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Road luminance at tunnel and underpass entrance for safe driving of elderly people

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ABSTRACT

To provide elderly people with proper lighting at the entrance of tunnels and underpasses for a safe driving an experiment was conducted to investigate how much illuminance should be increased for elderly people by using cataract experiencing goggles that simulated elderly eyes and by experimenting in a simulated environment for driving situation. It was found about 7 times of the tunnel lighting at the entrance suitable for young people would be proper for elderly people.

Keywords: Elderly people, Safe car driving, Tunnel lighting, Underpass lighting, Parking lot lighting, Cataract, Luminance threshold

1. INTRODUCTION

Tunnels, underpasses, and parking lots in a building are normally illuminated dimly compared to the outdoor. This situation imposes a serious problem to elderly people who drive a car because of their cataract eyes, which they get normally when they become older. The cataract crystalline lens becomes frosted which reduces the incoming light and scatters the light coming from the environment in the eye[1)]. The scattered light makes the entire visual field foggy and impairs the detectability of objects to see. The phenomenon particularly occurs at the entrance of tunnels, underpasses, and parking lots. It is urgent at the present aging society to provide elderly people with a safe and pleasant environment. The present paper tried to find out how much illuminance level needs to be elevated in such situations for elderly people compared to young people. An apparatus was built to simulate a tunnel or an underpass, or a parking lot and the detectability of a test patch was measured with cataract experiencing goggles and without the goggles.

2. METHOD

Figure 1 shows the apparatus, which was composed of two rooms, a subject room of 560 cm long and a test room of 300 cm long. The height was 200 cm and the width 340 cm. There was an opening W between the two rooms to simulate a tunnel entrance. The height was 140 cm and the width 52 cm. In the test room a test stimulus T was placed at the distance 120 cm from the entrance W and at the subject eye level of 110 cm. A subject sitting on a chair observed the test stimulus binocularly at the distance 3 m or 5.5 m from the stimulus, namely 180 cm or 430 cm from the entrance W.

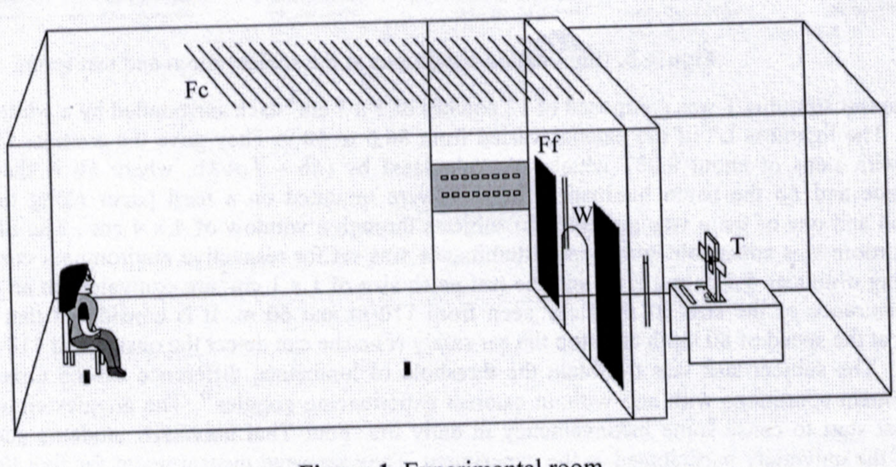

Figure 1. Experimental room.

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To simulate environment light in the outdoor 40 fluorescent lamps Ff of 40 W and the daylight type were installed on the front wall, 20 lamps at the left and the right of the entrance, respectively, and 29 lamps Fc at the ceiling. The arrays of the front lamps extended to 100 cm from the edge of the entrance, respectively and that on the ceiling extended to 300 cm from the front wall. When a subject sat at 5.5 m away from the test stimulus the nearest lamp to the subject was at 130 cm in a horizontal distance but at 3 m the last lamp located behind the subject at the distance 120 cm in a horizontal distance. Figure 2 is a photograph taken at the subject position, in which the dark opening at the center is the entrance W.

Figure 2. The front view of the subject. A dark area is the entrance W.

Five environment conditions were employed for both observing distances as shown in Fig. 3, where open circles indicate the lamps lit and filled circles lamps not lit. The upper lamp array in each condition indicates lamps at the ceiling, which were in fact arranged in the direction perpendicular to the paper surface. In both distances all the lamps were lit in the condition 5. The vertical plane illuminance Ev at the subject's eyes was listed in Table 1. The order of condition was arranged in the order of increasing illuminance. The bottom figure shows the lamps in the test room.

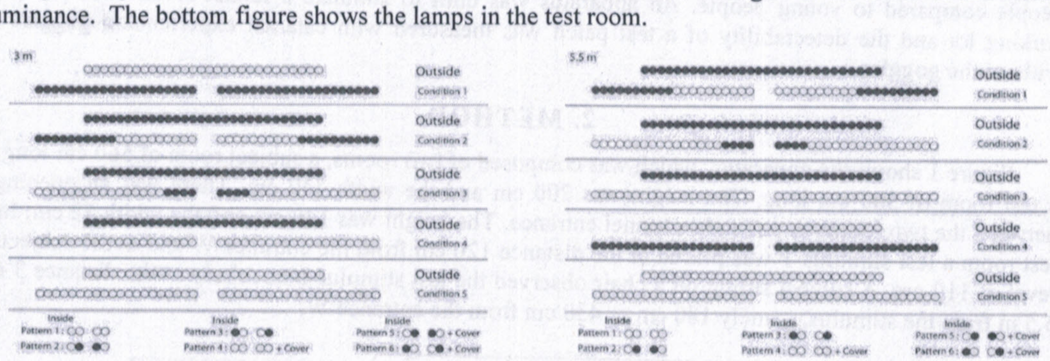

Figure 3. Illumination conditions at the subject room and test room.

The test stimulus T was composed of 17 patches of 1 x 1 cm^2 each surrounded by a white paper of L* = 88.4. The lightness L* of the patches varied from 86.6 to 60.9. They gave the contrast from 0.051 to 0.644 with steps of about 0.037 which was calculated by (Lb – Lo)/Lb, where Lb is the background luminance and Lo the patch luminance. Patches were mounted on a hard paper along the horizontal direction and one of them was presented to subjects through a window of 4 x 4 cm^2. The illuminance in the test room was adjustable and proper illuminance was set for respective environment conditions. The observing distances 5.5 m and 3 m, and the test patch size of 1 x 1 cm^2 are equivalent to an obstacle in a tunnel entrance of the size 20 x 20 cm^2 seen from 110 m and 60 m. It is considered that a car driver driving at the speed of 80 km/h can stop the car safely if he/she can detect the obstacle at 110 m.[2)]

The subject task was to obtain the threshold of luminance difference Lb–Lo under one of the environment conditions with and without cataract experiencing goggles[3)]. The goggles simulate cataract eyes that start to cause some inconveniency in daily life. Four Thai university students and one young staff of the university participated in the experiment. They repeated measurement for five times for each condition at different sessions.

Table 1. Illuminance of subject room in lx and log lx.

3 m		
Condition	Ev (lx)	log Ev
1	2536	3.40
2	3209	3.51
3	4475	3.65
4	5371	3.73
5	8415	3.93
5.5 m		
Condition	Ev (lx)	log Ev
1	707	2.85
2	1096	3.04
3	1573	3.20
4	1797	3.25
5	3503	3.54

3. RESULTS AND DISCUSSION

In Fig. 4 the results of 5.5 m are shown for the subjects NS and CP. Illuminance in the subject room is taken along the abscissa by logarithmic unit in lx and the luminance difference threshold along the ordinate in cd/m^2. Open circles connected by dotted lines were obtained without goggles and filled circles connected by solid lines with goggles. Short vertical bars indicate the standard deviation of five

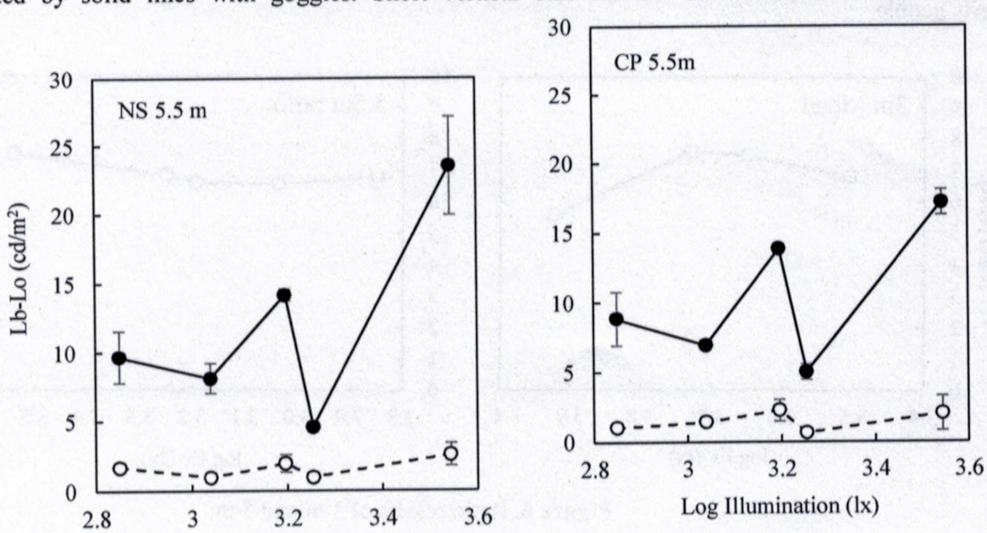

Figure 4. Results of subject NS and CP at 5.5 viewing distance.

repetitions. The two subjects showed similar trends. Larger thresholds were needed with goggles than the naked eyes without goggles showing the undesired influence of the environment light. The threshold increased for higher environment illumination. It is noted, however, the threshold dropped at the 4th condition in spite of the increase of the illuminance. The illuminance was given by only the ceiling lamps and the angle from the visual axis to the lamps θ increased for lamps nearer to the subject reducing the effective environment light, which gave lower threshold. In fact the concept of the equivalent veiling luminance *L*eq was introduced by Holladay[4] to quantify the effect of the environment light to the eyes, namely, $Leq = k \times Ev / \theta^2$, where Ev is the vertical plane illuminance and k is a constant 10. The angle θ was very large at the 4th condition and the equivalent veiling luminance became small to reduce the effect of the environment light for the difference threshold.

Means of the difference threshold of 5 subjects are shown in Fig. 5 for both viewing distances, 3 m and 5.5 m. Vertical bars show the standard deviation among 5 subjects. It must be noted that the 1st condition in 3 m case some of the ceiling lamps located behind subjects and the vertical plane illuminance became smallest and. Under this condition test patches with lower contract were not available and the thresholds were not obtainable.

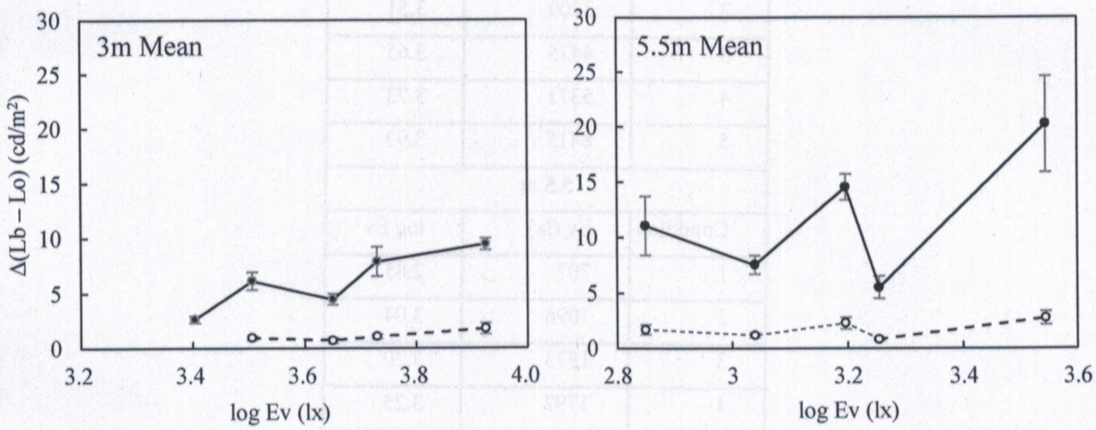

Figure 5. Mean results of 3 m and 5 m.

To see how much threshold should be elevated with the goggles the ratio of two thresholds, G/N was taken as plotted in Fig. 6. The ratio did not change for illumination condition and the average was 6.86 and 6.85 in 3 m and 5.5 m, respectively. We need to increase the road luminance about 7 times of the lighting designed for young people at the entrance of tunnel and underpass to assure safe driving by elderly people.

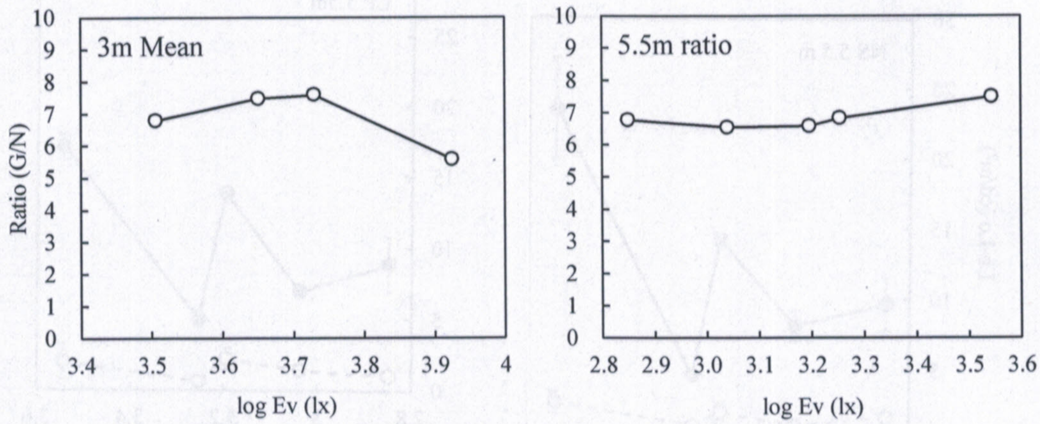

Figure 6. Ratio results of 3 m and 5 m.

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