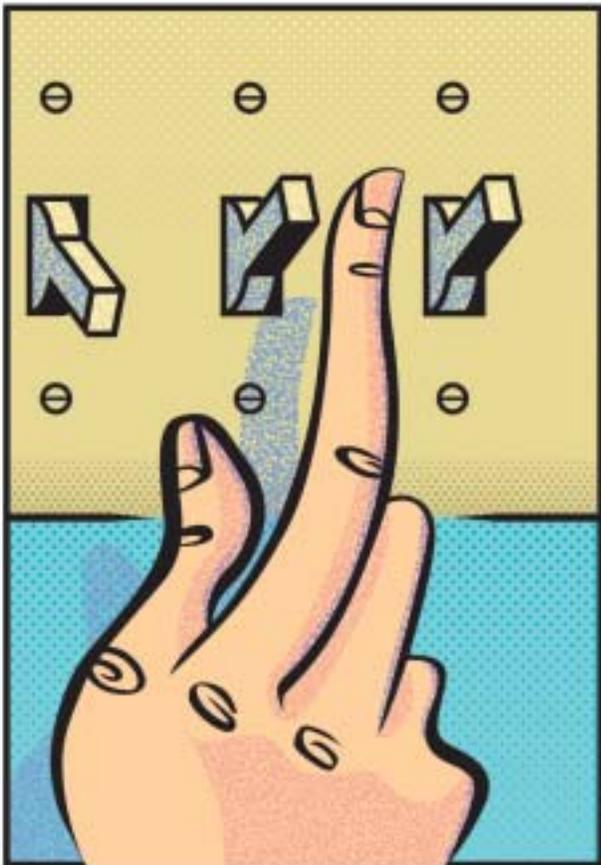# Bright Idea

Personal Control for Office Lighting

Providing light for the workplace has always been at the top of the list for those who build and manage offices. However, they have tended to focus on the effects lighting has on a building's performance, often at the expense of the people who work there. The cause of this focus has been the rising costs of real estate and energy.

Arguing for a human-centered approach to lighting, one noted expert says that "occupancy quality must take precedence over energy use and sustainability. These now lead. It's time to switch the focus to people and their task performance." [1]

While people prefer natural light, their workplaces, for obvious practical reasons, are lit by some combination of daylighting (perhaps with views to the outside) and artificial lighting. Within that range of illumination, people have clear preferences for how much and what kind of light they want.

The fact that preferences vary—among people and for the same person at various times during the day—argues for giving them some control. Whatever else people say about office lighting, they make it clear they want the ability to adjust it themselves. And they will adjust it quite differently based on the quality and visual performance of local lighting, ambient lighting, and daylighting.

Giving people control over their lighting helps them feel more satisfied with their workplace. It affects their performance, too, helping them stay engaged in tasks longer and to avoid fatigue. And, lighting that is appropriate for the individual can also increase energy savings if adjustability is part of the picture.

The individual's right to light

Anyone who has worked in a windowless office lit by fluorescent lights knows something people often take for granted—their affinity for natural light. The strength of that attraction has fueled the trend toward opening up the office with windows and skylights.

The push began in 1975 with the Workplace Ordinance in Germany. It, in turn, influenced the 1989 European Union directive that "workplaces must as far as possible receive sufficient natural light and be equipped with artificial lighting adequate for the protection of workers' safety and health." Recent laws in Denmark, perhaps the most stringent in Europe, require that all workplaces have access to daylight.[2]

In other areas, accreditation programs are taking the place of legislation. These include the Building Research Establishment Environmental Assessment Model (BREEAM) in the U.K., the Green Building Challenge (a collaboration of 20 countries committed to developing a global standard for environmental assessment),[3] and the Leadership in Energy and Environmental Design (LEED) system in the U.S.

All of these programs, however, only touch on natural lighting. For example, of the 57 available credits under the LEED program, one credit can be obtained by ensuring a minimum of 2 percent daylight factor over 75 percent of the floor space, and another credit by providing a direct line of sight to windows from 90 percent of the floor space.

The role of natural light in the workplace can also relate to business objectives. One pilot study conducted during the winter months found that office workers assigned to interior or windowed offices both occupied their workstation about the same amount of time. However, those with "windowed offices spent more time on computer tasks and less time talking on the telephone and to coworkers than matched workers in interior offices. The root cause of these findings remains unknown, but the results are consistent with the hypothesis that bright light during the day improves productivity during winter months."[4]

In addition to the positive effects of daylighting, it has a clear range of negative effects related to

- Luminance ratios of daylighting to the task

- Visual adaptation problems from reduced ability to see the task in the presence of bright daylighting

- Increased stress on the older worker because of uncontrolled daylighting

The tendency toward floor-to-ceiling glazed architecture combined with the desire for simplicity often results in uncontrolled glare, which reduces the ability to work.

Bringing individual control into the mix

Daylight, and the views to the outside often associated with it, are wonderful supplements to the artificial lighting that illuminates offices. In most cases, that artificial lighting takes several forms: general, or ambient (think rows of fluorescents); task (from under cabinet to freestanding); and vertical luminance (also known as "wall washing").

Most ambient lighting is direct, indirect, or some combination of these. It is often installed in regular patterns. Even when the layout of the ambient lighting is set up based on the use and density of an office, inefficiencies often result when offices move or a new tenant occupies the space. That has prompted many lighting professionals to lower ambient lighting levels overall and use task lighting to give people the illumination they need for their work. It has also fostered the use of asymmetric lighting that can be easily reconfigured along with workstations. One of the most efficient methods of dealing with light is to put it where it is needed and to have it turn off when occupants are not there.

Professional associations have begun to address the combination of ambient and task lighting by setting standards for various tasks. Most lighting practitioners work principally with illuminance values (foot candles, or lux.) The Illuminating Engineering Society of North America (IESNA) recommends, for example, 50 foot-candles for someone performing visual tasks of high contrast and small size but just 3 foot-candles for traversing public spaces.

The challenge for designers and lighting professionals is to balance the level of illumination and its quality, taking into account both artificial and natural lighting. They often do this by putting the computer in charge. Daylighting control systems typically com-

bine motorized window and skylight covers, dimmable lighting fixtures, and photo sensors to measure available daylight. A computer takes the information from the photo sensor and adjusts daylight controls and lights accordingly. This approach is quite effective for regulating illuminance on the work surface, but it is less so in controlling glare from daylighting.

Lighting experts agree, however, that these photocontrolled systems are ripe for improvement. The U.S. Department of Energy (DOE), for example, says these systems must increase their intelligence, levels of control, and ease of use. Better lighting control systems, notes the DOE, are one of the agency's three key technology development strategies for the future.[5]

Bringing some human control into the mix provides another opportunity for advancement. "A central challenge for future lighting systems is to allow end-user control of light intensity, color, color temperature, quality, and distribution within the space, and control technologies need to be easy, intuitive, robust, and simple, and must be integrated with interoperable building-level controls."[6]

And there is a new movement to provide temporally changing perceptual environments with lighting and colored lighting. It is "an effort to provide, independent of user input, environments that attempt to track user preference and to provide constantly adapting visual environments intended to please, stimulate, and comfort the occupant."[7]

The importance of getting humans involved is confirmed by research. A study in the U.K., for example, compared 410 office workers in 14 buildings. Half of the buildings had automatic lighting systems, the other half user-controlled systems. Even though the people working in facilities with no user control had lighting conditions that met current recommendations, they viewed their installations less positively than those who worked in facilities where they could control lighting quality and quantity.[8]

The authors of a review of research into daylighting in offices said the U.K. study "suggests that occupants preferred to have the capability to choose their own lighting environment rather than having to accept lighting levels chosen for them, even when these lighting levels were 'better' according to recommendations." They went on to conclude that "photocontrolled lighting systems have best accept-

Individual control is important because a fixed lighting environment cannot meet each person's preferences.

ance when there is individual override control provided to users." [9]

Individual control is important because a fixed lighting environment cannot meet each person's preferences. In a study of test participants who were given control over dimmable lighting circuits, researchers used simple regression to model the relationship between variables and arrive at a preferred desktop illuminance range—200 to 500 lux. The range didn't satisfy everyone, however. Those who experienced lit environments substantially different from their preferred level had significantly lower ratings of pleasure (mood), lighting quality, and overall satisfaction with the environment.

People with control over their lighting consistently report greater satisfaction with their work environment.

The researchers also looked at their data to determine what fraction of the participants would have been within 100 lux of their chosen illuminance. A plateau occurred between 275 and 600 lux. While this range might be used as a basis for deriving illuminance conditions for offices with desktop computers, the authors of the study noted "that no more than 40 to 50 percent of occupants can ever be within 100 lux of their preferred condition, with its associated satisfaction benefit, no mater what fixed illuminance is chosen. Here is a reason for providing individual control over lighting conditions." [10]

Giving control has become easier because of recent developments in the design of task lighting. Some furniture-attached task lighting now has better lenses that reduce veiling reflections, glare, and shadows. Well-designed freestanding articulated task lights can be adjusted to an individual's preferences and task requirements. In some cases, occupancy sensors turn task lights off when a person leaves his or her work area.

Other advances have broadened the adjustment of task lights to go beyond the physical positioning of the fixture. Some task lights now use LED (light emitting diode) technology to allow adjustment of light intensity and color temperature. Being able to make these adjustments affects both how people do their work and how they feel about their workplace.

Research conducted in the Netherlands found a rela-

tionship between the desktop daylight illuminance and the color temperature workers preferred. "This suggests that at low daylight levels (500 lux) the average preferred colour temperature was around 3300 K, while at higher daylight levels (1500 lux), the preferred colour temperature increased to 4300 K." This means that as lighting increases, occupants preferred cooler, "daylight" color temperatures. The authors of the study also found that "keeping a constant working plane illuminance would not meet occupants' needs and preferences." [11]

As a result of its adjustability—position, intensity, color—task lighting has become increasingly popular. In fact, lighting professionals typically turn to free-standing task lighting as their preferred way to give people illumination in their workstations.

In some cases, lighting control extends to automated, general, and personal control of color washes applied to areas of the office space. For example, lighting may illuminate the core walls in a building in response to outside weather conditions, cuing warm colored lighting on cold winter days or cool blue core walls on warm days. Each modulates in intensity in relationship to the momentary daylighting intensity. This same lighting may modulate from one color to another during the day in response to activity cues, such as the cycle of intensity of movement or sound in the office. Thus, by either direct control, or more likely, by computer control, the presence of and change in environmental colors may positively affect the aesthetics, mood, and information value of the space. [12]

How people see affects how they feel

People see based on visibility rather than illuminance. Visibility is a function of luminance (brightness), contrast, task size and difficulty, the demographics of the viewer, and the luminous conditions of the environment.

Although occupants respond to many of these variables, they do so quite automatically without really understanding them. This is one reason that individual control is very useful. Many parameters of the task and environment that would be very difficult to assess quickly can be assessed unconsciously by occupants used to meeting both reasonable performance conditions and their preferences. [13]

While it appears that the absence of lighting controls may not be crucial when overall lighting is high in quality, [14] control does have its benefits. People with control over their lighting consistently report greater satisfaction with their work environment.

In a field study conducted in an office in Albany, New York, nine participants experienced six different conditions using various combinations of direct and indirect lighting. The open office plan featured perimeter windows and access to a view, as well as translucent window shades to alleviate glare.

The workers did 15 distinct tasks under different lighting conditions for a typical eight-hour day per condition. In addition to collecting output measures on these tasks, the researchers asked subjects to complete a questionnaire at the end of each day to gauge their impressions of the lighting.

Typically, people operate lights at much less than maximum output.

About 70 percent reported that direct/indirect fixtures along with wall washing around the perimeter were more comfortable than lensed and parabolic fluorescent fixtures. Reports of comfort increased to 91 percent, however, for the environment that included dimming controls. People with dimming control also reported higher ratings of lighting quality, overall environmental satisfaction, and self-rated productivity.[15]

While further analysis of the data related to the effect of fixed lighting on task performance found no statistically significant correlation, there were indications of "some advantage of having personal control of the lighting for task performance over time. More importantly, these interaction effects suggest that the availability of control can offset declining performance over the working day; that is, it might be a means of inoculation against fatigue."[16]

The question of whether giving people control over their lighting affects the quality of their work has been difficult to answer. Most attempts have set up laboratory experiments to track how workers do on vision and cognitive tests. In one, 118 participants worked for a single day under one of four lighting designs. They had no control over the lighting until the latter half of the afternoon, when all participants were offered some form of individual dimming lighting control.

Those who made the biggest changes to lighting conditions after they were given control tended to register the biggest improvements in mood, satisfaction, and comfort outcomes.

Participants who made little change registered no improvements in outcomes. "Task performance results were more equivocal," the authors of the study note. "On many tasks, performance did significantly improve after control was introduced, but we attribute these improvements primarily to known practice effects."[17]

Some research findings do support the concept that seeing well—and having control over the position, intensity, and color of the light—helps people work longer and avoid fatigue. People also say that good lighting quality helps them work better. In a U.K. study, for example, researchers found "a small but statistically significant correlation (r = 0.16 to 0.49) between level of individual control of the environment and self-reported productivity in seven of eleven office buildings evaluated."[18]

The effect of personal control on energy use

Even without a clear correlation between individual lighting control and worker performance, the connection between controls and energy savings is strong. Studies have shown that in installations with individual lighting controls, people operate lights at much less than maximum output. Even when they choose these lower levels of illumination, people report they are satisfied with their overall environment. According to one researcher, this "suggests a great potential for energy savings without affecting negatively the occupants' perceived lighting quality."[19]

The U.S. government recently commissioned a study to identify ways to save 14,000 BTUs per gross square foot by 2014 in the buildings federal agencies occupy. The authors of the study identified four technologies that offer the greatest promise for energy savings. One of those technologies involves task and ambient lighting. "The use of advanced luminaire technologies and lower ambient (room) light levels in combination with localized task lighting offers savings in federal office areas of 15 to 25 percent, with scientifically measured occupant comfort improvements of 10 to 16 percent."[20]

Ambient lighting may soon take advantage of energy-efficient LED luminaires. The U.S. Department of Energy is sponsoring research that seeks to double or triple the power output of LEDs in three years.[21] Elsewhere, researchers have made semiconductor LEDs more than seven times brighter by etching nanoscale grooves in a surrounding cavity to guide scattered light in one direction.[22] If

development of this kind continues, LED lighting could eventually replace incandescent and fluorescent lamps for general illumination.

The attractiveness of new technologies, especially for energy savings, may divert attention from the individual's needs for lighting quality, however. To keep that from happening, everyone—lighting professionals, architects, building owners, facility managers—must remain vigilant. They have good reason to: Given that people represent about 85 percent of the costs associated with a building, it is logical that decisions about lighting, as well as other elements of the space that affect those working there, should take their cue from the occupants.

Notes

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