Institution: University of Surrey

Unit of Assessment: UOA 3 Allied Health Professions, Dentistry, Nursing and Pharmacy

Title of case study:

Improved work productivity and enhanced health and wellbeing through novel lighting systems

1. Summary of the impact (indicative maximum 100 words)

Circadian rhythms impact upon a large proportion of human biology. Disruption due to genetic or environmental (e.g. altered sleep patterns in shift workers) cues results in reduced quality of life and increased morbidity for millions of people every year.

Researchers at Surrey first demonstrated blue light sensitivity of the human circadian system, resulting in increased alertness and mood. This led to changes in international lighting standards and the development and use of novel lighting systems, such as blue-enriched polychromatic lighting. These systems have been employed in homes for older people, factories, offices, hospitals and schools, increasing health and wellbeing.

2. Underpinning research (indicative maximum 500 words)

Light is the major time cue for the synchronisation and entrainment of the human circadian timing system with the 24-h environmental light-dark cycle. Research at the University of Surrey led by the teams of Arendt (Professor of Endocrinology; now Emeritus), Dijk (Professor of Sleep and Physiology) and Skene (Professor of Neuroendocrinology) has established the importance of ocular light in the circadian system.

A pivotal study in blind people co-funded by the South Thames Regional Health Authority and Servier, determined the importance of the ocular light signal for circadian entrainment (**1**). The research demonstrated that this ocular cue was vital to ensure good sleep at night, reduced daytime napping and optimum performance and alertness during the day (**2**). In 2001, a second pivotal study funded through EU-FP5 determined the spectral sensitivity of human circadian photoreception by assessing the effect of a range of monochromatic light pulses at varying intensities on light-induced suppression of nocturnal melatonin production (**3**). The resulting action spectrum demonstrated for the first time that short wavelength blue light (440 - 480 nm) was the most effective light wavelength for light-induced melatonin suppression. In addition to proving that these human light responses were not primarily mediated by the classical rod and cone retinal photoreceptors, the results had important implications for the field of lighting and health.

Based on these findings, a joint clinical study co-operation agreement was initiated between Philips Lighting and the University of Surrey (September 2004) to identify potential areas for commercial development, which has led to several joint patents (EP1614441A1, published 11.01.2006; EP 1317302B1 published 7.06.2006; EP 2286862 published 23.09.10 and also granted in Australia, Taiwan and China).

In a series of publications, the initial observation that blue light is most effective in controlling the biological clock was extended with Surrey researchers demonstrating that blue-light intervention could phase-advance clock timing, increase alertness, improve mood and affect emotional brain responses. In 2005, it was demonstrated for the first time that older people have reduced melatonin suppression (**4**) and reduced alertness (**5**) in response to short wavelength blue light. These findings have important implications for the design of lighting for living environments of older

people. In collaboration with Philips Lighting and a 5 year New Dynamics of Ageing (NDA) Cross Council Research Programme, blue-enriched polychromatic lighting has been investigated in older people living in the community and in care homes.

Importantly, in addition to the observed benefits of blue-enriched polychromatic lighting for the elderly, research at the University of Surrey demonstrated that these benefits could be expanded to the workplace, improving self-reported alertness, performance and sleep quality (**6**).

3. References to the research (indicative maximum of six references)

1. Lockley, S.W., Skene, D.J., Arendt, J.,Tabandeh, H., Bird, A.C., Defrance, R. *Relationship between melatonin rhythms and visual loss in the blind.* Journal of Clinical Endocrinology and Metabolism. (1998) **82:** 3763-3770. DOI: 10.1177/074873049701200104
2. Lockley, S.W., Dijk, D.J., Kosti, O., Skene, D.J. and Arendt, J. *Alertness, mood and performance rhythm disturbances associated with circadian sleep disorders in the blind*. Journal of Sleep Research. (2008) **17**: 207-216. DOI: 10.1111/j.1365-2869.2008.00656.x
3. Thapan, K., Arendt, J. and Skene, D.J. *An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans.* Journal of Physiology (2001) **535**: 261-267. DOI: 10.1111/j.1469-7793.2001.t01-1-00261.x
4. Herljevic, M., Middleton, B., Thapan, K. and Skene, D.J. *Light-induced melatonin suppression: Age-related reduction in response to short wavelength light.* Experimental Gerontology (2005) **40**: 237-242. DOI: 10.1016/j.exger.2004.12.001
5. Sletten, T.L., Revell, V.L., Middleton, B., Lederle, K.A. and Skene, D.J. *Age-related changes in acute and phase advancing responses to monochromatic light.* Journal of Biological Rhythms (2009) **24**: 73-84. DOI: 10.1177/0748730408328973
6. Viola A.U., James L.M., Schlangen L.J., Dijk D.J. *Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality.* Scandinavian Journal of Work Environment and Health (2008) **34:**297-306. DOI: 10.5271/sjweh.1268

4. Details of the impact (indicative maximum 750 words)

The research conducted at Surrey has direct implications for lighting, its design and implementation, in the home and workplace and has led to a number of *International Policy, Health & Wellbeing* and *Commercial* impacts.

On the basis of work carried out by the research team on the impact of blue light on human action spectra, plus the related discovery by others of the novel photopigment melanopsin, and the intrinsically photosensitive retinal ganglion cells that drive these responses, a major *policy impact* on lighting standards has been achieved. International lighting standard organisations, e.g. DIN (Deutsches Institut für Normung); CIE (International Commission on Illumination), set up specific Task Forces to address this issue, with task force recommendations being incorporated into current guidelines from 2009 onwards (**Ref 1 and 2**).

This policy impact has paved the way for the development of blue-enriched lighting, providing a rationale for its use in personal, commercial and healthcare settings. One of the joint patents between the University of Surrey and Phillips Electronic N.V, complimented with novel clinical studies was used to develop a new range of lighting products; blue-enriched polychromatic lighting.

These products were initially developed as specialised light boxes, providing timed, blue-enriched polychromatic lighting for individuals at work or home (**Ref 3**). In addition to personal light boxes, the reach of this impact was further extended through the development of blue-enriched

polychromatic traditional light fixtures. These lights are suitable for use in the workplace, hospitals, schools and care homes, where they positively impact on health and wellbeing, and productivity. These lighting systems are proving to be of significant benefit in the workplace, for example in factories of shift workers (**Ref 4**); in care homes for the elderly (**Ref 5**); and in schools (SchoolVision® system; **Ref 6**). The impact of the SchoolVision® system of blue-enriched polychromatic lighting has been clearly proven in the classroom, where reading speed increased by 35%, frequency of errors fell by almost 45% and restfulness was reduced by 75% (**Ref 7**).

In summary, the identification of the health and wellbeing benefits of blue-enriched polychromatic lighting by researchers at Surrey has had a widespread impact. While the development of personal light boxes impacted the health and wellbeing of many at an individual level, the expansion of blue-enriched polychromatic lighting to traditional light fixtures extends this impact to a larger population with its incorporation in the workplace, schools and healthcare institutions. Equally, a significant, and on-going, commercial impact has been achieved through the sales of blue-enriched polychromatic lighting.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Ref 1. DIN Deutsches Institut für Normung E.V. – DIN V 5031-100: Optical radiation physics and illuminating engineering - Part 100: Non-visual effects of ocular light on human beings - Quantities, symbols and action spectra (2009).
http://www.fnl.din.de/cmd?level=tpl-art-detailansicht&artid=118398668&committeeid=54738975&bcrumblevel=4&languageid=en

Ref 2. International Commission on Illumination (CIE) - Proceedings of CIE symposium on Light and Health (2010)
http://www.cie.co.at/index.php/index.php?i_ca_id=719

Ref 3. Blue light-enriched lamps
http://download.p4c.philips.com/files/h/hf3227_60/hf3227_60_dfu_eng.pdf
http://download.p4c.philips.com/files/h/hf3310_60/hf3310_60_pss_aen.pdf
http://circadianbluelight.com/
http://lighting.com/blue-light-key-to-circadian/

Ref 4. Productivity Impact of blue-enriched polychromatic lighting in the Workplace
Quality System Manager / TPM Manager, ArcelorMittal (Contact details provided)

Ref 5. Health and Wellbeing Impact of blue-enriched polychromatic lighting in care homes
Principal Scientist - Light, Health & Well-being,
Brain, Body and Behaviour - Philips Group innovation, Research (Contact details provided)

Ref 6. Health and Wellbeing Impact of blue-enriched polychromatic lighting in schools
Case study: Wintelre School, Wintelre, The Netherlands
http://www.lighting.philips.com/pwc_li/nl_nl/application_areas/pdf/CaseStudy_Wintelre.pdf
http://nos.nl/video/191170-van-blauw-licht-krijg-je-meer-energie.html

Ref 7. Knowledge Transfer Network: Energy Efficient Lighting in the UK – a showcase guide
https://connect.innovateuk.org/web/espktn