

Lighting research at Aalto University – Lighting for health and wellbeing

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Outline

- Aalto University and Lighting Unit Intro
- Research Activities/projects
- Service to industry
- EU-project SSL-erate and Lighting for health and well being



Three Finnish higher education institutes, leaders in their field, formed Aalto University on 1st January 2010 Where science and art meet technology and business

> A community of: 20,000 students and 4,700 faculty & staff, with 340 professors.

School of Engineering School of Business

School of Chemical Technology School of Science

School of Electrical Engineering School of Art, Design and Architecture

School of Electrical Engineering

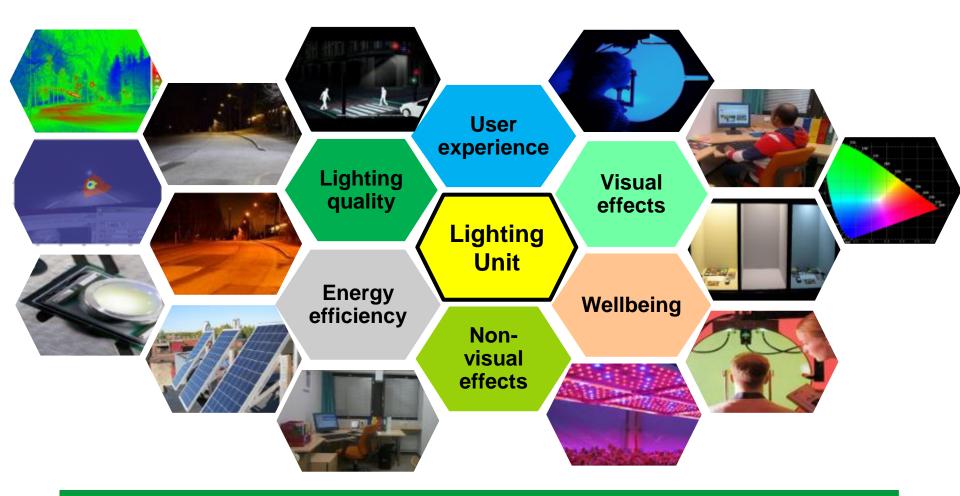
Basic research, latest technologies and high quality engineering

Areas covered:

Micro- and nanosciences Radio science and engineering Signal processing and acoustics Electrical engineering and automation Communications and networking

Research infrastructures: Metsähovi Radio Observatory Aalto Nanofab

Lighting Unit – about 10 people



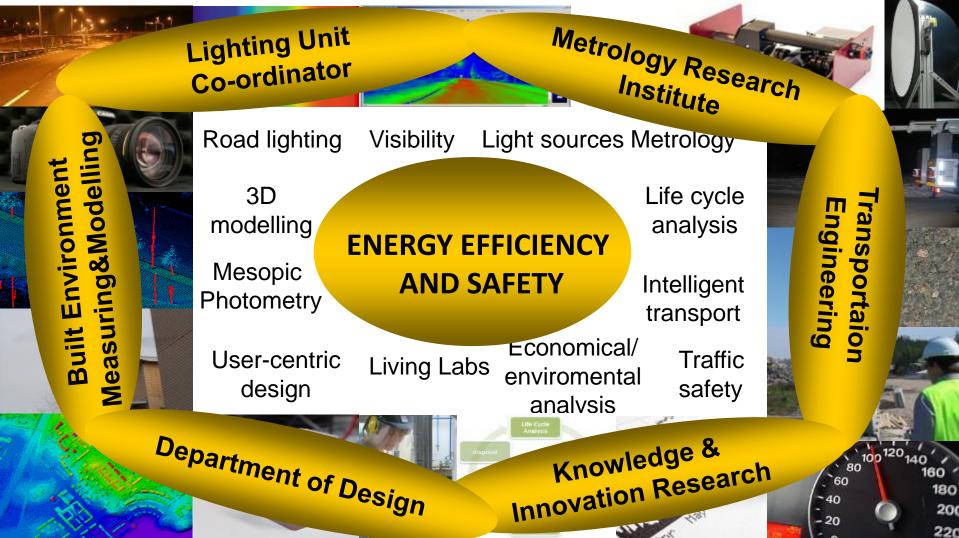


Lighting Unit - Doctoral Thesis Works 2005-2015

Marjukka Eloholma: Visual performace based mesopic photometry (2005) **Pasi Orreveteläinen:** Contrast sensitivity and reaction time at mesopic light levels (2005) **Jaakko Ketomäki:** Contrast threhold in the mesopic and photopic luminance ranges (2006) Henri Juslén: Benefits of lighting for industry - case studies (2007) Meri Liesiö: Visual performance at low light levels (2007) **Liping Guo:** Lighting control in street lighting (2008) **Paolo Pinho:** LEDs for plant applications (2008) Pramod Bhusal: Energy-efficiency of lighting in developed and developing countries (2009) Aleksandr Ekrias: Development and enhancement of road lighting principles (2010) Ater Amogpai: LED lighting compined with solar panel in developing countries (2011) **Emilia Rautkylä**: Biological effects of light (2011) **Anne Ylinen**: Development and analysis of road lighting energy efficiency (2011) Leena Tähkämö: Life cycle assessments of light sources (2013) **Heli Nikunen:** Perceived restorativeness, preference and fear in outdoor spaces 2013) **Wei Luo:** Visual adaptation and mesopic photometry in pedestrian way lighting 2014 **Mikko Hyvärinen:** Methodological questions in lighting acceptance and preference studies (2015) **Janne Viitanen**: Energy efficient lighting systems in buildings with integrated photovoltaics (2015) **Mohammad Islam**: User acceptance studies for LED office lighting (2015) **Rajendra Dangol**: Subjective preferences for light colour and LED lighting (2015) **Can Cengiz:** Visual Performance in mesopic conditions: Towards determination of adaptation luminance (2015) Mikko Maksimainen: Spatial phenomena of human vision in continuously transforming visual field (expected 201 **Rupak Baniya:** LED colour characteristics in office lighting (*expected 2016*)



Aalto Energy Efficiency - Light Energy (2012-2016 + 3 y) Efficient and safe Traffic Environments



CIE Mesopic Photometry

- Describes mesopic spectral sensitivity in the luminance region of 0.005 – 5 cd/m²
- Provides common metric for dimensioning and measuring lighting at low light levels (street, outdoor areas, pedestrian ways etc.)

$$V_{mes}(\lambda) = m V(\lambda) + (1-m) V'(\lambda)$$







Why do we need different photometry for low light levels (0.005 - 5 cd/cm²)?



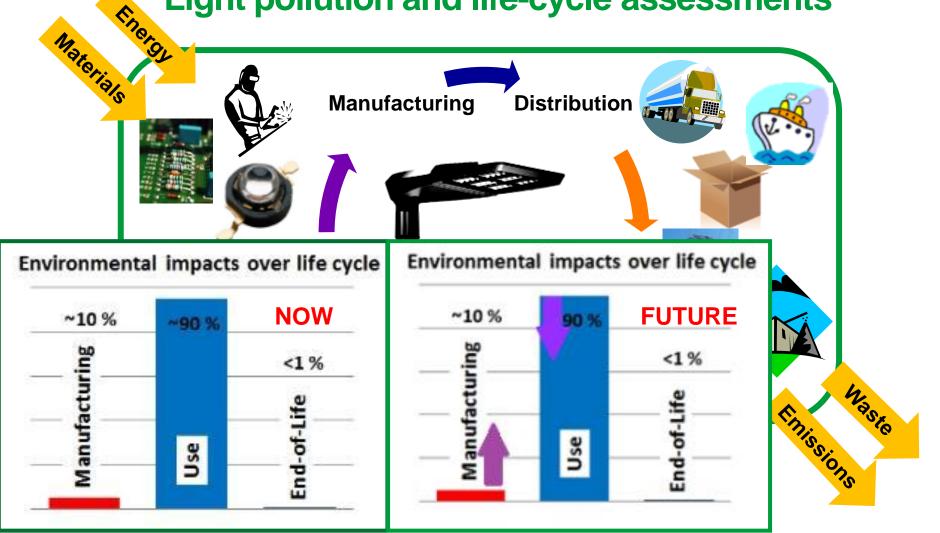
PHOTOPIC CONDITIONS DAYLIGHT CONES $V(\lambda)$ (est.1924) MESOPIC CONDITIONS RODS AND CONES $V_{mes}(\lambda)$ (est. 2010)

SCOTOPIC CONDITIONS MOONLIGHT *RODS* V'(λ) (est. 1951)

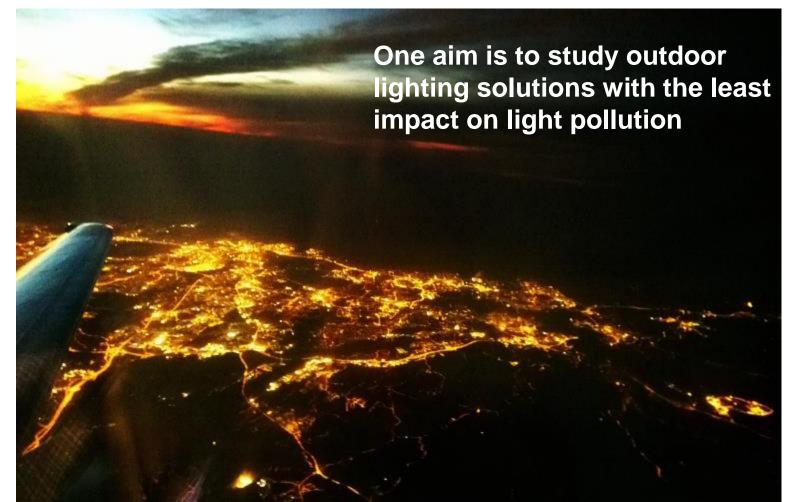


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Academy of Finland – Environmental impact of lighting: Light pollution and life-cycle assessments



COST Action ES1204 Loss of the Night Network (LoNNe)

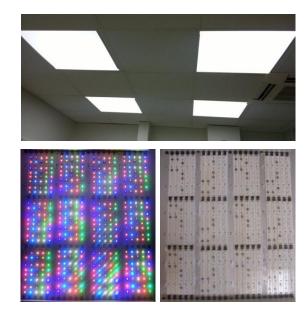


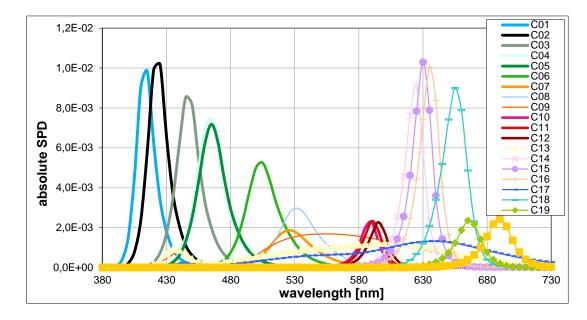
Horticultural LED Lighting

- Main goals
 - Efficient use of energy
 - Growth control and optimization (e.g. morphogenesis, germination, flowering and nutritional value)
 - Increase crop productivity
 - Implement versatile lighting tailored for specific crops



Color fidality and color preference studies

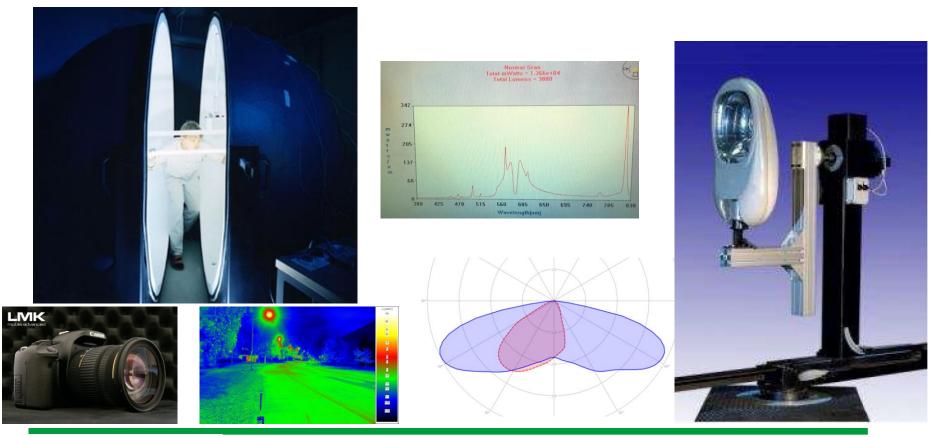






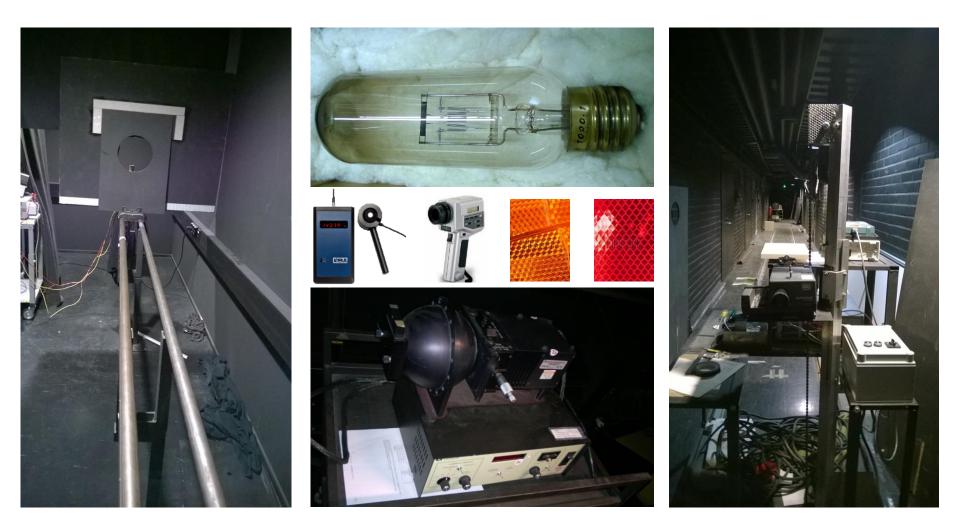


Lighting Unit – Services to Industry



Aalto University School of Electrical Engineering Lighting Unit Finland

Lighting Unit – Services to Industry



Education Development and Capacity Building Projects in Asia , Africa..

- PROMILL Promoting Illuminating Engineering Studies and Research in China (EC funded) 2003 - 2006
- ENLIGHTEN Educational and research networking between Europe and *Nepal* (EC funded) 2005-2008
- ELMCA Curricula Development for Universities in Thailand, Vietnam, Philippines (EC funded) 2007-2009
- Networking and capacity building project in Nepal, Vietnam (Foreign Ministry funded) 2011-2013
- Networking on Environmental Safety & Sustainability (EC funded)
 Japan, Korea, Australia, New Zealand 2012 2016
- Energy efficient lighting curricula development in Ethiopia, Nepal (Foreign Ministry funded) 2013-2015
- Networking and capacity building project in Nepal, Ethiopia (Foreign Ministry funded) 2014-2015



European Commission project SSL-erate: Accelerate SSL Innovation for Europe

24 partners / 13 countries



uster Lumière







gemeente Eindhoven



KU LEUVEN







Hochschule für Angewandte Wissenschaften Hamburg Hamburg University of Applied Sciences





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Centre for Chronobiology
Psychiatric University Clinics Basel
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LIGHTINGEUROPE	





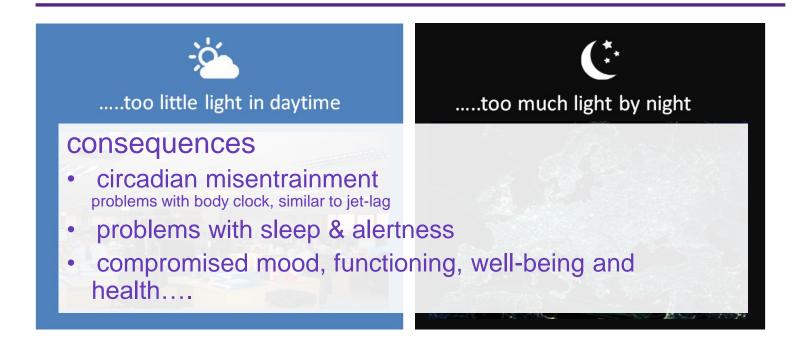








Light for life: are we using the right light?



HUMAN CENTRIC LIGHTING: designed to benefit human health & wellbeing the right light, at the right time & place

Health and wellbeing (SSL-erate WP3) non-visual effects of light

- Identify non-visual effects for five application domains (education, healthcare, workplaces, homes, cities)
- Create dose-response curves (scientific studies): which non-visual effects occur in what light intensity ranges
- Give guidance on which light metrics to use in practice

Accelerate uptake Solid State Lighting technology





Lighting in education scientific insights, new functions & use cases

- vary brightness and blue content
 - helps to get ready for the day
 - supports alertness and concentration during lessons
 - better sleep (duration & timing) and thus learning







Lighting in education scientific insights, new functions & use cases

- vary brightness and blue content
 - helps to get ready for the day
 - supports alertness and concentration during lessons
 - better sleep (duration & timing) and thus learning
- innovation opportunities
 - Dynamic regulation & presets (intensity, spectrum) to support activities (concentration, relaxation,...)
 - Context adaptation & personalization





Workplace Lighting scientific insights, new functions & use cases

- varying brightness and spectrum influences
 - alertness, vitality, cognitive performance, attention
 - environmental appraisal
 - subsequent sleep (duration & timing)
- From (well-controlled) lab to real-life
 - Balance acute effects & circadian effects











Workplace Lighting scientific insights, new functions & use cases

- varying brightness and spectrum influences
 - alertness, vitality, cognitive performance, attention
 - environmental appraisal
 - subsequent sleep (duration & timing)
- From (well-controlled) lab to real-life
 - Balance acute effects & circadian effects
- innovation opportunities
 - Adapt light settings to user and context
 - Dynamic regulation (intensity, spectrum,)
 - Promote alertness @ start work/shift & post-lunch
 - Flexible regulation (time of year, task, personalization,...)





Healthcare Lighting scientific insights, new functions & use cases

- Treating depression on a hospital ward
 - Intense daytime light exposure
 - **Dawn-simulation**
- Elderly: ٠
 - intense daytime light enhances adaptation of circadian rhythms to the natural day-night cycle
 - Dementia: limited evidence better neuropsychiatric behaviour











Healthcare Lighting scientific insights, new functions & use cases

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- innovation opportunities
 - User-tunable light (staff/patient/resident): being in control enhances independency, confidence and positive attitude (better mood/healing)
 - 24h light-dark cycle: dawn simulation, cool light that fluctuates with warm light over the course of the day (14h), warm light in the evening, sufficiently dimmed light at night (all rooms & corridors)
 - Use daylight in architecture as much as possible & avoid glare





Domestic lighting scientific insights, new functions & use cases

- In the evening, blue-enriched light
 - Alerts
 - Compromises sleep: longer sleep-onset, less deep sleep and sleep quality
- In the (early) morning, dawn simulation (bedroom): ۲
 - beneficial effects on sleep inertia & daytime well-being and cognitive performance
- lab results urgently need translation to real-life ٠





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- innovation opportunities ۲
 - Apply light in the early morning and late evening (best sensitivity)
 - During daytime use cooler color temperatures (i.e., blue-rich light) in rooms with little/no natural light entrance
 - Intelligent, dynamic light solutions: simulate dawn and dusk, automated photoperiod of about 12 hours of sufficient brightness and 12 hours of reduced light (relatively dim, blue-deprived light or dark)





Smart Cities & Lighting scientific insights, new functions & use cases

- ensuring sufficient visibility, higher perceived safety, reduce criminal activity
- encourage activity/recreation (pedestrian and cyclist), enhance atmosphere, social life & well-being in cities
- light at night must be handled with care, not to disrupt sleep and health



Da Nang Dragon Bridg Vietnam





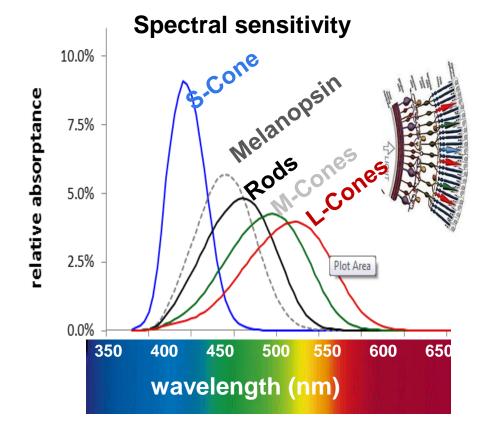


Smart Cities & Lighting scientific insights, new functions & use cases

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- light at night must be handled with care, not to disrupt sleep and health
- innovation opportunities
 - carefully choosing the spectra, determining the timing and defining the light intensity range (min and max) of the lighting system
 - Involve car manufacturers in future road lighting
 - Limit blue-content (less circadian active, fewer insects)
 - Address needs of (elderly) pedestrians



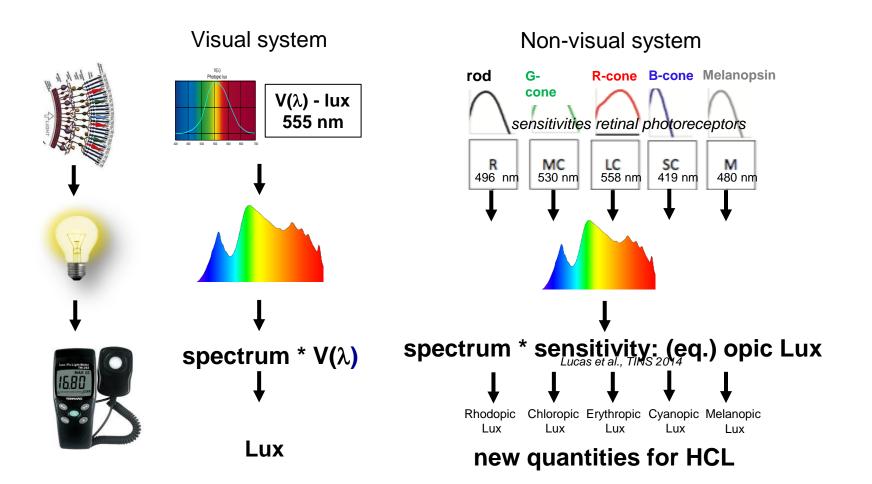
Quantify light via five photoreceptor inputs



photoreceptors interplay & total spectral sensitivity depends on (non-visual) effect, timing, intensity, adaptation state...

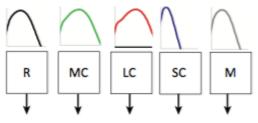
Lucas et al. Trends. Neurosci. 2014

Rethinking light beyond vision and lux...



Measuring light

 Lucas et al (2014) created a tool to quant photoreceptor weighted irradiances



Independent representations of irradiance

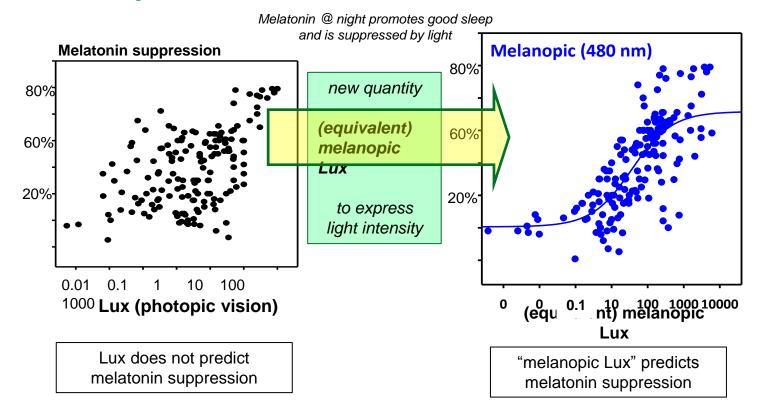
 Improved by Dieter Lang (α-opic daylight equivalent illuminance; and α-opic action factor)

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Daylight 4500-8000K			-/-	melanopic daylight equivalent efficacy [%]	melanopic daylight equivalent illuminance [lx]			
	•			84.7%	8473.57			
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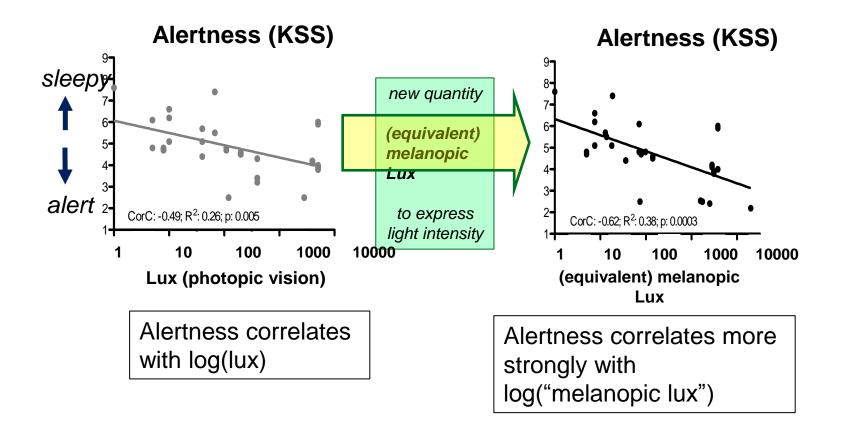
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		CONNECTING OPPORTUNITIES FOR INNOVATION provided to Lettraferosoph by Deter Lang Cater Lang@coran.com, Phone +48 85 8213 3321					
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Mercury High Pressure / HPL, HQL		equivalent illuminance					
Fluorescent RED		[b]		S-Cone cyanopic		"cyanopic lux "	
Fluorescent GREEN		7470.67		610.64 589.43		7810.82	
Fluorescent BLUE		scotopic daylight equivalent illuminance					
Fluorescent Fluora (Plant Grow)			[bx]	scotopic rhodopic		"rhodopic lux "	
Fluorescent Chip-Control		8764.48	1270.60 1359.03		9586.02		
Fluorescent Hg-free -2000							
Fluorescent Hg-free -6000	K (Planon)						
User defined spectrum							

"...allows calculation of melanopic and αopic data for different light sources at different intensities" "...primarily intended for

Melatonin suppression and light intensity



Alertness and light intensity



Conclusions

- Melatonin suppression: lux (photopic vision) is not predicting the response
- α-opic irradiances are expected to be useful predictors for non-visual effects of light in HCL, especially for narrow spectral bands, mixed colors or special whites
- The lighting practice needs SI compliant metrics:
 - unit " α -opic lux" is not SI-compliant
 - α-opic irradiance & α-opic daylight-equivalent illuminance (multiplication factors, definitions & notations pending in CIE)
- Start using α-opic irradiances to design light conditions that achieve, or avoid, certain non-visual effects.
- Application example for dynamic light solutions:
 - offer high melanopic irradiances during daytime
 - and minimize melanopic irradiance during the night

THANK YOU for your attention!

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Aalto University School of Electrical Engineering Lighting Unit Finland