Light Protection Equipments in Office Rooms

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1 Introduction and subject formulation

In a workroom it is always desired to have outward eye contact and to sufficiently illuminate the room with daylight simultenously. There are several reasons for this desire. On the one hand, these conditions are necessary for the workers' well-being; on the other hand, there are energy savings for illumination and heating. Thus, it is always tried to have as much daykight inside the room as possible. This, however, can result in negative effects such as direct glare by the sun, reflections on visual display terminals (VDTs) caused by window or wall luminance, and overheated rooms. Due to the reasons mentioned above light protection equipment is required. In a BAUA research project comparative investigations on 'classic' light protection equipment, such as light protection foil, vertical and horizontal slats, and blinds whose primary aim is not directing daylight, were performed.

2 General considerations

In a series of tests light protection equipment was characterised with respect to its effect and applicability. First, viewing conditions required were investigated. Primarily, this concerns luminance values which can result in direct glare and reflected glare on the VDT. As a result, limiting luminance values for different VDT classes were defined. Measurements were performed and test subjects were asked on horizontal, vertical and cylindrical illuminance in real office rooms and in a field test. In these tests the interaction between daylight and artificial illumination was especially tested. The test subjects were asked by means of questionnaires (see figure 1). If there was a good correlation between the answers of the test subjects and the measurement data, conclusions on convenient illuminance and luminance data could be drawn by means of regression.

The value 3.5 was considered to be the central point of the bipolar scale (i.e. the beginning of the positive assessment), and it was converterd into the photometric quantity. Therefore, the data found are minimum or maximum data. A value of 1.5 (class 1) was used as a glare threshold value according to the Söllner scale.

Bipolar-Scale:
dark oooooooooooooooooooooooo bright
0 1 2 3 4 5 6 7

SÖLLNER Scale:
0 o just imperceptible
1 o
2 ojust acceptable
3 o
4 o just uncomfortable
5 o
6 o just intolerable

Fig. 1: Example question and assignment of numerical data

3 Investigations with natural daylight in office rooms

Test subjects were asked on the parameters below in a real laboratory-like room which was illuminated by daylight.

1. illuminance distribution in the room
2. influence of horizontal, vertical and cylindrical illuminance on the effect of depth and on glare
3. influence of the sky

In a seminar room of the Ilmenau Technical University 24 test subjects were asked; photometric measurements were carried out. The windows of the room were at the southern part of the building. The tests took place from August 26 to September 21 between 9 and 12 a.m. (position of the sun 30°... 50°).

In the test room a workplace with a well-coated VDT was set-up near a window (figure 2). The test subjects were not allowed to change the position of the VDT. The position of the VDT was intentionally chosen to allow reflections on the VDT by the window behind the operator (rear window).

test 1: sunny, clear skies

test 2: overcast

test 3: overcast; with additional artificial illumination providing a total illumination of 750 lx at the beginning of the test

An example of a regression between survey result and measuring data is shown in figure 3. The convenient illuminance data found are summarised in table 2 (second column). Having assessed the illumination situations given the test subjects were asked to use the type of light protection equipment they needed. Vertical slats and blinds for both windows were available. Since the window behind the operator could cause reflections on the VDT, in most cases a protection against the sun was chosen regardless of the illumination situation (table 1). The window in front of the operator (front window) was only shaded when direct sunlight fell on the workplace. With overcast skies this window was mostly not shaded.

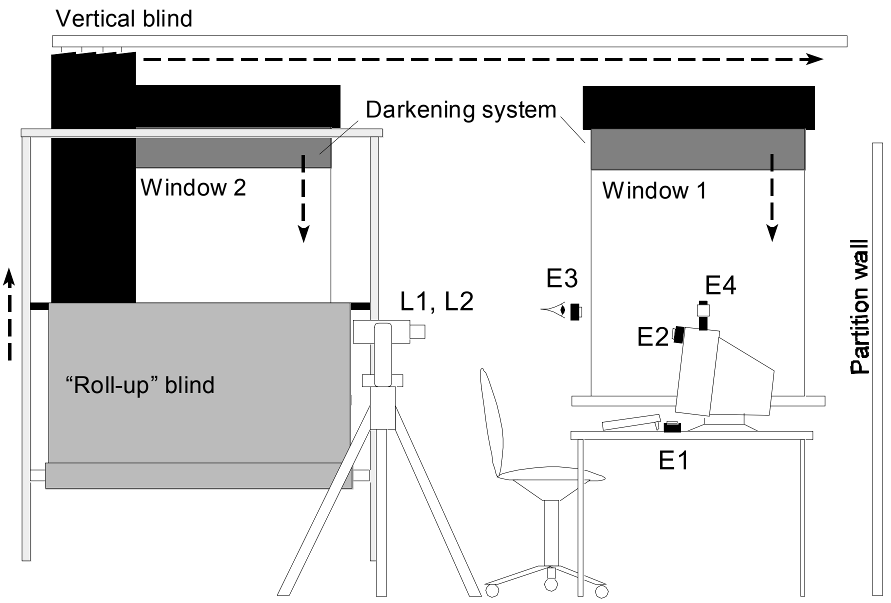

Fig. 2: Test installation

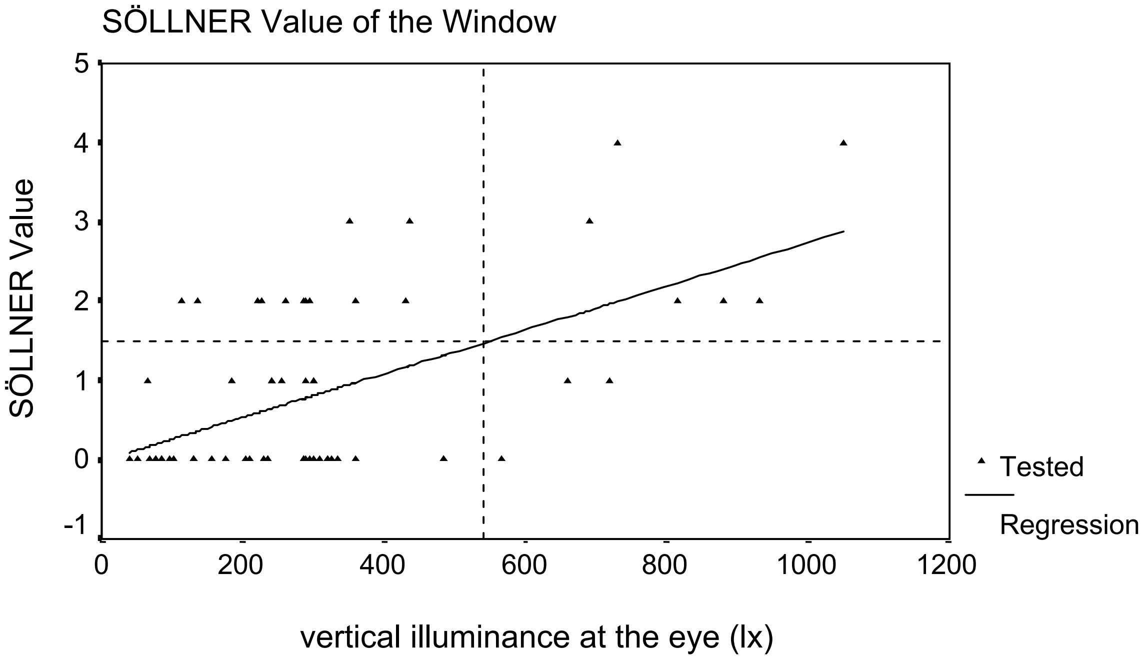

Fig. 3: Regression between vertical illuminance and glare evaluation (all tests)

situation	rear window (window 2)	front window (window 1)
sunny	100%	47%
overcast	96 %	12 %

Table 1: Shading frequency of the windows

Due to the light protection equipment chosen the room illuminance changed. The mean values of all test subjects in all tests are shown in figure 4. Above all there is a remarkable change in illuminance in test 1 (sunny).

The regression results and the results of fig. 4 are contrasted in table 2. The illuminance resulting from the light protection positions chosend are in good conformty to the regression results. In this test there are considerably lower values for the vertical illuminance at the eye.

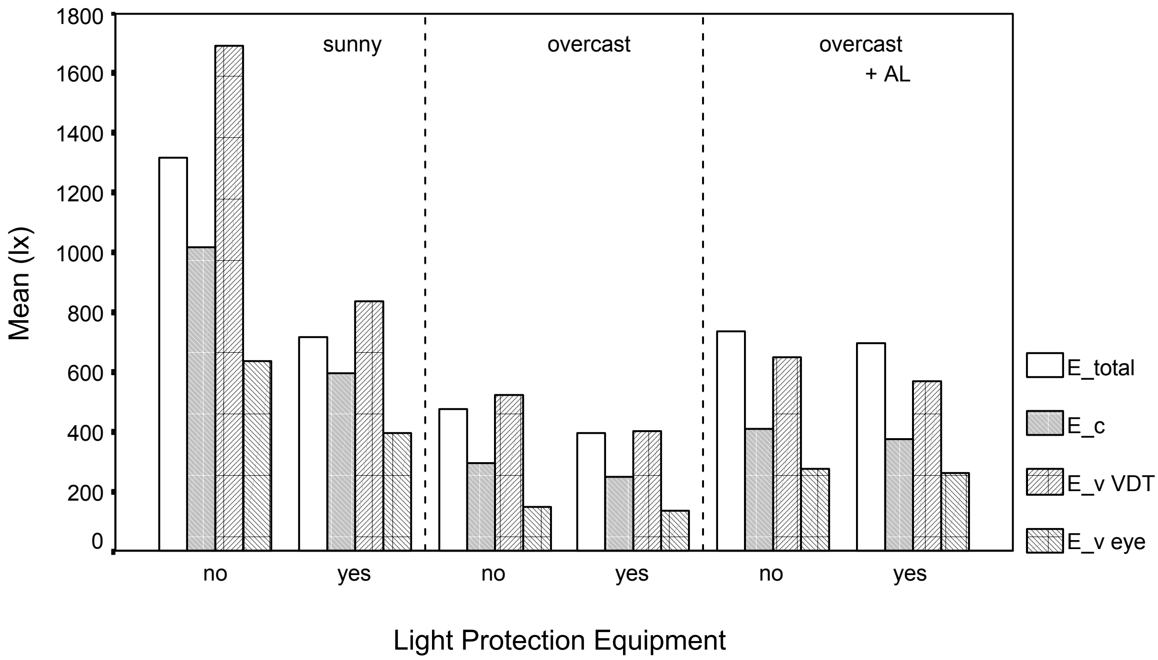

Fig. 4: Illuminance change due to light protection chosen

illuminance	specifications by regression	conclusions from fig. 4
cylindrical illuminance E_c	glare from 600 lx up	In test V1 E_c is reduced to approximately 600 lx. In V2 and V3 E_c is alredy below 600 lx and is only slightly changed by the light protection equipment.
vertical illuminance at the VDT $E_{v,\ VDT}$	max. 850 lx	In test V1 $E_{v,\ VDT}$ is reduced to about 850 lx. In V2 and V3 $E_{v,\ VDT}$ is already below 850lx and is decreased by the light protection equipment by 100 lx .
vertical illuminance at the eye $E_{v,\ eye}$	if sunny glare from 1200 lx up	In test V1 $E_{v,\ eye}$ is reduced to about 400 lx.
	glare from 350 lx up	In V2 and V3 $E_{v,\ eye}$ is below 350 lx and is just slightly reduced by the light protection equipment.

Table 2: Specification of illuminance according to light protection chosen

4 Investigations at an artificial window

In tests with real daylight it is nearly impossible to have constant ambient conditions. There are for example variable amounts of cloud and the changing position of the sun. Hence, each test subject evaluates the situation under different conditions thus making the assessment more difficult. Therefore, the following investigations were performed at an artificial window. The max. luminance of the window which could be realised was 17000 cd/m^2. The foils and slats were placed at the artificial window in succession. Table 3 shows an overview on 8 types of light protection equipment tested. In three cases the assessment was additionally carried out together with a general illumination of 500 lx (AL). Furthermore, a luminance of 200cd/m^2 and 1000cd/m^2 was included.

name	light protection equipment	L_{max} (cd/m²)	L_{min} (cd/m²)
none	window	17000	17000
foil 1	metal foil	300	300
foil 1 + AL	metal foil + 500 lx		
foil 2	metal foil	400	400
foil 3	metal foil	1400	1400
horizontal 1	slat, 50mm, white	250	100
horizontal 2	slat, 50mm, white, perforated	1500	250
horizontal 2 + AL	-“- +500 lx		
horizontal 3	50mm, mirrored, partially perforated	400	100
vertical 1	vertical slat	400	200
vertical 1 + AL	vertical slat + 500 lx		
vertical 2	vertical slat	2500	1300
200cd/m²	window luminance of 200cd/m²	200	200
1000cd/m²	window luminance of 1000cd/m²	1000	1000

Table 3: Light protection equipment tested (AL ... general illumination = 500lx)

VDT	1	2	3
type	CRT	CRT	flat-square screen, active display
coating	bad	very good	very good
pos. polarity	II	I	I
class (neg.polarity)	II	I	I

Table 4: VDTs and VDT classes testet according to ISO 9241-7

All the illumination situations shown in table 3 were evaluated by the 24 test subjects by means of a questionnaire. 3 VDTs (table 4) were assessed (positive and negative polarity as well).

The mean values and the standard deviations of all assessments are shown in figures 5 and 6. The influence of the VDT polarity is obvious. The influence of the general illumination (0 and 500 lx, respectively) is significant only once (vertical 1, VDT 2, negative polarity).

If the value 3.5 is considered to be neutral and all the other values above to be ‘positive’, results in the overview of table 5. The light protection equipment permissible according to this assessment is assigned to the VDTs tested. Therefore, there is the max. permissible window luminance for the different VDT classes (table 6). The results of flat-square screen 3 differ remarkably from those of VDT 1. They are shown separately.

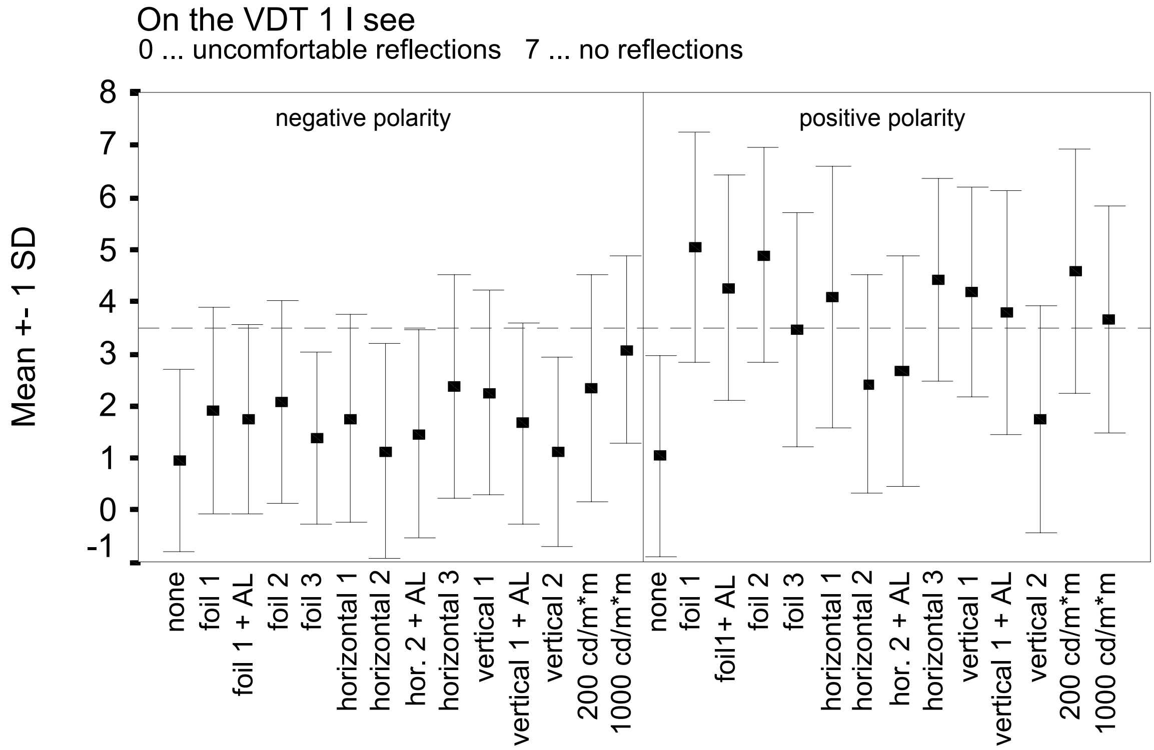

Fig. 5: Mean value and standard deviation of the assessments for VDT 1

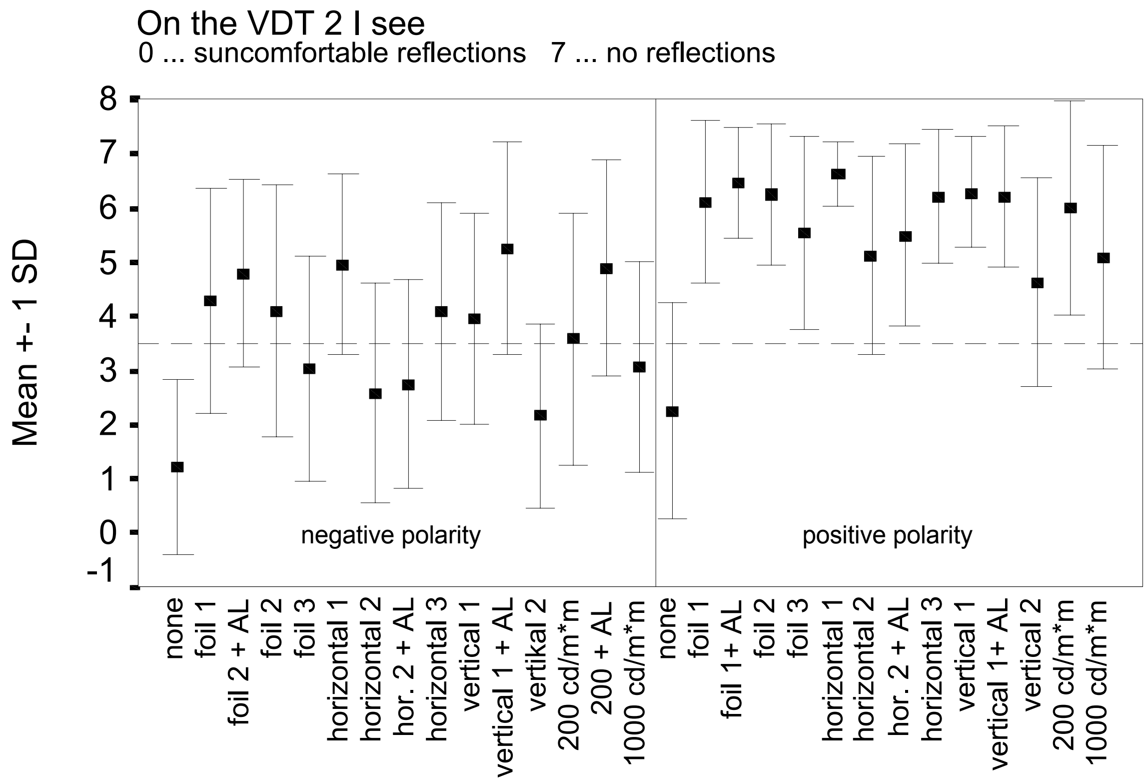

Fig. 6: Mean value and standard deviation of the assessments for VDT 2

	permissible light protection equipment	max. luminance in cd/m²	class according to ISO 9241-7
VDT 1 negative polarity	none		II
VDT 1 positive polarity	foil 1 foil 2 horizontal 1 horizontal 3 vertical 1 200 cd/m² 1000 cd/m²	300 400 250 400 400 200 1000	II
VDT 2 negative polarity	foil 1 foil 2 horizontal 1 horizontal 3 vertical 1 200 cd/m²	300 400 250 400 400 200	I
VDT 2 positive polarity	all	up to 2500	I
VDT 3 negative polarity	all	up tp 2500	I
VDT 3 positive polarity	all windows without light protection	up to 2500 17000	I

Table 5: Permissible light protection equipment for VDTs and VDT polarities based on the assessment of test subjects

class	VDT polarity	permissible luminance
II	negative positive	below 200 cd/m² 1000 cd/m²
I	negative positive	400 cd/m² 2500 cd/m²
flat-square screen	negative positive	2500 cd/m² 17000 cd/m²

Table 6: VDT classes and permissible luminance

5 Evaluation of light protection equipment at a real window

The evaluation of light protection equipment at an artificial window was possible only with restriction. Thus, for example, the outward view and glare by direct sunlight could not be evaluated. Therefore, the test subjects were asked at a real window.

The survey was planned to be performed with clear skies and in sunshine. Unfortunately, the weather conditions were rather unstable during the test period, and, for lack of time, the test had to be stopped after 6 test subjects. Futhermore, photometric measurements were carried out (table 9), and the heads of the test worked out their evaluations (table 10). The light protection equipment horizontal 3 is a mirrored horizontal slat which was tested under two conditions: in the closed state and in the open (light-directing) state.

0 ... imperceptible glare 2 ... acceptable glare 4 ... uncomfortable glare 6 ... intolerable glare	direct glare		glare by reflection at a VDT coated extremely well	
light protection equipment	direct sunlight	sky luminance (25000 cd/m^2)	direct sunlight	sky luminance (25000 cd/m^2)
foil 1	6	0	4	3
foil 2	6	0	4	1
foil 3	6	0	4	6
horizontal 1	0	0	4	4
horizontal 2	6	0	4	6
horizontal 3 open	6	5	4	3
horizontal 3 closed	2	1	3	0
vertical 1	0	0	0	0
vertical 2	6	6	6	6

Table 7: Evaluations by the heads of the tests

The test subject assessments are basically influenced by the fact whether the sun is in the field of view or not. As expected, the evaluation of glare is influenced by this condition. But the room brightness and the outward view assessment are influenced, too. Of course, adaption plays a certain role as well. In figures 7 and 8 these clear differences in evaluation are shown.

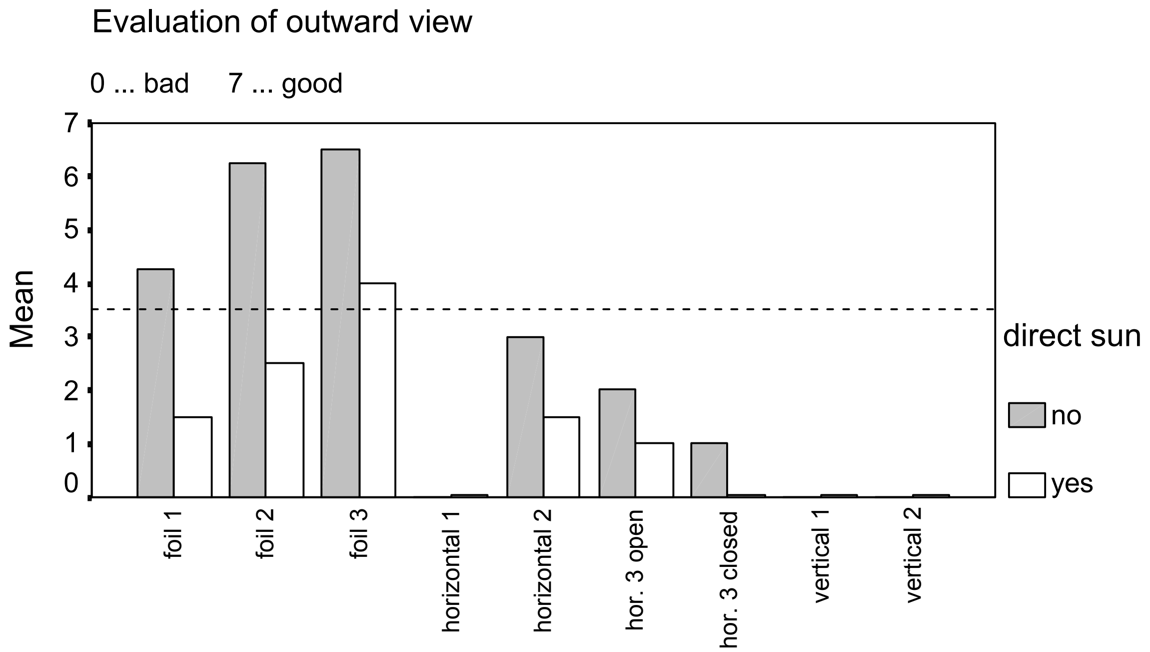

Fig. 7: Evaluation of outward view

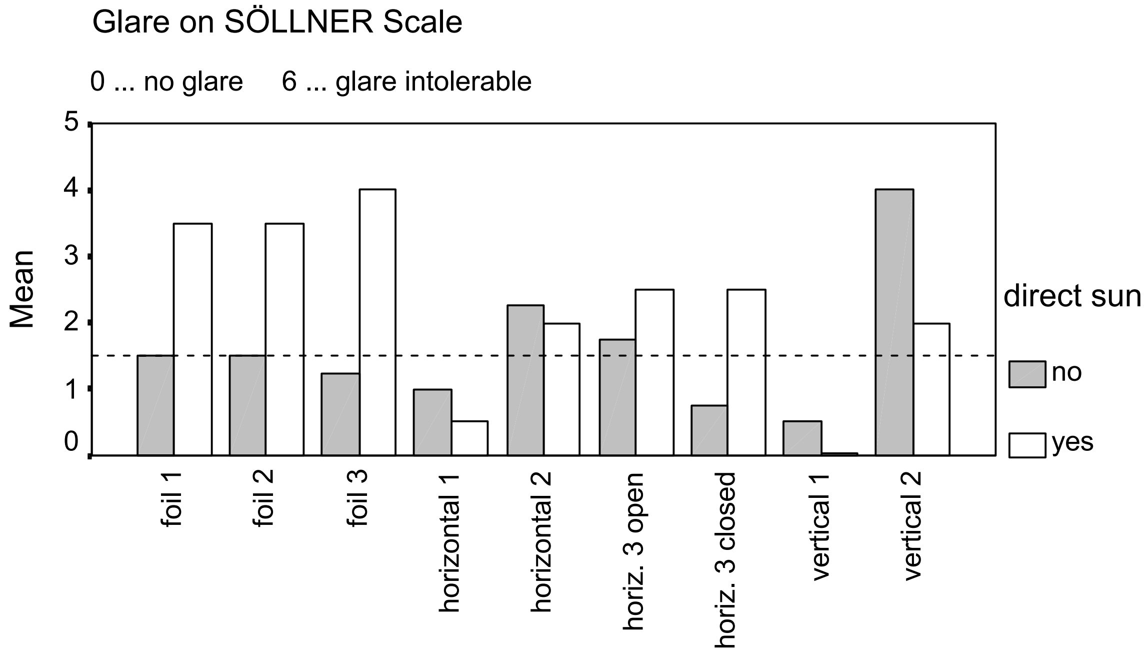

Fig. 8: Evaluation of glare on Söllner scale

The problems of light protection equipment are again clearly shown in this part of the investigations. It is nearly impossible to meet all requirements to everyone's satisfaction. Less glare is only possible by less illuminance and less outward view. The advantages and drawbacks of the different systems are summarised below.

Light protection foils

Light protection foils provide an excellent outward view. However, they do not stray the light which results in problems with direct sunlight. Despite the low transmission level of the foils the sun luminance causes glare. The low transmission provides low illuminance levels. The foils can be recommended for rooms without direct sunlight.

Horizontal slats

If the position of the sun is high, the slats provide a good outward view. If the position, however, is low, they have to be closed in order to avoid glare. Slats with light direction offer a high level of illumination and avoid glare as well.

Vertical slats

Workplaces with direct sunlight can be shaded by adjusting the angle of the slats, whereas there is still sufficient outward view from the other places. Due to the diffuse light transmission a high illuminance level in the room can be achieved even with closed slats. There is a certain risk of glare if the transmission level of the slat material is too high.

Based on the results mentioned above there is no system that can be considered as 'the best one'. There can be great differences even within the systems themselves.

6 Summary

The guidelines that can be derived from the test results are as follows:

Total illuminance:	min. 500 lx
Cylindrical daylight illuminance:	300 to 1400 lx
Vertical illuminance towards the window:	800 to 1300 lx
Vertical illuminance on VDT:	max. 850 lx

Permissible glare luminance for VDTs:

negative polarity :	class II: below 200 cd/m^2	class I: 400 cd/m^2
positive polarity:	class II: 1000 cd/m^2	class I: 2000 cd/m^2