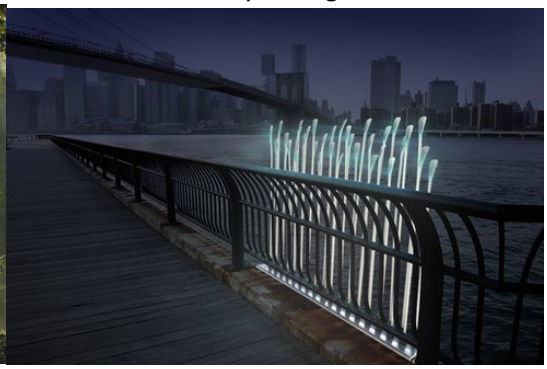
Secret Life of Light
Liberation of Light &
Certificate Engineering
Intelligent Lighting BSc

Innovations in lighting are timely, urgent
and require a multidisciplinary perspective.
The Intelligent Lighting certificate program is designed
to train engineers from different backgrounds,
uniquely equipped to face the challenges in lighting innovation.
Key themes:
multidisciplinary, user-centred, sustainable, integrative, innovative.

Introduction

The lighting domain is changing radically. Three major developments have spurred this revolution: (1) society's growing awareness of the **need to save energy**, (2) recent insights in light's **pathways through the brain** – the discovery of a 5th photoreceptor - and its impact on human health & functioning, and (3) the **introduction of LED**, a low power, flexible light source, offering potential for miniaturization, embedding, and advanced dynamic control. All these developments have direct implications for users and society at large.

The **Secret Life of Light USE** is designed to raise awareness of the impact of light on human functioning to equip engineers from different backgrounds with the necessary insights in psychological and biological lighting needs and with tools to address such needs, and to face the challenges in multi-stakeholder lighting innovation. This USE sequence is coordinated by the Intelligent Lighting Institute (ILI).

With the introduction of LED, a low power, long lifetime, highly colour flexible light source emerged, offering potential for miniaturization, embedding, and advanced and dynamic control: Lighting has gone digital. We can now offer more rich and complex dynamic, interactive, tailored light conditions to optimise human performance, health and wellbeing, and balance human needs with environmental impact of lighting applications.

"Light, which was captured in a bulb, is liberated as it were. On several levels relating to light – functional, emotional, biological, social, cultural and regarding control and durability – there are new possibilities and challenges."

The aim of **the Liberation of Light** is to provide students with the necessary knowledge to make an electrical lighting design, and allows for doing research in the light area. It prepares the student for entering further classes in the 'Engineering Intelligent Lighting' program. In the advanced quartile of the Liberation of Light trajectory we offer in-depth technical knowledge in the lighting domain. This knowledge is vital for making a good lighting design and includes technical and physical knowledge on the creation of light as well as its interaction with the physical environment. Students will get acquainted to all necessary topics both in theory and practice.

Intelligent Lighting Institute (ILI)

The TU/e Intelligent Lighting Institute (ILI) was established in 2010 to investigate novel intelligent lighting solutions that will come within reach by the large-scale introduction of LED technology. ILI's mission is to search for revolutionary lighting solutions. It does this using an interdisciplinary approach that takes society as its laboratory. Well-being and sustainability are given top priority in all facets of its research and resonate throughout all of the strategic programs. In addition ILI aims at providing scientific evidence for the claims that go with these novel lighting solutions.

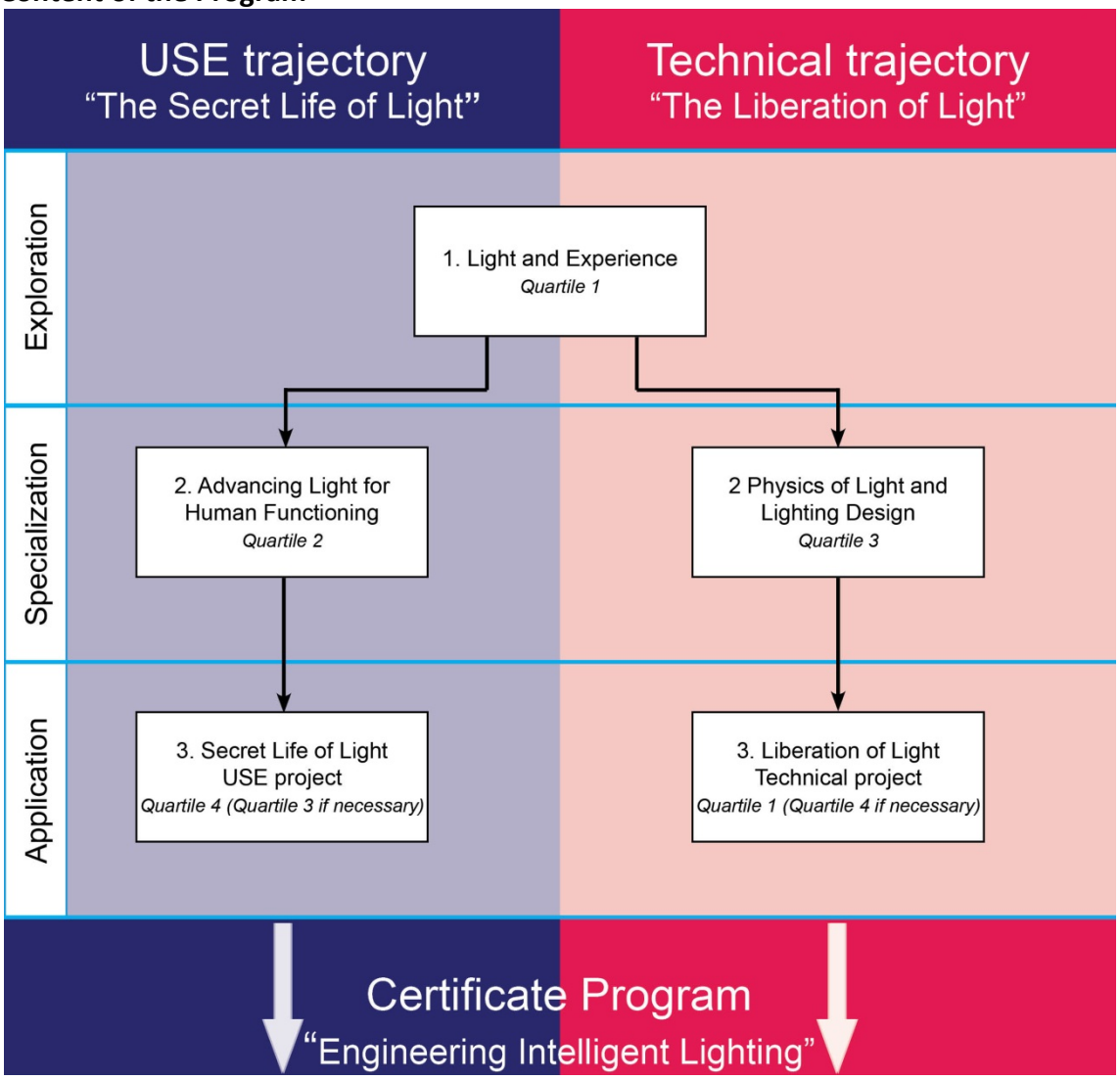
Multidisciplinary character

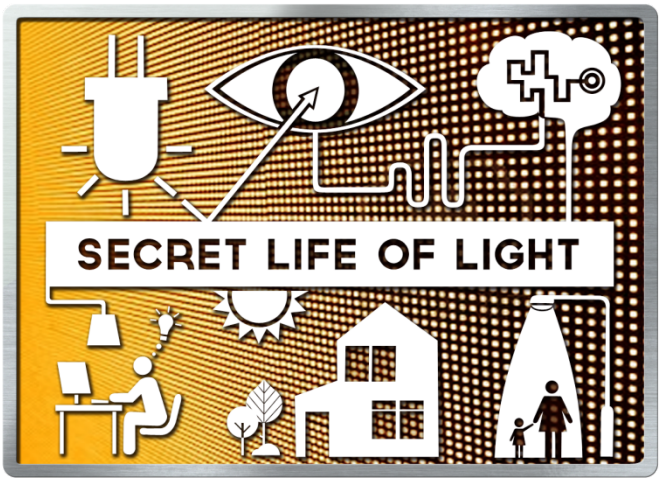
The scientific lighting domain is inherently multidisciplinary. Six departments currently participate in ILI: Built environment, Electrical Engineering, Industrial Design, Industrial Engineering & Innovation Sciences, Applied Physics, Mathematics & Computer Sciences. The certificate program aims to bring together these disciplines also on an educational level.

Competences and expertise required to ensure the development of effective, healthy, sustainable and easy-to-use lighting technology and applications include:

USE aspects	Technical aspect
• Perception • Interaction design • Human factors • Psychology of light • Biology of light • Understanding, measuring, and designing for preferences & effects	• Lighting technology • Distributed systems control • Building physics • Computational intelligence • Media processing • Simulating building performance

Content of the Program





The Secret light of life

Leerlijnleider dr.ir. Yvonne de Kort (IE&IS)
Start Q1 van 2013/2014
Capaciteit maximaal 120 studenten
Taal Engels

Exploration

The exploratory course Light and Experience aims to familiarise students with basic insights in developments in light sources, lighting controls, and or growing insight in light's psychological, biological, and social effects. Students will get acquainted with both theoretical and practical understanding of user needs and preferences, light's effects on health and behaviour, interaction with light and the many stakeholders around innovative light applications. We start with 'base camp': one week of introduction into light as a physical phenomenon, the visual system, and lighting design. Students will then explore three themes around intelligent lighting: 1) Light for health and wellbeing; 2) Smart urban lighting; and 3) New interaction styles with light.

Specialization

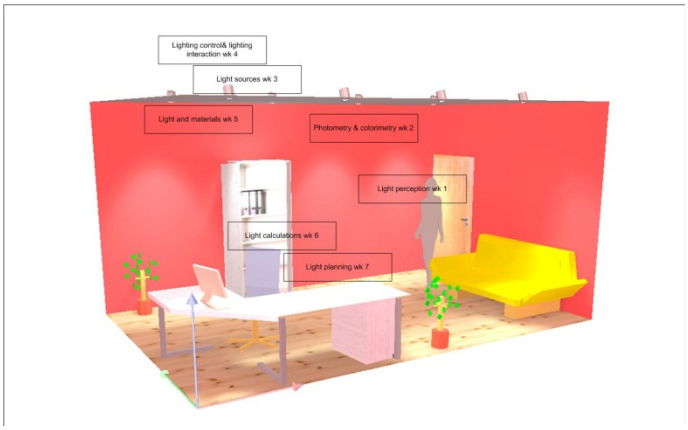
The specialized course *Advancing Light for Human Functioning* offers more in-depth knowledge in a number of domains, structured in modules. Modules adhere to one of the USE perspectives and give students a more thorough understanding of the user, societal issues, or entrepreneurship in the domain of light & lighting. All modules run twice. Students select two modules from the set:

- *The basis of light perception and experience*,
- *The appraisal of light – measuring & understanding consumers' reactions*,
- *Sensory design,*
- *Interaction design for intelligent light*, and
- *Business aspects of intelligent lighting solutions*.

During the final two weeks, students write a research proposal integrating the insights gained from the chosen modules.

Application

In the final phase of the Secret Life of Light USE sequence, students select a project team (±5 students) and assignment during an exciting matchmaking event. Every team will work for an ILI partner (client) and will have (at least) one ILI coach. For each thematic programme, clients and ILI staff together define a small number of challenges, which clearly refer to the USE components. This renders a set of 6-9 challenges/projects to choose from.
Assignments may have a research or design orientation. Research assignments consist of an investigation and a formulation of a vision. Design assignments consist of a design exploration, prototype design, and evaluation. Whether research or design oriented, the assignments should be grounded in a basic understanding of the user, contextual, and technical requirements of innovative light applications, and involve empirical data gathering and analysis, i.e. user-research. Examples of a research and a design-oriented project can be found in Application section of the deliverables for the USE sequence.



The Liberation of Light

Coordinatoren: dr.ir. Yvonne de Kort (IE&IS) & Marëlle Aarts
Start Q1 van 2013/2014
Capaciteit maximaal 40 studenten
Taal Engels

Exploration (same as Secret Life of Light)

The exploratory course Light and Experience aims to familiarise students with basic insights in developments in light sources, lighting controls, and or growing insight in light's psychological, biological, and social effects. Students will get acquainted with both theoretical and practical understanding of user needs and preferences, light's effects on health and behaviour, interaction with light and the many stakeholders around innovative light applications. We start with 'base camp': one week of introduction into light as a physical phenomenon, the visual system, and lighting design. Students will then explore three themes around intelligent lighting: 1) Light for health and wellbeing; 2) Smart urban lighting; and 3) New interaction styles with light.

Specialization

After an introduction in the physics of light, optics, photometry and colorimetry, several lamp types are introduced and discussed: classical light sources like incandescent and halogen lamps, but also plasma lamps, LED and OLED. The chemical processes - for example the role of phosphors - are addressed. In addition to knowledge on light sources, the course introduces luminairs and intelligent lighting control. Last, students are introduced to a calculation program to enable them to predict lighting conditions in an environment.

Application

In the third phase of the Liberation of Light technical trajectory, students work in teams. Every team will work for an ILI partner (client) and will have (at least) one ILI coach. The client and ILI staff define a selection of challenge, each embedded in one of the program lines.
All assignments consist of a thorough exploration, prototype design, and prototype testing. In each assignment there should also be a clear and explicit consideration of the user perspective. The technical character of projects may vary and have an emphasis in for instance architectural lighting design, innovative controls & interaction, dynamic lighting applications, or energy efficiency/smart materials.
Students start with an orientation on their assignment (PACT analysis). In the second week, project mentors & program managers organise a dedicated in-depth workshop for all the groups in their particular challenge. Then each group continues with their own assignment. The assignments should be grounded in a basic understanding of the user, contextual, and technical requirements of innovative light applications, and origininal technical research and design work.

Certificate program Engineering Intelligent Lighting

Target group

The program is aimed at all BSc students of TU/e as well as external students.
The program is offered in English.

Workload

The workload consists of 20 ec. At least 5 ec have to be followed on top of the regular BSc program. The USE program consists of 3 sequential courses and so does the technical coherent package. Both lines consist of the same explorative course, a deepening course and a project.
The requirements of the certificate are:

- Successfully obtain (1) the explorative course, (2) both advanced courses, and (3) one project (USE or technical, free choice)
- Doing at least one of the courses over and above the regular study program (in other words extra or on top of the 180 ec of the total BSc program).

Course code	**Course name**	**Coordinator**	**Number of ec**
0HEUA0	Light & experience	Dr.ir. F. Beute	5
0HSUA0	Advancing light for human functioning	Dr.ir. Y.A.W. de Kort	5
0HK30	Physics of light and lighting design	Ir. M.P.J. Aarts	5
*And **one** of the following projects:*			
0HAUA0	Secret life of light USE project	Dr. ir. Y.A.W. de Kort	5
0HK40 (TBD)	Liberation of light technical project	Ir. P.P.J. Aarts	5

Pass/Fail

The certificate program is successfully completed when the student passes every element of the certificate program by obtaining a 6 or higher or by fulfilling the requirements and by having a total package of at least 185 ec. The successfully completed certificate program will be signed by the dean of the Department of Industrial Engineering and Innovation Sciences.

Learning Goals

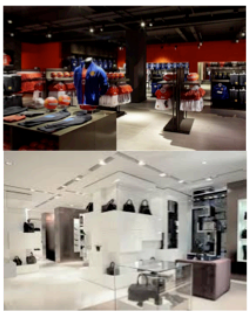
- Knowledge of light as a physical phenomenon, light sources, and its behaviour in physical spaces.
- Knowledge of the perception and human factors of light, and awareness of the multifaceted nature of light's effects on human functioning
- Basic knowledge of distributed control, operating systems, computer networks, sensors & signal processing,
- Awareness of the challenges for lighting design and control in terms of system transparency and user interaction
- Basic skills and expertise to synthesize and apply the knowledge in these various disciplines, either in formulating and performing applied research, or in developing and designing innovative applications within the multidisciplinary domain of intelligent lighting.

Example projects for USE

Project description | Secret Life of Light USE project
Design Project

Title:
Shop of the future

Background
In the competitive world of shopping, what distinguishes companies is often the customer experience. Light plays a major role in shop decoration and the customer experience. Light is emotion. Something you see, feel and experience. Obviously, shops in different segments like food and clothing have different lighting need/requirements, but especially within these categories, different companies have completely different lighting designs in their shops, aiming not only at different target groups, but also at a different experience while in the shop. To design for a better experience in a shop relates to developing a service according to the needs of all participants. Services should be user-friendly, competitive and relevant to the customers, translating the behavior of customers, their needs and motivations, into service experiences that are delivered in an achievable, efficient and meaningful fashion.



Design Assignment
The opportunities to create customer experiences with light are enormous. With the use of new technologies in media and light, and with new interaction styles, the shopping experience can be enhanced from a functional or an aesthetical related perspective. Combined with internet technologies and widely emerging web shops, this opens opportunities for completely new experiences.

Objective
How do you envision the "Shop of the Future", and what role does light play in this future shop? How to create added value to a physical shop? What can be the experience of a customer in a future store, and how can (interaction with) lighting add value and experience to the customer journey. What about branding, product showcase, and experience?

This project evokes a discussion on how we will be shopping in the future. Do we actually visit a shop? Will there still be physical products in the store? How will we enter the store, will we walk through it, or sit and let the products come to us? Will there still be a shop attendant, or is the service virtual? How will the check-out be? One thing we do know is that everything will change, and sooner than you can imagine. With this project we want to challenge you to envision and design an interactive light experience.

Expected deliverables are a context analysis, including a trend research; A storyboard /experience flow both of the current situation as well as for the envisioned designed situation; Also a design

Project description | Secret Life of Light USE project
Research Project

Title
Daily light for daily living

Background
The ageing eye is different from younger eyes. We are hearing a lot about non-image forming requirements for lighting, but in fact we are also missing relevant information in terms of required intensity and spectrum to optimally support visual tasks in daily life of elderly people. New light sources (LED) are already available and according to the professionals, will become the major light source.

Research Question
It will be your task to design a study to determine the lighting requirements for elderly people.
The focus will be on the daily tasks.

Research Objective
The results should lead to recommendations for lighting to support the daily tasks of elderly people.

Suggested method(s)
In a pre-defined light set-up you ask elderly people to perform different daily tasks under different light conditions. The correctness, time it takes to perform these tasks can be an indication for the best light source. For the future resistance of the results, the use of LED light sources is strongly recommended.

Relevant literature
Aarts, M.P.J. & Westerlaken, A.C. 2005. Field study of visual and biological light conditions of independently-living elderly people. *Gerontechnology*, 4, (3) 141-152
Davis R.J. & Garza A. 2002. Taks lighting for the elderly. *Journal of the illuminating Engineering Society*, 31 (1) 20-32
Sinoo, M.M., van Hoof, J., & Kort, H.S.M. 2011. Light conditions for older adults in the nursing home: Assessment of environmental illuminances and colour temperature. Building and Environment, 46, (10) 1917-1927

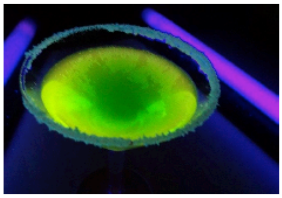
Planning (8 weeks)
First consider the current light situation of this target group (described in the literature) and the typical tasks users want to perform and experience as visually challenging. Than specify what you exactly want to research (taken into account your time schedule). The next steps are to design a research set-up, perform the research, analyse the results, and draw conclusions.

Week 1: Orientation (PACT & literature)
Week 2: Research Design (literature study continued)
Week 3: Research Design (preparation)
Week 4: Data collection (pilot)
Week 5: Data collection
Week 6: Data collection and data analysis
Week 7: Analysis and report writing
Week 8: Report writing and vision formulation

Keywords

Project description | Secret Life of Light USE project
Research Project: Tasting with your eyes?

Background
Sometimes the stimulation of one sensory modality can cause an experience in a different modality. It is well known that our vision is linked to our perception of taste. "The first taste is always with the eye" claimed van der Laan et al. (2011). The color of a food or beverage can influence its flavor as well as the hunger state of the user. Several studies have indicated that the color of a specific food or drink can influence taste and smell. Oberfeld et al. (2009) knew about the effect of food coloring on the perception of taste and went one step further by investigating the effect of ambient lighting color on taste. A group of wine buyers where presented the same wine under different ambient lighting conditions and where asked to value them according to tastiness. It appeared that, on average, the subjects were willing to pay 1 euro more for the same wine when they tasted it in a red and blue environment compared to a green and white environment. Lastly, hunger and cravings for sweet, starchy and salty foods are under the influence of our circadian system and hence potentially sensitive to light exposure.



Research Question
How can light change the taste experience?
What is the relation between light and food choice?
How can light change eating behaviour?

Research Objective
Investigate if, by choosing a specific lighting condition, you can persuade people to choose different kind of food or to eat more or less.

Suggested method(s)
Lab organized study with different types of food and a panel to taste.

Relevant literature
Laan LN van der, Ridder DT de, Viergever MA, Smeets PA (2011). The first taste is always with the eyes: a meta-analysis on the neural correlates of processing visual food cues. *Neuroimage*. 55(1):296-303
Oberfeld D, Hecht H, Allendorf U, Wickelmaier F. (2009). Ambient Lighting Modifies the Flavor of Wine. *Journal of Sensory Studies*. 24(6): 797-832.

Keywords
Taste, light, color, persuade

Supervisors and stakeholders
Name M.P.J. Aarts Faculty: bwk
Name K.C.J.H. Smolders/Y.A.W. de Kort Faculty: IE&IS

Stakeholder:
Vinny Jones, light designer – responsible for the light & food experience during the social event of Experiencing Ligh1 2014

Project description | Secret Life of Light USE project
Research Project

Title:
Exploring the Concept of Reassurance for Investigating Critical Distances when Approached by a Stranger.

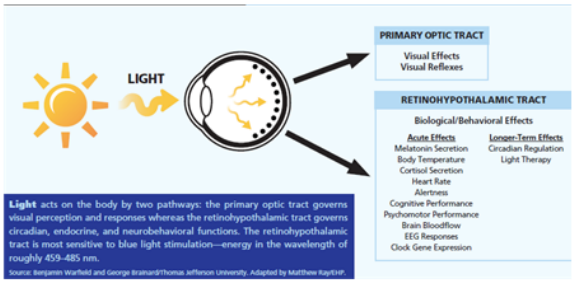
Background
In the past, guidelines for road lighting have been determined in a rather haphazard manner; based largely on experience and intuition combined with the scarce empirical literature on street lighting evaluations by street users—evaluations that are not only few but far apart. One emerging trend, however, is to ground street lighting guidelines more firmly in theory, especially with respect to the critical tasks that support pedestrian functioning at night. Currently three critical tasks have been identified: Obstacle avoidance, orientation, and face recognition (for safety perception). The latter of these tasks requires the highest illuminance levels, and thus largely determines current lighting guidelines and designs. The guidelines currently state that adequate facial recognition is required at a four meter distance. However, some researchers have criticized the idea that the ability to recognize faces of fellow pedestrians is indeed a critical pedestrian task: Is it not more important, for example, to be able to make a timely judgement on the intention of the other individual? At the same time, no empirical evidence exists to support four meters as the distance at which recognizing another individual becomes critical. Determining the critical task for safety perception is not a trivial issue: If facial recognition at a four meter distance is not the most critical task then we may well be lighting our streets too heavily at night—or too little if a more light intensive critical task is discovered—leading to unneeded light pollution and energy consumption.

Recently, some researchers have argued that the concept of perceived personal safety is perhaps too ill-defined—and too difficult to operationalize—to be used in urban lighting research. Instead, they propose the concept of reassurance, broadly defined as a pedestrian's confidence to use a street, as a likely candidate for replacing safety as the dependent variable. The concept of reassurance offers a potentially fruitful way of studying the lighting requirements when making a safety related judgement when being approached by another pedestrian. What, for example, is the minimum distance at which a pedestrian needs to be reassured that an approaching individual does not pose a threat to their personal safety? In other words, at what distance do people want to have gathered sufficient information about the approaching individual to make a safety judgement. Is this critical distance the same for everyone or does it, for example, depend on the individual's perceived power in avoiding a possible assault. And, subsequently, what lighting levels are needed for an average individual to feel reassured at that distance? This research project focusses on the first two questions. Answering these questions is a first step in defining the critical task related to perceived personal safety.

Research Questions
What is the average critical distance at which pedestrians want to feel a sense of reassurance when approached by a stranger, and is this critical distance dependent on such personality traits as perceived power, vulnerability, and attractiveness to criminals?

Research Objective
The research objective is to determine the minimum distance, and the individual variation in this distance, at which people need to feel reassured about the possible threat of an approaching individual. A second objective is to explore whether the expected individual differences in this critical distance depend on personality traits related to power, vulnerability and attractiveness to criminals.

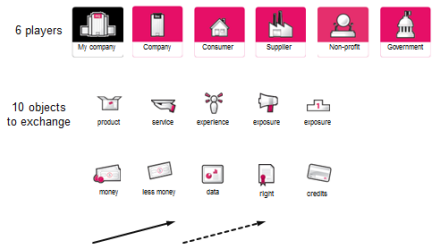
Two major pathways



Source: Holzman DC 2010. What's in a Color? The Unique Human Health Effects of Blue Light. Environ Health Perspect 118:A22-A27. doi:10.1289/ehp.118-a22

Build your business model with the following 16 blocks

(download this file to edit)



More info: boardofinnovation.com

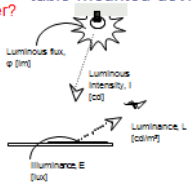
Introduction

Importance

- **Be able to reproduce the same results**
- **Forbes et al.(2009)** *". . . there is insufficient evidence to assess the value of light therapy for people with dementia. Most of the available studies are not of high methodological quality and further research is required."*

"table-mounted device of 10,000 lux"

Position observer? Where?



Light spectrum?

/ built environment

TU/e Technische Universiteit Eindhoven University of Technology

23-4-2014 Page 2

Experience Design: incorporate Why

Why? – **utility**, "be-goals", human needs, **relevance**
(focus on the *Activity* – people satisfying a *Need*)
Science

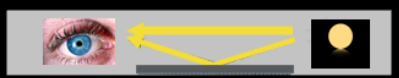
What? – **usefulness**, "do-goals", tasks, functionality, **specificity**
(focus on the *Action* – people pursuing a *Goal*)
Design

How? – **usability**, interaction, senso-motoric, **feasibility**
(focus on the *Interaction* – people performing a *Task*)
Engineering

LIGHT AND DESIGN.

Week 7 Lighting design

- Simulation methods

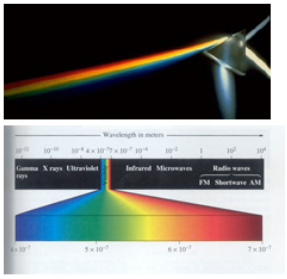


the receiver the path the source

-Method to simulation
-Using simulation programs

Newton (1643-1727)

- **According to Newton:**
  - **white light is composed of pure rays:**
    - **monochromatic beams**
  - **each ray "stirs" a sensation of colour**
    - **Spectral colours**
- **Goethe main opponent**
  - **denying that white light is pure is blasphemy**
  - **Non-spectral colours**



TU/e Technische Universiteit Eindhoven University of Technology

SFD Mission and Vision

- New functionalities into polymer materials towards new applications or solutions in
  - sustainable energy
  - water & air
  - personal comfort and healthcare

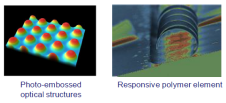
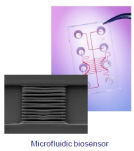


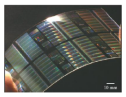
Photo-embossed optical structures

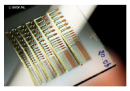
Responsive polymer element


Microfluidic biosensor

- Integration of these new polymers in devices to employ their functionality


Solar energy concentrators

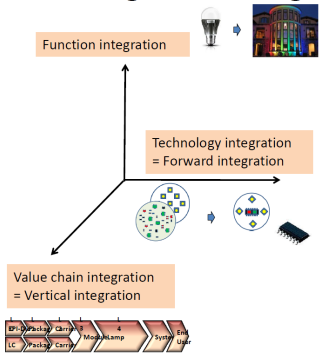

Organic transistors


Integrated polymer optical actuators

SFD

TU/e Technische Universiteit Eindhoven University of Technology
Physics of light and lighting design (0HK30)

Integration along three dimensions



- Function integration
  - Add-on functionality
  - Eg: presence detection, auto calibration, light on demand,....
- Technology integration
  - Collapse of levels 0-3,4
  - Eg: collapse of L0+L1= CSP, collapse of L1+L2= CoB
  - Eg: integration of discrete electronics into SiP and Logic IC's
- Value chain integration
  - Logical split based on decoupling points in value/ supply chain
  - Eg: L0+L1 at LED supplier, L2,3,4 at assembly factory

6