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FLUCTUATION AND TYPES OF TASK**

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GLARE FROM WINDOW CONSIDERING TIME FLUCTUATION AND TYPES OF TASK

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Abstract

Glare control is one of the important tasks for active daylighting, which is requested not only for energy saving but also for human health. However, glare evaluation method which can be applied in real situations, i.e. glare source with non-uniform luminance distribution and varies with time, is not still established. This paper reports the results of subjective experiment conducted in the experimental room assuming an office space. Two pairs of the experimental room were prepared, the one was equipped with the real window and the other was with the LED panels, to identify the effects of time fluctuation in the exposed luminance on discomfort glare. The results showed a possibility that the working occupants may sense less glare than predicted by the existing evaluation method.

Keywords: Discomfort glare, Daylight, Window, Subjective experiment

1 Introduction

The importance of daylighting is being re-recognized from the viewpoint of not only energy savings but also human health and well-being. Controlling discomfort glare from window is an important task for active utilization of daylight.

Up to now, various formulae to evaluate discomfort glare have been developed. Most of them are based on the momentary subjective evaluations obtained in laboratory experiments dealing with four parameters related to the glare source, which is quite constant and uniform - i.e. source luminance, source size, background luminance and position of the source. However, in actual situations, light source such as window has non-uniform luminance distribution and the luminance of the source varies with time, weather condition and etc.

CIE JTC7 had worked to propose a method to modify UGR taking into account the non-uniformity of glare sources such as LED luminaires. However, it only focuses on the luminance distribution of LED luminaires, which have no view nor time fluctuation. It also has been pointed out that gaze behaviour which depends on the type of task and lighting condition should be considered for better understanding of discomfort glare (Khanie, 2018).

In this paper, the results of the subjective experiment to identify discomfort glare from the window considering luminance distribution within the window, time fluctuation and the types of task are reported.

2 Methods

2.1 Experimental room

Two pairs of the experimental room as shown in Figure 1 (4.3 m in width, 3.2 m in depth and 2.5 m in height) were prepared for the experiment. The experimental rooms were located on the 17th floor of the building. One of them was equipped with the real window facing south whose size was 970 mm in width and 890 mm in height on the front wall. The view from the window included both of sky and surrounding buildings' surface. The other experimental room was equipped with two different kinds of the artificial light source, the one was the artificial skylight (Coelux®45SQ, 270 W, 4300K) and the other was the LED panels (XL574PFVJ RZ9, 5530 lm, 5100 K). Both of them had the same size with the real window in the other room. Each light source was settled at 1.2 m in height from the floor. In the case with the artificial skylight,

the interior wall of the room became too dark for its directivity. Two spot lights illuminated the front wall of the experimental room to be around 100 cd/m^2 in average in the case with the artificial skylight. The interior surface of the experimental rooms was finished quite uniform with the wall paper of 90% in reflectance.

Figure 2 shows some examples of the relative spectral distribution of each source (JETI Specbos1201). Not only spectral power distribution but also luminance distribution and luminous flux of the window varied with time during the experiment. On the other hand, those of the artificial skylight and the LED panels were quite uniform during the experiment.

Figure 1 – Plan of the experimental rooms and experimental scenery

Figure 2 – Relative spectral power distribution of each light source

2.2 Experimental procedure

Subjective experiment was conducted during October 24th and December 17th 2018. Thirteen university age students (11 male and 2 female, 22 years old in average) participated in the experiment as the subjects. One subject at a time was seated facing each light source at a distance of 2.5 m away from the source (the solid angle of each source was 0.138 sr). He/she stayed in the experimental room for about one hour with doing the two types of task, reading a book or text typing each for 20 minutes. The luminance of the PC screen for text typing task was set about $120\text{--}140 \text{ cd/m}^2$ for white setting. Figure 3 shows the experimental procedure. After each task, he/she measured CFF (critical fusion frequency of flicker)(HE-104, NIPPON ALGORITHM Co. Ltd.) and answered a sheet of questionnaire identifying the degree of discomfort glare using GSV scale shown in Figure 4 (Glare Sensation Vote, 0: just perceptible,

1: just acceptable, 2: just uncomfortable, 3: just intolerable), workability and visual fatigue during the task, the visibility of letters on paper/VDT and the acceptability of the light environment as a workplace.

Figure 3 – Experimental procedure

Figure 4 – Evaluation scale for discomfort glare

Thirteen subjects experienced 122 different conditions in total in the experimental room with the window (6 subjects*6 times*3 days + 7 subjects*2 times*1 day) prior to the experiments with the artificial skylight and the LED panels. The average luminance of the LED panels was adjusted to be the same with that of the window he/she experienced. The output of the artificial skylight was not sufficient enough to be adjusted as the same level with that of the window. Therefore, the average luminance of the artificial skylight was set constant at maximum, about 205 lx of the vertical illuminance at the subjects' eyes.

2.3 Measurement items

Horizontal illuminance on the desk (0.7 m from the floor, TR-74ui, T&D), vertical illuminance on the window surface and that at the subjects' eyes (1.2 m from the floor, TR-74ui, T&D) and colour temperature at the centre of the experimental room with the window (0.7 m from the floor, KONICA-MINOLTA CL200) were measured during the experiment at intervals of 30 sec. In addition, luminance distribution within the subjects' visual field was obtained both at the beginning and at the end of each experiment by using digital camera (CANON EOS 70D, HDR image was required via a HDR construction algorithm QUAPIX, IWASAKI ELECTRIC Co., Ltd.).

3 Results

The luminance of the artificial skylight was extremely lower than that of the window and that of the LED panels. So in this paper, the results of the experiment with the window and those with the LED panels were compared to identify the effects of the luminance distribution and time fluctuation in the luminance within the occupants' visual field on discomfort glare.

3.1 Variation of illuminance during the experiment

Figure 5 shows the median of the vertical illuminance at the subjects' eye and that of the horizontal illuminance on the desk the subjects' experienced during each task. The vertical illuminance at the eyes both in the cases with the window and with the LED panels could be adjusted about the same in the median. On the other hand, horizontal illuminance on the desk in the case with the window was higher than that in the case with the LED panels, because direct sunlight hit on the desk in some cases with the window.

Figure 6 shows the relationship between the vertical illuminance in the median and the quartile value of that during each task. In the case of reading book task, the quartile value of the vertical illuminance varied between 40% and 191% of the median. In the case with text typing task, the quartile value of the vertical illuminance varied between 16% and 226% of the median.

Figure 5 – Illuminance the subjects experienced during the task

Figure 6 – Time fluctuation of the vertical illuminance during the task

3.2 Glare sensation vote during task

Figure 7 shows the relationship between PGSV (predicted glare sensation vote) (Tokura et.al, 1996) and GSV (glare sensation vote). PGSV was calculated with L_s obtained by averaging the luminance within the source and with L_b obtained by averaging the luminance of the whole area of the subjects' visual field except for the light source measured by digital camera at the end of each experiment. There could be seen no significant difference between GSV in the case of reading book task and that in the case of text typing task.

Figure 7 – Comparison of PGSV and GSV

It can be seen that GSV against the LED panels, whose luminance was rather constant and uniform, varied from -0.5 to 3 for the same level of PGSV, i.e. there was a large difference among the subjects. In addition, especially in the case of reading book task, there can be seen large differences among individuals with the similar PGSV value. The individual difference among the subjects should be eliminate for statistical analysis. Modified GSV_{mod} was obtained assuming that the individual difference in glare sensation was equal to the difference between GSV and PGSV against the LED panels as shown in Eq(1).

$$\text{modified } GSV_{mod} = GSV - (GSV_{-L} - PGSV_{-L}) \quad (1)$$

where

GSV_{-L} : Glare sensation vote against the LED panels

$PGSV_{-L}$: Predicted glare sensation vote against the LED panels

Figure 8 shows the relationship between PGSV and modified GSV_{mod} . In the case of reading book task, modified GSV_{mod} against the LED panels almost agreed with PGSV against the LED panels. On the other hand in the case of text typing task, there still remains difference between PGSV and modified GSV_{mod} .

Figure 8 –Comparison of PGSV and modified GSV_{mod}

PGSV was developed assuming the situation of paper task. The occupants do their task adjusting their eyes to the desktop illuminance and move their eyes to windows for rest and daylight from window causes discomfort glare. To calculate PGSV value, average luminance of the window can be applied to the source luminance L_s and the average luminance of the

occupants' whole visual field except for the window can be applied to the background luminance L_b if the luminance contrast within the window is larger than $1/20$ (Mochizuki, 2008).

Figure 9 shows an example of HDR image of the window the subject evaluated after the task. Luminance contrast between the average luminance of the sky and that of the ground was higher than $1/20$, i.e. luminance distribution within the window was not so large. The difference between PGSV and modified GSV_{mod} might be due to the time fluctuation of the exposed illuminance during task (adaptation level varied).

Figure 9 – HDR image of the window the subject evaluated (10:30 a.m., Nov. 5th, 2018)

3.3 Variation of illuminance during task and discomfort glare

Figure 10 shows the relationship between the median of the illuminance the subjects adapted during the task, i.e. the desktop illuminance in the case of reading book task and the vertical illuminance at the eyes in the case of text typing task, and modified GSV_{mod} . The error bars in the x-axis direction mean the range of quartiles of the subjects' adapted illuminance. GSV_{mod} became higher as the adapted illuminance became higher for each task. For the LED panels, GSV_{mod} can be almost determined by the adapted illuminance during the task. On the other hand, for the window, there was large differences among the subjects and there can be seen a tendency that GSV_{mod} became higher in the case when the variance in the adapted illuminance was larger.

Figure 10 – Relationship between adapted illuminance during the task and modified GSV_{mod}

Figure 11 shows the relationship between the coefficient of variance of the adapted illuminance during each task and the difference between modified GSV_{mod} and PGSV. It can be seen that the larger the variance of the adapted illuminance during the task, the larger the difference in glare sensation and PGSV, that is to say there is a possibility that the occupants sense less glare than predicted by the existing glare evaluation method in real working situations.

Figure 11 – Variation of adapted illuminance during the task and glare evaluation

4 Conclusion and future tasks

Subjective experiment was carried out to identify the effects of time fluctuation in the exposed luminance during office work on discomfort glare. Comparing the window and the LED panels has identified that individual difference in glare evaluation is larger in the case with the window than in the case with the LED panels. The results of the subjective experiment also showed a possibility that the subjects may sense less glare than expected in the situation of working in variable lighting environment. The experimented conditions in this paper are limited. So, we will conduct more experiments under various conditions in the future.

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