New Guide Provides Daylighting Designs To Maximize Students' Health And Performance

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The body's internal clock is responsible for regulating the timing of our sleep and other daily biological cycles, called circadian rhythms. During school months, however, teenagers miss out on essential morning light needed to stimulate the 24-hour biological clock. For this reason, professors at the LRC developed a daylighting design guide that balances the photobiological benefits of daylighting with well-known daylight design techniques that can be applied in schools.

"When done properly, these dynamic interiors support human health and activities while also reducing energy demand," said Russ Leslie, LRC associate director, professor, and lead author of the newly published book, Patterns to Daylight Schools for People and Sustainability.

The book is the culmination of a research project that began in 2008, sponsored by the U.S. Green Building Council (USGBC) and, in part, by a grant from a Trans-National Institutes of Health Genes, Environment and Health Initiative (NIH-GEI), to scientifically quantify the impact of daylight design on students' well-being and performance in K-12 schools and investigate the underlying biological mechanisms associated with this possible link.

"When light enters the human eye, the visual system responds differently to it than does the circadian system, which is much more sensitive to short-wavelength (blue) light and needs more light to be activated than the visual system," said Mariana Figueiro, Ph.D., LRC program director, associate professor, and principal investigator. "Today's rigid school schedules requiring teenagers to be in class early in the morning causes them to miss the essential morning light needed to stimulate the circadian system, which regulates body temperature, alertness, appetite, hormones and sleep patterns."

Most schools typically do not provide adequate electric light or daylight to fully stimulate the circadian system, according to Figueiro. However, if designers provide sufficient daylight, which contains ample short-wavelength light, in classrooms, school buildings will be able to provide more circadian stimulation and, therefore, promote improved health, performance and well-being.

Leslie recommends architects use the new book to identify potential approaches, or "patterns," to daylight schools. Similar to traditional architectural pattern books, this one gives model designs that can be adapted to a particular school project. The book includes a "daylighting dashboard" to quickly compare the patterns graphically with indicators of cost, comfort, the visual environment, and energy use. The publication offers conceptual daylight approaches for the three most common spaces in schools: classrooms, corridors, and gymnasiums.

LRC Senior Research Specialist Aaron Smith, LRC Lead Research Specialist Leora Radetsky, LRC Associate Professor Mariana Figueiro, and LRC graduate student Lisa Yue contributed as co-authors of Patterns to Daylight Schools for People and Sustainability.

Setting the body's clock

The human biological clock runs with a period slightly greater than 24 hours. Each morning when we receive sufficient light, the biological clock is "reset" to match the 24-hour solar day. Bright days and dark nights are ideal for regulating this biological system, called the circadian system. One of the biological functions regulated by the circadian system is the production of melatonin, a hormone produced in the evening and under conditions of darkness that indicates to the body when it is nighttime. Sleep typically occurs about two hours after the onset of melatonin.

Field tests quantify the impact of daylight design on students

Figueiro and LRC Director Mark Rea, Ph.D., performed a series of field tests in 2009 funded by USBGC and NIH-GEI to examine the impact of removing morning light on teens' melatonin onset and sleep times, as well as the seasonal impact and the increased evening light exposure during the spring months on teens' melatonin onset and sleep times.

Each subject wore a Daysimeter™, a small, head-mounted device developed by the LRC to measure an individual's exposure to daily "circadian light," as well as rest and activity patterns. The definition of circadian

light is based upon the potential for light to suppress melatonin synthesis at night, as opposed to measuring light in terms of how it stimulates the visual system.

“The field tests support the general hypothesis that the entire 24-hour pattern of light/dark exposure influences synchronization of the body’s circadian clock with the solar day and thus influences teenagers’ sleep/wake cycles,” explained Figueiro. “As a general rule, teenagers should increase morning daylight exposure year round and decrease evening daylight exposure in the spring to help ensure that they will get sufficient sleep before going to school.”

Results of the studies were detailed in the following papers:

-Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students,” published by the journal, Neuroendocrinology Letters. The paper can be accessed here.

OBJECTIVE: **Circadian timing affects sleep onset**. Delayed sleep onset can reduce sleep duration in adolescents required to awake early for a fixed school schedule. **The absence of short-wavelength (“blue”) morning light, which helps entrain the circadian system, can hypothetically delay sleep onset and decrease sleep duration in adolescents.** The goal of this study was to investigate whether removal of short-wavelength light during the morning hours delayed the onset of melatonin in young adults.

METHODS: Dim light melatonin onset (**DLMO**) was measured in eleven 8th-grade students before and after **wearing orange glasses**, which removed short-wavelength light, for a five-day school week.

RESULTS: DLMO was significantly delayed (30 minutes) after the five-day intervention, **demonstrating that short-wavelength light exposure during the day can be important for advancing circadian rhythms in students.**

CONCLUSIONS: Lack of short-wavelength light in the morning has been shown to delay the circadian clock in controlled laboratory conditions. The results presented here are the first to show, outside laboratory conditions, that **removal of short-wavelength light in the morning hours can delay DLMO in 8th-grade students**. These field data, consistent with results from controlled laboratory studies, are directly relevant to lighting practice in schools.

-Measuring circadian light and its impact on adolescents,” published by the journal, Lighting Research and Technology. The paper can be accessed here.

Abstract

A field study was conducted with eighth-grade students to determine the impact of morning light on circadian timing, sleep duration and performance. Before and during school hours for a week in February 2009, half the students studied wore **orange glasses that minimized the short-wavelength light exposure** needed for circadian system stimulation. A control group did not wear the orange glasses. The **Daysimeter**, a circadian light meter, measured light/dark exposures in both groups for 7 days. **Circadian timing was significantly delayed for those students who wore orange glasses** compared to the control group. **Sleep durations were slightly**, but not significantly, **curtailed in the orange-glasses group**. Performance scores on a brief, standardized psychomotor vigilance test and self-reports of well-being were not significantly different between the two groups.

-Evening daylight may cause adolescents to sleep less in spring than in winter," published by the journal, Chronobiology International. The paper can be accessed here.

Evening daylight may cause adolescents to sleep less in spring than in winter.

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Abstract

Sleep restriction commonly experienced by adolescents can stem from a slower increase in sleep pressure by the homeostatic processes and from phase delays of the circadian system. With regard to the latter potential cause, the authors hypothesized that because there is more natural evening light during the spring than winter, a sample of adolescent students would be more phase delayed in spring than in winter, would have later sleep onset times, and because of fixed school schedules would have shorter sleep durations. Sixteen eighth-grade subjects were recruited for the study. The authors collected sleep logs and saliva samples to determine their dim light melatonin onset (DLMO), a well-established circadian marker. Actual circadian light exposures experienced by a subset of 12 subjects over the course of 7 days in winter and in spring using a personal, head-worn, circadian light measurement device are also reported here. **Results showed that this sample of adolescents was exposed to significantly more circadian light in spring than in winter**, **especially during the evening hours when light exposure would likely delay circadian phase.** Consistent with the light data, DLMO and **sleep onset times were significantly more delayed, and sleep durations were significantly shorter in spring than in winter.** The present ecological study of light, circadian phase, and self-reported sleep suggests that **greater access to evening daylight in the spring may lead to sleep restriction in adolescents while attending school.** Therefore, **lighting schemes that reduce evening light in the spring may encourage longer sleep times in adolescents.**