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LIGHTING AND PRODUCTIVITY – NIGHT SHIFT FIELD STUDY IN THE INDUSTRIAL ENVIRONMENT

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Abstract

The influence of (artificial) lighting levels on productivity has been the subject of several investigations during the past 100 years. Recent findings of non-image-forming, psycho-biological effects via a photo-biological pathway in the brain and the increasing demand for higher productivity have made the issue even more important. The results of this field study show that under a higher lighting level, the speed of night shift manual assembly in an electronics factory was increased.

General Introduction

Improving the lighting at the workplace has several positive effects on the performance of the workers. Lighting influences productivity factors such as output, error and accidents (van Bommel et al., 2002; Völker, 1999). A literature search yielded several field studies in which effects brought about by changes in the lighting were measured in an industrial environment (Ruffer, 1925 and 1927; Schneider, 1938; Goldstern and Putnoky, 1931; Bitterli, 1955; Stenzel, 1962a and 1962b; Crouch, 1967; Lindner, 1975; Carlton, 1980; Völker, 1999). Unfortunately, very few of these studies are well documented. Some are simply offered as examples in general papers, while most of them are old though still of use.

In fig. 1 and 2 the results of the studies found in literature have been put together.

Fig. 1 gives the increase in work output and fig. 2 the decrease in errors or rejects, as a function of task illuminance. The dotted lines connect the 'before' and 'after' situations for each individual

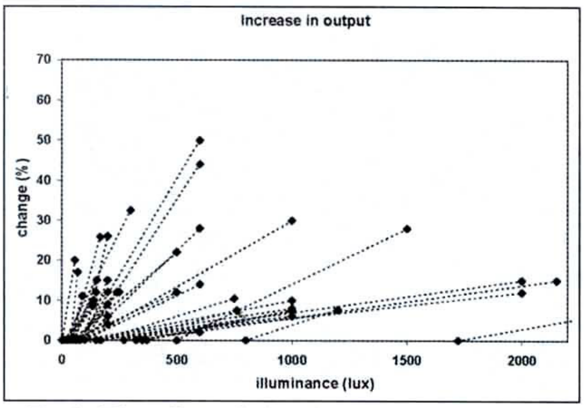

Fig. 1. The effect of the change (increase) of the illuminance on work output. The dotted lines show the results of the individual tests

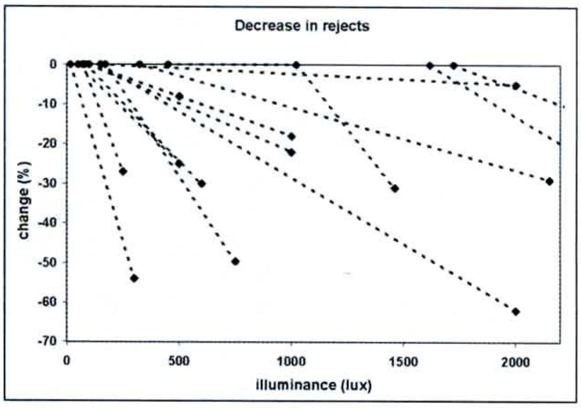

Fig. 2. The effect of the change (increase) of the illuminance on rejects (errors). The dotted lines show the results of the individual tests

study. Many of the studies started with very low illuminances. Almost all studies show an improvement in performance after the lighting change. In most cases, the illuminance has been increased, but the exactly how strong the influence of the illuminance is on performance remains unclear since other factors may also have played an important role.

It should be kept in mind that in experiments on human performance, any increase in productivity could be caused by the so-called «Hawthorne effect». The Hawthorne effect (Mayo, 1933; Bloggs and Draper, 1996) is the effect that the study or evaluation itself has on those concerned; the feeling of being observed and paid attention to can lead to improved performance. The Hawthorne effect will be stronger in laboratory tests where the subjects are monitored intensively outside their normal environment.

Industrial lighting is a very diverse field, because the eye's tasks differ largely for different types of industry. To be able to estimate the effects of lighting on performance in industry, better documented field studies in different types of factories are necessary. In principle, the more information we have from a field study, the better.

Lighting level and speed of the manual assembly during night shift

Introduction

To see if lighting influences the speed of manual assembly, a study was carried out in an electronics factory in the Netherlands. The main part of the production took place during the daytime (Juslén et al. 2004). But a part of the production took place at night, and it is the night-shift results that are reported in this paper.

The factory produces electronic gear for gas-discharge lamps. Machines install part of the components before the products are transported to the manual-assembly area. The workers install components on the circuit boards manually (fig. 3). The number of manually installed components varies depending on the product. The tasks are performed mainly in a horizontal plane. The lighting installation consists of continuous luminaire lines (luminaires 2×49 W, T5, white reflector). The installation provides approximately 1200 lx on the horizontal plane of the workbenches. Fig. 4 shows the luminances in the working area.

To see if lighting level influences the speed of manual assembly, the horizontal illuminance at the assembly surface was alternated between 800 lx and 1200 lx. During a shift, the illuminance was kept constant, the changes occurring between shifts. During the measurement period (from 5-1-2004 to 5-3-2004), the lighting level was changed by switching on or off every third luminaire. The night shift was scheduled from 2400 to 6000 hours. During the night shift five people were normally working in the manual-assembly area.

Results

Only products produced under both lighting conditions were analysed. Seven product types were produced under both conditions. Five of these were produced faster and two slower under the higher lighting level. The average production times for these products ranged from 36 seconds to

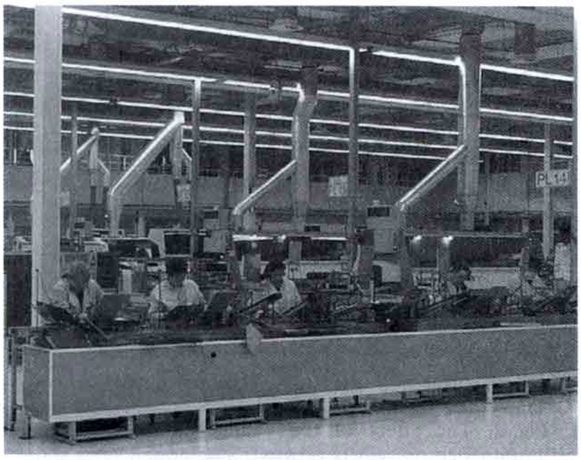

Fig. 3. Part of the test area

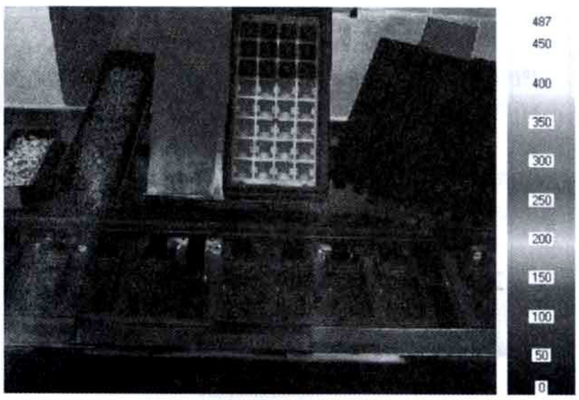

Fig. 4. Luminances in the working area (cd/m^2)

78 seconds per product. Because of this range, the average production times cannot be compared between the products. The data have therefore been normalised, and the relative difference in production time between the higher and lower lighting level has been calculated for each product. The mean of these means shows that the production time was 7.7 per cent faster when more light was employed. Two-factor analysis of variance (dependent variable production time, factors light and product type) was performed to test the difference. The statistical test results are shown in table 1. Fig. 5 shows the relative differences for all product types.

Table 1

Result of two-way ANOVA

The two-factor analysis of variance showed significant main effect for the light factor (800 or 1200 lx):
$F(1, 3174) = 26{,}1$, $p < 0.01$
significant main effect for the product types factor:
$F(6, 3174) = 14{,}5$, $p < 0.01$
interaction between light and product type was significant for both periods:
$F(6, 3174) = 14{,}4$, $p < 0.01$

The two-way ANOVA yields a significant effect for light, showing that at 1200 lx the speed of manual assembly was 7.7% higher than at 800 lx.

Discussion

The result of this test shows that lighting level had an influence on production speed. It also confirms that lighting is not the only factor influencing productivity. Some products were turned out faster in the darker conditions. Absenteeism or differences in experience were not controlled during this night-shift study. The influence of other factors was reduced by alternating the lighting level. It is very unlikely that any other factors had the same rhythm, so their influence will be averaged out over both lighting conditions. The question arises: why was the production faster under the higher lighting levels? The difference is too great to be caused only by increased visual performance. We could assume that part of the effect was caused by biological effects of light, such as direct brain stimulation or a change in the setting of the biological clock. The extent of the effect was great compared to the relatively small change from 800 to 1200 lx. Since the lighting level was alternated, no conclusions can be drawn about the sustainability of these effects. Possible long-term effects of lighting level cannot be studied with this approach.

Conclusion

The study showed clearly that under the higher (1200 lx) lighting level production speed during the night shift manual assembly was significantly higher than under the lower lighting level (800 lx). The underlying cause of this effect might be sought in visual performance or psycho-biological effects.

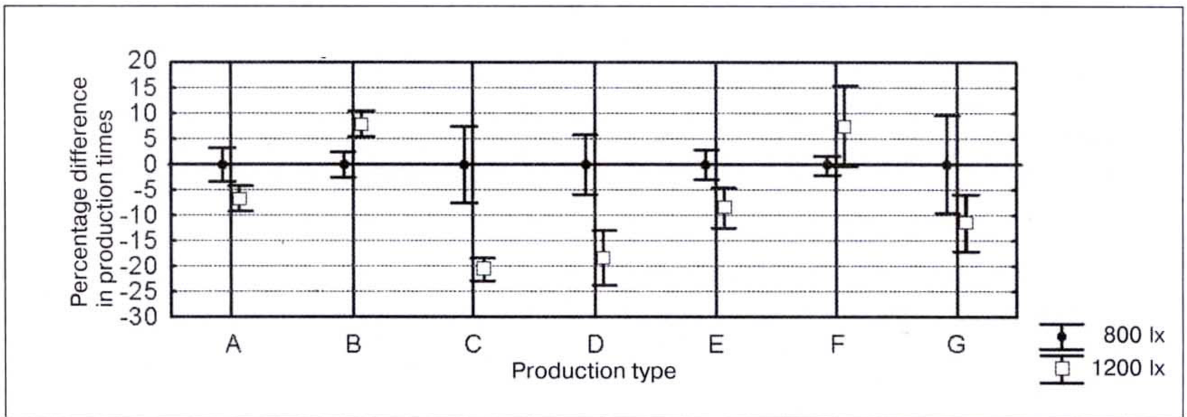

Fig. 5. Relative production time differences of the different product types under the different light conditions. The data points show the difference between 1200 lx and 800 lx. The open squares are the 1200 lx data, the black dots are the 800 lx data used as the reference. (Vertical bars denote 0.95% confidence intervals)

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