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COMPARING INDIVIDUAL DIMMING CONTROL TO OTHER CONTROL OPTIONS IN OFFICES

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By most estimates, lighting is responsible for 30-40% of electrical energy use in office buildings. As such, in the drive towards sustainability, lighting has been a principal target for energy savings. Energy codes, guidelines, and green building rating schemes all encourage lighting energy savings. While these documents have often focused on reducing installed lighting power density (LPD), there is growing interest in using more sophisticated lighting controls to substantially lower energy use. After all, energy use depends not only on the power draw of the lighting system at full output, but also the time that it is off, or at partial output.

We have recently completed two studies that examined the energy savings from individual dimming control in offices, and compared these to the performance of other control options. In the latter study we also looked at the energy savings of individual dimming control, daylight harvesting, and occupancy sensors in combination. The results, assessed alongside prior research, suggest that individual dimming control may be worthy of greater consideration as a sustainable lighting control option.

Laboratory Study

Participants were seated towards the back of a large private office with large, low-transmission windows facing just east of south, located in Ottawa Canada. The participants conducted typical office work during a day, but were prompted every 30 minutes to use software on their computer to choose their preferred light output from recessed parabolic luminaires. The maximum electric light on the desktop was around 700 lx, whereas the maximum daylight contribution was around 500 lx [Newsham et al., 2007] during the April-July period of the study.

The mean desktop illuminance preferences of the forty individuals varied widely, from around 200 lx to 900 lx (Figure 1). But throughout the day, the choices of an individual varied almost as much. This is interesting because daylight harvesting systems are typically designed to deliver the same constant light level (typically 500 lx) to all, but this is clearly not what occupants choose for themselves.

The wide range of preferred illuminances meant a similarly wide range of lighting energy use on each day. However, on average, energy use with individual dimming control was 25% lower than if the same lighting system had delivered a constant 500 lx of electric lighting. Although we did not measure a daylight harvesting system directly, the data indicated that a perfect closed-loop system set to 500 lx would have saved 38%.

Field Study

In this study, led by my colleague Anca Galasiu, we monitored for a year the performance of a lighting system installed on four floors of a typical open-plan office building [Galasiu et al., 2007]. The workstation-specific, direct-indirect luminaires had two downlamps, and one uplamp (Figure 2). The luminaires featured integral occupancy sensors (OS), integral light sensors for daylight harvesting (DH), and individual dimming control (IC) accessed through sliders on the occupants' computer screens, to control the downlamps; the uplamp was on at full output during the work day.

This lighting system used 69% less energy than the conventional recessed parabolic system installed elsewhere in the building (Figure 3). Two-thirds of these savings were due to the lower LPD of the system (5.8 W/m^2 vs. 10 W/m^2), and one-third was associated with the controls. Furthermore, there were concomitant reductions in the daily peak power demand for lighting. The daily average effective lighting power density, accounting for the fact that not all luminaires were on at full power at any given time, peaked at only 3 W/m^2. This represents an important benefit for electric utilities. These results demonstrate that these controls can be successfully implemented even in open-plan offices.

System data allowed us to derive the energy savings that would have occurred had one type of control had been installed, so we can compare the relative energy savings potential of each control option. If used on their own, and averaged across all 86 studied workstations, the occupancy sensors would have saved about 35% compared to the direct-indirect luminaires at full power. In comparison, daylight harvesting would have saved about 20%, and the individual controls about 10%; as expected, savings for both these control types would have been higher near to windows.

The Pros and Cons of Each Control Option

Although every site will have its peculiarities, there is enough published research to be able to rank-order the various control types on several dimensions: energy savings, effects on occupants, and initial cost. This is shown in Table 1.

Our findings on energy savings are largely consistent with previous studies [e.g. Figueiro, 2004; Rubinstein et al., 1999]. All control types save energy; occupancy sensors save substantial amounts of energy in all offices, daylighting harvesting can save as much near windows but not further away, and individual controls save the least.

When it comes to effects on people, the best that automatic controls can be is neutral, and they are often negative. It is not unusual for daylight harvesting systems to be disabled because they behaved in ways that did not match occupant expectations [Heschong Mahone Group, 2006], and we have all had the experience of occupancy sensors leaving us in the dark. On the other hand, there is growing evidence that individual dimming controls improve occupant satisfaction [Newsham et al., 2004], and perhaps some aspects of performance [Boyce et al., 2006]. In our field study people typically used the controls when first available to pick a general preferred level, and then only rarely after that, on average about once every 50 days. This infrequent use is often presented as an argument against providing individual control. But their use is similar to how people use controls on office chairs, and few would suggest these controls do not have value.

For initial cost, occupancy sensors can be expected to be the cheapest, because in isolation they do not require dimming ballasts. Successful daylight harvesting generally does employ dimming ballasts, and also requires more complex commissioning and control logic. Individual control does not require any sensors, but, if enacted through on-screen software, does impose IT costs.

Table 1. Comparison of lighting control options for offices on several dimensions.

	Energy Savings	**Effect on People**	**Initial Cost**
Occupancy Sensors	+ + +	☹	$
Daylight Harvesting	+ +	☹	$ $ $
Individual Control	+	☺	$ $

It is clear that lighting controls can facilitate substantial energy savings in offices. For a truly sustainable solution one should consider the relative merits of different control options in several dimensions and applied to the specific site, and not focus only on the option that is expected to save most energy. In this context, individual control may deserve more consideration by the green building design team.

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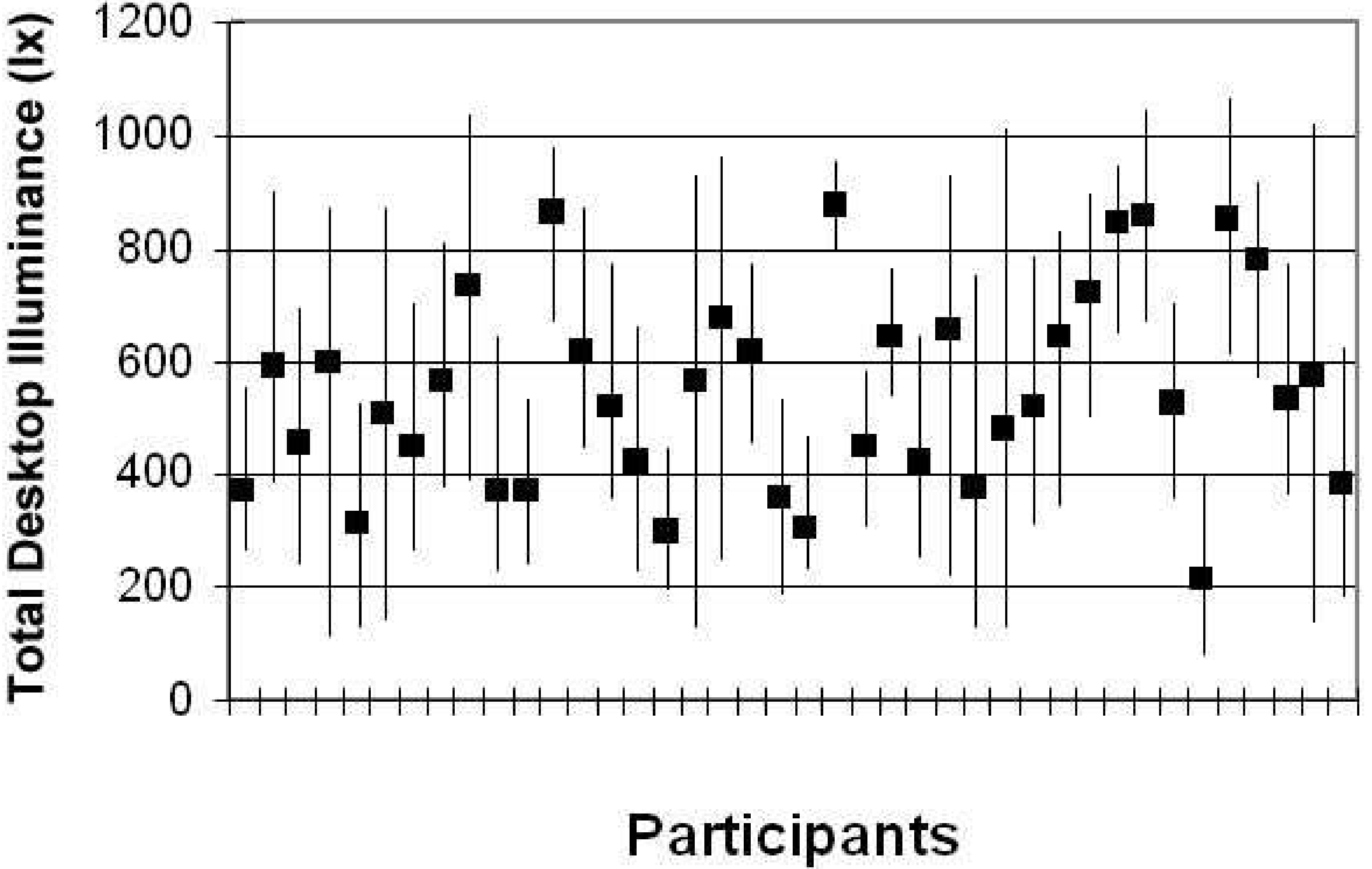
Figure Labels

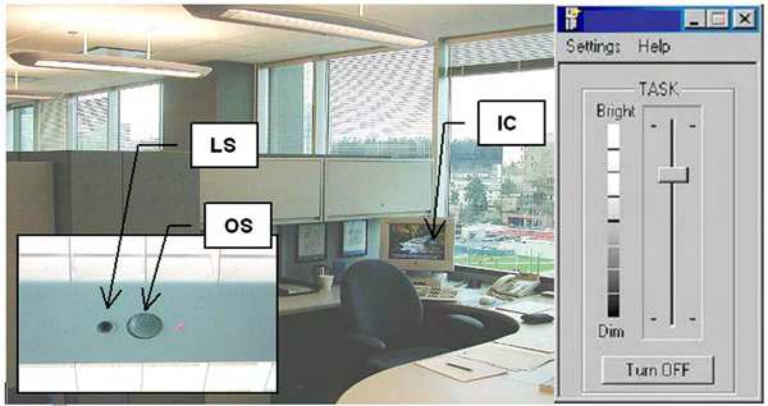
Figure 1. Mean, maximum and minimum total desktop illuminance chosen by each participant during the day.

Figure 2. The luminaires and the three control options for the downlamps

Figure 3. Luminaire daily average energy use for various control scenarios, compared to the conventional lighting system in other locations.



Total Desktop Illuminance (lx)
1200
1000
800
600
400
200
0
Participants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OS
IC
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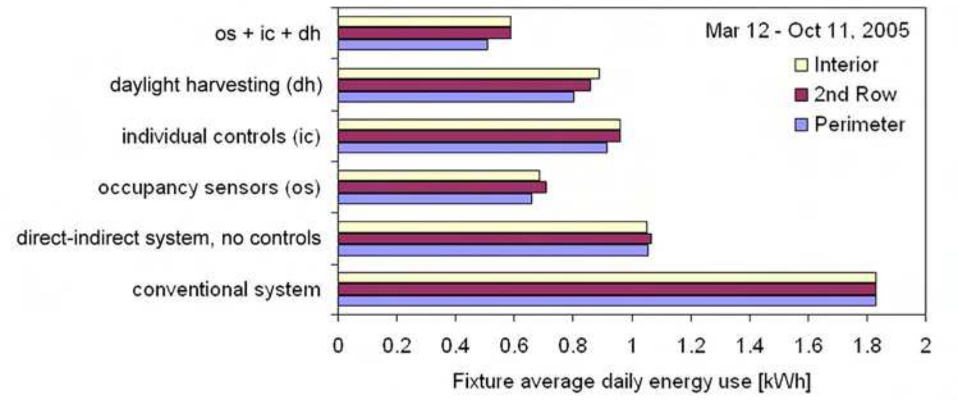
Help
TASK
Bright
Dim
Turn OFF



Mar 12 - Oct 11, 2005
Interior
2nd Row
Perimeter
os + ic + dh
daylight harvesting (dh)
individual controls (ic)
occupancy sensors (os)
direct-indirect system, no controls
conventional system
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Fixture average daily energy use [kWh]