Conflict and Control: The use of locally addressable lighting in open plan office space

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Summary

The use of locally addressable dimmable lighting systems has been examined in 14 open plan office buildings. Investigations reveal certain occupants are discouraged from using controls due to conflict with others, and further that avoidance of using controls is associated with negative perceptions of the luminous environment. High perceived lighting quality means conflict is unlikely to occur as the desire to use controls is not created. However the subjective nature of lighting quality means occupants making differing assessments of lighting needs is likely. This paper contains advice on system design and management that should reduce the likelihood of conflict occurring. It is hoped the lessons learnt will be translatable to other areas where local control is possible.

1. Introduction

Work at the University of Liverpool and the Building Research Establishment is investigating various aspects of user controlled lighting. Systems under investigation are those where luminaires equipped with dimming ballasts are divided into control groups of 1-6 luminaires with outputs being directly determined by occupants. The control devices are most often hand held infra red devices although other devices used include rocker switches, potentiometers and the telephone. These controllers allow individuals to switch lamps on or off, or to dim / brighten lamps typically over the range 10% to 100% of maximum output. All systems are in continually occupied open-plan office space and between them may be considered representative of current UK stock. Appendix A contains further information on individual buildings and systems.

14 buildings where user controls have been installed have been surveyed. Surveys have involved a questionnaire being administered to occupants, a photometric survey of occupants' workspaces and the recording of light outputs from each group of luminaires. Statistics relating to working plane illuminance and systems' electrical output at the time of surveys (afternoons during Winter 1998) may be seen in appendix A. In addition long term monitoring of switching behaviour has been conducted at four installations.

This paper reports on aspects relating to human interaction with systems, particularly how users in open plan space run into conflict with each other, the result being that certain users withdraw from the control loop. Exclusion from the control loop may have a negative impact on occupants' perceived degree of control which in turn may have a detrimental impact on perceptions of lighting quality. It is hoped the lessons learned will be translatable into other areas of building services design where local control is possible.

2. Benefits of Systems

The reported benefits of systems are outlined below:-

i - *Occupant comfort.* Studies have shown that preferred illuminances exist and vary widely[1 2]. Local control is a way of improving the likelihood of occupant satisfaction. Comfort is linked to occupational health, i.e. incidence of building sickness symptoms[3].

ii - *Productivity*. Users report environmental effects on productivity of up to +/- 10%[4]. Occupants with perceptions of having control are more likely to report a positive environmental effect.

iii - *Energy Efficiency*. Personal preference and the ability to use locally available daylight mean these systems typically consume half the energy of conventional systems[5].

The summation of these factors is a potential measure of competitive advantage to organisations adopting such systems.

3. Transferable Technology

Given the nature of the production and behaviour of electric light it is not surprising that local lighting controls have been the "first wave" of controls aiming to satisfy multiple and diverse preferences in open plan office space. Although such systems are uncommon, given the personal and societal benefits outlined above there seems little to prevent their more widespread application. Further the technology could be applied to other areas e.g. chilled ceilings and passive ventilation, and reports of experimental installations containing such systems exist[6 7 8].

4. Exclusion from the Control Loop: Cause and Effect

4.1 Cause

One of the prime reasons people drop out of the control loop appears to be the occurrence of conflict. A questionnaire was administered to occupants, part of which aimed to elicit the degree of conflict experienced by users and how this effects use of controls. (See appendix B for the relevant excerpt from the questionnaire.) The relationship between conflict experienced and avoidance of use of controls is shown in Table 1.

		Do you avoid using controls for fear of conflict					***Total***
		Never	Towards never	Neutral	Towards frequently	Frequently	
Do you experience conflict with others when trying to exercise control	Never	**41**	5	6	3	0	***55***
	Towards never	12	**11**	6	1	2	***32***
	Neutral	7	10	**15**	5	2	***39***
	Towards frequently	3	8	12	**11**	1	***35***
	Frequently	3	0	1	5	**13**	***22***
Total		***66***	***34***	***40***	***25***	***18***	***183***

Table 1: Crosstabulation of responses to questions; "Do you experience conflict with others when trying to exercise control" & "Do you avoid using controls for fear of conflict"

Table 1 shows that those who experience conflict are more likely to avoid using controls than those who do not experience conflict. Further the distribution of the totals figures (see Figure 1) suggests that where conflict occurs stronger personalities may be dominating. That is to say more occupants report frequent experience of conflict than frequent avoidance of using controls, thus certain occupants appear to be using controls irrespective of levels of conflict.

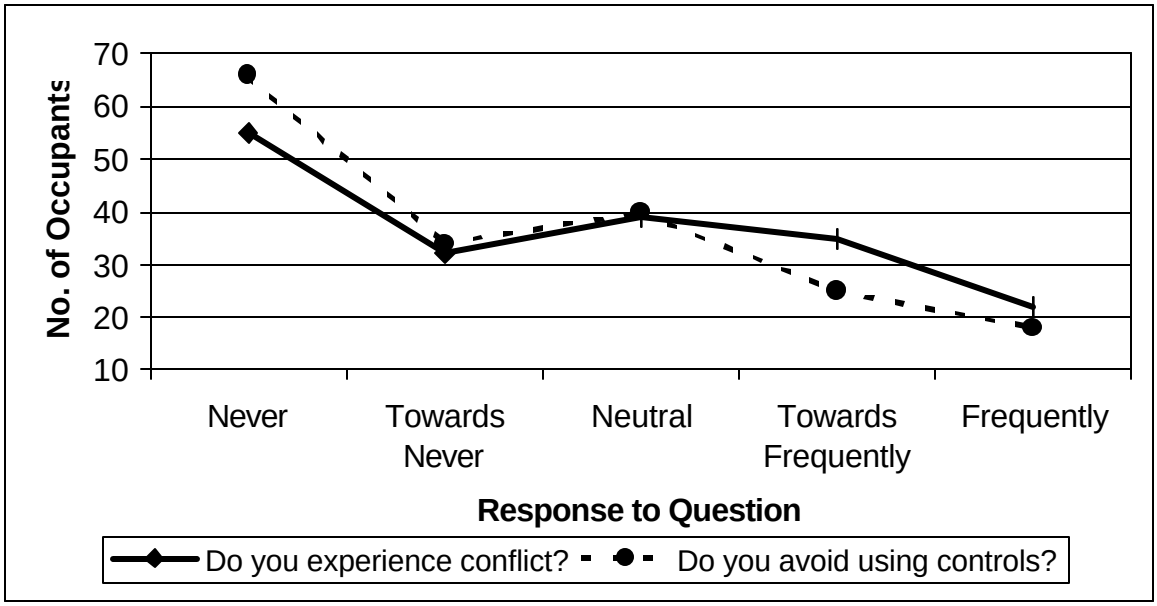
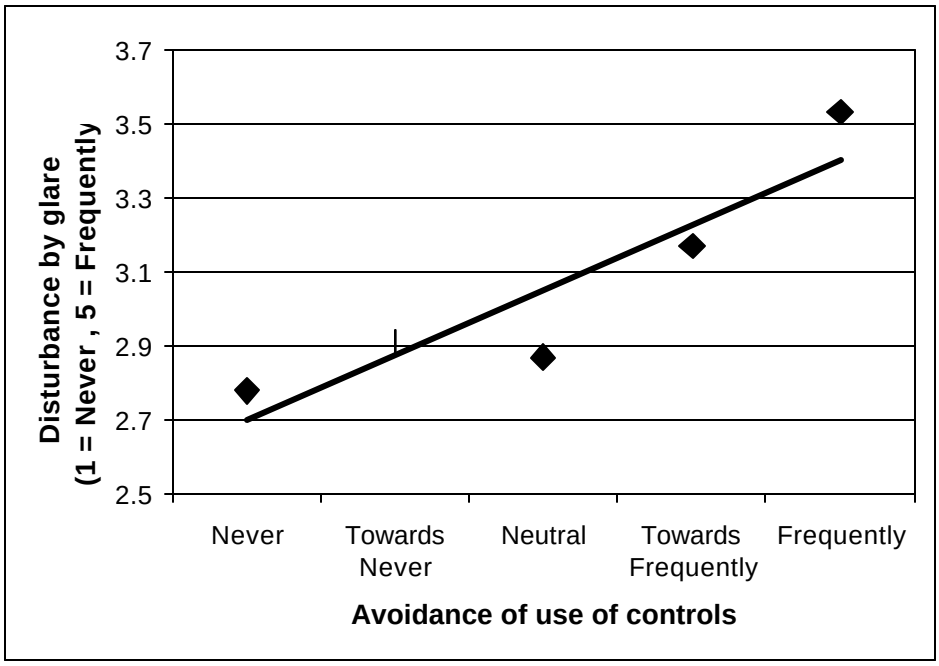


Figure 1: Graph to show distribution of totals figures from Table 1

An alternative explanation for the behaviour pattern in figure 1 is that it could be a "crisis of discomfort" that is responsible for providing certain individuals with the impetus to use controls regardless of conflict levels. Figure 2 shows the relationship between reported glare problems and the avoidance of using controls. Occupants were asked to assess how often they were bothered by glare on a 5 point Likert scale (see appendix B) a response of 1 indicated never being bothered by glare while a response of 5 indicated frequent incidence of glare. The data from the glare question has been grouped according to the 5 responses to the "avoidance of using controls" question. Mean group responses are plotted in Figure 2. The graph shows a positive relationship between worsening problems with glare and the tendency to avoid using controls. Given that glare is the most likely source of a "crisis of discomfort" it appears that motivation to use controls as a result of discomfort is not as an important determinant in their use as individuals' personalities.



Pearson correlation co-efficient 0.92, significant at 95% confidence level

Figure 2: Graph to show relationship between reported incidence of glare problems and avoidance of using controls

4.2 Effect

Conflict results in avoidance of using controls, and it would appear disproportionately affects the less vociferous. What then is the effect of this?

The avoidance of using controls control was found to be strongly negatively correlated with the degree of control occupants perceived they had, and their ensuing satisfaction with this degree of control. (See Table 2). The perception of having control is considered as important as the actual exercise of control. Thus regardless of actual conditions, negative opinions regarding control are likely to have a detrimental effect on occupants' assessments of their environment[9].

Table 2 shows the strength of correlations between the questions relating to conflict and the avoidance of using control and the questions on degree of, and satisfaction with, levels of control present.

		Do you experience conflict with others when trying to exercise control	Do you avoid using controls for fear of conflict
What degree of control do you have over the electric light over your desk?	Pearson Corr.	-0.15	-0.29
	Significance	0.05	0.00
How satisfied are you with this degree of control?	Pearson Corr.	-0.27	-0.30
	Significance	0.00	0.00

Table 2: Correlations between conflict and control questions

Perceptions of not having control and the dissatisfaction this often causes are linked to negative perceptions of lighting quality. Part of the questionnaire assessed occupants' opinions regarding lighting quality and quantity (see appendix B). Analysis of these questions revealed that when conditions were perceived as good, satisfaction with control would be high regardless of the perceived level of control that existed. However when conditions were perceived as poor occupants tended to report low perceived levels of control and dissatisfaction with the perceived degree of control. This is consistent with the thinking that "comfort is the absence of discomfort"[10]. Thus those who feel unable to use controls are more likely to have a poorer perception of their luminous environment than those who are prepared to use controls.

Figure 4 highlights the above mentioned relationship. In appendix B, and in Figure 3 below it can be seen that lighting quality and quantity questions were asked on a 5 point Likert scale, the scale running between two extreme responses (e.g. from too bright to too dim).

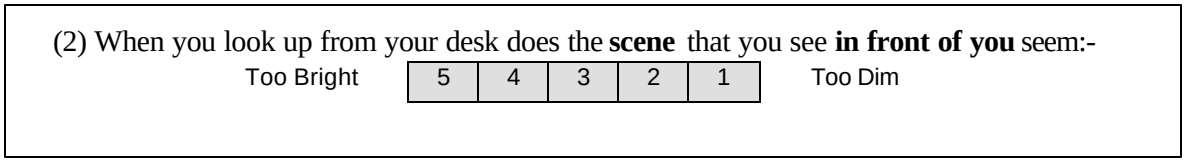


Figure 3: An example of the format of the lighting quality and quantity questions contained in the questionnaire

This data has been recoded so the extremity of response may be taken into account. Thus responses in boxes "1" and "5" of the Likert scales in the original questionnaire, representing dissatisfaction, have been assigned a new value of "2". Some dissatisfaction indicated by responses in boxes "2" or "4" given a value of "1", and satisfaction indicated by a response of "3" recoded as "0". In this way a measure of overall dissatisfaction can be obtained, i.e. a figure between 0 (satisfaction) and 2 (dissatisfaction). The recoding procedure is summarised in Table 3 below.

Original Response	Original Meaning of Response	Recoded Value	Meaning of Recoded Value
1	Too dim / too little light	2	Dissatisfaction
5	Too bright / too much light	2	Dissatisfaction
2	A bit too dim / a bit to little light	1	Some dissatisfaction
4	A bit too bright / a bit too much light	1	Some dissatisfaction
3	Satisfactory	0	Satisfaction

Table 3: Recoding of the data from the lighting quantity and quality questions

Figure 4 shows the relationship between avoidance of using controls and mean dissatisfaction with the amount of light on the working plane and the brightness of the principal axis of view.

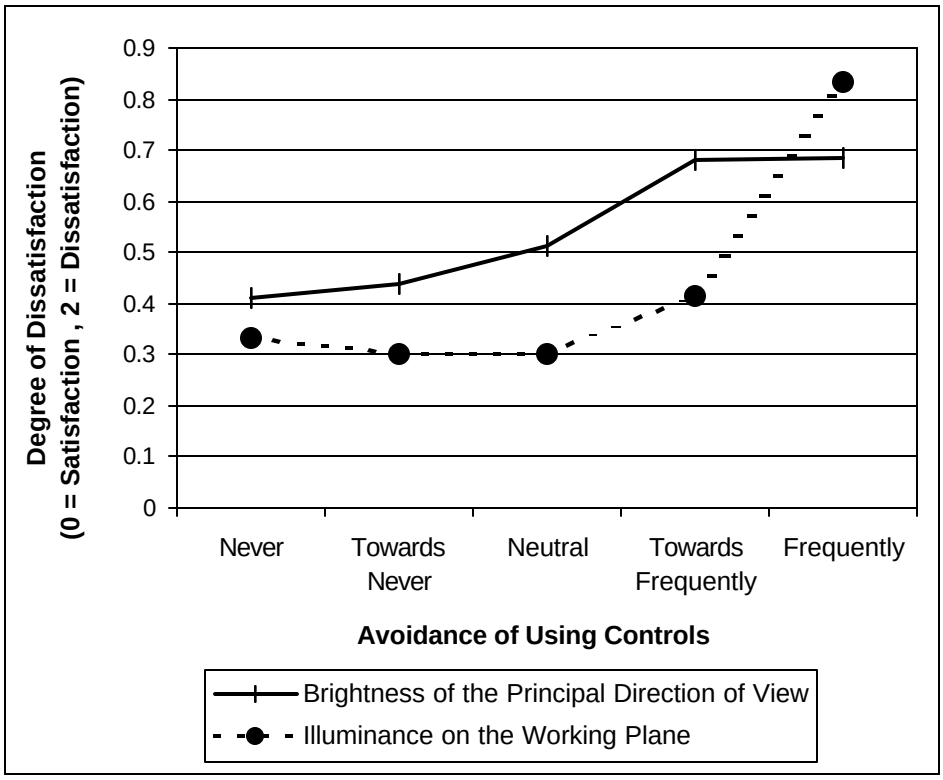


Figure 4: Graph to show relationship between avoidance of use of controls and mean assessments of the luminous environment

Figure 4 shows the experience of conflict and the avoidance of using controls is associated with perceptions of a poor quality luminous environment.

4.3. Perceived lighting quality and perceived control: Which is the cause and which the effect?

Lighting quality and satisfaction with control can be said to have something of the "chicken and the egg" conundrum. Some commentators have suggested conditions will shape attitudes towards control [11] whilst others have suggested that the reverse is true [12]. This may be a false dichotomy with both mechanisms in fact at work. For example perceived degree of control correlated significantly with many of the lighting quality and quantity questions, however when the effect of satisfaction with control was controlled for via a partial correlation the only significant correlates were ratings of working plane illuminance and vertical illuminance on VDUs. That these two factors correlate with perceived degree of control is important as it is really only these that occupants have any control over.

Thus it appears that controls are being used to create preferred conditions. Further the exercise of control and ensuing satisfaction with conditions in one part of the luminous environment is likely to be having a knock on effect in other areas[13] or creating what has been termed the "forgiveness" effect [10]. Thus it may be this which is responsible for the much touted relationship between perception of control and lighting quality.

5. Causes of Conflict

As mentioned above conditions perceived as poor will often be the root cause of conflict, as it is these which create the desire to use controls. The following factors may have an impact on the likelihood of conflict occurring in the event of perceived poor conditions.

5.1 Size of Control Group

Size of control group ranged from 1 to 6 luminaires. Size of control group was found to be correlated with the experience of conflict (significant at the 95% level), but not however with the avoidance of using controls, providing further evidence that control decisions will frequently be taken autocratically as opposed to democratically.

This effect is expected as where groups of occupants are expected to work under the same level of illuminance they are unlikely to agree on the suitability of the illuminance[14 15]. However the relationship was not as strong as expected.

One reason for this may be that small control groups will still cause conflict as a result of overspilling light. To test this an independent samples t-test was carried out to compare: the degree of conflict experienced by those who reported disliking disturbance caused by others operating systems against those who did not. The sample was restricted to installations where size of control group was 3 or less. The difference in reported degree of conflict was significant at the 99% confidence level, and indicated that disturbance caused by others switching was a significant contributor to conflict. Thus it would appear that systems would benefit from attention to luminous distribution, particularly trying to prevent overspill of light to areas outside the local control group. Current designs based upon unitary switching use overlapping distributions of light for modelling and uniformity purposes, this may not be the most appropriate approach to design for locally dimmable systems. It may in fact be necessary to divorce task lighting from peripheral lighting. That is to say adopt separate design strategies for the controllable horizontal lighting and the decorative vertical lighting.

Also larger control groups may not necessarily cause conflict. Appropriate zoning and work team to luminaire group layout may be important. An independent samples t-test was again conducted. This time to assess how occupants who reported zoning as a problem compared to those who did not report zoning as a problem, with respect to levels of conflict and size of control group worked under. Perceptions of poor zoning were linked to experience of conflict (significant at the 99% level) however control group size did not differ significantly between the two groups. Thus pro-active facilities management combined with systems which may easily be reconfigured and repositioned may offset some of the problems larger control groups can cause.

5.2 Location of Control Device

Systems have either a local (desk sited) or a distantly (wall or column mounted) sited control device. Local controls are usually hand held remote control devices and distantly sited devices are typically potentiometers or rocker switches.

Device location appears to have consequences for conflict. The mean response to the question regarding the occurrence of conflict was 3.1 for occupants using distantly sited controls and 2.4 for occupants using locally situated controls. (5= frequent conflict, 1=no conflict). These means were found to be statistically significantly different at the 99% confidence level.

There was however a very strong correlation between device location and group size, that is systems with larger control groups tended to have column mounted controls. However even when the effect of group size is controlled for, location of control device remains statistically significantly associated with occurrence of conflict. (partial correlation significant at the 95% level)

It is hypothesised that a locally sited control device will facilitate greater dialogue between individuals with regard to appropriate working plane illuminance. This effect is not however clear as no significant differences were observed in assessments of lighting quality and quantity between groups with local and remotely sited controls. Notwithstanding this the group using local controls reported having a statistically significantly greater degree of control than those with remotely sited controls. This may be the attributable to the effect of the perception of having control rather than its actual exercise.

5.3 Switch on Regime

These can broadly divided in two. Firstly there are systems which have a pre-defined on level which will either be time or presence detection activated and secondly there are systems which occupants must consciously activate.

Although conflict was slightly more prevalent at installations where users had to switch themselves the reverse was true for the avoidance of using controls, however in statistical terms the differences did not reach significance.

Switch on regime was however statistically significantly associated with a number of the lighting quality and quantity parameters, for example satisfaction with brightness in the principal field of view. These associations indicated that when "forced" to switch on users will create conditions more acceptable than those created when a pre-set switch on level is used.

Evidence to support this comes from the fact that at installations where there were pre defined switch on levels, these switch on levels were found to be very strongly correlated with luminaire outputs recorded at the time of our surveys. Thus often controls would not be used when there were predetermined outputs. However the group of buildings where users had to select an initial output exhibited a great range of lamp outputs (mean output 52%, standard deviation 37%) Thus switch on regime may have an impact on lighting quality which in turn may effect the likelihood of conflict occurring.

Another hypothesised reason why switch on regime may effect perceptions of lighting quality, is that levels set will be largely dependant on the preferences of the user who arrives at work first, this will to some extent counter some of the problems caused by stronger personalities, as once set luminaire outputs are rarely adjusted[15 16] thus there may be the sense of users having “their day”, and being more compromising on subsequent days.

The effect of "forced" use of controls may also have an effect on occupants perceptions of lighting quality as occupants will become used to systems and become capable and confident operators of them. Occupants who are forced to switch report a higher, although not statistically significant, awareness of how systems work.

6. Other Factors Affecting Perceptions of Control

Besides the above there are other factors that may affect perceptions of control and the likelihood of conflict occurring. For example perceptions of control are strongly associated with an awareness of how systems work. Thus facilities managers have a role in educating users so they become confident users of systems.

Control devices need to be user friendly and let users know that change is occurring. With lighting change is fairly rapid, yet 1 in 8 occupants still complained of time lags in systems this indicates that personal cooling/heating controls would benefit from features that ensure occupants know change is occurring.

Finally actually being able to locate a control device is important complaints of hoarding and a parsimonious initial distribution were not uncommon, to this end PC or telephone control could solve many problems.

7. Conclusions

Problems with user controlled lighting arise largely as a result of the attempt to introduce personal controls into open-plan environments. Conflict between users occurs and some users choose to avoid using controls. Avoidance of using controls is associated with poor perceptions of the luminous environment.

When lighting quality is perceived as good there is a reduced likelihood of conflict as users will not want to use controls. However the subjective nature of lighting quality means conflict is probable. It is possible to reduce the likelihood of conflict through the use of small control groups, paying attention to luminous distribution, locally situated controls, and possibly by encouraging users to consciously switch.

In short control needs to be as far as possible individually tailored, as use of controls even by small groups of occupants shows that all though in theory "all animals are created equal" in practice "some animals are more equal than others".

8. Acknowledgement

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Appendix A - Breakdown of recorded working plane illuminances by building, including average electrical outputs and descriptions of each building and its lighting system

Installation	Details of Building	Lighting Equipment and Controls	Elec. Output as a % of max.	Illuminances (lux)					
				Mean	Min	1st Quartile	Median	3rd Quartile	Max
1	Urban site, slab shape, 13m wide, central corridor	Vertical. venetian manual blinds, clear glazing, 600mm square downlights, Control: 3,6 or 9 luminaires, IR on columns	*43*	240	17	95	118	375	727
2	Urban Site, L-Shape, 12m wide, offset corridor	Automatic internal horizontal blinds, external light shelf, clear glazing Perimeter uplights, rest symmetric downlights. Control: single luminaires, HHIR	*52*	137	41	86	136	187	230
3	Urban site, L-Shape, 12m wide, offset corridor	Automatic internal horizontal blinds, external light shelf, clear glazing perimeter uplights, rest symmetric downlights. Control: single luminaires, HHIR	*36*	183	6	79	122	201	606
4	Urban site, P-shaped, 15m wide, recent refurb.	Venetian manual blinds, clear glazing, 600mm sq. down- lights, wall washers. Control: pairs of luminaire via HHIR, or groups of 6 lums. via wall mounted on/off switches.	*23*	113	35	84	108	133	230
5	Urban site, L shape plan,13m wide, central corridor	Vertical. Venetian manual blinds, clear glazing, 600mm square downlights, Control: single luminaires, HHIR	*53*	413	34	281	371	575	746
6	Urban site, courtyard, 14m wide, cent. corr.	Manual roller blinds, T=50%, 600mm square downlights, Control: 1,2,3 or 4 luminaires, HHIR	*36*	273	61	150	211	365	655
7	Urban site, deep plan, 22m wide, cent. corr.	Manual roller blinds, T=50%, 600mm square downlights, Control: 1,2,3 or 4 luminaires, HHIR	*66*	350	117	269	344	433	576
8	Rural site, courtyard, 12m wide, central corridor	Internal venetian horizontal blinds, external shading,T=35%., 1500mm linear downlights Control: single luminaires, HHIR	*53*	429	103	290	414	562	804
9	Urban site, slab shape, 12m wide, central corridor	Vertical venetian manual blinds, clear glazing, 1200mm linear downlights, Control: 3,4,6 or 9 luminaires, rotary switch on columns	*62*	243	38	82	235	359	702
10	Urban site, courtyard, 12m wide, central corr.	Vertical venetian man. blinds, clear glazing, 1500mm linear downlights, Control: 2 or 4 luminaires, HHIR on columns	*67*	300	40	184	279	407	681
11	Rural site, deep plan, slab shape, atrium	Vertical venetian man. blinds, clear glazing, 600mm sq. downlights, Control: 6 lums., rocker switch on columns	*36*	465	163	368	483	543	809
12	Rural site, deep plan, 27m wide, no formal corridors	Vertical venetian manual blinds, glazing T=50%, 1200mm linear downlights, Control: 2,3 or 6 luminaires, column mounted rocker switches	*58*	503	80	366	543	649	759
13	Urban site, J-shape plan, 16m wide, central corridor	Vertical venetian manual blinds, T=50%, 600mm linear downlights, Control: 3 luminaires, Telephone control	*45*	189	10	87	162	257	629
14	Rural site, deep plan, atrium, no formal corridor	Vertical venetian manual blinds, clear glazing, 600mm square downlighters, Control: Individual luminaires, control via telephone call to facilities help desk	*41*	217	6	67	120	406	565

HHIR = hand held infra-red controller.

Appendix B: Excerpt from questionnaire

(A) Lighting Quantity

(1) Would you say that the **amount of light on your desk** is:-

Too Much | 5 | 4 | 3 | 2 | 1 | Too Little

(2) Would you say the **amount of light on your VDU** is:-

Too Much | 5 | 4 | 3 | 2 | 1 | Too Little

(B) Lighting Quality

(2) When you look up from your desk does the **scene** that you see **in front of you** seem:-

Too Bright | 5 | 4 | 3 | 2 | 1 | Too Dim

(3) **Does glare** (Glare is unwanted brightness viewed either directly or via reflection) ever **disturb or annoy** you?

Frequently | 5 | 4 | 3 | 2 | 1 | Never

(C) Lighting Control

(1) What degree of **control do you have over the electric lighting** above your workstation:-

Full Control | 5 | 4 | 3 | 2 | 1 | No Control

(2) **How satisfied are you** with this level of control:-

Satisfied | 5 | 4 | 3 | 2 | 1 | Unsatisfied

(4) Do you ever **experience conflict with other users** when trying to exercise control over the lighting:-

Frequently | 5 | 4 | 3 | 2 | 1 | Never

(5) Do you **avoid using available lighting controls** for fear of upsetting other occupants:-

Frequently | 5 | 4 | 3 | 2 | 1 | Never