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OFFICE WORKER PREFERENCES OF EXTERIOR SHADING DEVICES: A PILOT STUDY

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Abstract – Solar shading devices are commonly used in offices to reduce cooling loads and glare from windows, but they also affect daylighting and the view to the outside. In this study, the function and operation of an awning and an exterior venetian blind as well as their influence on the view out was assessed by fifty office workers. The preferred position of the shading devices, the interior illumination and the weather conditions were recorded. An interior dimmable lighting fixture was introduced in order to see if there was a difference between the shading devices regarding the need of complementary electric lighting. The awning was found easier to adjust than the venetian blind. Both shading devices somewhat affected the view to the outside. The shading devices were used frequently to avoid glare from the window. However, preliminary results show no or weak correlation between common lighting concepts such as interior illuminance or sky luminance and how much the shading device was pulled down. On the other hand, there was a weak relationship between the existence of sunlight patches in the room and the position of the shading device. Further, the awning showed to be sensitive to wind, creating a disturbing “flickering” sunlight patch on sunny, windy days. There was no difference between the shading systems in the use of complementary electric lighting.

1. INTRODUCTION

Shading devices are often used in buildings, perhaps mainly to reduce cooling energy use, but also to control glare and daylighting. The control of daylighting is actually very central because it is linked to occupants’ satisfaction and performance.

At Lund University’s, Dept. of Construction and Architecture, there is a large ongoing project on solar shading devices in buildings (Wall & Fredlund, 1999). This project primarily deals with the thermal aspects of shading devices. However, the daylight aspects are equally important, not only the effects on illuminance levels, but also on the view out and the perception of a room. Further, increased knowledge on the preferences of occupants would be useful in the selection process of shading devices and also to improve automatic control systems.

According to Littlefair (1999) shading of windows is needed for three main reasons: to reduce overheating, to reduce glare from windows and to provide privacy. Even so, some sunlighting may still be wanted. The positive impacts of sunlight is to enhance the visual, emotional, and psychological well-being of occupants, or using it as a heat source (Boubekri et al., 1991). However, their study largely failed to demonstrate the effect of window size or sunlight patches on office worker’s mood and satisfaction. However, all subjects were exposed to sunny conditions and never to a condition without sunlight penetration. Compared to having no access to windows or view out, people generally prefer windowed space,. (Collins, 1976).

1.1 Glare

Among the mentioned negative impacts of windows is glare. Since the luminance of the sky may well be several times higher than that of the interior walls – even on an overcast day – glare discomfort can arise from a direct view of the sky (Chauvel et al. 1982). They also found that glare from windows is perceived differently than glare from large artificial sources, due to the psychological differences in the contents of the field of view. Chauvel et al. also found large individual differences in the tolerance of glare. In another study on sunlight penetration, glare was only moderately affected by window size (Boubekri & Boyer, 1992).

1.2 Occupant behaviour

In a study on office worker’s behaviour, Rubin et al. (1978) changed the position of venetian blinds during weekends to either fully up, or down, closed, and then studied the occupant’s response by taking external photographs of the facades of the building. They found that most blind positions were changed only once per week. Moreover, they were generally put back in the same position as before the treatment. The most significant influence was that of the orientation: on the north side, blinds were generally kept more open than on the south side. There were also some effects, although more subtle, of climatic season and view out.

In another study, Vine et. al. (1998) compared occupant response and satisfaction of an automated blind with an auto user control mode (manual override of auto mode) and with full manual control. Although no statistical analysis was made of the subjects’ responses, over 75% of the subjects preferred more daylight in the auto mode. They were generally satisfied with the lighting in the auto user control mode, but experienced some glare in the manual mode.

Boyce (1997) claims that if people sitting near to a window have expectations of thermal or visual discomfort to occur, and if they consider that their electric lighting is adequate, they will leave the blinds down, unless they have strong values about the environment. He further believes that few people have such values. He calls this seemingly lack of response to changing environmental conditions for human inertia. For any new automation system to be successful, this inertia must be used to its advantage. He suggests that a simple timer might be enough: one that for example switches off the lighting at a time in the morning when the daylight is usually sufficient, or pulls up a blind at dawn.

2. EXPERIMENTAL DESIGN AND METHODS

2.1 Aim of the study

The aim of this study was to investigate the function, operation and effect on daylight of a couple of solar shading devices. Further, when people are allowed to control the shading devices we wanted to see how they decide to use them in relation to the outdoor climate.

Another issue was whether different shading devices need more or less complementary electric lighting. The experiment was considered as a pilot study to identify typical positions (or settings) of the shading devices for use in later studies.

Since this was considered as a pilot study to develop a test method only two different shading devices were included: one awning and one exterior venetian blind.

2.2 Test rooms and solar shading devices

At a laboratory at the Dept. of Construction and Architecture, there were already two identical south-facing office rooms, 3.0×3.6×2.45 m (W×D×H), used in an earlier study by Bülow-Hübe (1994). New office desks in blond wood were purchased, the walls were repainted in a warm white colour (NCS 0003-Y20R), trimmings and ceilings were white, and the linoleum floor had colours in beige-blue-brown. (R_{wall} = 0.8, R_{ceil} = 0.9, R_{floor} = 0.4, R_{desk} = 0.5).

Each room was furnished and equipped with a computer to resemble a real office room. (Fig. 1). The lighting consisted of a pendant direct/indirect luminaire with dimmable HF-ballast, one T8 36 W facing upwards, and two downwards. The control mechanism was a potentiometer placed on the desk. Measured workplane illuminance was 900 lux at full light output (potentiometer setting = 35), fully dimmed it was 25 lux (setting = 0).

The 1.2×1.3 m, triple-glazed window was in one room equipped with an exterior retractable venetian blind with 80 mm aluminium slats. (Fig. 2). In the other room, it was equipped with an exterior retractable awning with a beige and brown striped fabric. (Fig. 3). In both rooms the shading device could be operated from the inside by two buttons placed on the desk. One button was for retracting the shading device (up position), the other for closing it (down position). For the venetian blind, the adjustment of the slat angle was done with the same two buttons, which meant that to change the slat angle, the position of the bottom slat had to be changed somewhat. (Figs. 1-3).

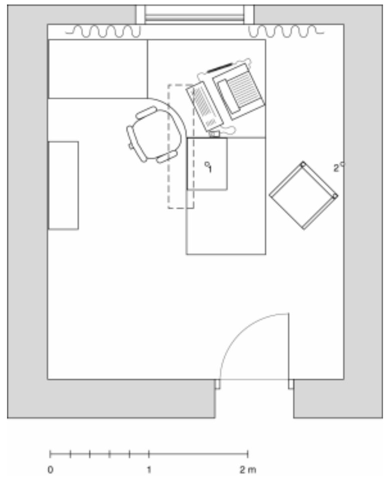

Figure 1 Plan of the offices with 2 points for illuminance measurements as indicated.

Figure 2 Interior of the office with a venetian blind.

2.3 Method for room assessment

The subjects performed two tasks. The first task consisted in adjusting the shading device until a pleasant daylight situation was created. A simple questionnaire was filled in containing three questions: (1) How well does the operation system of the shading device work? (bad–good) (2) How satisfied are you with the lighting conditions?

(unsatisfied–satisfied) (3) How does the shading device affect your possibility to see out? (not at all–to a large extent).

The second task was to see whether the lighting situation was improved with electric lighting, and if so adjust the light level until a pleasant situation was reached. This was followed by a last question: (4) How satisfied are you with the lighting conditions? (unsatisfied–satisfied).

Figure 3 Detail of the office with an awning.

On all 4 questions, the answers were given on seven-grade scales with the word-pair given in brackets above on either side of the scale.

2.4 Procedure and subjects

The study was conducted in September and October 1998. The rooms were assessed by 50 subjects in a balanced design with repeated measures. This meant that each subject assessed both rooms at one occasion.

Upon arrival to the laboratory, the subject was given a short introduction to the experiment. Thereafter, he/she was shown into the first room where further instructions were given on the computer screen. At the start of each experiment, the shading device was always fully open (up) and the lighting was turned off.

Before the experiment started, the experiment leader noted the weather and lighting conditions, time and temperature and measured the interior illumination levels (see below). The subject was then left alone to perform the first task.

The experiment leader then returned to note the position of the shade and repeat the lighting measurements before the subject could proceed with task 2. When this was finished, the lighting measurements were again repeated and the potentiometer setting was recorded. After that, the subject was guided to the other room to repeat the same procedure.

The subjects were recruited from the School of Architecture, and consisted of office workers: clerks, researchers and doctoral students. They were all used to working close to a window. Totally, 24 women and 26 men between 23 and 64 years participated (*mean* = 43.3; SD = 10.8).

2.4 Measurements

As a reference of the outdoor lighting conditions, both the interior horizontal illuminance level and sky luminance seen through the window of a neighbouring office room were measured continuously by two Hagner Universal photometers (S2) connected to a data logger.

Before and after each room assessment, the weather situation, lighting conditions in the room, time and indoor temperature were recorded. The illuminance level was measured at the desk (work surface) (pt. 1) and vertically on the wall in front of the person, 1.2 m above the floor (pt. 2, Fig. 1), with a hand-held Hagner digital luxmeter (EC1). If there was a sun patch in the visual field, this was noted as follows: 1 = no, 2 = sometimes (varying conditions), 3 = yes. The weather situation was rated on a four-grade scale: 1 = sun, some lighter clouds may exist, 2 = sunny, there are clouds that sometimes cover the sun, 3 = cloudy, there are some blue spots were the sun can be seen, and 4 = overcast, the sky is covered by thick clouds. Further, the cloudiness was rated on an 8-grade scale, that defines how many eighths of the sky are covered by clouds.

If the electric lighting was turned on, the potentiometer setting was recorded.

The position of the shades were assessed in the following way: For the awning we constructed and mounted a protractor on the boom which allowed for reading the boom angle with the accuracy of ± 1°. The boom angle *ba* was later transformed to the awning's slope by the simple relationship: $slope = 45 + ba/2$. (Fig. 4).

For the venetian blind, a scale was drawn next to the window, so that the bottom slat position could be read from the interior to the accuracy of ± 5 cm, while the slat angle was estimated manually.

2.6 Data analysis

The data from the rating scales was treated by analysis of variance using the SPSS MANOVA procedure (Norusis, 1993). The design included both within-subject and between-subject variance.

Further, regression analysis was used to study the relationship between the position of the shading device and the lighting and weather conditions.

Since the position of the shading devices had been assessed, a transformation of these data was made to determine which portion of the window surface was covered by the shade, called here the coverage of the shade.

For the awning it was made in a simple way: The measured boom angle was transformed to a percentage: when the awning was fully retracted, this was interpreted as a bare window (coverage = 0 %). The fully down position was interpreted as fully closed awning (coverage = 100 %). (Figure 4).

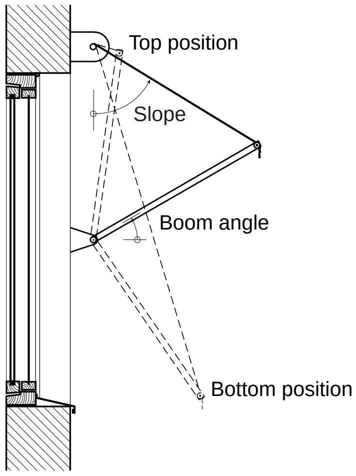

Figure 4 Section through window with awning, and definition of boom angle and slope.

For the venetian blind two factors were weighed together to estimate the coverage: (1) the distance of the bottom slat to the top of the window and (2) the slat angle. (Figure 5). From the position of the viewer, the percentage of how much of the window that was covered by the blind had previously been estimated for different slat angles. This value was then multiplied by the distance (1) (in per cent) to give the coverage.

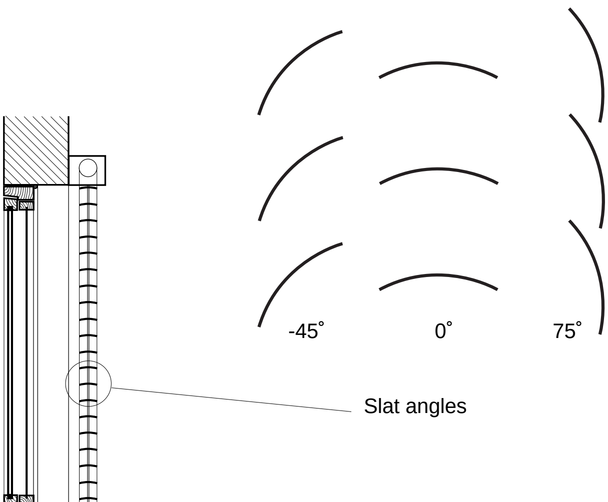

Figure 5 Section through window with exterior venetian blind, and examples of slat angles.

3. RESULTS

3.1 Weather, light and temperature

The illuminance levels, sky luminance, indoor temperature and weather recordings before and after the assessments in the two rooms are summarised in Table 1. The differences between the two rooms are very small and are not significant. Therefore, the environmental conditions must be considered equal between the two rooms (awning and venetian blind).

Table 1 Summary of measurements of environmental conditions before and after assessments. (Mean values).

	Awning		Venetian blind	
Illuminance level (lux)	Before	After	Before	After
Point 1	2590	675	2610	580
Point 2	950	460	875	400
Ref. room, pt 1	2500	2400	2960	2870
Sky luminance (cd/m^2)	14400	16400	14700	15200
Indoor temp. (°C)	20,7	20,7	20,4	20,4
Weather type (1–4)	2,60	2,66	2,60	2,60
Cloudiness (1–8)	4,36	4,38	4,36	4,38
Sun in visual field (1–3)	2,06	1,58	2,08	1,66

3.2 Perception of shading devices

The operation system of both the awning and the venetian blind was perceived to function well (*mean* = 6.4/4.9 awning/ ven. blind respectively on the seven-grade scale), but the awning was most easy to operate ($p = 0.000$). The subjects were rather satisfied with their lighting situation after task 1 ($m = 5.5/5.7$). After having tried the electric lighting in task 2, they were somewhat more satisfied with the lighting condition than before ($m = 5.7/6.0$). The possibility to see out was somewhat affected by the solar shading devices ($m = 3.4/3.7$). However, there were no significant differences between the shading devices in questions 2–4.

There was a grouping effect of age in question 2 (the satisfaction of the lighting condition): the older the subject, the more satisfied ($p = 0.008$). The subjects had then been divided into three age groups: (1) 23–38 years, $N = 16$; (2) 39-50 years, $N = 18$; (3) 51-64 years, $N = 16$.

The answers were also checked for interaction effects regarding sex and age, but no such effects were found.

3.3 The position of the shading devices

The shading devices were used frequently to control glare. They were not only used on clear sunny days, but also on overcast days. Typical positions of the shading devices are perhaps best described by frequency distributions as for the awning's slope in Figure 6. This shows that the awning was used by all but 7 subjects, and that the most frequent position was when the boom angle was close to slope 45° (0 degrees boom angle). Only 7 subjects chose to pull it down significantly more than that.

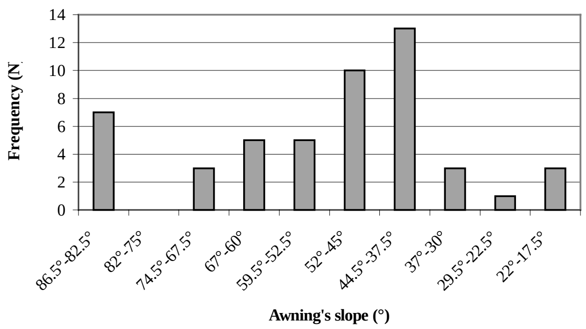

Figure 6 Frequency distribution of the slope of the awning.

For the venetian blind, most subjects did not pull it down fully. Over 50 % of the subjects pulled it down less than 70 cm compared to the glazing height of 120 cm. (Fig. 7). Normally, an automatic motorised blind will be pulled down fully, and the manual override is limited to adjusting the slat angles.

Concerning the slat angles, 75 % of the subjects chose a slat angle of 30° or larger. Only on 4 occasions did the subjects choose a negative (sky view) slat angle (Fig. 8). Beyond slat angles of approximately 45°, the view through the blind becomes very limited.

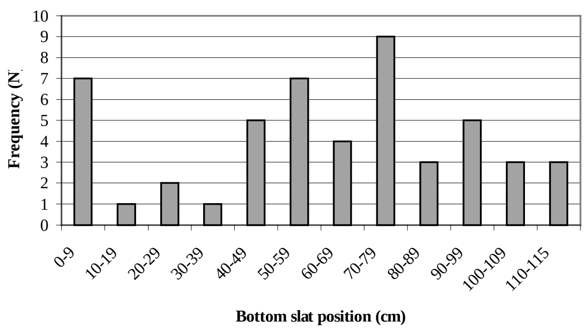

Figure 7 Frequency distribution of bottom slat position of venetian blind.

At a linear regression analysis between the coverage of the shading device and the measured parameters, no relationships were found between illuminance levels or sky luminance. However, a relationship was found between the coverage and the existence of sunlight patches in the field of view. This was found both for the awning and for the venetian blind. The cloudiness also appeared in the regression equation for the blind. The regression equations could however only explain a small part of the variation (adj. R^2 = 0.22–0.34).

Since the existence of sunlight patches appeared in the regression equations, two new variables were introduced: the azimuth of the sun's position (i.e. the angle between the horizontal projection of the sun and the south axis) and the perpendicular distance from the wall to the end of the sunlight patch. However, they did not appear in the regression analysis.

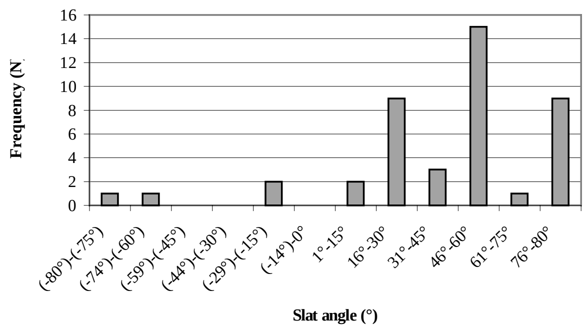

Figure 8 Frequency distribution of slat angles of venetian blind.

Another test was made with a logarithmic transformation of the measured lighting data. Both the logarithm (to the base of ten) of the desk illuminance and the sky luminance appeared in the regression equation, but only for the venetian blind. The adj. R^2–value was also low (0.34). Since these variables only appeared for the blind, the interpretation of this regression equation was unclear.

3.4 Artificial lighting

The artificial lighting was used in about 30 % of the cases, just as often in connection with the awning as with the venetian blind. There was no significant difference in the use of this complementary lighting between the awning and the venetian blind. The potentiometer was used frequently to control the light level, and the average setting was 19 which corresponds to an additional 350 to 500 lux. (The uncertainty is due to how long the lighting has been turned on).

3.5 Comments

The subjects were encouraged to give their own comments on the questionnaire, and some of the more common ones have been put together here:

Regarding the artificial lighting: the user's ability to dim the electric lighting generated several positive comments, but it became obvious that the chosen lighting installation was not optimal. Many subjects commented on the fact that there was no individual light source, just the ceiling mounted luminaire. Most people wanted more light on the desk to be able to read, than on the computer screen, and this was not possible with the chosen solution. When the subjects chose a setting for the lighting it was obvious that most persons did this according to the computer task, but more light was really needed for paper tasks.

Regarding the operation of the shades: The awning was more easy to adjust than the venetian blind as previously mentioned. Most subjects agreed that the venetian blind would have been more easy to operate if the function for adjusting the slat angle had been separated from the function of bringing the blind up or down, as was the case. The motor pulling the venetian blind up and down was also perceived as being too slow.

A few people said that they made a compromise between glare and the possibility to see out: they would have been more comfortable with the lighting situation if they had pulled down the shade even more, but they chose a more open position in order not to loose too much of the view out.

On windy days it became apparent that the awning was much more wind sensitive than the venetian blind. This lead to a disturbing noise created by the fabric, but even more disturbing was the light flicker of the sunlight patch. On sunny afternoons, the sunpatch could often not be totally removed on the desk due to the oblique angle of the sun. As the sunpatch was in the field of view, the flickering effect that was created when the awning was blowing up and down in the wind gusts was rather disturbing.

The two shading devices also created quite different impressions of the two rooms. While the grey slats of the blind did not affect the colours in the room, the fabric of the awning gave a yellowish tint to the whole room. One person remarked that it reminded her of an old striped men's pyjamas, while for another person it recalled happy memories of childhood camping trips. A few others commented on the blinds: for them, the wide slats created associations with prison bars.

4. DISCUSSION

This study demonstrates the difficulty in predicting when and how much solar shading devices need to be pulled down, in order to create a good interior lighting environment. Glare or contrasts are probably responsible for when solar shading devices need to be used, but there seems to be a large individual spread as to how much glare people tolerate. This is in line with the findings of Chauvel et al. (1982). Given more measuring points on luminances in the field of view, it would perhaps have been possible to find relationships between these and the use of the shading devices, but in this study no relationships between the sky luminance or the interior illumination level and the use of the shading devices were found. One parameter showed a weak relationship to the use of the shading device: the existence of a sunpatch in the field of view. But this could only explain a small portion of the variance. Since the variance among people is large, even more subjects and more weather situations would also have been needed.

Generally, solar shading is needed as soon as the sun enters the room, since the sunpatch will often directly, or indirectly cause disturbing glare and reflexes in the computer screen. One example is when the sunpatch is on the wall behind the subject, it will be so strongly lit that it will cause disturbing reflexes on the screen. This agrees with the opinions of Littlefair (1999).

The placement of the computer and of the furniture in relation to the window will of course strongly influence the glare situation in each individual case. This will, in turn, affect when and to what extent shading is needed. It is however clear that computer tasks require some sort of glare control during a major part of the day, be it interior or exterior shading devices or curtains, single or in combination.

The fact that the shading devices and the electric lighting could be controlled was perceived as very positive. This is a general conclusion in experiments of similar nature: individual control over physical parameters in a person's environment are preferred to having no control (Bell et al, 1996).

This study also shows that there is no simple relationship between the use of electric lighting and the lighting parameter that is most often used to estimate the potential for energy savings of electric lighting through dimming: the interior illuminance on the work surface. Only when it became very dark outdoors (and indoors) was there a trend that the subjects used the electric lighting more frequently. Also here was there a large individual variation. However, it did not matter whether it was an awning or a venetian blind: the same amount of additional electric lighting was preferred.

Another conclusion is that individual task lighting should be present so that the lighting on the paper task can be different from that on the computer screen since more lighting is generally preferred on the paper than on the screen.

Clearly, shading devices can have effects on mood and the general perception of a room. Which effects, and if these are enough to affect satisfaction and performance remain to be answered.

This study indicates that several aspects of shading devices must be considered. Even if the solar shading properties of shading devices are central, it is also necessary to pay attention to the daylight properties, effects on view, presence of sunlight patches, adjustability, etc. For example we found that awnings caused disturbing flickering sunlight patches on sunny, windy days, an effect which was not present for the venetian blind. However, in measurements, Wallentén (1999) found that light coloured awnings had better shading properties than exterior venetian blinds.

5. CONCLUSIONS

The main conclusions from this study are:

- It is difficult to predict the use or need for shading devices by common measurable factors such as interior illuminance and sky luminance.
- There is some correlation between the use of shading devices and the existence of sunlight patches in the room.
- Shading devices are necessary to control glare in the working environment.

6. ACKNOWLEDGEMENTS

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