

Preferred luminance distribution in working areas

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KEYWORDS

pilot study, preferred luminance distribution, open plane offices, luminance ratio, luminaire light distribution, field of view, Fagerhult, NUTEK, University of Jönköping

ABSTRACT

This paper describes a pilot study carried out at the University of Jönköping with the co-operation of NUTEK (The Swedish board for Industrial Development, which was in charge of implementing the Swedish energy policy up to 1998), and the Swedish lighting industry represented by Fagerhult.

It was undertaken to give a basis for improved lighting in the classroom (and even larger workplaces, such as open-plan offices) by finding out at which luminance ratio (between the luminaire luminance and the luminance of the surroundings) visual acuity started to suffer.

The study aimed at determining an appropriate luminaire light distribution in open plane areas based on general lighting and to investigate suitable lighting luminance distribution within the field of view.

BACKGROUND

Energy authorities are charged with encouraging the use of energy efficient technologies. This can be achieved by persuading both clients and developers to incorporate energy efficiency requirements into the design brief. In Sweden, lighting accounts for about 10% of total energy consumption, so this area offers considerable potential for energy saving.

But energy efficiency advice must be accompanied by recommendations on lighting quality; otherwise require-

ments for energy efficiency could be set too high and adversely affect quality. By combining recommendations on quality and energy efficiency in lighting, the energy authorities hope to elicit a more widespread response and promote the spread of good, energy-efficient lighting.

The Swedish energy authority, NUTEK, saw a demand for improved lighting quality in schools at a very early stage, and by 1994 had made recommendations for school lighting. Daily teaching activities give rise to very demanding visual tasks, including intensive reading work, and the careful study of children's facial expressions.

In Sweden today, luminaire luminance limits for working areas are partly expressed in absolute figures; however, luminance contrast is also important. The eye adapts to the average luminance in the visual field, the so-called adaptation luminance. But this process is also much more complex than simple figures would suggest. If the eye is adapted for high lighting levels, the bright area does not appear to produce as much glare as if the eye is adapted for low lighting levels; for instance, glare from a luminaire set against a dark background causes more difficulty than that from a luminaire set in a light background.

To improve school lighting (and also lighting in workplaces in general) new ways of defining requirements for luminances have to be developed, including putting more emphasis on the luminance distribution. At present our knowledge of luminance distribution is limited.

Purpose

The University of Jönköping, NUTEK and the Swedish lighting industry represented by Fagerhult cooperated in carrying out the pilot study.

Figure 1. The test site at the University of Jönköping



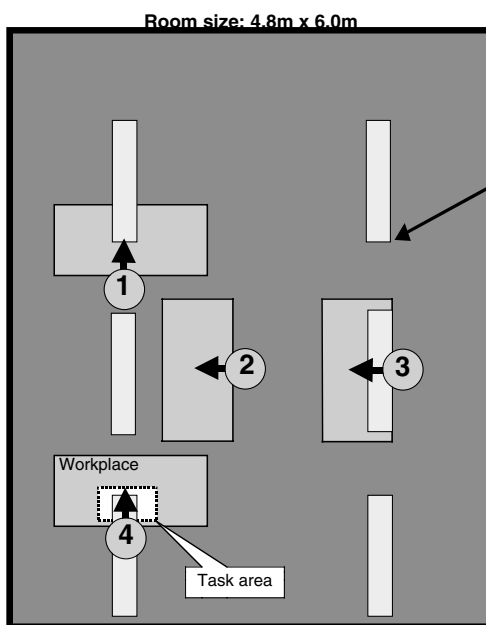
Test laboratories in lighting at the University of Jönköping

Purpose

The purpose of the pilot study was to determine an appropriate luminaire light distribution in open plane areas based on general lighting and to investigate suitable lighting luminance distribution within the visual field of view



Figure 2. Description of the test room



Area: 4,8x 6,0m≈ 30m² Ceiling height: 2,94 m

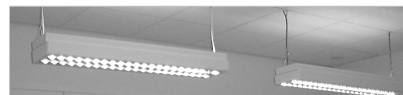
Reflection factors:
ceiling: 85% walls: 85% floor: 35% desk: 35%

Desk-size =1,40x0,70 m Desk-height = 0,72 m

Luminaire Mounting height =2,40 m

Downward flux ; dimmable: 2x28W,T5-3000K
louvre double parabolic, semi diffuse

Upward flux ; dimmable: 2x28W, T5 3000K



←○ Test position 1-4 -orientation

Position 1 :nearest luminaire within the field of view 45° above the line of sight - axial plane

Position 2 :nearest luminaire within the field of view 45° above the line of sight - across

Position 3 :nearest luminaire within the field of view 25° above the line of sight - across

Position 4 :nearest luminaire within the field of view 25° above the line of sight - axial plane

It was undertaken to give a basis for improved lighting in the classroom (and even larger workplaces, such as open-plan offices) by finding out at which luminance ratio (between the luminaire luminance and the luminance of the surroundings) visual acuity started to suffer.

IMPLEMENTATION OF THE STUDY

In the pilot study, a number of people adjusted the light distribution of luminaires (eg the ratio between up- and downlight components) in the test room, to give the most appropriate light distribution for carrying out visual tasks, while keeping a constant illuminance level within the task area. Subjects carried out the visual tasks at different viewing angles.

The lighting installation was based on a conventional general lighting system of today using a uniform array of suspended identical luminaires with an indirect/direct lighting.

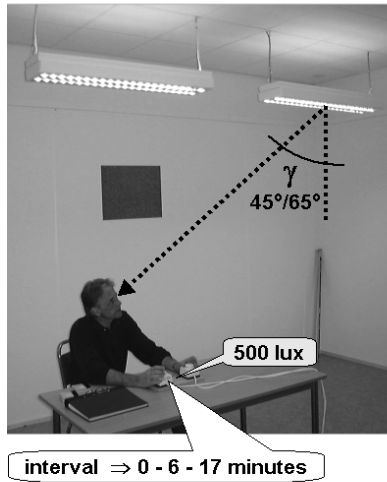
The different tasks were carefully described for each subject before it was carried out.

The subjects also had the possibility to practice in adjusting the required illumination level of 500 lux within the task area and also in setting the proportion of upward and downward flux. All luminaires were adjusted together so that the proportion of the upward and downward light was the same for each luminaire.

The total time for carrying out the test on each position was 20 minutes.

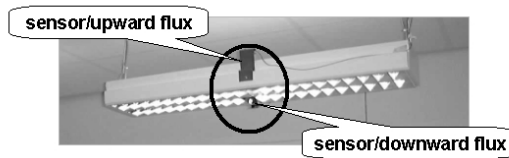
Figure 3. Methodology of the study

Methodology



- Study used **40 subjects (TP)** -lighting experts and laymen divided into two groups of 20
- Test was carried out in **four positions**, along axial and perpendicular to nearest luminaire with an angle of elevation $\gamma = 45^\circ/65^\circ$
- TP adjusted the illumination to a level of **500 lux** at each position within the task area and set the **preferred light distribution** of upward and downward flux by to dimmers
- TP set the illumination level of **500 lux** with the preferred light distribution on three occasions during test at each position, **0 - 6 - 17 min**
- TP carried out **different task during the test**
- The preferred values was covered by the **two sensors**

Luminaire used in the study



The following tasks were carried out of the on each position:

1. First adjustment of the 500 lux level within the task area while setting the preferred proportion of upward and downward light.
2. Reading a part from a book.
3. Summing up numbers from boards placed on the walls.
4. Second adjustment of the 500 lux level within the task area set the preferred proportion of upward and downward light.
5. Selecting a picture in a book and copying the selected picture on a tracing-paper. While carrying out this task (5) the subject had the possibility to adjust the proportion of upward and downward flux.

6. Third and final adjustment of the 500 lux level within the task area set the preferred proportion of upward and downward light.

In order to carry out the study, a full-scale test room was constructed at the University of Jönköping.

Implementation of the study

The following images describe the implementation of the study and the evaluation of the data (figures 3-4).

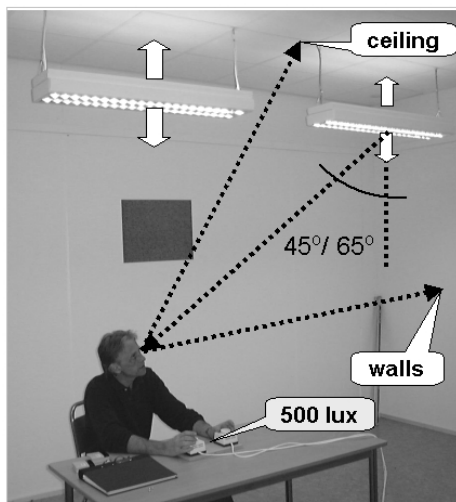
RESULTS

Preferred light distribution

The average values chosen by the subjects for the light distribution of the luminaires for the different test posi-

Figure 4. Evaluation of data

Evaluation of measurements



- The **light distribution** of the luminaire was calculated in percentage for the different positions 1-4
- The **spot and average luminance** of the luminaire was measured at the elevation angles of $45^\circ/65^\circ$, across and along the luminaire
- The **luminance of the room surfaces** - ceiling and walls was measured and calculated based on the preferred average values in the different positions 1-4
- The **luminance distribution ratio** between the luminaire and the room surfaces was calculated based on the preferred average value of the different positions.
 - luminaire : ceiling
 - luminaire : walls
 - luminaire : walls + ceiling

Figure 5.
Preferred light distribution in position 1-4

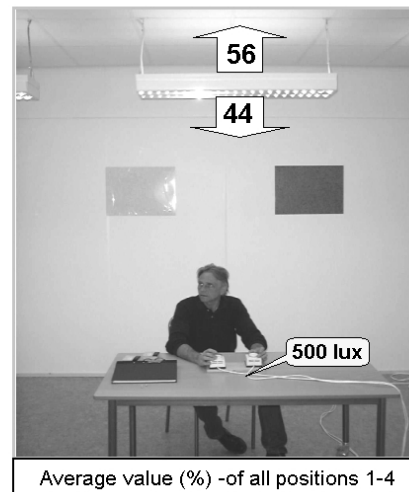
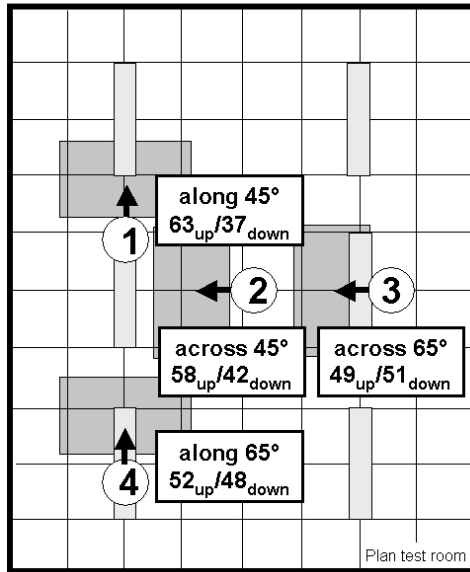
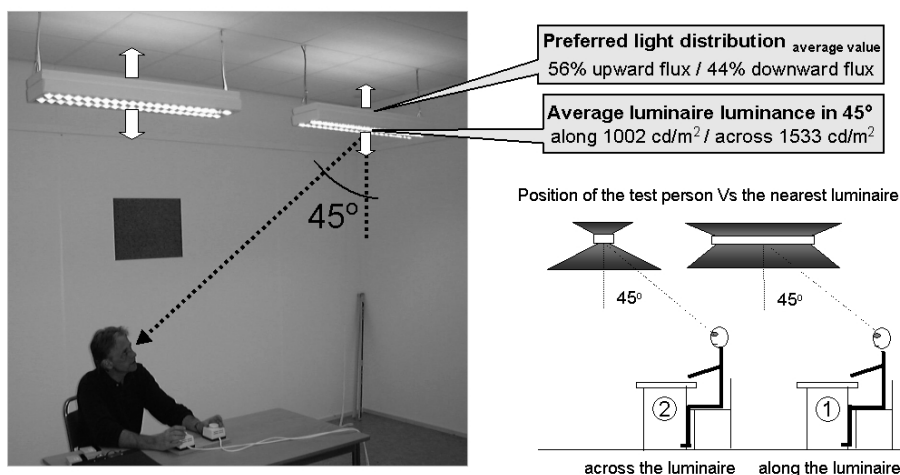


Figure 6.
Preferred light distribution / average luminaire luminance



tions and the overall average are given in the diagrams below (figures 5 and 6).

Average luminances of the room surfaces

To determine the subjects' preferred luminance ratios between the luminaire and the different room surfaces within the visual field, the luminances of walls and ceiling within the test room were measured and the average values calculated.

Preferred luminaire luminances

Luminaires were set at the overall preferred light distribution, the spot luminaire luminances were measured and the average luminaire luminances calculated.

Figure 9. Preferred luminance distribution: luminaire (spot luminance) vs. background (spot luminance) - background

Light distribution of the luminaire used in the test

The polar curves below shows the light distribution from the luminaires that were used in the test.

All luminaires were equipped with 2x28W T5-fluorescent tubes downward light and separately 2x28W T5 upward light. The upward and downward lights were individually dimmed in a preferred proportion to achieve the required illumination of 500lux on the task area. When setting the preferred proportion of the upward and downward light all luminaires were adjusted together so that the proportion of the upward and downward light was the same for each luminaire.

All luminaires were equipped with a semi diffuse double parabolic for the downward flux to fulfil an average luminance limitation of 1000 cd/m² at elevation angles above 65° and above from the downward vertical.

(In accordance with ISO 9241-7 – Luminance limits of luminaires which can be reflected in Display Screen Equipment (DSE) including VDUs)

Figure 7.

Average luminance - room surfaces

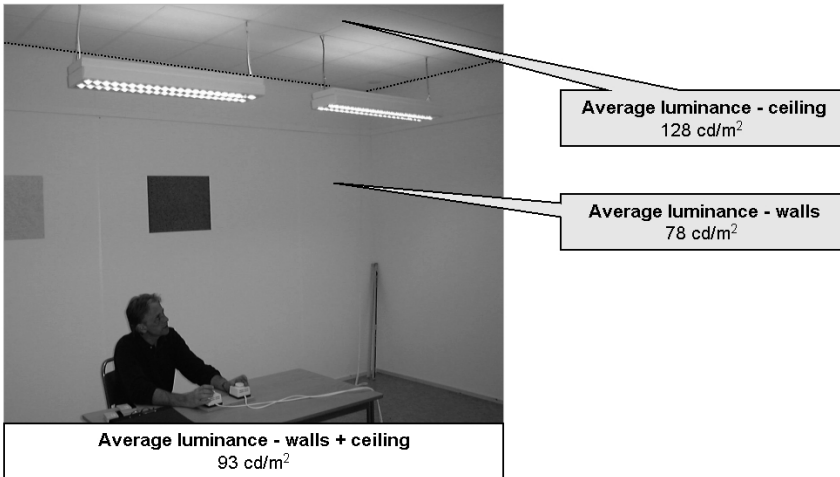
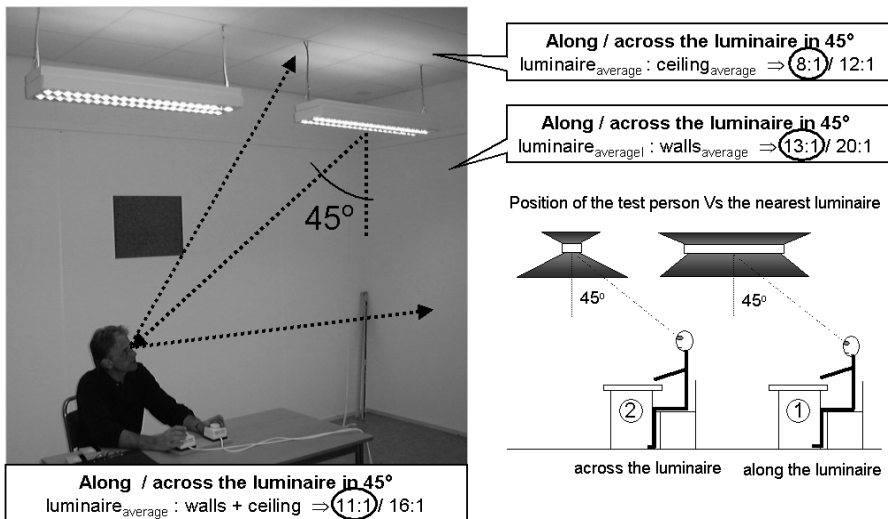


Figure 8.

Preferred luminance distribution ⇒ luminaire (average luminance) - background



CONCLUSIONS

The pilot study gave the following average figures as preferred values for the light distribution of luminaires under the test conditions described above.

Using the overall preferred light distribution, 44% downlight and 56% uplight, the luminance ratios between the luminaire and the luminances of the different room surface were calculated (see tables in figure 11).

The average preferred light distribution for the luminaires varied slightly between the different test positions: the average values of the uplight component varied between 49-63%, and those of the downlight component varied between 37-51%, depending on the position of the subjects with respect to the luminaires.

The preferred average value for lighting distribution for all positions was found to be 56% uplight and 44% downlight.

The pilot study showed that the subjects compensated for an increase in luminaire luminance downwards by increasing the uplight component.

The report showed that the preferred luminance ratio between the average luminaire luminance and the luminance of the ceiling and average luminance for the walls, was 11:1 axially and 16:1 perpendicular to the luminaire.

There was a good correlation between measured and calculated values for both illumination and luminances.

It should be noted that the results of the pilot study correspond well with general lighting conditions in office areas with bright walls and ceiling surfaces.

The pilot study was carried out in the absence of daylight.

Figure 9. Preferred luminance distribution: luminaire (spot luminance) vs. background

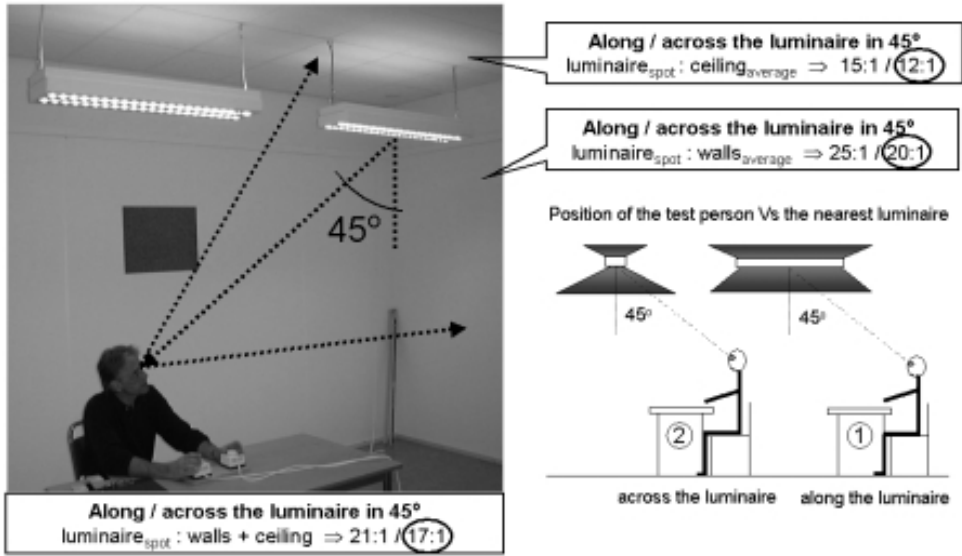
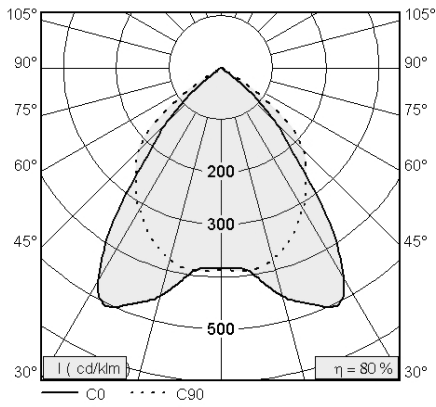


Figure 10. Light distribution of the luminaire used in the test

Light distribution of the downward flux
 (cd/klm, downward flux)



Light distribution of the upward flux
 (cd/klm, upward flux)

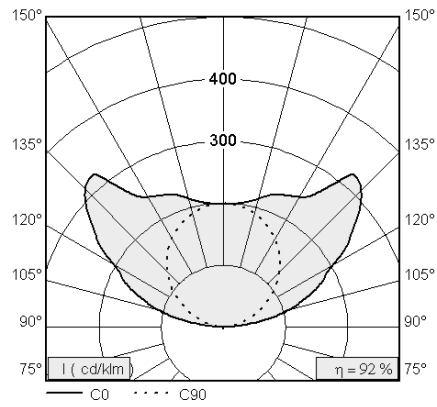
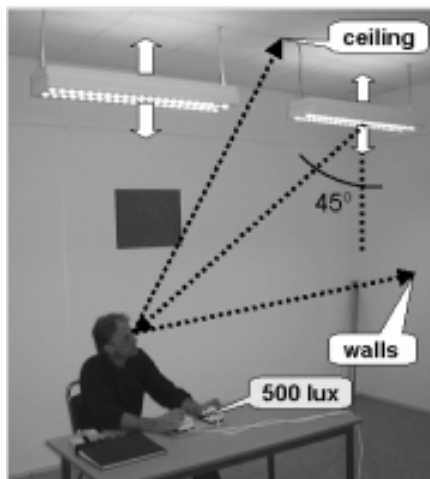


Figure 11. Summary of results.



Conclusion / Results

Preferred lightdistribution Average value of position 1-4	Downward flux (%)	Upward flux (%)
Test-luminaire	44	56

Luminance ratio Luminaire in 45° / surrounding Measured values based on preferred light distribution 44% / 56%	Luminaire Average luminance	Luminaire Spot luminance
Ceiling -average	8:1	12:1
Walls -average	13:1	20:1
Ceiling + walls -average	11:1	17:1