptive, personalized strategies, and in-time (light) interventions to promote healthy sleep-wake patterns. ■

1) https://neurocast.nl/
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When psychology meets cyber-security: **Lessons learned from the COCOON project**

Domestic use of Internet-of-Things (IoT) is increasingly popular and offers convenience, comfort, and home security. IoT, however, is not without risks. One risk specific to IoT is the cyber-physical assault.

IoT devices often can control some aspect of the physical environment, and hence hacking of IoT can have adverse physical consequences. Just imagine ransomware preventing you from leaving the house or turn on the bedroom lights while you are sleeping. The cyber-risks of IoT also extend beyond the end-user, as for example when devices are exploited for so-called Distributed Denial of Service (DDOS) attacks to critical national infrastructure. IoT security is mostly sought along the technological axis. This makes sense given the premise of IoT as self-organizing, self-configuring, and self-securing. However, technological solutions alone are unlikely to suffice. According to Consumenten-bond (2020), 1 out of 4 devices on the Dutch market show severe security vulnerabilities and can be hacked with little effort. Moreover, there is often no guarantee that a device will receive security updates during its full lifetime, especially with unsuccessful products.

In the Chistera 2017 project *"COCOON: Emotion psychology meets cyber-security"*, we investigated the role of the end-user of domestic IoT in cyber security; bringing together cyber-security experts–University of Greenwich and Reading (UK) and ETH Zurich (CH)–and psychologists from Ghent University (BEL) and TU/e (NL). The goals were to investigate (a) the risks of IoT and how these are perceived by home users, (b) their emotional responses to cyber-physical assaults, and (c) their capacity to detect cyber-physical assaults–thus recasting users as an integral part of the security system.

Central to the project was an experiment conducted in eighteen households. Each household received a set of IoT devices *(see picture)*. After getting acquainted with the devices, the participants were subjected, unknowingly, to a series of simulated attacks. These included, for example, toggling the light or opening and closing the camera's privacy shutter once or multiple times, having devices toggling in morse code, or adding a false weight to the online account of the smart weighting scale. Ethical constraints prevented more severe attacks. In the last phase, participants were informed about these simulated attacks–without revealing their exact nature– and were again subjected to the same attacks. During all phases, data was collected using online surveys, diaries, and inter-views. Depending on the household, the study lasted 2 to 3 months.

We found participants to have little awareness and concerns about cyber-security risks (Huijts, Haans, et al., 2022). This

very likely made them less vigilant and thus less likely to report and be disturbed by the simulated attacks. Indeed, participants seldomly noticed the attacks or did not experience them as significant events. Some indicated beforehand that they would notice any un-authorized opening of the camera's privacy shutter, but later mentioned that the sound of the TV might have masked the sound of the shutter. When an attack was noticed, participants had difficulties ascribing it to a hack. Instead, it was ascribed to a bug in the device or to something they or a household member did. Although more attacks were noticed and identified after we informed participants, many other irregularities–not caused by the experimenters–were reported as possible attacks as well, and uncertainty remained as to what caused what.

The most important lesson perhaps is that domestic IoT and the home environment itself present a high level of background noise from which it will be difficult to detect a cyber-physical attack.

Since participants never really attributed the simulated irregularities to hacking, we were unable to measure their emotional responses to cyber-physical attacks.
As an alternative, the consortium reached out to former victims of cyber-crime (Budimir et al., 2022) and used vignette studies (Budimir et al., 2021) to investigate these emotional responses. We learned that the emotional processes are similar to those of burglary victims, but with the victim often facing the inability to act upon these emotions, for example due to a lack of knowledge. As such, assaults to IoT may have more severe consequences when the victim is incapable to overcome the attack (e.g., to regain control over the smart thermostat).

Cyber-security from the end-users' perspective thus requires being able to not only prevent and detect assaults, but also the ability to remediate the situation when devices get compromised. Increasing end-users' resilience to cyber-physical threats, hence, involves increasing risk awareness and cyber-hygiene (e.g., assisting them in making choices as to which device to buy), and to ensure access to help to recover from an assault. There thus is beside the technological, also a social axis to consider (Huijts, Budimir, et al., 2022). The responsibility of cyber security is not just with IoT manufacturers, but is shared with retailers and online retail platforms, internet providers, government and other regulators, and end-user alike. The smart home should be a safe haven to its occupants, and it is the responsibility of all to ensure that this remains so even in an age of increased cyber-insecurity. ■

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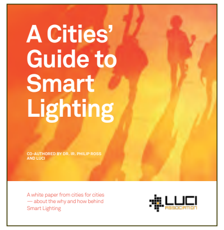
ILI SHORT

End of Interreg Project SMART-SPACE

The Interreg Project SMART-SPACE ended on 31 March 2022. With nine European partners, the TU/e worked together to facilitate the uptake of smart lighting in small and mid-size municipalities. The Intelligent Lighting Institute and TU/e LightHouse were strong contributors to a long-term work package and a customer evaluation task. Among others, deliverables are a transition roadmap for smart lighting, an accompanying implementation toolbox, and a user experience evaluation toolbox. Two publications for cities are available to spur further realisation: Co-authoring with LUCI, Philip Ross published *"A Cities' Guide to Smart Lighting: A white paper from cities for cities - about the why and how behind Smart Lighting"* (available through the LUCI website).

Rianne Valkenburg and Elke den Ouden published *"The Value of Smart Urban Lighting – Making technology work for improving life in public space"* (free download available through the TU/e LightHouse website)



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