

Impacts of Various High Beam Headlight Intensities on Driver Visibility and Road Safety

J. Prasetijo^{*1}, Z. Mohd Jawi², M. A. Mustafa³, Z. Zadi⁴, H. A. Majid¹, M. H. Roslan¹, I. Baba¹ and A. F. H. Zulkifli¹

¹Department of Transportation Engineering Technology (STSS), Universiti Tun Hussein Onn Malaysia, 84600 Panchor, Johor, Malaysia

²Malaysian Institute of Road Safety Research (MIROS), Lot 125-135, Jalan TKS 1, 43000 Kajang, Selangor, Malaysia

³Department of Road Safety Malaysia (JKJR), Johor Bahru City Square, Malaysia

⁴Department of Road Transport Malaysia (JPJ), 83300 Batu Pahat, Johor, Malaysia

^{*}Corresponding author: joewono@uthm.edu.my

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Abstract – Based on several studies, driving above certain speed at night while using low beam headlights has been found to result in insufficient visibility to respond to road hazards. Luckily, vehicle headlight technology has advanced so much and the system is commercially available in many parts of the world. However, the technical development for optimal photometric performance raises a few questions. The use of high beam headlight system creates a glare to drivers of oncoming and preceding vehicles (because of both oncoming headlights and preceding taillights), to the extent that it has become necessary to determine the need to put a limit on the luminous intensity of high-beam headlights. This study shall therefore summarize and investigate visual performance that allows for evaluation of the potential benefits of increased luminous intensity by considering glare rating related to safety. Two different car models; the Proton Prevé and the Perodua Myvi were used in the experiments. The results showed that the highest average illuminance [lux] for single vehicle was 17.5, 7.5, 5.0 and 1.0 for the distances of 30m, 60m, 120m and 150m. However, the average illuminance based on total number of vehicles was 1.0, 0.5, 0.0 and 0.0 at distances of 30m, 60m, 120m and 150m, which were considered below maximum recommended safety level (max. 9.0 – 11.0 lux). The current average vehicle high-beam headlight control was found at the level of acceptable glare control (glare to oncoming and preceding drivers) and below the maximum level of illuminance rate with the normal speed of 40 km/h.

Keywords: Headlights beam, lumens, flux level, illumination, traffic safety

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1.0 INTRODUCTION

The use of high beam headlight system is found to create a glare to drivers of oncoming and preceding vehicles (Bullough, 2014a). Various high beam headlights emit certain quantity of visible light to the human eye and such a quantity is measured as lumens per square meter [lux]. According to Bullough (2014b), visual performance of drivers may be seriously affected due to the glare and luminous flux level (illumination).

Previous studies have managed to demonstrate the visual effects of high-beam headlights to oncoming and preceding vehicles (Bullough et al., 2013). Such studies have also emphasized the need to limit the level of luminous intensity of high-beam headlights. Based on an extensive investigation conducted by the Crash Reconstruction Unit of MIROS, it was found that risky driving, speeding and fatigue were the main causes of road accidents (JKJR, 2014). Factors involving lighting; be it during the day or at night (headlights effects) were not mentioned. Nevertheless, environmental factors have been identified to result in 8.5% of accidents (445 cases) (JKJR, 2014). Although such factors significantly contribute to road crashes, poor visibility could also play a significant part in the mishap (IIHS, 2016).

Since 1969, the Federal Motor Vehicle Safety Standard 108 has specified that all vehicles sold in the United States must have separate switches for manually selecting low beam and high beam headlamps, with low beams required to limit glare to oncoming or leading vehicles. On the other hand, high beams are required to maximize forward illuminance in the absence of other traffic. The most important issue, nevertheless, is the more frequent use of high beam headlighting that creates glare to the drivers of oncoming and preceding vehicles. Thus, it is necessary to understand the acceptable glare and high-beam illumination level to ensure safety of road users.

This study has been conducted to determine the level of high beam headlights and ascertain their intensity at various vehicle positions and road geometric. The results shall allow for an evaluation of the potential benefits of increased luminous intensity on forward visibility, as well as the probable implications as regards safety and level of visual discomfort (preliminary stage).

2.0 METHODOLOGY

A field study was carried out along several roads within close proximity to the Universiti Tun Hussein Onn Malaysia campus and two (2) sections along the Federal Roads; namely FT001 and FT005 (Figure 1). The roads have typical geometric features with double carriageways as well as an average width of 7.5m. In addition, the roads have seen a fairly high rate of crashes (Prasetijo & Zainal, 2016).

2.1 Field of Experiment

This study utilized accident data and information from the Road Transport Department Malaysia (JPJ) and Road Safety Department Malaysia (JKJR). The two federal roads registered a high rate of accidents with high fatalities in Batu Pahat since 2011 to 2016 with 192, 176, 158, 165, 197 and 207 fatalities, respectively (Prasetijo & Musa, 2016); which is why they were picked for this study. The study locations are as follows:

- i. Federal Road FT001 Jalan Johor Bahru – Ayer Hitam
- ii. Federal Road FT050 Jalan Batu Pahat – Kluang

A short, straight, flat and isolated road segment of 300 meters was selected within the Universiti Tun Hussein Onn Malaysia (UTHM) compound for experimental purposes. The road remained closed during all the experiment sessions. The study also considered five (5) road locations along Jalan Kluang – Batu Pahat due to the high number of accidents and fatalities (4-5% per year) (Prasetijo et al., 2017). Several studies have shown that road characteristics and traffic performance would prove significant to the vehicle crash model (Hosseinpour et al., 2013).

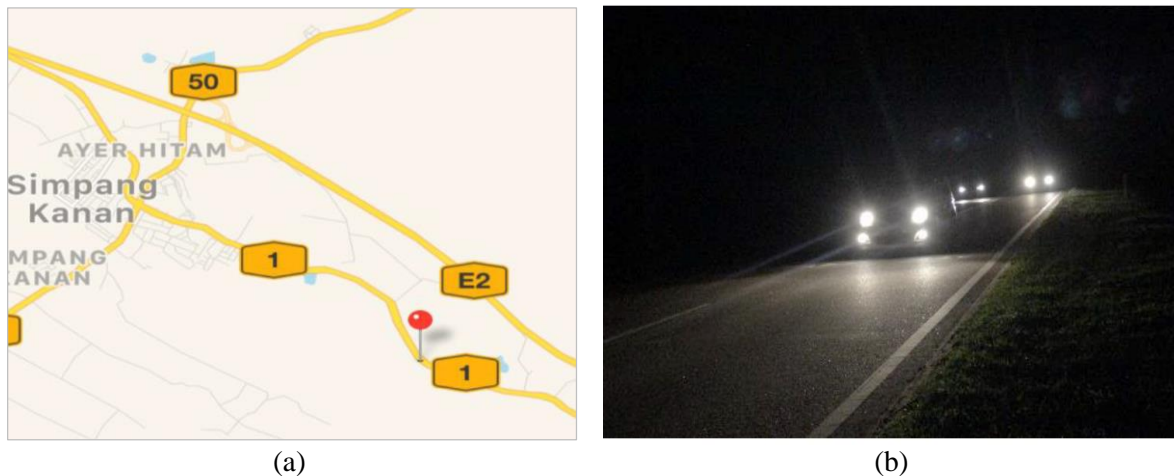


Figure 1: (a) Federal Road FT001 Jalan Johor Bahru – Ayer Hitam; (b) Normal road traffic at night along the Federal Roads FT050 and FT001

2.2 Experiment Setup

Two double carriageway roads with a width of 7.5m were set up for a car driven from the front (opposite) and the back (preceding) in both the low beam and high beam experiments. A jig/stand for light meter and camera camcorder were placed (static) on the opposite lane of the driven car (Figure 2). The jig/stand was designed at 130cm in height and 90cm in width according to the commonly used design (Bullough et al., 2016). It was placed at a distance of 30m, 60m, 120m and 150m from the driven car; as illustrated in Figure 3. The selected distances were recommended in the assessment of headlight glare by Prasetijo et al. (2018). The longest distance was recommended at the area where the high beam headlight should be dimmed to low beam (Flannagan & Sullivan, 2011; Rumar, 2000). The light meter used was SD-1128 while the camera model was camcorder HDR-CX100 AVCHD (Figure 2).

Measurement of high and low beams relied on video camera data. The equipment was placed on the roadside and mounted on a jig/adjustable stand at a height of 1.3 m (Figure 3). As a vehicle passed through an observation site, its headlight illumination was recorded (by the light meter) and the camera also recorded the illumination pattern; time, speed. The camera kept a time signature of passing vehicles, and this was used to determine the vehicle moving pattern. The field experiments on the local road within UTHM were conducted on a 300-meter straight road. All of sessions started at 21.00 hours and they were done during clear and dry weather condition. The test cars (Perodua Myvi/Headlamp D20N and Proton Prevé 1.6/Headlamp P3 RHD) were equipped with low and high beam headlights system. The system

was manually controlled to produce light pattern that conformed to the specifications. The cars would be driven at a speed of about 40 mph as suggested by Bullough et al. (2016).



Figure 2: (a) Adjustable stand for camcorder and Light Meter; (b) Light Meter; (c) Camcorder HDR

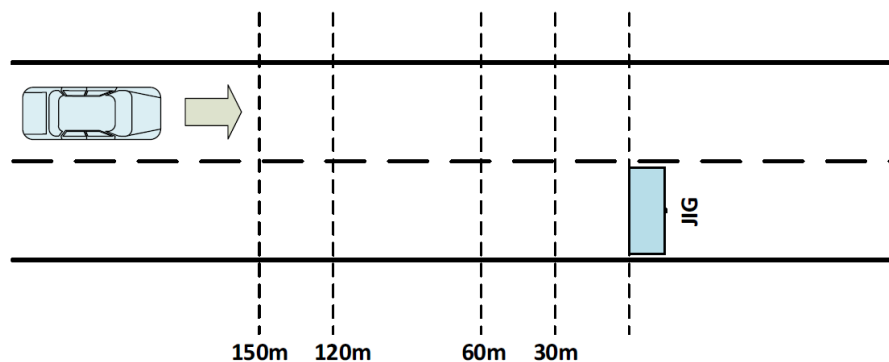


Figure 3: Equipment set-up and measurement distances

2.3 Discomfort Glare Experiments

Twelve (12) subjects/respondents took part in the experiments. The number was considered sufficient and suitable as documented by De Boer (1967). First, the subjects' eyes were examined by an ophthalmologist for myopia. Upon passing the eye test, the subjects were asked to sit in a parked passenger car. A test car was then driven from behind the parked car at a speed of approximately 40 mph and soon drove past the test subjects. The subjects were asked to look ahead, and as the test car drove passed them, they were asked to rate the overall level of discomforting glare by using the nine-point scale; with 1 being unbearable, 2, 3 (disturbing), 4, 5 (just permissible), 6, 7 (satisfactory), and 8, 9 (just noticeable) (De Boer, 1967; Bullough et al., 2016).

3.0 PRELIMINARY FINDINGS (SITES AND PROFILES)

Factors related to the headlight low beam and high beam were identified. The study therefore considered; light distance, height and speed, illuminance (luminous flux/light intensity), time and location (lane). Furthermore, the study also identified the experiment sites; namely two flat Federal Roads (FT001 and FT050) with relatively high travelling speed, accident rate, and number of fatalities. Preliminary investigation along both Federal Roads FT001 and FT050 (Figure 1) identified typical low and high car headlight beams as shown in Figure 4.

The preliminary experiment featured a car model, namely Proton Prevé 1.6 with average Low Beam (LB) of 1842 lux and High Beam (HB) of 3668 lux. Its average of illuminance [lux] at the distance of 30m, 60m, 120m and 150m were 1.2, 1.0, 0.8 and 0.6 lux (for LB) and 9.7, 5.0, 2.6 and 1.4 lux (for HB). The findings may produce insignificant difference of illuminance along the distance due to light meter sensitivity (HDR-CX100 AVCHD).

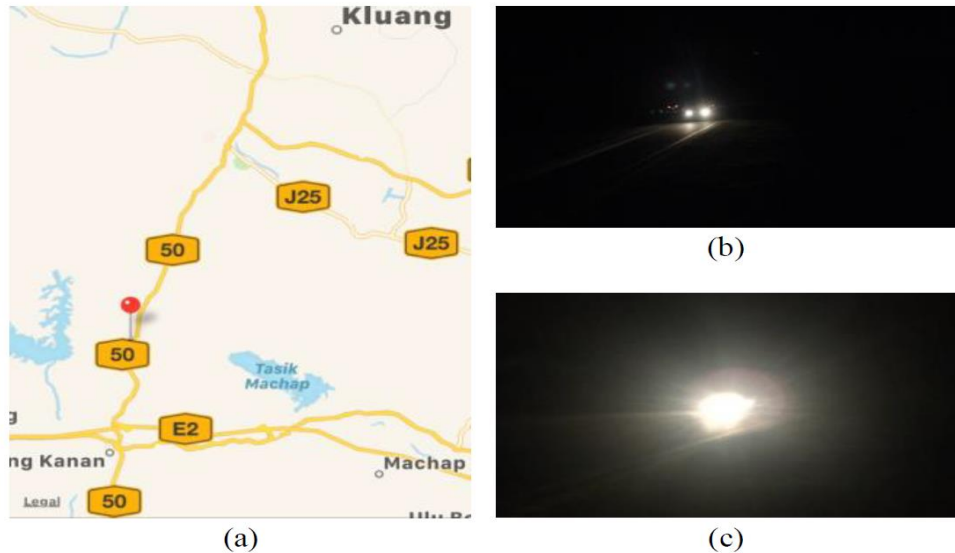


Figure 4: (a) Federal Road FT050; (b) Low beam; (c) High beam

However, a typical illuminance profile for one of the time trials can be predicted as in Figure 5. The figure shows the tendency of illuminance [lux] – distances – time in the trials which increased as the test car drew nearer. The illumination level [lux] is explained in the common luminance equation as:

$$E = \frac{345 \bullet k^2}{ISO \bullet t} \quad (1)$$

where E is luminance [lux], k is shutter, t shutter speed and ISO as film speed ASA.

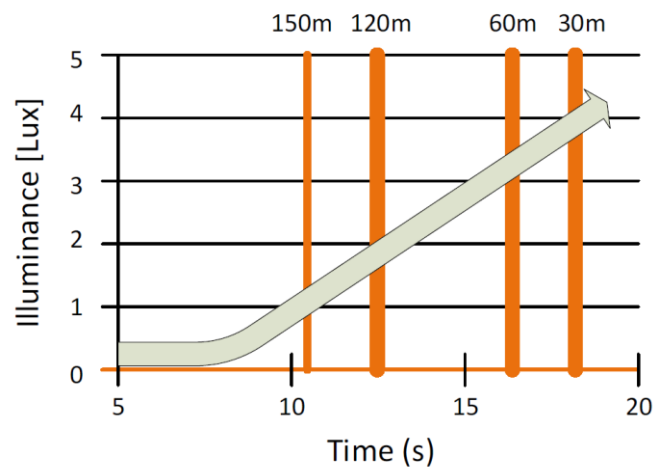


Figure 5: Illuminance profile for one time trials

4.0 RESULTS AND DISCUSSION

4.1 High Beam Headlights

The proper high-low beam experiments were later conducted using two different car models, namely the Proton Prevé and Perodua Myvi. The experiments were set-up as in Figure 3. Each car was driven to find the luminance of high beam, low beam and headlight intensity toward the front car mirror. It was found that the average of illuminance [lux] at distances of 0m, 30m, 60m, 120m and 150m with high beam were 17.0, 7.5, 5.0, 1.0 and 1.0 for Proton Prevé; while Perodua Myvi had 22.5, 12.0, 7.0, 2.0 and 1.0. The value of lux increased along with the distance as shown in Figure 6.

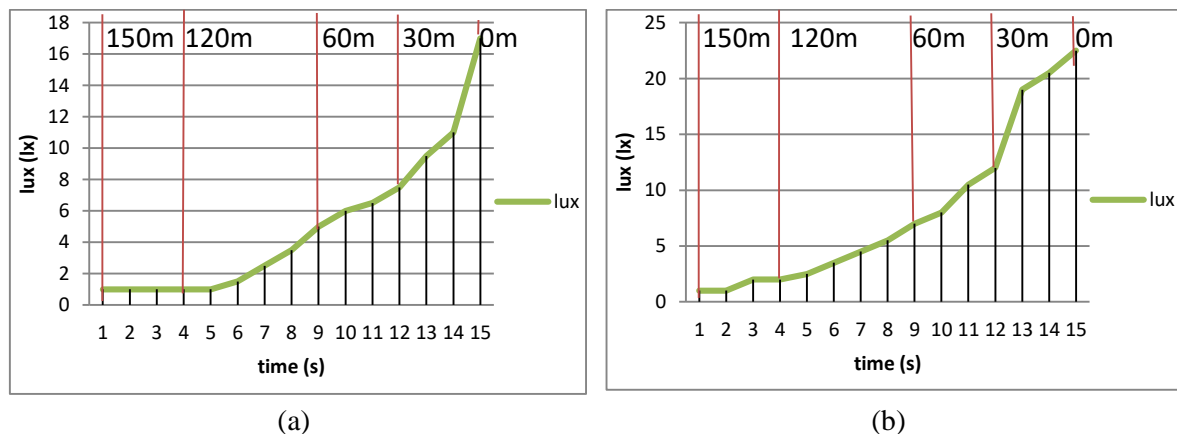


Figure 6: Average data for High Beam Headlight Proton Prevé (a) and Perodua Myvi (b)

The low beam headlight registered different value due to the different pattern of light distribution. This was due to the low beam being designed with its headlamp and bulb type producing low light. The findings also found the average lux value for low beam at the distance of 0m, 30m, 60m, 120m and 150m to be 1.0, 0, 0, 0, and 0 for Proton Prevé; while the Perodua Myvi had 1.0, 0.5, 0, 0, and 0. Lux increased along with the distance as shown in Figure 7.

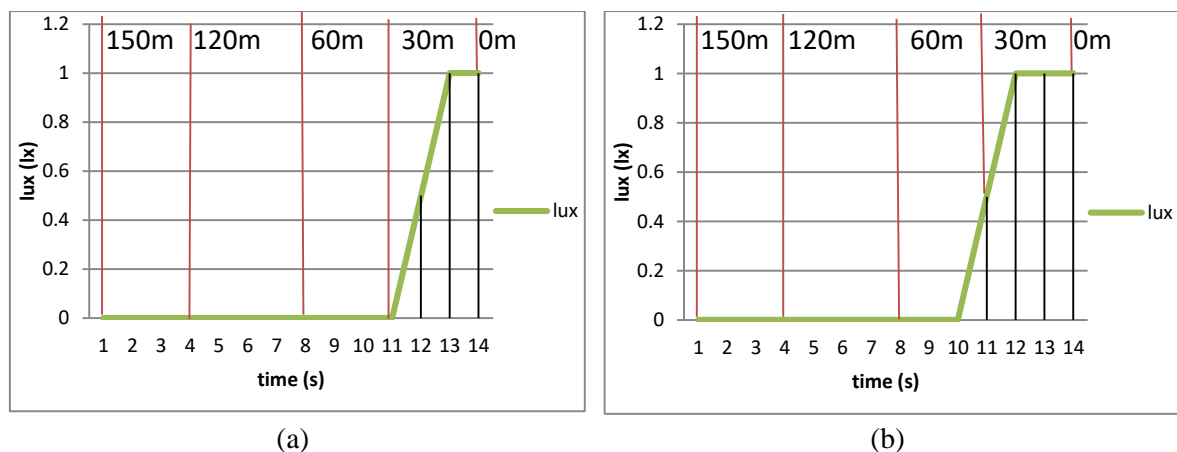


Figure 7: Average data for Low Beam Headlight Proton Prevé (a) and Perodua Myvi (b)

The last finding was on the value of luminance [lux] toward the front car mirror. The values were found on the reflection of light from the test car rear view mirror. The average lux values for the rear mirror at 0m, 30m, 60m, 120m, and 150m were 1.0, 1.0, 0.5, 0 and 0 for

Proton Prevé. For the Perodua Myvi, the values were 5.0, 2.5, 0.5, 0 and 0. The findings of both tests showed an increase between 120m and 60m before continuously climbing until 0m. High beam headlight was used due the low value of lux for low beam that produced less than 0lx in the mirror test. Figure 8 shows the average data for rear view mirror using high beam, whereby the luminance increased with the distance.

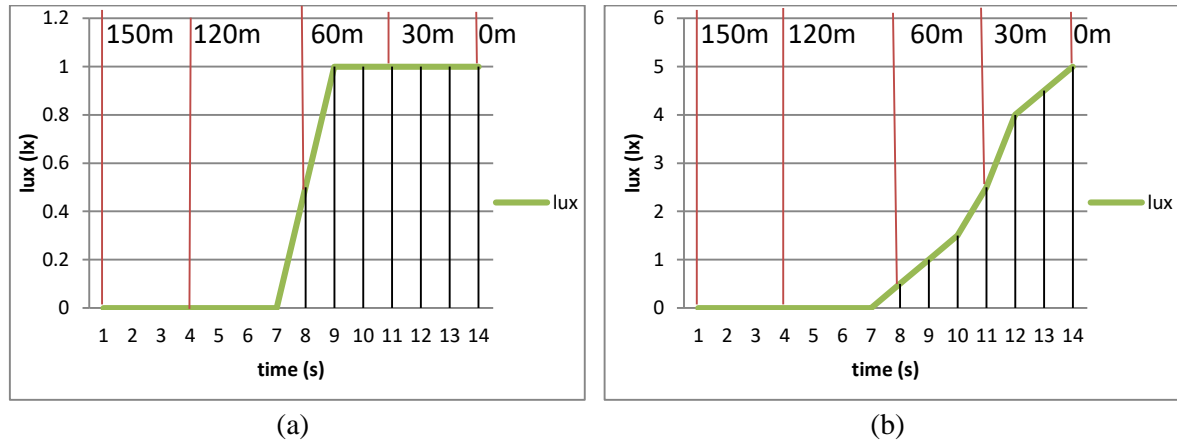


Figure 8: Average data for back mirror Proton Prevé (a) and Perodua Myvi (b)

The findings therefore showed various values of luminance [lux] due to the different type of headlamp in both cars, whereby the Prevé used a projector type of headlight while a reflector headlight was used in the Perodua Myvi. Another factor affecting light intensity is road surface, where uneven road produced fluctuating value of lux due to the unstable light distribution.

4.2 Discomfort Glare

Glare is defined as a contrast in brightness between different objects in one's field of vision. The contrast may sometimes reach the level of disability glare. Headlights of oncoming traffic/vehicles and headlights in rear view mirror when driving at night are defined as direct glare and indirect glare. The common model of rated discomfort (De Boer) with 87% accuracy is explained as:

$$R_{de\ Boer} = 3.45 - \log_{10} \left(\frac{(L_g \times \omega)^{2.21}}{L_b^{1.02} \times \theta^{1.62}} \right) \quad (2)$$

where L_g is luminance of glare source, L_b is luminance of background and ω , θ is solid angle at eye and deviation of glare source.

Another experiment was conducted to find human response toward headlight beam, where the test featured three groups of subjects with different eye strength. They were asked to sit in a car and rate the oncoming car with headlight beam using 9 to 1 De Boer rating. The results for low beam headlight are shown in Figure 9(a).

The finding showed a rating range of 4 and 5 for high eye strength subjects representing "just permissible" rate for low beam headlight whereby the light produced discomfort glare, but in intermediate amount and therefore was acceptable for driving. For middle eye strength subject, the rating ranged from 5 to 6 thus representing 'just permissible' and 'satisfactory' whereby low beam headlight was in the mild and intermediate amount acceptable for driving

visibility. The low eye strength group had a range from 6 to 7 representing ‘satisfactory’ whereby discomfort glare was tolerable for driving visibility.

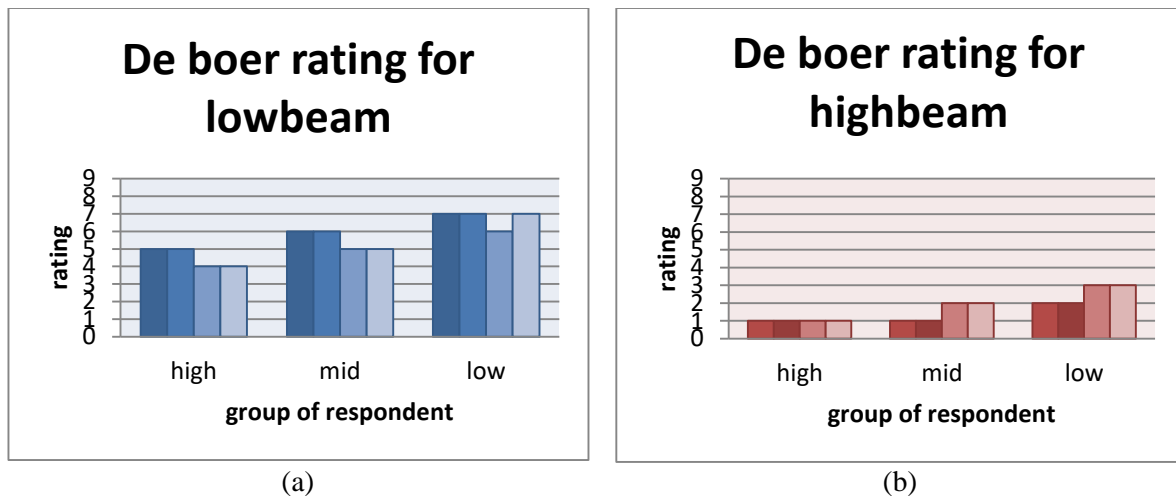


Figure 9: Subject response to Low Beam Headlight using De Boer Rating (a) and Subject response to High Beam Headlight using De Boer Rating (b)

The high beam headlight findings gave evidence that the light had in fact affected the driving visibility as shown in Figure 9(b). The strongest eyesight group selected rating 1, which represented ‘unbearable’ amount of beam from the headlight and resulted in bad driver visibility. For the mid eyesight group, their response ranged from 1 to 2, thus representing ‘unbearable’ and ‘disturbing’ light beam which produced annoying glare to the driver and reduced visibility. For the poor eyesight group, their rating ranged from 2 to 3 thus representing ‘disturbing’ high beam which produced annoying glare to driver and reduced night-time driving visibility.

5.0 CONCLUSION

Findings of the experiments as summarized in this report have managed to uncover the effects of headlight system on driver visual performance and discomfort. In addition, this study has also suggested several substantial steps to improve safety of high beam, for night driving. All in all, the results also show that the illuminance intensity and glare conform to the normal level and safety standard of less than 20 lux and normal respond glare rating. Further experiments must, however, be conducted for consistent results by using Light Meter and Data Logger SD-1128 with higher specifications.

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