

Artificial 'Daylight' Lighting in the Office: Case Study

Mark Handley reports on a trial of artificial 'daylight' lighting in offices at BAE Systems in New Malden – and the unexpectedly positive results

Introduction

I work for BAE Systems (Integrated System Technologies) Ltd. at New Malden, as a systems engineer, which is part of the company's naval cluster. Our main products are the command and control systems for warships. Human factors have always been an important consideration in our system displays, but they are far removed from the assessment of lighting quality in offices. I recently bought some 'full-spectrum' lighting for my philately pursuits at home and was most impressed by the improvement it made to colour and print clarity.

I had also noticed for some time that I felt far more tired after a full day at the office compared with the equivalent hours on my home computer. This made me wonder whether the lighting in our office could be improved. I therefore persuaded my employer to allow me undertake a lighting trial. The following report expresses my own personal views.

Background Information

I read various reports on the issue, including those on the use of blue-saturated Philips ActiViva tubes to help improve sleep patterns. I also came across a brief article in the *Daily Telegraph*⁽¹⁾ about the design of the officers' quarters in the next generation of nuclear submarine fleet, making a reference to plans for daylight-style lighting

in shared spaces and 'mood' illumination in sleeping areas. Joseph Brennan's award-winning report, 'Effects of Light on Humans'⁽²⁾ was extremely informative. It included some important guidance, such as 'It has also been shown that an increase in lighting levels can not only increase alertness, thus reducing accidents, but that lighting has a direct effect on the mental and physical health of humans'. It also covers topics such as human circadian rhythms and the blue-light receptors in the ganglion cells, which affect the secretion of melatonin.

The Van den Beld and van Bommel report⁽³⁾ included a graph from the GJ Fortuin research⁽⁴⁾, showing how lighting needs increased with age, implying that the approach of providing uniform levels of lighting in an office environment was far from ideal. The Bodart & Deneyer report⁽⁵⁾ on office workers' views on windows reports an almost unanimous preference for natural daylight. Some 97% of respondents found it more visually comfortable than electric lighting. Paradoxically, it also concluded that more than a third of people interviewed thought that daylight and artificial light were equally good to work under.

Working Environment and Staff Sample

Our premises are a 15-storey tower block constructed in the early 1960s with a fairly low ceiling height (2.5m) and windows all round. The layout of the first floor is shown below, with the three main working areas, A, B and C. The grey area includes aisles, kitchens, meeting rooms, lifts, stairwells, store rooms, toilets etc.

The number of staff for area A is lower than the other areas, as building and site service staff were excluded from the results for the purposes of this paper. The total sample was 50. There are also numerous hot desks and desks dedicated to test/support equipment.

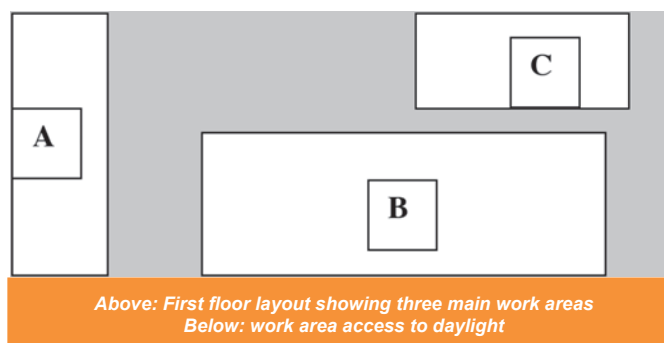
The working hours are very flexible with open hours from 6.30am to 21.00pm. The working environment has a large number of desktop PCs with each individual having two on average. The lighting for the floor, including the aisles, consists of almost 200 fixed-array, four-tube

luminaires, with GE T8 standard halophosphate 18W lamps (CCT 3450K and a CRI of Ra54). Desks are laid out independently of the location of the luminaires. An individual light switch may control between three and six luminaires, affecting several desks.

Upgrade Selection and Implementation

The options considered for the lighting upgrade were:

- Equipping every luminaire with a dimming ballast or multi-lamp switching or dynamic lighting control in line with *Advanced Lighting Guidelines 2003* from the New Buildings Institute Inc⁽⁶⁾.
- Philips ActiViva lamps with a colour temperature of 17000K
- Full spectrum lamps such as the Viva-Lite® full spectrum tubes.
- Daylight Deluxe lamps with a colour temperature of 6500K and a CRI of 80-90 – in this case the Sylvania Luxline Plus.



Work Area	No of staff	Level of sunlight at start of the trial period
A	8	Receives direct sun much of the day
B	29	Receives small amount of sun early in the day
C	13	Receives direct sun in late afternoon

Floor	Desks by Windows		Desk furthest from window (2 in)
	Under luminaire with 2 tubes	Under luminaire with 4 tubes	Under luminaire with 4 tubes
1st	570*	608	645
2nd		530	410
5th		610	535
10th		625	550

Fig 1: task lighting levels for various floors (in lux)

*By the afternoon, this had dropped to 515

Given the economic climate, the Sylvania Luxline Plus lamps were selected as the only change. They offer a higher light output of 72 lm/W compared to 64 lm/W for the GE standard halophosphate sources. Fewer tubes are required by some people thereby reducing the company's carbon footprint. This was achieved through having some tubes switched off at the individuals' discretion in a luminaire. Daylight Deluxe lamps also offer reduced maintenance costs, due to their longer life of over 15000 hours compared to 9000 hours, which was a further bonus offering some compensation for the additional cost of the new tubes.

I also hoped that the lamp change could achieve improvements in staff well-being, at the same time as improving lighting efficiency. In order to assess these changes, staff surveys were conducted about three weeks before the change-over, immediately after the change-over and 2-3 months later. It must be appreciated that this was done from February to May, well after the shortest days of winter. The parameters of the surveys included alertness, fatigue, visual acuity, eyestrain, headaches, mood, performance, sleep and more. We also requested data on interviewees' ages. The completion of surveys was optional – completion

rates of 80%, 70% and 64% of the total sample were achieved for the three surveys.

To minimise staff disruption, facilities staff decided to roll out the new lighting over a weekend across the entire floor. The starters all needed changing, as well as the tubes. The old tubes were re-used to replenish lighting on other floors. Due to the 10% higher light output some people found their lighting too bright and facilities had a sudden surge in requests to address this problem.

Lighting Levels

Sample illuminance readings, using a lux meter, were taken in the building at around 8.00am in early August. The first floor has the tri-phosphate lamps and the second, fifth and tenth floors all have halophosphate lamps. (The results are shown in Fig#1). Across the road, there is a similar 15-storey building, so the lower floors are affected by its shadow at this time of day.

The pictures right show the difference between the lighting on the tenth and fifth floors which have a Colour Temperature of 3450K and the Daylight Deluxe lighting on the first floor with a Colour Temperature of 6500K at just after 8.00am on a cloudy day at the beginning of July.



Existing lighting on the tenth floor



Existing lighting on the fifth floor



New lighting on the first floor

Survey: Analysis of Key Parameters

Despite earlier research which indicates that the lighting needs of individuals increase with age, this study found no correlation between age and the assessments of the new lighting. Indeed, the relationship between age and lighting needs was turned on its head in one case: with two pairs of staff sitting in similar locations next to windows, with a cumulative age difference of over 25 years, the older pair preferred only two tubes on in the luminaire above their desks, while the younger pair preferred to use all four. Despite this discrepancy, the general need for more light as people age should be borne in mind in office lighting design – something that will be exacerbated by current demographic trends towards an ageing workforce.

1. Rating of the Lighting

When members of staff were asked to mark the lighting out of 10, (Fig 2) the Daylight Deluxe lighting was given a fairly positive rating. The existing lighting scored on average 6.1 out of 10, while the Daylight Deluxe scored 7.75, immediately after change-over, rising to 8.1 when all necessary adjustments had been made and time had been allowed for people to become accustomed to the new lighting.

In the feedback, comments included the following: 'better Lighting, better performance', 'brighter is better', 'improved mood', 'everything is sharper and crisper' and 'it's brighter inside compared to the yellow gloomy lights'. In the survey immediately after the installation, two people

reported that the new lighting was more like a cloudy day as the prevalence of yellow in the original lighting was reminiscent of a sunny day. One of them strongly disliked the new lighting, but following light level adjustments there was no negative feedback from them in the final survey.

2. Alertness and Fatigue

A simple scoring mechanism was used for people to report how they felt at different times of the day in terms of alertness and fatigue (Fig 3). A positive change in the fatigue index should be read as people feeling more awake. The table below represents that aggregate for all participants in the surveys

Analysing the results to a greater level of detail showed that alertness improved for every area of the floor whereas the fatigue index found a significant improvement in area B, which receives little direct sunlight during the working day.

3. Visual Acuity, Eye Strain and Headaches

A simple scoring mechanism was used for people to report the level of these symptoms (Fig 4) they experienced. In the final survey, the survey

asked if these symptoms had improved, worsened or remained unchanged under the new lighting. People did not have access to their previous submissions.

Most notably, nobody reported that any of these symptoms had worsened. Analysing the results by area showed marginal statistical improvements for visual acuity and headaches but a more significant drop in the level of eye strain. Once again the greatest improvements were in area B.

4. Mood, Performance and Sleep

In each of the surveys the question was asked about whether individuals perceived the office lighting affecting their mood, performance or sleep. The issue of sleep was included in line with the report into Philips ActiViva lighting, which argues that adding an additional blue to standard white-light fluorescent tubes could help workers sleep better at night.

In the initial survey, before the lighting was changed, over one in four reported an adverse effect on their performance from the white lighting. The effects on sleep and mood were similarly negative. The problems

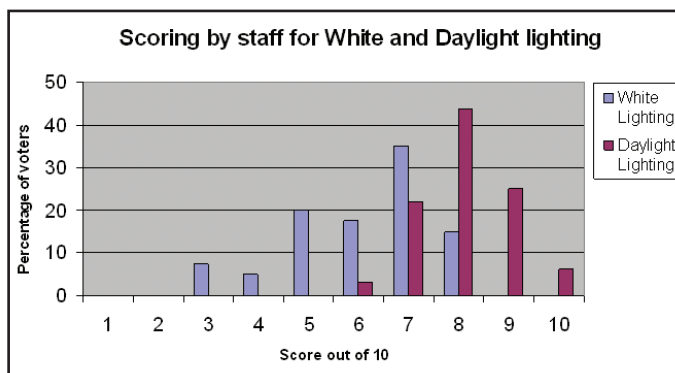


Fig 2: Graph showing survey scores for the original (White) and new (Daylight Deluxe) lighting

Alertness	Start of the day	Lunchtime	An hour before leaving	When departing	Overall
Percentage Change in Alertness Index	+11.8	+17.9	+13.5	+15.3	+14.6
Percentage Change in Fatigue Index	+11.9	+25.8	+9	-5.6	+10.2

Fig 3: alertness and fatigue assessments

	Visual Acuity	Eye Strain	Headaches
Percentage of people reporting an improvement under the new lighting	48	45	23

Fig 4: visual acuity assessments

	Mood	Performance	Sleep
Percentage of people reporting being negatively affected by the white lighting	8	28	15
Percentage of people reporting being positively affected by the daylight lighting by the final survey	16	19	7

Fig 5: assessments of mood, performance and sleep

Ambivalent	In favour	Strongly in favour
19%	50%	31%

Fig 6: views on of the new lighting being rolled out across the building

included harshness, glare, reduced concentration and greater fatigue. After the initial rollout most of the feedback was positive about the effects of the new lighting. By the final survey feedback remarks were all positive (fig 5).

There have been some attempts to claim that Daylight Lighting is the answer to Seasonal Affective Disorder which affects 6% of the population, but research appears to show that much higher lighting levels – 2000 lux in some cases – are required to make a difference. Three people declared in the survey that they were affected by SAD and while one found the lighting very uplifting, for the other two the jury is still out, until they have worked under the new lighting for a full winter season.

5. Other Survey Findings

Of the respondents to the first survey, three in five (much higher than the 36% quoted in the Bodart & Deneyer paper⁽⁵⁾) reported a significant preference for sitting next to a window. Of those who worked on a computer at home, over 1 in 4 reported that their fatigue was comparatively worse after working in the office.

Conclusions

The main thing that stood out from this trial project is

how different individuals' lighting needs are. This would indicate that the conventional practice of providing uniform lighting in offices is almost certainly detrimental to productivity.

One question in the final survey asked whether the new lighting should be rolled out elsewhere in the business (Fig 6). The responses as tabulated below show a fairly strong consensus. Even those who were ambivalent admitted how much better the new lighting was for reading -- and how helpful it was for people located away from windows.

The generally positive results of this pilot have led management to indicate that they might install the new lighting across another floor at New Malden, in the near future, to see if there is a similar positive sentiment. However, at another site where refurbishment has taken place recently, daylight lighting is already being adopted -- and there is interest at other sites within the business about the findings of this survey. Daylight lighting is now considered as part of the likely design on future major refurbishment projects.

There is still the possibility that the Hawthorne effect could be shown to play some part in these positive

findings -- and as indicated, the project was rolled out at the end of winter, rather than in the period of minimum daylight access. A further survey covering the key parameters is planned for late November/early December 2009, to gauge if the positive findings still obtain. This will only be given to members of staff who haven't moved from the floor in the last nine months.

References:

1. 'BAE Systems Calls in Luxury Yacht Designers' by Roland Gribben, *Daily Telegraph*, Dec 7, 2008 <http://www.telegraph.co.uk/finance/newsbysector/industry/defence/3659542/Bae-calls-in-luxury-yacht-designers.html>
2. 'Effects of Light on
3. 'Industrial Lighting, Productivity, Health and Well-being', by Gerrit van den Beld and Wout van Bommel, Philips Lighting, 2001
4. 'Visual Power and Visibility', by G J Fortuin, Philips Research Report 6, 1951
5. 'Analysis of the survey on office workers' interest in windows', Magali Bodart and Arnaud Deneyer, IEA 31 – Subtask A, September 2004.
6. *Advanced Lighting Guidelines 2003*, the New Buildings Institute Inc., White Salmon Washington, USA <http://www.advancedbuildings.net/ALGOnline.htm>

LJ Editor, Carl Gardner, comments: This project, to research the background issues, encourage the BAE Systems management to trial new lighting of this kind and then to systematically research the effects, is a highly admirable initiative on the part of someone who is not a lighting specialist. The fact that the findings were so positive, when the project only involved changing the lamp type and colour temperature in existing, older, specular T8 louvred downlights, shows that the move to 'cool', better quality light sources could be a worthwhile move in any office. A further step forward from this might be to invest in modern T5 lamps in luminaires that offered an indirect lighting component, rather than simply direct downlighting. The positive effects would undoubtedly be even more spectacular – and could prove to be a worthwhile investment, in terms of staff well-being, productivity and further energy savings.