Maximizing Energy Savings with Optimized Dimming Ramp Rates in Retail and Museum Buildings

According to a study conducted by the U.S. Department of Energy, lighting accounts for 18% of the energy used by commercial buildings in the U.S., making lighting upgrades with controls a significant opportunity for energy savings. When properly designed, today’s LED technology pairs well with advanced controls. One example of a lighting control strategy typically used in circulation spaces for commercial buildings like offices and schools is occupancy sensing, which automatically turns lights off when spaces are unoccupied and turns lights on when spaces are occupied. Studies show that occupancy sensors—also known as motion sensors—can help reduce electrical lighting energy use ranging from 25% to 50%. The actual savings realized depend on decisions made during the commissioning process of the lighting system, including the desired “low level” light output used during unoccupied periods and the rate at which the system changes its light output from high to low, known as a “ramp rate.”

Despite this, museums and retail stores do not generally accept dynamic dimming of their lighting systems due to the potential for visual disruption and distraction. This limits smart lighting implementation in these applications, which could contribute to deeper energy savings. To determine the ideal ramp rate where occupants will ideally not be disturbed, researchers at UC Davis’ California Lighting Technology Center, in collaboration with the Universidad Autónoma de Guadalajara in Mexico, recently conducted a study with 70 participants. This study focused on exploring the Just Noticeable Difference (JND)—also known as the difference threshold—which is the minimum level of stimulation that a person can detect 50% of the time. Researchers tested perception to changes in light levels with both central and peripheral vision at different dimming ramp rates.

Central Vision Experiment. For the central vision experiment, researchers described the worst-case scenario typically experienced by visitors to museums and retail applications when they are looking at art or product displays. In particular, the experiment focused on a representative art exhibit with changing vertical illuminance levels. The study compared the responses of 70 participants when shown varying lighting conditions where lights were dimmed gradually using 5-second, 10-second and 20-second ramps rates; the experimental setup can be seen in Figure 1.

A white canvas was placed in front of the study participant as the targeted view. In the experiment, three ceiling-mounted lighting fixtures that each produced 1,690 lumens were placed 4 ft away from the target. Full output lighting conditions from these fixtures provided 14 footcandles of vertical illuminance on the white canvas. The lights were controlled by a DMX lighting control system capable of precise changes in light output.

The experiment tested conditions that included changes from 100% light output to 95%, 90%, 85%, 80%, 75% and 70% full light output with four different ramp rates:
1. No ramp rate
2. 5-second ramp rate
3. 10-second ramp rate
4. 20-second ramp rate.

Each condition was tested in
a randomized sequence to minimize the impact of learning patterns on the results. Participants were seated and asked to direct their attention to the white canvas for each condition. They were then asked if they could see any change in the light level on the canvas after the presentation of each condition, with possible responses of “yes,” “no” or “maybe” (known as a “forced choice” survey question).

**Figure 2** provides the results of the central vision experiment. The most significant difference in visual perception was noted between instant changes in light output and changes coupled with the ramp rates tested. For each of the tested conditions, researchers implemented a control condition where the lights did not change, and participants reported that they noticed changes in light output. This evaluated the participants’ baseline attention, and it is represented in the following chart in negative as “experiment uncertainty” with a final value between 6% and 8%.

The results of this study demonstrate that the use of ramp rates when dimming lighting systems can effectively minimize the perception of changes in light output compared to instantaneous dimming. For instance, when the most aggressive scene was tested, where the light output went from 100% to 70%, 60% of the participants were unable to detect this change when paired with the 20-second ramp rate. Similarly, when the light output was reduced from 100% to 80% with a 20-second ramp rate, 80% of the participants could not perceive any change in their lighting environment.

The study found that all three tested ramp rates had a similar effect on reducing perception, with only minor differences observed between each ramp rate. The responses from participants were similar for both the
5-second and 10-second ramp rates in terms of their ability to detect changes in light output. However, extending the duration to a 20-second ramp rate slightly enhanced the reduction in perception.

This data indicates that implementing longer ramp rates can be beneficial in instances where maintaining an undisturbed user experience is a priority—such as high-end retail establishments and museums. In addition, the data supports the dimming of light levels by a minimum of 20% of full light output to save energy and avoid the visual distraction typically thought to be caused by dimming.

**Peripheral Vision Experiment.** For the peripheral vision experiment, researchers described a representative scenario where people walking through a museum or retail space would perceive a change in light levels with their peripheral vision when they are looking at art displays. The responses of the same 70 participants from the central vision experiment were compared to understand if there is a perception difference between the complete human field of vision.

The experiment tested conditions that involved changes from 100% light output to 90%, 80% and 70% full light output with three different ramp rates:

1. No ramp rate
2. 5-second ramp rate
3. 10-second ramp rate.

**Figure 3** displays the experimental layout, with the participants’ eyes directed toward the left side of the room. They were instructed to focus on the statue in their foveal vision while a white canvas, identical to the one used in the central vision experiment, was placed in their peripheral vision. When asked if they could detect changes in light levels in their peripheral vision, participants were required to respond with a forced choice of “yes,” “no” or “maybe”.

The results of the peripheral vision experiment are presented in **Figure 4**. It was observed that the human eye was slightly less sensitive to minor changes in light levels in the peripheral vision compared to the central vision results. However, participants experienced fewer false positive perceptions when the lights were not changed on the No ramp rate section and the 10-second ramp rate section, thereby reducing experimental uncertainty. This graph shows that dimming lights to 80% of light output with a 10-second ramp rate was not detectable to 90% of the participants; however, it was noticed by 80% of participants when the lights changed instantly.

This research demonstrates that the immediate dimming of lights can be easily perceived by the typical human eye, with over 70% of participants able to detect reductions in light output of more than 5%. To minimize these distractions in spaces such as commercial buildings including offices, schools, retail establishments and museums, it is recommended to employ ramp rates when dimming lights.

For lighting designers, the findings of this research can be utilized in defining occupancy sensing settings, as this approach promotes both energy savings and reduced disturbance for occupants. The study indicates that 5-second and 10-second ramp rates are the optimal choice for lighting designers aiming to achieve a
5-20% reduction in power without causing disturbance to most occupants. This translates to an average reduction of 30 lumens per second—or, as tested in this experiment, decreasing at a rate of 0.7 watts per second for each of the three fixtures. To achieve a power usage reduction of more than 25%, it is advised to use ramp rates of at least 20 seconds or longer. This corresponds to an average reduction of 25 lumens per second—or, as tested in this experiment, decreasing at a rate of 0.5 watts per second per fixture. These findings will help building owners achieve energy savings and decarbonization efforts where visual performance and sensitivity are critical. The next steps for this research include exploring JND studies when ramping up light levels in real-world scenarios.

THE AUTHORS
Diana Valeria Araiza Soto is a survey researcher at CLTC, graduated with a Master of Fine Arts from the University of California in Davis, and is an associate professor at the Universidad Autónoma de Guadalajara in Mexico.

Jae Yong Suk, Ph.D., is the associate director of the CLTC and associate professor in the Department of Design at UC Davis.

Michael Siminovitch, Ph.D., is the director of the CLTC and associate director of the Energy and Efficiency Institute at UC Davis.

Nicole Hathaway, LC, is an R&D engineer IV and the communications director at CLTC.

References:
1. Desroches and Gabersy, 2011
2. Von Neida et al., 2013