Illuminating ENGINEERING SOCIETY

IES TM-18-18

Light and Human Health: An Overview of the Impact of Optical Radiation on Visual, Circadian, Neuroendocrine, and Neurobehavioral Responses

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Publication of this Technical Memorandum has been approved by the IES. Suggestions for revisions should be directed to the IES

Prepared by:
The IES Light and Human Health Committee

Approved by the IES Standards Committee, April 4, 2018, as a Transaction of the Illuminating Engineering Society.

Published by the Illuminating Engineering Society, 120 Wall Street, New York, New York 10005.

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Printed in the United States of America.

ISBN # 978-0-87995-369-0

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1.0 INTRODUCTION

Light is currently defined as optical radiation entering the eye that provides visual sensation in humans.[1] Despite this specific vision-related definition, light has been increasingly related to a range of ocular circadian, neuroendocrine, neurobehavioral, and therapeutic responses in humans. Technically, the term *optical radiation* should be used to describe the portion of the electromagnetic spectrum spanning ultraviolet, visible, and infrared radiation that stimulates all these biological responses. Since the term *light* (or *lighting*) is so widely used to describe optical radiation in the lighting community as well as in the biological and medical research community, the reader is advised that these terms are often used interchangeably in these communities. In this document the term *optical radiation* is used when referring to biological responses other than the visual ones.

Most publications from the Illuminating Engineering Society (IES) to date have described light's impact on the human visual system. In some instances, such as in *The Lighting Handbook*, 10th ed., certain physiological and psychological effects of optical radiation are also discussed. The neurophysiology and neuroanatomy of the human visual system are well documented, and almost all lighting technologies, standards, measurement devices, and applications have (until now) been based solely on that understanding. In this Technical Memorandum, however, the Light and Human Health Committee summarizes the extant body of knowledge on a topic that is new to the architectural lighting community: the impact of optical radiation on circadian, neuroendocrine, and neurobehavioral systems. This document is not concerned with the impact of optical radiation on the skin or other tissues, only ocular exposures.

Much like the dual functions (audition and balance) long associated with the ear, the mammalian eye has dual roles in detecting optical radiation for image-formation (vision) as well as for circadian, neuroendocrine, and neurobehavioral responses. Although this is not a new area of scientific investigation, it is a relatively new topic for many IES members.

Most published scientific research in this area has come primarily from controlled laboratory and clinical experiments, although some studies have attempted to integrate the results into practical situations where they would be beneficial. Therefore, readers will find that the information discussed in this Technical Memorandum is mostly research-based. Recommended practice and application advice are not included.

Since the effects of optical radiation can be profound for human health and well-being, it is increasingly important for the lighting community to understand the direct biological influences of light/dark cycles. It may be possible to develop new lighting technologies and applications that will have health benefits. It may also be possible to employ existing technologies in novel ways to positively influence human health. The counterpoint is also true: it may be possible to employ existing and new technologies in ways that are deleterious to human health.

In brief, this Technical Memorandum describes the retinal mechanisms involved when optical radiation signals are converted into neural signals (a phenomena called *phototransduction*) for vision and for other body functions. Optical radiation reaching the retina not only impacts on how humans see the world, it also regulates physiology and behavior, both directly and indirectly. This includes acute effects such as suppressing pineal melatonin production, elevating morning cortisol production, increasing subjective alertness, enhancing psychomotor performance, changing brain activation patterns to a more alert state, elevating heart rate, increasing core body temperature, activating pupil constriction, and even stimulating circadian clock gene expression.

Perhaps the most important and long-term effect of optical radiation is its ability to reset the internal circadian body clock and synchronize it to local time. Circadian rhythms are daily rhythms that repeat approximately every 24 hours and are driven by an endogenous clock. Nearly all behavioral and physiological parameters exhibit circadian rhythms, and thus circadian clock synchronization is paramount to the body's efficient and appropriate functioning. The neurobehavioral (e.g., sleep/wake cycle) and neuroendocrine (e.g., hormone production) axes are thus influenced by optical radiation both directly (acute effects) and indirectly, via circadian clocks that drive and coordinate the rhythmicity in these systems.

One of the most exciting discoveries in science during the past decade was the identification of a novel type of photoreceptor in the retina, called *intrinsically photosensitive retinal ganglion cells* (ipRGCs). This discovery led to a series of studies to better understand the characteristics, function, and role of the ipRGCs. Questions that have been studied thus far include how the ipRGCs respond to optical radiation, how they regenerate after an optical radiation stimulus, how they provide input to