Optimum luminous intensities of traffic lights for day and night

Johan Alferdinck[1], Natasja van der Leden[2]

Abstract

In a psychophysical experiment the adequate luminous intensities for traffic lights were measured as function of time of day, colour, size and three perception criteria minimum, optimum, and maximum. By day the traffic lights were adjusted at average luminous intensities of 124 cd, 369 cd, and 616 cd for the perception criteria minimum, optimum, and maximum. By night these average luminous intensities are, respectively, a factor 35, 17 and 10 lower. By day small effect of colour and size was found. A performance level 2/1 of standard EN 12368, with a luminous intensity range from 200 cd to 800 cd fits the best on the experimental results. For dark environments a dimming factor of 10 is recommended for yellow and green lights and 4 for red lights.

Keywords: Traffic lights, Luminous intensity, Perception, Dimming

1. Introduction

Traffic lights in the Netherlands has to comply with the European norm EN 12368 [1]. The European standard has three performance levels with minimum luminous intensities of 100 cd, 200 cd, and 400 cd in the reference axis of the lamps. Each European country has to follow this standard and can choose one of the three performance levels. In the Netherlands is chosen for the highest performance level with a minimum luminous intensity of 400 cd and a maximum of 1000 cd. After complaints of road users about glare doubt was raised by the manufacturers and traffic experts about the correctness of the class choice. Especially for traffic situations in rural areas the highest performance level seems to be too high. The European standard gives no requirements for reduced output operation in night-time light conditions. Since no proper dimming regime is present the traffic lights outside the build-up areas without public lighting often cause glare during night-time. We conducted a psychophysical experiment in order to find the adequate luminous intensities for traffic lights in day and night-time conditions and to make a founded advice.

2. Methods

On a closed terrain two experimental signal heads with background screens were installed on a construction (Figure 1). One signal head had 20 cm diameter traffic lights and the other was supplied with 30 cm diameter traffic lights, both in the colours red, yellow and green. The subjects were standing at a distance of 98 m and perceived the traffic heads against the sky. By means of a rotary knob the subjects were able to adjust the luminous intensity of the one of the six traffic lights (Figure 1). Both traffic heads were supplied with LED light sources. The colour and the luminous intensities of the traffic light comply with EN 12368 (performance level 3/1) [1].

Twenty-seven subjects (21 men, 6 women) with ages between 14 and 61 years (mean 41.5) participated in the experiment. All subjects had normal colour vision and normal visual acuity (mean: 1.6 TNO Landolt-C).

The task of the subjects was to adjust the luminous intensity of the traffic light according three perception criteria (Table 1). They had to imagine that they were driving in a traffic situation and encounter a traffic light which is standing out against the sky. The task was free-viewing, meaning that the subjects determined the duration of looking at the traffic light.

Each time the subjects made 18 adjustments (2 diameters x 3 colours x 3 criteria).

[1] TNO Human Factors, P.O. Box 23, 3769 ZG Soesterberg, NL, johan.alferdinck@tno.nl
[2] TNO Human Factors, P.O. Box 23, 3769 ZG Soesterberg, NL, natasja.vanderleden@tno.nl

Immediately after an adjustment by a subject the position of the rotary knob was recorded and the luminance of the surrounding sky the traffic lights was measured. The relation between the position of the rotary knob and the luminous intensity was known since the knob was calibrated at night-time.

The experiment was performed during three days and three nights with clear and dry weather.

Table 1. Perception criteria.

Perception criterion	*Explanation*
Minimum	Just allowable minimum
Optimum	Optimal. Sufficient outstanding but not too bright
Maximum	Just allowable maximum. Not glaring.

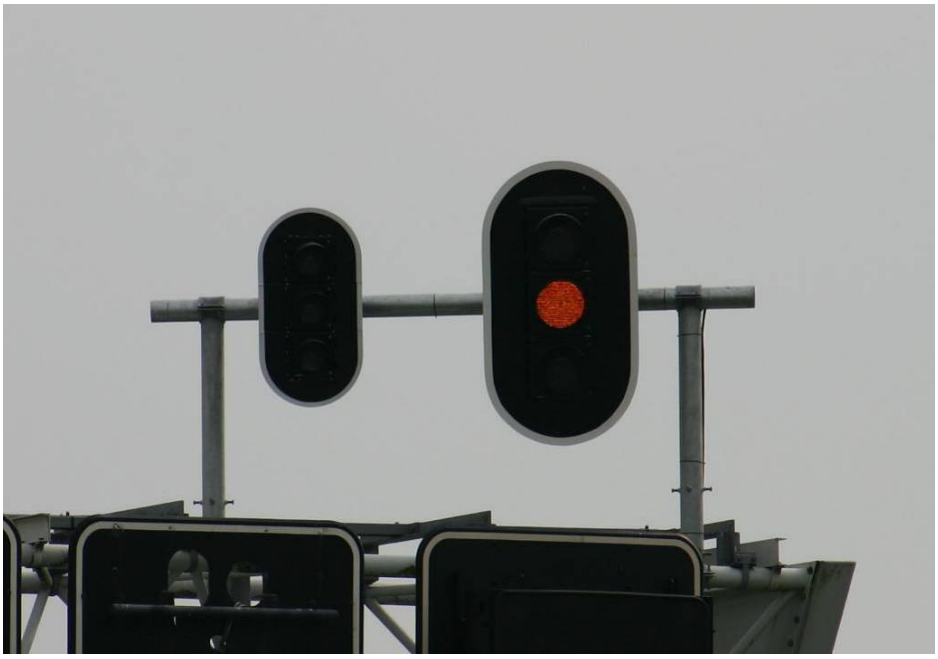

Figure 1. Experimental signal heads with lights of 20 cm (left) and 30 cm (right) diameter.

Figure 2. Subject adjusting the luminous intensity with a rotary knob. Right: light meter for measuring the surrounding luminance and the luminous intensity of the traffic lights.

3. Results

The results were divided into two parts: day and night. The day data were measured with a surrounding luminance of more than 2180 cd/m^2 (mean: 12758 cd/m^2); the night data were measured with a surrounding luminance of less than 0.29 cd/m^2 (mean: 0.12 cd/m^2).

The data was statistically analysed with an analysis of variance and a post-hoc Tukey test, with independent variables time of day, diameter, colour, and perception criterion. The logarithm of the luminous intensity, which was normally distributed, was the dependent variable. There was a statistically significant main effect of all variables and three significant interactions (time of day x criterion, diameter x criterion, colour x criterion).

As expected, the luminous intensities by night were adjusted far lower than by day. Figure 3 shows the luminous intensities, averaged over the two diameters and three colours, as a function of perception criterion and time of the day. There is a difference between the criteria by day and night. The luminous intensities for the perception criteria minimum, optimum, and maximum by night were adjusted a factor 35, 17 and 10 lower than the intensities by day. The range between minimum and maximum is smaller by day (factor 5) than by night (factor 18).

Small effects of diameter and colour were measured. By day the luminous intensities of the yellow lights were adjusted a factor 1,6 higher than the intensities of the red and green lights, for the perception criteria minimum and optimum (Figure 4). For the perception criterion maximum and by night there was no significant difference between the colours. This effect of a higher luminous intensity for yellow is also found in an other study on the traffic lights [3].

By day the luminous intensity of the red light with a diameter of 30 cm was adjusted a factor 1,19 higher than the red light with a diameter of 20 cm. For the other colours and by night there was no effect of the size of the traffic lights.

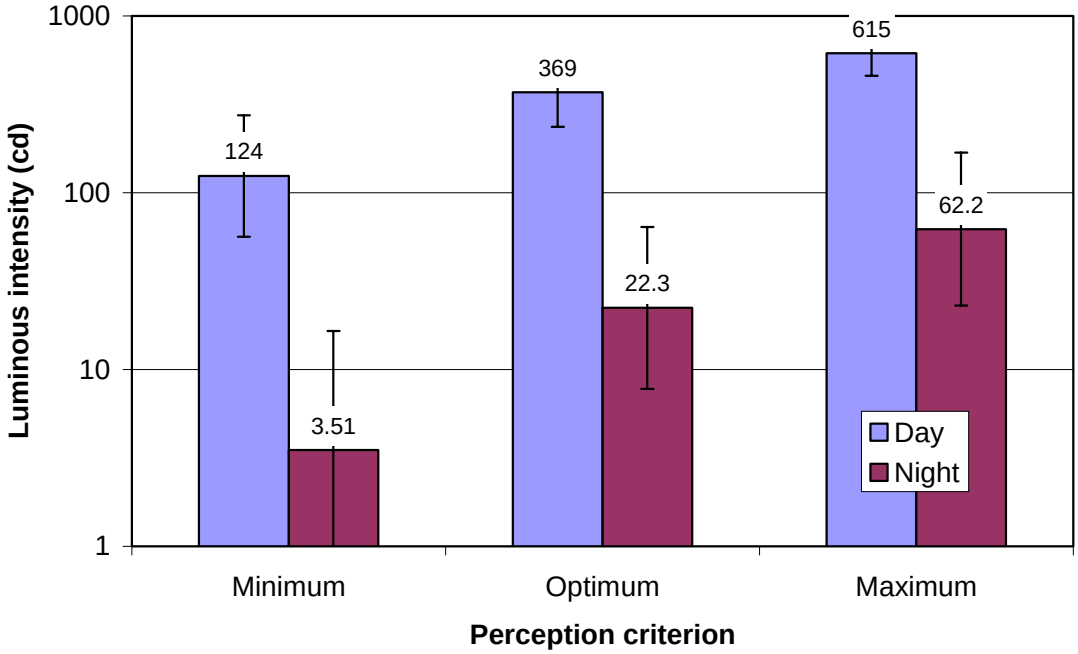

Figure 3. Average luminous intensities as a function of perception criterion and time of the day (Day, Night). The spreading indication is the standard deviation.

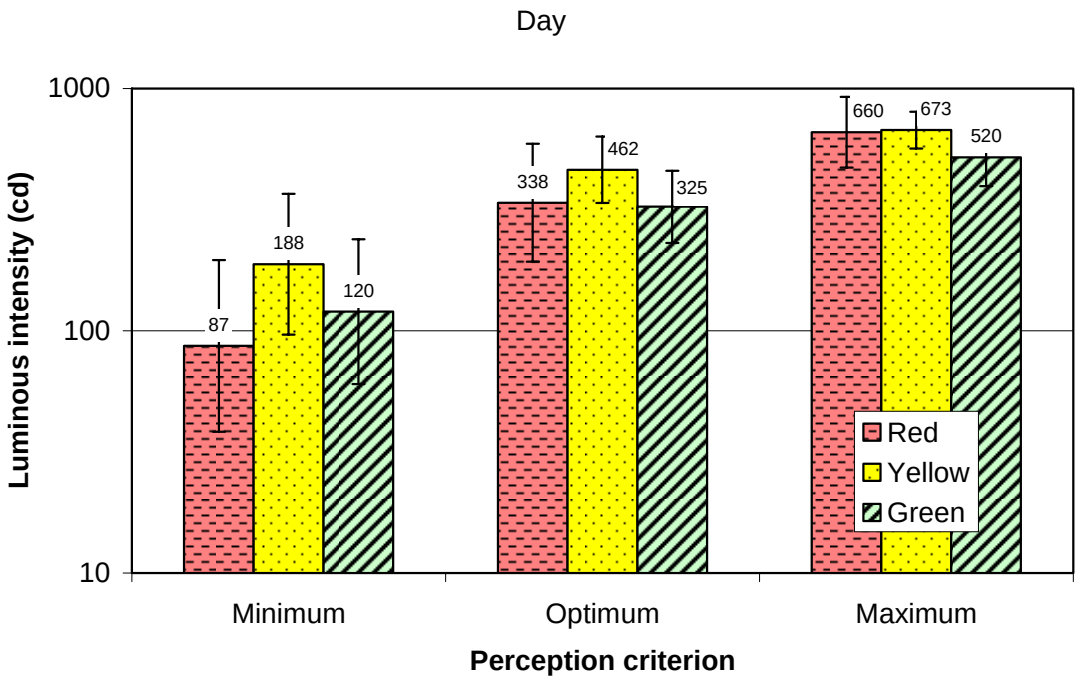

Figure 4. Average luminous intensities at day time as a function of perception criterion and colour. The spreading indication is the standard deviation.

4. Discussion

The adjusted luminous intensities of the current study are compared with the performance levels of the standard EN 12368 [1]. The average and the standard deviation of the luminous intensities for the day of Figure 3 can be used to find the performance level that fits the data best in terms of the highest percentage of satisfied observers. We considered the three considered performance levels 1/1 (100-400 cd), 2/1 (200-800 cd), and 3/1 (400-1000 cd). It should be noted that the requirements of the standard apply for new traffic lights. In practice on the road the light output should not drop below 80%, according to the standard. Let us assume that due to aging and dirt the light output drops to 70%. In that case the lower and upper limit of performance level 2/1 will be 140 cd and 560 cd. in practice. This lower level is higher than the average luminous intensity of 124 cd for minimum as we have measured in this study. This upper level is lower than the measured average luminous intensity of 615 cd for maximum. We can conclude that performance level 2/1, with a minimum of 200 cd and a maximum of 800 cd fits the best.

The average dimming factor for the optimum criterion is 17. However, when a dimming factor of 10 is used, the luminous intensity is as high as possible, without being too high. Therefore a dimming factor of 10 seems to be the best choice. However, it should be noted that It is very risky when the red signal is not visible enough and is missed by the road user. In a traffic situation with many other lights, such as traffic, public lighting, building, advertising, etc. (visual clutter), the conspicuity of a traffic light can drop considerably. Therefore it is advised to use dimming only in a dark environment without visual clutter that compete with the traffic lights. If dimming is used, a smaller dimming factor for the red signal should be used. Following the recommendations of the ISO [2] we advice a dimming factor of 4 for red. Based on an EN 12368 performance level 2/1, a dimmed red light has a minimum luminous intensity of 50 cd and a maximum of 200 cd. In Table 2 all the recommended luminous intensities are summarized.

Table 2. Recommended luminous intensities.

Colour	Luminous intensity (cd)			
	Day		Night (dimmed)	
	Minimum	Maximum	Minimum	Maximum
Red	200	800	50	200
Yellow	200	800	20	80
Green	200	800	20	80

The experiment was performed in a static way and the subjects were aware of the position of the traffic lights. In practice on the road the task of the road user is more complex. The position of the traffic light is not always the same and the viewing time is limited. This may have an effect on the required minimum luminous intensities.

5. Conclusions

Based on a perception experiment we found that performance level 2/1 of the standard EN 12368, with a minimum luminous intensity of 200 cd and a maximum of 800 cd, fits the best on luminous intensity adjustments the observers at day time.

To avoid uncomfortable perception situations the traffic lights can be dimmed by night when the surrounding is dark and with no cluttering lights. Based on a performance level of 2/1 we recommend a dimming factor of 10 for yellow and green traffic lights and a dimming factor of 4 for red traffic lights.

References

1. CEN (2000). Traffic control equipment – Signal heads (European Standard EN 12368). Brussels: European Committee for Standardisation (CEN).

2. ISO (1999). Road traffic lights - Photometric properties of 200 mm roundel signals (International standard ISO 16508:1999). Geneva, Switzerland: International Organization for Standardization.
3. Bullough, J.D., Boyce, P.R., Bierman, A., Hunter, C.M., Conway, K.M., Nakata, A., & Figueiro, M.G. (2001). Traffic signal luminance visual discomfort at night. Transportation Research Record, 1754, 42-47.