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Autor/ es
Author/s

Henri Juslén
Erik Kremer

Afiliación/ es del autor/ es
Affiliation/s of the author/s

MSc. Henri Juslén Eng. Erik Kremer

Dirección principal
Mail address

Henri Juslén, IDMAN Oy (Philips Lighting), Mattilantie 75, PL 4, Mäntsälä, Finland
Erik Kremer, Philips Lighting B.V. Rondweg Zuid 85 Winterswijk, NL

Teléfono, fax. e-mail de la persona de contacto
Phone, Fax number and e-mail address of the contact person

Henri Juslén
Phone +358 19 6892309
Fax +358 19 6883231
henri.juslen@philips.com

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Localised lighting for efficient use of energy and better performance – Field Study in the factory

Henri Juslén and Erik Kremer

1 Abstract

In this test, the lighting of the factory hall concerned was changed from fixed uniform general lighting to more flexible localised lighting. The main objective was to use less energy for lighting and at the same time to improve the lighting conditions. The new lighting installation used 39 per cent less energy than the old one. Users opinions were measured with questionnaires before and after changing the lighting installation. Most of the users felt that the changes in the working environment and lighting conditions were positive. Normal factory data was used to monitor productivity and absenteeism. After the change of lighting conditions, the productivity in the test area increased while the absenteeism decreased. Productivity data in the reference area showed for both productivity and absenteeism a much weaker but opposite trend.

Keywords: lighting, energy saving, localised lighting, productivity, industrial environment.

2 Introduction

Although the energy used for lighting in industry is limited compared to other energy-consuming systems, the pressure to reduce the energy consumption of lighting installations is still very actual. Modern lighting techniques offer the option to save energy without compromising the performance and well-being of the employees. It is the challenge to reduce energy consumption whilst improving visual conditions, resulting in improved productivity and perceived well-being of the workers.

The influence of the (artificial) lighting on productivity has been the subject of several investigations during the past 100 years. Lighting influences productivity factors such as output, errors and accidents (Völker 1999, van Bommel and van den Beld 2004, Juslén and Fassian 2004). The effects of light can be divided into visual and psychobiological effects. Besides the amount of light, glare, spectral distribution and spatial distribution of light are important for seeing. Knowledge with respect to biological effects is still rather limited. Recent findings of non-image-forming, psychobiological effects via a photo-biological pathway in the brain (Brainard et al. 2001, Hattar et al. 2002, Berson et al. 2002) have increased our knowledge about biological effects. People need sufficient light to stay alert.

So, if we are trying to save energy in lighting, we should in fact increase rather than decrease the vertical and horizontal illuminances in the working area concerned. This means rethinking where the work has to be performed, when it is performed, and what the most important parts of the work are. Possible lighting changes are for example:

- better use of lighting control, such as time switching, occupancy sensors, daylight dimming, or personal control
- new luminaires with better optics and the highest energy efficiency
- new installations, such as more localised or task-based lighting.

3 Methods

3.1 Experimental set-up

3.1.1 Lighting

The factory presented in this study is a luminaire factory in The Netherlands. Originally the factory hall was equipped with only a general fluorescent lighting installation. This supplied uniform lighting all over the area (2*58 W, 4000 K, CRI 85). Only limited daylight via windows is available. However, daylight does not contribute to the general illuminance. Switching off the lighting was done at the end of the working day.

The change in the lighting installation was realised in June 2004. Figure 1 shows the new lighting installation. It consists of two parts, namely reduced old general lighting installation at ceiling level in combination with suspended localised lighting by dedicated low-glare luminaries (2*54 W, 4000 K, CRI 85) above the main task areas. The general lighting is grouped in such a way that time switches ensure this lighting is only switched on in those areas where work is actually being carried out. Two or three persons are working at one workplace, and they are able to switch off the localised lighting from the assembly line when they no longer need it.

Figure 1. New localised lighting installation. General lighting by white reflector luminaires and localised task lighting by suspended low-brightness luminaires.

Illuminances in the factory before and after the change are shown in Table 1. As can be seen, the general illuminance decreased by approximately one-third, while the illuminance at the assembly tables was doubled.

Table 1. Horizontal and vertical illuminances at the test area.

	General lighting		Assembly tables	
	E_h (lux)	E_v (lux)	E_h (lux)	E_v (lux)
Old installation	400 – 650	100 - 300	450 - 600	100 - 300
New installation	300 – 380	100 - 170	800 -1300	250 - 500

3.1.2 Tasks, subjects, and performance measurements

The products assembled were different for the different workstations, but the tasks that had to be performed were similar for all assembly workstations. The subjects assembled luminaire components such as the frame, the gear, and optical parts. Connecting the wires is visually the most demanding part of the work. The tasks were mainly in the horizontal plane. In the European standard EN 12464-1 (2.6 electrical industry, 2.6.2 assembly work, medium) the minimum maintained illuminance for this kind of work is 500 lux.

A total of 42 persons were working in the area. Their average age was 42. Sixty-nine per cent of the subjects were female. Efficiency and absenteeism were monitored employing normal factory data. So no extra productivity measurement was set up for this study. Personal opinions regarding the working environment and lighting conditions were monitored by questionnaires filled in before and after changing the lighting installation.

4 Results

4.1 Questionnaires

The ‘before’ questionnaires were completed by 21 persons working in the test area, while 26 persons completed the ‘after’ questionnaires. The results are shown in Figures 2 and 3. Practically all parts of the working environment were evaluated as being better after the change. The biggest change was in the brightness of the working environment. Lighting conditions were also assessed as being better after changing the lighting installation. Of the 26 persons who completed the ‘after’ questionnaire, 11 did not notice pronounced effects on their work, 12 were strongly in favour of the new lighting, while interestingly, there were 3 who felt that the new lighting disturbed them more than it helped.

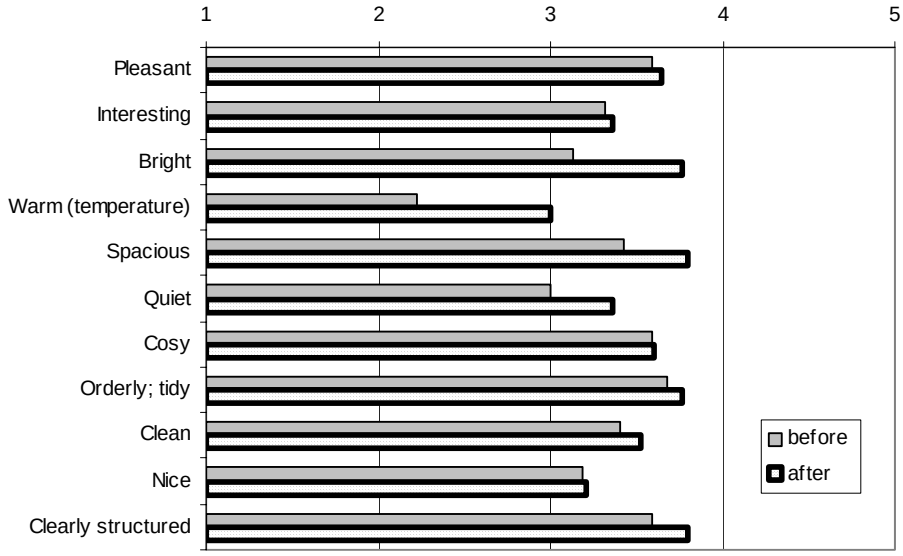

Figure 2. Answers to the question "What is your general impression of your working environment?" Answers given before and after changing the lighting installation. (Scale: 1 – very negative, 2 – negative, 3 – no opinion, 4 – positive, 5 – very positive)

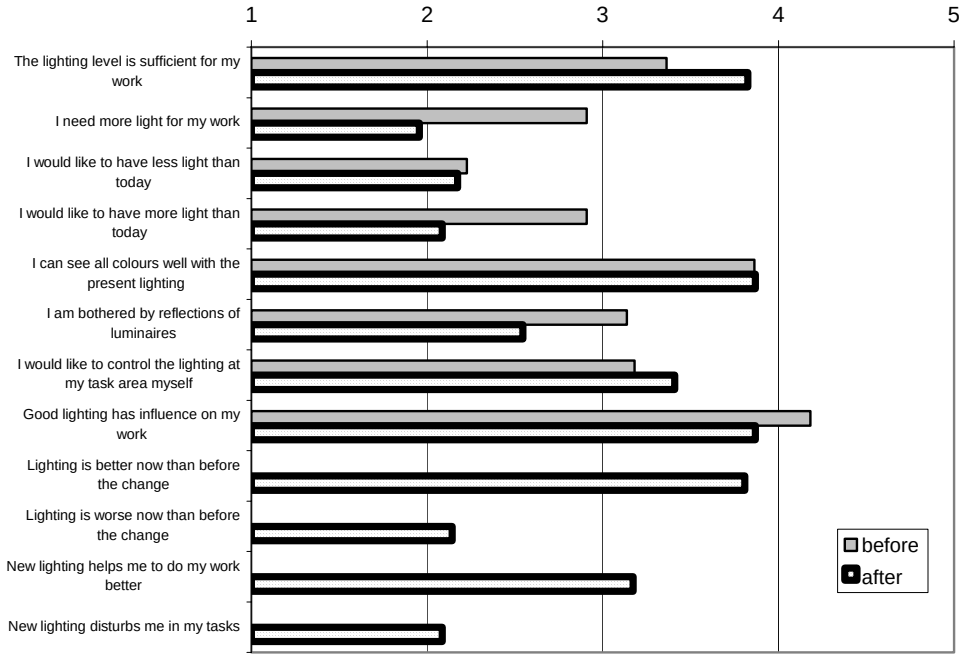

Figure 3. Answers to the request: "Please indicate if you agree or disagree with the next statements", given before and after changing the lighting installation.
(Scale: 1 – totally disagree, 2 – disagree, 3 – no opinion, 4 – agree, 5 – totally agree)

4.2 Energy results

Although the installed power was reduced by only 7 per cent (from 45 kW to 42 kW), the energy consumption could be reduced by 39 per cent, from 207 to 127 MWh/year. This enormous reduction in energy consumption is mainly due to the fact that the localised lighting was only switched on when and where it was needed, and the reduced general lighting was grouped per larger working area, and was switched off automatically outside working hours.

4.3 Productivity and absenteeism

Monitoring productivity and absenteeism is a standard procedure in the factory. Table 2 shows changes in both productivity and absenteeism figures. Unfortunately, during the autumn of 2003, changes were made in the factory, which made it impossible to include values from before that time in the comparisons. The productivity in 2004, prior to the lighting change, has been set as reference value, and changes after the new installation are shown as percentages. Values from the reference hall have been shown in the same way, although there was no lighting change here.

Setting the absenteeism rate in both halls for 2003 (weeks 26-52) as the reference value, any changes in absenteeism could be assessed. The changes are shown in the table.

Table 2. Changes in productivity and absenteeism rate in both the test hall and the reference hall.

	Productivity		Absenteeism	
	Test hall	Reference hall	Test hall	Reference hall
Week 26-52 (2003)	NA	NA	reference	reference
Week 01-20 (2004)	Reference	reference	-5.80 %	-0.60 %
Week 26-52 (2004)	+5.50 %	-1 %	-8.30 %	-0.20 %

5 Discussion

5.1 Methodology

In this study, the change in lighting conditions was made only once. In a production environment there are always several actions running as all parties try to achieve better results in terms of efficiency, productivity, fault reduction and reducing absenteeism. So although the use of reference group helps us to detect the influence of lighting, we cannot separate fully the influence of the improvement of lighting from other issues. Other possible reasons for improvements could, for example, be actions of management and the psychological effect of being listened to.

5.2 Employees' opinions

The results of the questionnaires were clear. Most of the subjects preferred the new lighting conditions and resulting impressions of their working environment over the previous ones. It is also important to note that some subjects were strongly of the

opposite opinion. Discussions afterwards indicated that the reason for this might lie partly in the process adopted: involvement of the subjects in the processes of change could have been better.

5.3 Energy savings, productivity, and absenteeism

Energy savings in the test were quite high. Although the reduction in installed power was rather limited, the measured reduction in energy consumption was impressive: 39 per cent. Reducing general lighting and improving localised lighting seems to be an effective way of improving conditions and reducing the use of energy. But we have to remember that this kind of change also limits the degree of flexibility afforded in positioning the workplaces. In those areas where the positions of the workplaces are fixed, the combination of added localised lighting and reduced general lighting seems to be a good solution. Positive results in reducing absenteeism and improving productivity show that a significant reduction in the use of energy can be realised without decreasing efficiency.

6 Conclusions

This simple before-and-after case study shows clearly that energy savings in this kind of old installation are possible. General lighting can be reduced by employing better task lighting and an improved lighting control system to yield an increase rather than a decrease in efficiency. This change leads to significant energy savings, although the installed power remains more or less the same.

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