Optimizing lighting for better learning

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Larkmead School. Credit: CC-BY-SA-2.5,2.0,1.0

The intensity of artificial lighting has been shown to have a range of effects on our mood and our ability to concentrate. New research explores the color of lighting and its effect on our cognitive performance. The study, published in in the journal *Optics Express*, from The Optical Society (OSA), was conducted by Kyungah Choi and Hyeon-Jeong Suk, associate professor of industrial design at the Korea Advanced Institute of Science and Technology (KAIST) in South Korea and head of the Institute's "color laboratory."

In their study, Choi and Suk looked specifically at the effects of different correlated color temperatures, or CCTs. The CCT is a simple way to characterize the color appearance of a light source. A low

CCT—below 3500 Kelvin (K)—provides light that appears "warm" (yellowish white), while a high CCT—more than 5000 K—provides light that appears "cool" (bluish white).

"Incandescent light bulbs emit light between 2500 K and 3000 K, which is perceived as yellowish white, and daylight CCT is about 6500 K and is perceived as bluish white," explained Suk. Fluorescent lamps can be purchased with fixed CCT options ranging from 2500 K to 5000 K. "The notable feature of light-emitting diodes [LEDs] that is absent in conventional light sources such as incandescent and fluorescent lamps is that their CCT can be controlled," she said.

In a preliminary study with adult volunteers in a laboratory setting, Suk and Choi examined the effect of different CCT lighting conditions (3500, 5000 and 6500 K) on the level of physiological alertness, measured using electrodes placed on the skin of the wrists and ankles for recording of electrocardiogram (ECG), which is known to exhibit different characters depending on the alerted state of a subject. The study was conducted in a room equipped with an LED luminous ceiling, with the CCTs of the ambient lighting controlled by adjusting the red, green, blue, and white levels of the light. As predicted, the 6500 K lighting condition led to the highest level of physiological alertness while the 3500 K condition was the most "relaxing."

Next, the researchers tested the effect of the three different lighting conditions on the academic performance and recess activities of fourth-grade children in a simulated classroom in the same lab. To test academic performance, students were given timed arithmetic tests. Curiously, Choi and Suk found no significant variation in performance under the various conditions. In other words, the "stimulating" 6500 K CCT light did not help the students do better on tests. "A plausible explanation for the lack of meaningful in-lab results is that the test subjects were placed in an artificial setting and exposed to the lightings for only a short time," Suk said.

To see if prolonged exposure to the lighting conditions would produce a different outcome, Suk and Choi studied two additional groups of fourth-grade students in real-life classrooms—one equipped with LED lights that can be tuned to CCT of 3500 K, 5000 K, and 6500 K and the other with standard fluorescent lights, as a control. Here, as expected, the students scored best on academic tests when they worked under the 6500 K lighting condition and performed best on recess activities under 3500 K lighting.

The research result shows that the 6500 K condition led to stimulation of higher alertness states—and the greatest enhancement of academic performance—follows the predictions of the so-called Yerkes-Dodson Law. Developed more than a century ago by psychologists Robert Yerkes and John Dodson, the law postulates that there is a curvilinear relationship between mental arousal (or stress) and performance. That is, people tend to perform best at certain intermediate levels of mental arousal (in this case, under the 6500 K lighting condition) and worse when these levels are either too low or too high.

This suggests, not surprisingly, that there is a limit to how intense classroom lighting can be before academic performance would stop improving, and eventually decline. The duration of exposure to the intense lighting condition could also affect performance. "Future work could be done to investigate the ideal exposure time for each lighting condition," Suk said.

At the end of their study, the research team demonstrated a mobile-app-based dynamic lighting system with preset conditions of "easy," "standard" and "intensive" for smart learning environments. In addition, Choi is now developing an integrated visual system that can adaptively tune the CCT of visual-display terminals, such as electronic books and smart boards, in correlation with that of lighting to optimize the effects on learning and performance.

"We believe that small changes in classroom environment, such as lighting conditions, could make a dramatic difference in supporting students' learning," Suk said.

More information: Kyungah Choi and Hyeon-Jeong Suk, "Dynamic lighting system for the learning environment: performance of elementary students," *Opt. Express* 24, A907-A916 (2016).
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