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User attitudes toward occupant controlled office lighting

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The use of locally addressable dimmable lighting systems has been examined in 14 open-plan office buildings. This paper discusses user attitudes toward control systems and the luminous conditions they produce. The majority of users are satisfied with both the quantity and quality of light on their workstations and are generally positive towards systems. This is despite large numbers of them working in illuminances significantly below current CIBSE recommendations. This indicates a significant potential for energy saving, since increased personal control leads to the use of lower lighting levels without detriment to occupants' perceived lighting quality and visual comfort.

1. Introduction

Much interest in recent years has centred on user controlled general lighting systems for office buildings. User controlled systems are those where luminaires are divided into control groups, typically of up to six luminaires, with the output of each group being directly determined by occupants. The control devices, usually hand-held infra-red transmitters, rocker switches, potentiometers or telephones, send signals to a receiver in or close to a luminaire which then communicates with a dimmable ballast, this allows individuals to dim or brighten lamps typically over the range of 10%–100% of maximum output. In addition, most systems also permit switching on or off of lamps.

A previous paper reported achieved workstation lighting conditions at a number of times of the year in a series of continually occupied open-plan office buildings.[1] The results confirmed the occurrence of a wide range of measured lighting levels, many of which were significantly below CIBSE recommendations. This indicated a potential for reducing the energy consumed by lighting if it could be shown that the lower lighting levels were achieved without detriment to occupants' perceived lighting quality. Users' views of the systems and the conditions they created were collected in parallel with the quantitative study. This paper sets out and discusses the results of the survey of occupants.

2. The surveys

The 14 UK office buildings in the study contained modern lighting equipment and controls. Ten of the buildings had accommodation that was approximately 12 m wide (window to window), the remaining four buildings were deep plan. The installations were lit almost exclusively by mirrored louvered downlighters with tubular or compact fluorescent lamps. For control purposes luminaires were controlled either individually or in groups of two to six

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luminaires. The groups were controlled by either hand-held or column mounted infrared devices, rocker switches, potentiometers or telephones which enabled users to switch on/off and to vary lighting levels over the range of 10%–100% of lamp output.

Two visits to all buildings each of one day duration were made, the first (the 'summer' visit) being in April/May 1997, with the subsequent 'winter' visit being in January 1998. A third visit (the 'spring' visit) was made to seven of the installations during the period January to March 2000. A questionnaire was administered at the time of the winter and spring visits in tandem with a detailed photometric survey of each building area and determined users' knowledge of the lighting system, their likes and dislikes of it, their views on control and their perceptions of lighting quality.

The questionnaire was based on rating scales, these were chosen due to their reliability and ease of statistical analysis. The advantages and disadvantages of rating scales in both a general research context, and specifically in relation to lighting have been widely discussed.[2] The questionnaire used in this work was based on a series of questions in the format shown in Figure 1.

This approach is a hybrid of the Likert scale and semantic differential scale, (the two most popular rating scales used in lighting research) and was adopted for the following reasons. Strict Likert scales require occupants to agree or disagree with a statement, a method of response that has been criticized due to the emotive nature of 'agree–disagree'. However the question format of the Likert scale, with a clear definition of the response stimulus and a single response category was retained. The semantic differential approach on the other hand, uses multiple responses to often fairly loosely defined stimuli and this was felt unnecessary as the responses of interest and the stimuli involved had been clearly defined at the outset of the project. A further reason for not adopting the strict semantic differential approach was that the nature of the study necessitated collection of a wide range of data, thus it was vital to produce as concise a questionnaire as possible both that it should be acceptable to employers, and not bore respondents leading to unconsidered or null responses. However single semantic differential rating scales were adopted as their wording can be applied unemotionally, the response definition can be clearly defined and the scales tend to be used more linearly than their Likert counterparts.

Where appropriate, some questions used the tick-box approach illustrated in Figure 2. To avoid potential bias there was space in the question for free response in case the response categories did not cover a not anticipated and significant potential response.

The questionnaire contained four sections. The first related to occupants' personal and employment circumstances, this being important to control for non-lighting issues affecting perceptions of the lit environment. The remaining sections related to lighting quantity, lighting quality, and perceptions and use of control. The questionnaire was completed by a total of 410 occupants.

3. Users' views

Users' knowledge of the lighting system, their opinions of it and perceptions of their luminous environment, were extracted from the questionnaire results.

Figure 1 Rating scale question

(d) Do you ever use the controls to:-

< > Turn on lights in the morning
< > Turn lights off when leaving in the evening
< > Turn lights off when leaving for lunch / meetings etc.
< > Turn lights off when leaving desk for a short time
< > Vary light levels when external conditions change
< > Vary light levels for different tasks
< > Vary light levels dependant on your mood
< > Other (please state) _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

_ _

Figure 2 Tick box question

3.1 Lighting quantity

The first questions related to the amount of light on occupants' desks and VDUs and the amount of daylight reaching desks. The responses were on a 5-point scale, ranging from 'too much' to 'too little'. Figure 3 shows the responses expressed in percentage terms across all buildings and combines the data from both seasons. There was no statistically significant difference in distribution of responses between the seasons.

The majority of people were satisfied with the amount of light on their VDUs and desks (around 70% in both cases), with complaints of too much light being more common than those of too little. However, only about half of the respondents were satisfied with the amount of daylight reaching their desks, with over seven times as many respondents expressing a preference for more rather than less. These findings are consistent with the large body of work on preferred light sources.[3]

No relationships were observed between any of the responses relating to the amount of light and actual levels of illuminance recorded at the time of the winter surveys. Figure 4a shows a box-plot of the responses to the question assessing the amount of light on occupants desktops against actual desktop illuminance recorded. Figure 4b shows that the range of illuminance considered acceptable is wider than that considered unacceptable, and that the range of illuminance considered too low is very similar to the range of illuminance considered too great. Note, in Figure 4 responses have been categorized as follows: a tick in box 1 or 2 = 'too little',

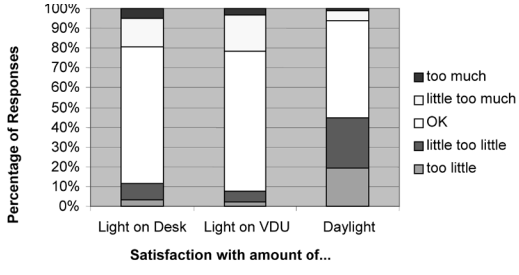
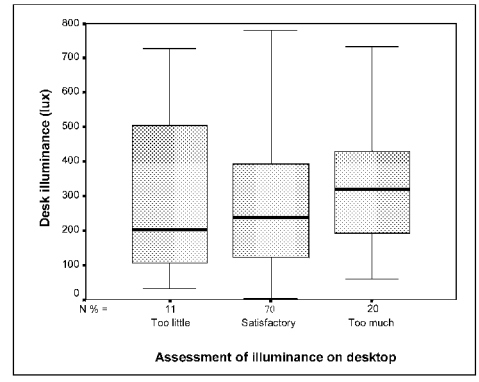


Figure 3 Distribution of responses on quantity of light



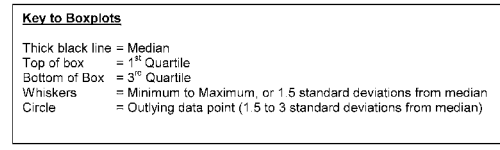


Figure 4 (a) Range of workstation illuminance rated too high, satisfactory and too low (winter survey). (b) Range of workstation illuminance rated too high, satisfactory and too low (spring survey).

a tick in box 3 = 'satisfactory', and a tick in box 4 or 5 = 'too much'.

A weak but statistically significant ($P < 0.05$) correlation between illuminance and perceptions of lighting levels on desks was observed in the spring surveys. This correlation was however felt to be spurious and in fact linked to daylight availability. Individuals' responses to the lighting quantity questions were very highly correlated, and a partial correlation between planar illuminance and subjective assessments of planar illuminance, which controlled for the effects of subjective assessments of daylight availability, failed to reach significance. Conversely, the reverse procedure (a partial correlation between illuminance and perceptions of daylight levels whilst controlling for the effects of assessments of planar illuminance), produced a very strong correlation ($P < 0.01$). Additionally, of the occupants who reported their working plane illuminance as being too low during the winter survey, only one did not also report levels of daylight being too low. This may help to explain

the reason why relatively high illuminances were reported as being too low in Figure 4a. The effect of daylight on perceptions of lighting level is not surprising given its popularity.[3]

These results, together with the generally high levels of satisfaction support the idea of Tregenza *et al*.[4] that a universally preferred illuminance does not exist since in both seasons the range of illuminance deemed acceptable is greater than the range considered as unacceptable. Although in the spring there does appear to be a difference between the illuminances viewed as too low and those being seen as satisfactory or too high, this is believed to be primarily attributable to daylight availability. Further, no differences can be observed between illuminances viewed as satisfactory or too great. One of the reasons for this lack of association may be that conditions for task visibility are satisfied and occupants have adapted to a given level of light. Boyce[5] noted a similar lack of association between illuminances and their subjectively viewed suitability when subjects were carrying out realistic tasks, that is tasks for which visibility requirements were satisfied at relatively low levels of illuminance. Thus in such conditions the visual cues people are using to make assessments may not be directly linked to actual levels of light present, and the evidence above suggests that daylight availability may be such a cue.

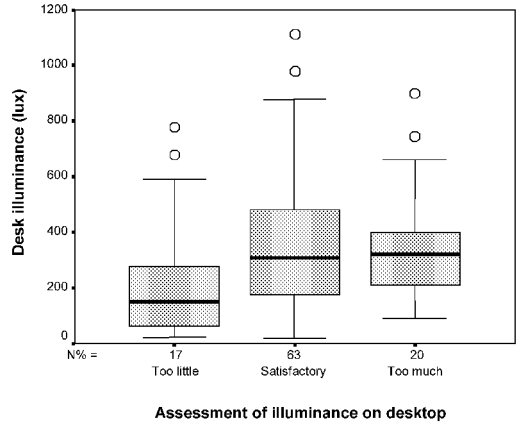


Figure 5 Questionnaire responses regarding quality of light

3.2 Lighting quality

Although there is currently no definitive answer to the question 'what is lighting quality' there is a broad consensus that perceptions of surface luminance are important. Thus occupants were asked to rate the brightness of the scene in front, to the left and to the right of them, and also to assess the brightness of the ceiling. Figure 5 shows the responses from both seasons across all buildings. The majority of users were satisfied with conditions, although the degree of satisfaction was not as high as for the quantity of electric light. This was expected as occupants have little control (often none) over the light sources remote from them which are largely responsible for creating the luminances within their field of view. Further in the wider field of vision glare sources such as luminaires, the sun and the sky will tend to be more visible than in the near field of vision, and conversely if these light sources are not glaring but contrast with an otherwise relatively dark interior complaints about spaces being too dim could be expected. Whereas with quantity of light the majority of those dissatisfied expressed views that there was too much rather than too little light, the reverse is true here. The majority of complaints about too much brightness may be attributable to glare, with very strong correlations being observed between complaints of too much light and the incidence of glare. That people are more likely to complain of their surroundings being too dim as opposed to too bright, and that overbrightness appears to be primarily attributable to glare could be seen as evidence to support the assertion that preferred environments should have a degree of perceived visual lightness.[6]

These generally positive results indicate that the characteristic uneven surface luminance caused by user controlled lighting does not seem to unduly affect subjective evaluations of brightness as the satisfaction ratings are similar or better than those in comparable work.[7] However, user opinion could possibly be improved through the introduction of peripheral lighting and/or

brighter surface finishes to counter the effects of dimmed luminaires which may light walls as well as work stations. Such a strategy may also be of additional benefit to VDU environments. Researchers have found that for VDU work, screen to background luminance in the range of 3:1 to 1:1 are preferred, with complaints being more likely when screen to surround luminance exceeds levels of 5:1.[8,9] Positive contrast VDUs have a luminance in the region 80–100 cd/m^2 and without separate peripheral lighting, dimmable lighting will frequently lead to wall luminance being at levels below 20 cd/m^2 (e.g., five times darker than screens). It is thus necessary to ensure these do not contrast uncomfortably, by for example causing the gloom phenomenon.[10] Conversely too bright a periphery may cause occupants to increase local levels of lighting thus negating the energy savings these systems offer. The work by Flynn and his colleagues gives some clues as to the effects that separate task and peripheral lighting could have.[11] A later part of this work will examine these issues in more detail.

Finally a question asking whether people liked their visual environment resulted in 70% saying 'yes' with 30% saying 'no'. This can be compared to the Building Use Studies data regarding lighting in which peoples' impressions of lighting quality were 40% positive, 30% neutral and 30% negative.[12] This suggests that the presence of local controls does not adversely affect peoples' perceptions of lighting quality, and should be viewed in the context of the significant energy savings that such systems realize.

3.3 Lighting control

Previous research has examined the links between perceptions of control, user comfort and increased self-reported levels of productivity. Although the ability of personal lighting controls to improve productivity in a directly measurable sense may be questioned, there are few doubts that they can promote comfort. There is also evidence that lighting perceived as poor can be demotivating and adversely affect productivity, and that a way to improve an individuals perceptions of their environment is the devolvement of control to them.[13]

The questionnaire revealed that people place a high level of importance on being able to control electric lighting. The question 'How important is it to you that you are able to control the level of electric lighting over your desk?' was answered on a 5-point scale, 1 representing unimportant and 5 important, the mean response was 4.2. Another question 'How important is it that you are able to control the lighting of your desk separately from other desks?' elicited the same mean score, possibly indicating that experienced users of shared controls in open plan office space do not find the arrangement entirely satisfactory. Further within the questionnaire there was a space for occupants to write down any changes they would make to systems. By far the most frequent response was that people wanted control over an individual luminaire suggesting that people perceive control as important and that perceptions of control could be improved through smaller control groups, ideally single luminaires.

The response to the question 'what degree of control do you have' is shown in Figure 6. A similar question regarding satisfaction with the perceived level of control produced a very similar graph. The skew of Figure 6 compares favourably with that of Building Use Studies data in which perceptions of control are measured in terms of feelings of low, medium and high levels of control, and are reported as being 51, 29 and 20%, respectively.[12] Although these responses show that perceptions of control may

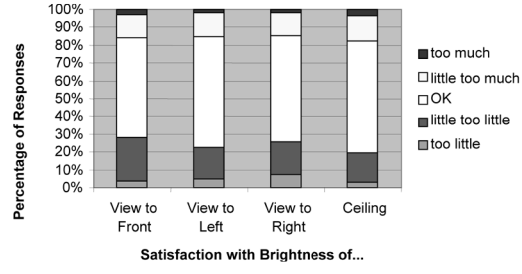


Figure 6 Questionnaire responses regarding perceived degree of control

on average be better for user controlled lighting than for other lighting systems, around one-third of occupants express negative perceptions of, and dissatisfaction with control. The dissatisfaction of this one-third of occupants is particularly important as it has been shown that negative outcomes, for example reduced job satisfaction, are associated with feelings of being unable to exercise potentially available control.[14]

An inverse statistically significant relationship ($P < 0.01$) was observed between the importance placed on control and the satisfaction with perceived level of control. This was expected as it has been shown previously that in the event of discomfort the importance of control rises and satisfaction with given levels of control falls.[15] Less expected was a positive relationship between degree of perceived control and the importance of control ($P < 0.01$), thus what may be in evidence is people viewing control as important in its own right, and not solely as an antidote to discomfort. Or put another way, some groups of occupants may be taking advantage of the control possibilities offered to them by learning how to use systems in order to create preferred conditions. This is not unreasonable when one of the findings from work on control generally, and reaffirmed by the current work, is that control is something that individuals want. Further in this work, occupants who report having a high degree of control, or who place a high degree of importance on having control, were more likely to report high levels of system awareness than those not reporting such perceptions. System awareness could be attributed to the quality of training offered to users but, as levels of awareness tended not to differ greatly between buildings, this suggests that it is the attitude of users towards control that will to a large extent determine how aware of their control possibilities they become.

The questionnaire revealed differences in attitudes towards systems between users who had positive rather than negative perceptions of both their degree of control and satisfaction with control. The main differences were that people with positive perceptions found control devices easy to use and knew how systems operated. People frequently commented that control devices lacked user friendliness and that they were unsure of exactly which luminaires they had control over. There was also a very strong correlation between the avoidance of using control for fear of conflict and feelings of dissatisfaction with the perceived degree of control. This suggests stronger personalities may tend to dominate control decisions, rather than them being reached by consensus. This is supported by the fact that when distance from windows is statistically controlled for, perceptions of degree of control over daylight and degree of control over electric light were strongly correlated, suggesting some occupants feel generally able to use all available controls and vice-versa. Small control groups are the key to reducing conflict and this is highlighted by the fact that size of control group and levels of conflict were statistically significantly correlated ($P < 0.05$).

3.4 Degree of control, satisfaction with control and quality of the luminous environment

Table 1 shows correlations between assessments of lighting quality and quantity, and occupant perceptions of control and satisfaction with control. Note that the data from the lighting quality and quantity questions has for the purposes of this section been recoded, into three rather than five groups. These groups are: first occupants who were satisfied with conditions (e.g., those ticking '3' on the 5-point scale); secondly occupants giving extreme responses (responses '1' and '5' on the scale, representing a deviation of two points from satisfactory); and thirdly respondents expressing slight dissatisfaction with conditions (responses '2' and '4' on the scale, a deviation of one point from satisfactory). This recoding allows extremity of response to be taken into account thus permitting an assessment of overall dissatisfaction.

Table 1 shows that that perceived degree of control is not as strongly associated with lighting quality or quantity issues as satisfaction with the perceived degree of control is. The strength of

Table 1 Correlation between lighting quantity and quality parameters and perceptions of control and satisfaction with control

Lighting quantity and quality issues		What degree of control have you over the electric light over your desk?	How satisfied are you with this degree of control?
How satisfied are you with this degree of control?	Correlation coefficient	0.71	n/a
	Significance	0.00	n/a
Dissatisfaction with brightness in the principal axis of view	Correlation coefficient	−0.14	−0.27
	Significance	0.01	0.00
Dissatisfaction with brightness of the view to the left	Correlation coefficient	−0.05	−0.14
	Significance	0.31	0.00
Dissatisfaction with brightness of the view to the right	Correlation coefficient	−0.21	−0.28
	Significance	0.00	0.00
Dissatisfaction with the brightness of the ceiling	Correlation coefficient	−0.08	−0.13
	Significance.	0.11	0.01
Dissatisfaction with level of working plane illuminance	Correlation coefficient	−0.15	−0.30
	Significance	0.00	0.00
Dissatisfaction with level of illuminance on VDU	Correlation coefficient	−0.07	−0.20
	Significance	0.15	0.00
Dissatisfaction with level of daylight reaching workstation	Correlation coefficient	−0.08	−0.17
	Significance	0.12	0.00
Do you like your visual environment?	Correlation coefficient	0.20	0.30
	Significance	0.00	0.00

association between satisfaction with the degree of control and many of the quality and quantity parameters, suggests that the happier people are with aspects of the luminous environment the more satisfied they will be with their given degree of control and vice-versa. This may indicate that satisfaction with the degree of control will be high when conditions are perceived as good irrespective of the actual degree of control available, an association noted in previous work.[15] If this is so then it may be that perceptions of good quality lighting will not be improved through the addition of controls. However, bearing in mind the wide range of conditions which have been shown to be acceptable to certain users yet unacceptable to others it is unclear how lighting can be designed which will be viewed as high quality by all occupants without the inclusion of manual controls.

Figure 7 provides further evidence that conditions may influence attitudes towards control and not vice-versa. Figure 7a shows that perceived degree of control is not related to assessments of satisfaction with the brightness of the scene in front. However, Figure 7b shows that

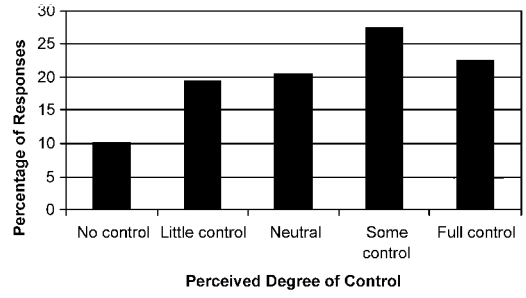


Figure 7 (a) Relationship between assessment of brightness of the scene in front and perceptions of degree of control. (b) Relationship between assessment of brightness of the scene in front and satisfaction with perceived degree of control

satisfaction with the degree of control improves as the satisfaction with brightness of the scene to the front improves. Further this finding should be considered in the context that the great majority of occupants had very little control over brightness levels in front of them.

Notwithstanding the above there do seem to be areas where control is important. Table 1 shows that degree of control is linked to certain quality issues. However Table 1 also shows the

very strong relationship between the degree of perceived control people and satisfaction with this degree of control. By carrying out partial correlations it was possible to isolate the effects of perceived degree of control from effects of the satisfaction felt with control and the results of this are shown in Table 2.

Table 2 shows that degree of control appears to directly influence perceptions of the suitability of illuminances on desks and VDUs, and that these effects are independent of satisfaction with the given level of control, or put another way, independent of individuals' comfort. This effect provides evidence to support the hypothesis that certain occupants are pro-actively using controls to create preferred conditions, as opposed to solely reactively using them to counter discomfort. That these effects are shown to occur only in the areas where occupants actually have any real control, i.e., in the immediate vicinity of their workstations, enhances their robustness. The importance to overall perceptions of lighting quality which locally controllable lighting can make may be enhanced if in engendering satisfaction with local conditions is capable of generating the 'forgiveness effect'[13] when assessing more remote areas. Evidence to support such an occurrence comes from the fact that the responses to the lighting quality and quantity questions were all strongly positively correlated (for example see Figure 8). This means that a

Table 2 Partial correlation between perceived degree of control and various lighting quality and quantity issues, controlling for the effects of satisfaction felt with control

Lighting quantity and quality issues	Perceived degree of control	
	Correlation coefficient	Significance
Dissatisfaction with brightness in the principal axis of view	0.08	0.17
Dissatisfaction with brightness of the view to the left	0.05	0.39
Dissatisfaction with brightness of the view to the right	0.01	0.80
Dissatisfaction with the brightness of the ceiling	0.00	0.98
Dissatisfaction with level of working plane illuminance	0.10	0.05
Dissatisfaction with level of illuminance on VDU	0.11	0.05
Dissatisfaction with level of daylight reaching workstation	0.06	0.30
Do you like your visual environment?	−0.02	0.73

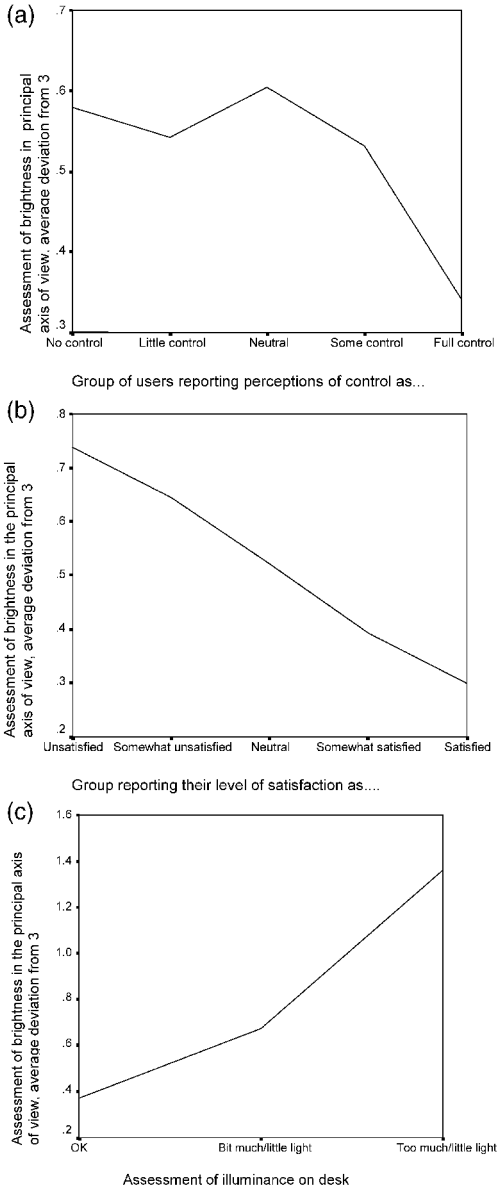


Figure 8 Relationship between ratings of desktop illuminance and luminance in the principal direction of view

positive response in one area is likely to mean positive responses in all areas and vice-versa, and indicates that if positive perception can be created in one area (for example with desktop illuminance) then it may have a positive effect on assessments of other areas, or at least create perceptions that are not as negative as they might otherwise be. Conversely if people feel unable to use controls, then this may lead to the formation, or exacerbation of negative perceptions with local conditions, this in turn adversely affecting perceptions of the wider area in a reverse of the forgiveness effect — the resent effect.

4. Conclusions

A questionnaire was developed and administered to 410 people located in 14 buildings in order to assess how the permanent occupants of open-plan office space perceived locally controllable dimmable lighting systems and the luminous conditions created by them. The questionnaire revealed that the systems and the conditions they create appear on the whole to be acceptable to users, with satisfaction ratings being at least as high as high as those in comparable work.[7]

Robust relationships between perceptions of illuminance and actual levels of illuminance were not observed. This was partially expected as adequate light for task visibility was generally available, and preference for the illuminance of work surfaces in commercial interiors has previously been shown to vary widely.[4] In contrast to previously reported work on user controlled lighting[16,17] the high degree of acceptance of illuminances below those prescribed by current norms does not provide any evidence to support the notion that given a free choice occupants will choose levels of illuminance well in excess of current norms.

Satisfaction with brightness was not as high as satisfaction with illuminance, although levels were generally similar to, or higher than, levels reported in comparable studies despite surface luminance in all spaces being typically low and non-uniform. There is evidence in previous work[6] that spaces are more appreciated when they have a degree of perceived visual lightness. At first sight user controlled systems typically running at 50% of maximum do not seem to be the ideal method of creating such conditions and although there does not appear to be an obvious conflict between low energy use and occupants' perceptions of visual lightness, this remains a potential source of dissatisfaction and one that requires further investigation.

The finding that lighting control is important to people, and that it becomes more important as levels of discomfort rise has been previously reported. However what this work also provides is evidence to suggest that certain people are pro-actively using controls to set preferred conditions and not solely using controls in response to discomfort. Perceptions of control are of an order higher than those reported in work examining more conventional lighting systems with around two-thirds of occupants reporting positive perceptions of control. The finding however that around one-third of occupants report negative perceptions of control is a cause for concern and indicates a partial failure of current systems. It is hypothesized that failure of systems will generate a 'resent' effect in the same fashion that the success of systems generates the 'forgiveness' effect.

There appears to be significant evidence to suggest that user controlled systems save large amounts of energy without detriment to occupants' perceived lighting quality. This indicates that schemes to encourage the adoption of energy efficient lighting should be extended to encompass locally controllable systems.

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Discussion

Comment 1 on 'User attitudes toward occupant controlled office lighting' by T Moore, DJ Carter and AI Slater

GR Newsham (National Research Council, Ottawa, Canada)

I believe that occupant-controlled lighting is the most effective way to meet occupant needs for lighting and save energy, and therefore I welcome this paper. Much effort has been expended on the issue of how to fabricate lighting controls and integrate them into buildings, and too little effort has been expended on the question of *why* we should install controls in the first place. In my opinion, the industry has been technology – rather than occupant-driven.

This paper focuses on the *why* question, showing that there are benefits to occupant satisfaction, and energy savings. The energy savings aspect is important because it counters the belief that giving individuals control over an energy source that they don't have to pay for will lead to waste. Nevertheless, although the cost of controls will decline, it is debatable that energy savings alone will justify the investment in controls. A far stronger case can be made if future studies can translate the short-term satisfaction benefits

into longer-term health improvements for the individual, and balance sheet benefits for the organization they work for.

I also support the authors' comment that design of controls and interfaces is generally poor. This is a further illustration of a lack of consideration of user needs that will limit the market uptake of occupant-controlled lighting.

Despite my general appreciation for the paper, I do have some specific concerns and comments:

1. It is frustrating that details of the buildings, photometric measurements, and energy savings were only provided *via* reference to another paper. A summary in this paper would certainly have helped interpretation of findings.
2. The authors conclude that the uneven surface luminance that inevitably results from user-controlled lighting was not problematic. This is good news because some practitioners suggested this as a barrier to the adoption of such controls in open-plan environments. Another barrier is the distraction caused when neighbours change their lighting. Do the authors have any data on this?
3. The authors found little correlation between measured photometric conditions and satisfaction with lighting, and suggest reasons. Another reason might be that occupants were answering the questionnaire with reference to longer-term lighting conditions in their workplace, rather than those measured at the time of the questionnaire's administration. Can the authors comment?
4. They do describe a correlation between illuminance and perception of daylight levels, and I would like to see this graphically. However, I find the box plots of illuminance *vs*. questionnaire response to be of limited use. I would rather see a scatter plot of all responses *vs*. photometric conditions, with a regression line, r^2 and F statistic.
5. The authors use their data to support the suggestion that there is no universally preferred illuminance. I agree that the range of individual preference is wide. Nevertheless, in the regrettable absence of user controls in most buildings, the task of providing a single, uniform illuminance for all is a common one. I think it would be wrong to give the impression that there are not choices that suit more people than other choices. A new method to derive such a best choice is described in reference 1.
6. The findings illustrated in Figures 7 and 8 are interesting, but the conclusions drawn need to be supported by the numerical results (e.g. p, r^2 and F statistic) of statistical tests. Again, I would rather see scatter plots of all data, or error bars showing the range of responses to each x-axis category.

For those readers interested in other studies of occupant-controlled lighting and the satisfaction and energy benefits demonstrated, I can suggest additional references 2–5.

I encourage the authors to continue this valuable work.

References

1 Newsham GR, Veitch JA. Lighting quality recommendations for VDT offices: a new method of derivation. *Lighting Research and Technology*, 2001, 33 (2), 97–116.

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4 Maniccia D, Rutledge JB, Rea MS, Morrow W. Occupant use of manual lighting controls in private offices, *Journal of the Illuminating Engineering Society*, 1999, Summer, 42–56.

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Comment 2 on 'User attitudes toward occupant controlled office lighting' by T Moore, DJ Carter and AI Slater

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Some months ago an item appeared in the 'City Diary' of a well-known national daily paper. It told the story of an incoming top manager of an European equities operation who had noticed the low levels of lighting used by his staff. Thinking this was too conducive to sleep he had the lighting turned up to maximum output. This resulted in the staff complaining about harsh working conditions and a call to the Health and Safety Executive!

Unfortunately the report did not say how the staff had arrived at their preferred level of lighting in the first place; nor, indeed, whether they had any individual choice. But this incident does support the view that, given the choice, people work in lower lighting levels than we expect. Carter *et al*. have now tested this objectively using quantitative methods and confirmed the anecdotal and subjective evidence we have noted when working with our clients' lighting installations. In parts of one particular project we noted that staff had requested 'capped' lighting levels of just 20% of full output.

So now we have clear confirmation that dimmable lights with individual control are perceived as being beneficial in an open plan environment. There is also support for the view that the better the user understands the controls, the more comfortable they are. This demonstrates the importance of (a) taking care with the commissioning process (involving the client especially) and (b) training and informing all levels of users appropriately. As an aside it is also noted that seating like minded people together helps; there are occasions when severe conflict occurs between neighbours who desire very different lighting levels!

The work does raise the issue of lighting quality and notes that there is no definitive answer to the question 'what is lighting quality?' In discussing this aspect, the lighting of areas beyond an individual's immediate surroundings is addressed. A solution to this concern is to ensure that a lighting control system relates remote lighting (e.g. wall washers) to local work station lighting so that the right contrasts are maintained while the building is occupied. This suggests that lighting management systems need to be interactive and dynamic to provide both individual choice and the correct overall ambient lighting, taking into account contributions from daylight. This conclusion suggests further areas for research.

First do we now need to turn our attention to private office occupants and their attitudes? Will they have a different view because they are, in effect, in control of their own workspace?

Second – and more importantly – is there now a need to take these results on board and develop new strategies for the control of internal lighting installations? Would it be beneficial to vary overall lighting levels at certain times of day and/or alter the colour temperature, whilst still allowing local control? And would the local control element need to be held within prescribed limits?

It is certainly welcome news that lighting controls are indeed beneficial to individual users. But let's not stop at dimming alone, when lighting technology will allow us to move on and develop better solutions, with a real prospect of ultimately defining lighting quality.

Authors' response to GR Newsham and J Aston

T Moore, DJ Carter and AI Slater

The authors are grateful to Dr Newsham and Mr Aston for their thoughtful comments, suggestions and additional information. We will respond to their comments in turn.

The authors sympathize with Dr Newsham's comments regarding aspects of the study provided *via* other published material. In writing up such a large piece of work for publication, we had to split the study into detailed papers each describing separate, but related, aspects of the work. Whilst we have tried to make each a self-

contained story under the circumstances, some cross-referencing is necessary.

Long-term lighting conditions in some of the installations have also been studied and are the subject of a further paper. The general pattern was that occupants switch on at the beginning of the working day with switching at other times being an exception, and outputs, once set, remain unadjusted irrespective of changing daylight conditions. The amount of switching recorded during working hours was negligible, and thus not a cause of distraction to neighbours. It is possible that occupants were answering the questionnaire with reference to long-term conditions rather than those at the time of the 'snap-shot' and repeat administration of the questionnaire over a period of several weeks yielded similar results. This is perhaps to be expected since occupants used the control system to re-create similar or identical photometric conditions each day (depending on reset mechanism of the particular system).

The authors are grateful for the new information on the derivation of illuminance conditions in offices that is potentially very useful in commissioning of these systems.

The authors smiled after reading Mr Aston's comment regarding increase of illuminance levels by an incoming manager of an equities operation, since this was exactly what happened in one of the buildings studied! However, in this case the users were able to set their own levels and the system ran at an average of some 60% of maximum output. We certainly endorse the comments regarding the need for commissioning and user training. In some cases we found that facilities staff who did not understand the systems simply disabled them, and the importance of simple-to-use controls cannot be overstated.

The suggestion of linking the control of local and remote lighting systems to maintain acceptable conditions is novel and worthy of further work. However, it must be remembered that in many open plan offices, the user's field of view is mainly that of the vertical and horizontal surfaces of their workstations and the ceiling. As a result, the role of the wall luminance in the field of view is sometimes limited. Similarly, the prospect of systems that enable variation of both illuminance and colour temperature is a very exciting one, particularly since recent work has shown that human preferences for both are interlinked.