"For the rest of my life, I will reflect on what light is."

—Albert Einstein

I was first introduced to the concept of human-centric lighting by my older brother in the 1990s. I had recently been accepted into the School of the Art Institute of Chicago and moved to the city. My small apartment in Wicker Park was fitted with the old-style yellowish fluorescent tubes, and my brother recommended that I replace them with GE Reveal fluorescents—and what a difference it made. That was only the beginning. My brother, a materials engineer specializing in polymers and composites, was experimenting with using light to combat episodes of seasonal depression. I remember him sitting in front of his makeshift setup, providing a very robust light stimulus, with four 1,000-W portable halogen work lights. He had re-created the sun in his living room.

Today my brother is still experimenting with lighting, but for a different reason. After a scuba diving incident in which he experienced acute decompression sickness, he now has permanent neurologic complications, with symptoms similar to those associated with mild Alzheimer's disease, including a disrupted sleep cycle. To regulate his sleep timing, he has implemented a light-dark pattern with bright light in the morning, dim light in the evening, and darkness at night—with excellent results. This is only a study of n=1, but here at the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute, we are conducting large-scale studies, funded by the National Institute on Aging (NIA), with similarly promising results. Three examples follow.

'Lighting Interventions' Can Touch Many

Three research initiatives at the LRC explore the potential of human-centric lighting

BY REBEKAH MULLANEY

Photo: Ken Glander, Duke University

The populations testing the LRC's Daysimeter have ranged from humans to lemurs.

TREATING ALZHEIMER'S SYMPTOMS

Most people associate Alzheimer's disease with profound memory loss, but it is often the symptoms—sleep disturbances, depression and agitation—that are a challenge to treat, and can significantly reduce the quality of life for both the affected individual and their family members and caregivers.

The director of our research center, Dr. Mariana Figueiro, has been investigating the effects of light on human health for the past 22 years. She presented her newest research results at the Alzheimer's Association International Conference (AAIC) in July, showing that a tailored lighting system can positively impact sleep and mood in people with Alzheimer's disease who are living in long-term care facilities. During the study, participants experienced a lighting intervention from the time they woke up until 6 p.m. Forty-three (43) residents participated in a short, four-week study and 38 residents have completed the long, six-month study thus far, recruited from 10 long-term care facilities in the New York State Capital District; Bennington, VT; and South Bend, IN.

Study participants received light from either a custom-designed LED light table or individualized room lighting, depending on where the participants spent the majority of their time. The short-term study used active lighting delivering high circadian stimulus (CS) or an inactive placebo delivering low CS. The long-term study used only the active lighting delivering high CS, and data were compared to baseline, prior to the lighting intervention. The experimental lighting was measured in terms of CS, which characterizes a light source's effectiveness for stimulating the circadian system. As part of a long-term research effort exploring light's effects on the circadian system, LRC researchers developed the CS metric, which is based on light's ability to acutely suppress the body's production of melatonin after a one-hour exposure.

During the study, each participant wore a Daysimeter to record their CS exposures during baseline and intervention. Sleep disturbances, depression and agitation were evaluated using standard questionnaires and actigraphy. The Daysimeter was developed by the LRC in 2004, and has been used in frequent studies since that time in populations ranging from premature infants to U.S. Navy submariners to lemurs.

Compared to baseline and to the inactive condition, the active lighting delivering high CS significantly decreased sleep disturbances, depression and agitation. While all measures improved, the most significant improvement was seen in sleep quality and rest-activity rhythms consolidation. The depression scores were also impressive. Participants were significantly less depressed while receiving the light treatment. The participants experienced these positive results during the short-term study and continued to improve throughout the duration of the long-term study.

Dr. Figueiro is still accepting participants for the ongoing, long-term study, so we will release additional results in the coming months—however, according to the results we have seen thus far, it appears the positive impact of light is cumulative. Participants continue to improve; their symptoms which affect quality of life continue to decrease.

Recent evidence suggests that disruption of circadian rhythms and fragmentation of daily rest-activity rhythms are not only consequences of Alzheimer's disease but may also drive disease pathology. Sleep-deprived professionals, take note, and continue reading.

The LRC is investigating luminous workstation partitions and a "light oasis" where office workers could receive extra CS.

LIGHTING FOR THE OFFICE

The LRC conducted a study looking at how light can affect office workers, who spend their days indoors in the built environment. Since Americans spend approximately 90 percent of their life indoors, this represents a majority of the population.

In 2017 the LRC published a study showing that office workers who receive high CS during the daytime experience better sleep, and lower levels of depression and stress, than those who spend their days in dim or low light levels. The team of LRC researchers, led by Dr. Figueiro and sponsored by the U.S. General Services Administration, measured existing light levels for 109 participants at five federal office buildings designed to maximize daylight availability indoors. The research team found that even in open offices with many large windows, office workers were not receiving enough light to stimulate their circadian system during the day, due to factors such as season, cloud cover, desk orientation and window shade position.

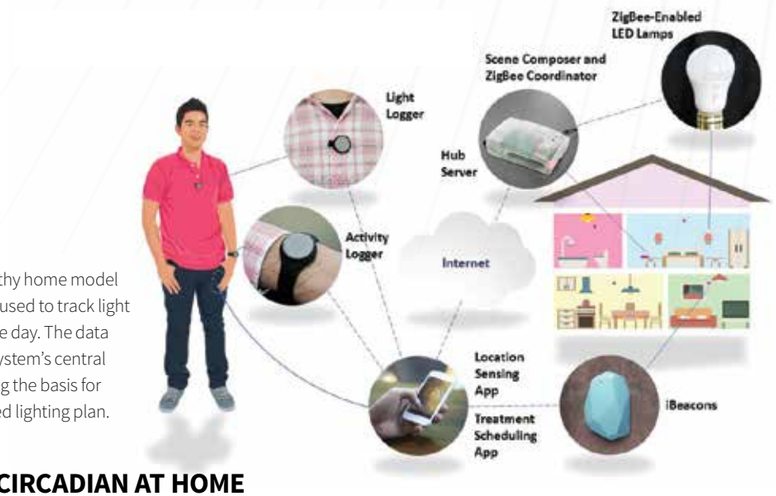
In response to these findings, the LRC theorized that supplemental electric lighting could be used to ensure that office workers receive enough light during the day—and put their theory to the test, installing circadian-effective lighting for 68 participants at two additional U.S. federal government office sites and two U.S. embassies, and evaluating whether the lighting intervention would reduce sleepiness and increase alertness, vitality, and energy. Overhead lighting donated by Cree, Inc. and linear desktop lamps designed by the LRC provided circadian-effective light during the intervention. Each participant wore a Daysimeter to record their CS exposures, and completed standard questionnaires inquiring about their sleep habits, stress, vitality and energy levels.

The participants received significantly higher amounts of CS while at work during the intervention compared to baseline. The study results showed that participants' sleepiness scores were significantly reduced during the intervention and, as hypothesized, they reported feeling significantly more vital, energetic and alert during that time. These results demonstrate that lighting systems delivering a high amount of CS, especially early in

the workday, can reduce sleepiness in office workers while also improving mood and alertness.

The most recent phase of this study, conducted in autumn 2017, evaluated whether a lighting intervention designed to deliver high CS blue light in the morning to promote entrainment and low CS red light in the afternoon to promote alertness would increase office workers' nighttime sleep quality and daytime alertness. Twenty office workers from the U.S. Department of State in Washington, D.C., participated in the study. The LRC developed and built 20 LED luminaires, similar to those pictured, to be placed near the participants' computer monitors. Results show that the high CS blue light in the morning resulted in earlier bedtimes and earlier wake times for the study participants. The low CS red light in the afternoon increased feelings of vitality and decreased sleepiness during the post-lunch dip.

The LRC has developed designs for how this research could be applied, including luminous workstation partitions and a "light oasis" where office workers could receive extra CS, with the aid of a circadian software application that informs them about what type of light (or dark) they need and when they need it.



At the center of the healthy home model is the LRC's Daysimeter, used to track light exposure throughout the day. The data are transmitted to the system's central control station, providing the basis for each user's individualized lighting plan.

CIRCADIAN AT HOME

One question I frequently receive from the media and the general public is: "Are you doing anything with lighting for the home?" And the answer is yes, but it's complicated. For several years, the LRC has been working with Lund University and the Swedish Energy Agency on a project called the Swedish Healthy Home. The Swedish Healthy Home system promotes health and well-being through circadian entrainment while minimizing wasted energy via intelligent control of dynamic lighting.

Imagine a system that can track your light exposure throughout the day, while you are at the office. When you arrive home, the data are transmitted to the central control system, which "prescribes" your ideal lighting plan tailored to your own individual needs. As you step through the door in the evening after work, the system senses your arrival and automatically powers on, with a warm, low light, to minimize circadian disruption in the evening. As you move into and out of any room in the home, the lights power on and off accordingly, so you never need to touch a light switch, thanks to a series of sensors. When you retire for the night, the system dims to its lowest level, providing only enough light to safely navigate. Upon arising the next morning, the lights power on with a robust blue, throughout the home—in the kitchen as you enjoy a cup of coffee (or tea!) and even in the shower—perfect to entrain the circadian system and get you feeling alert and ready for the day. And the system can individualize the treatment for each resident, even if one resident is say, a physician who works nights at the hospital.

At the center of this system is the LRC's Daysimeter, used to track light exposure throughout the day. The data are transmitted to the system's central control station, providing the basis for each user's individualized lighting plan. Sensors determine user location within the home, and the lighting system responds, dynamically adjusting the lighting to provide an intervention specific to each resident to support optimal health and well-being, every day.

FUTURE DIRECTION

Taking a step back from this, you may ask, what about the significant number of individuals who don't have the means, or the desire, to invest heavily in the latest technology? And moreover, the public may wonder, why should they care about lighting?

Every day we at the LRC are discovering new ways in which light can be used to address many of the critical issues of our time. With funding from the National Cancer Institute (NCI), the LRC is currently working with Mount Sinai Hospital to deliver CS, using lamps specially built by Acuity, to benefit cancer survivors. The LRC is also developing incubator lighting to help premature infants in the NICU stay healthy, and ascertaining how UV light can be used to improve disease resistance and reduce the use of agricultural chemicals on crops, while increasing yield.

In a paper published a few months ago in the 50th anniversary issue of *Lighting Research & Technology*, Dr. Figueiro writes, "A new lighting profession needs to emerge, such as personal light and health coaching…" She also notes that another area of research for real impact could be lighting for children in schools. "The next steps would be to educate teachers and parents about the significance of a robust 24-hour light-dark pattern." As children reach adolescence, they can become chronically sleep deprived due to fixed, too-early wake-up times on school days, which has been linked to depression, behavioral issues and poor performance in school. This problem can be compounded by adolescents spending most of their days indoors in dimly-lit classrooms. With new laws passed just this year in New York State and Virginia mandating mental health education in public schools, this may be the perfect time to start educating our nation's children about how light can impact health.

ADDITIONAL RESOURCES

The LRC offers many educational resources, including a series of short videos on the science of lighting for human health, an open-source web-based CS calculator that allows users to estimate the potential CS value that a lighting system will deliver, and CS look-up charts, along with more than 100 research papers and posters. The LRC's website "Lighting Patterns for Healthy Buildings" provides lighting designs for circadian health and alertness, as well as lighting for visual task performance. These resources are available at *www.lrc.rpi.edu/programs/lightHealth/index.asp.* □

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