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Effects of Daytime Running Lamps on pedestrians visual reaction time: implications on vehicles and human factors

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Abstract

The beneficial effects of Daytime Running Lamps (DRL) to avoid traffic accidents, especially those involving pedestrians and cyclists, have been known for some decades thanks to several pioneer studies analyzing the results yielded after the introduction of this function in some countries of the world. In spite of this proven efficacy, the question about potential negative effects related to the visual interaction between DRL and other functions in automotive lighting remain extremely important. This work describes a macro experiment carried out with 148 pedestrians in different situations involving turn indicator activation. The target of the experiment was the identification of factors influencing the Visual Reaction Time (VRT) of these observers when the turn indicator was activated in presence of lit DRL. The knowledge of these factors has a critical importance for carmakers, regulatory bodies in road and vehicle safety and drivers and pedestrians themselves, since VRT is an effective and widely used parameter in road safety to provide information about the probability of accident avoidance. Besides some vehicle and headlamp related variables found by means of an Analysis of Variance (ANOVA), some other variables inherent to pedestrians characteristics such as visual defects and gender, alone or combined with DRL color (white as required by law in ECE countries or amber as allowed in USA and Canada) were found to be statistically significant using Classification and Regression Tree (CART) as exploratory analysis, and a Generalized Linear Model (GLM) for validating the results. The conclusions of this pioneer study, not previously reported in the literature, point out that there is still very much to investigate with regards to Daytime Running Lamps, their design (distance to other functions), characteristics (color of light emitted) as well as their interaction with other functions of critical importance in automotive lighting such as turn indicators, but also on the human perception of this complex interactions. Our understanding and considerations about these findings could have a deep impact on road safety and vehicle design.

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1. Introduction

Before any consideration it is necessary to give a precise definition of Daytime Running Lamps (DRL). According to Regulations ECE 87 [1] and ECE 48 [2], "Daytime running lamp means a lamp facing in a forward direction used to make the vehicle more easily visible when driving during daytime". Since paragraph 2.7.25 of Regulation ECE 48 states that "National requirements may permit the use of other devices to meet this function", we will distinguish between "R87 DRL or specific DRL" and "other means of signaling during daytime" like Low Beam, dimmed High Beam or steady burning Turn Indicators.

In ECE countries, specific DRLs and their installation in motor vehicles are regulated by Regulations ECE 87 and 48 respectively. According to the last one, this function is automatically switched ON when the device which starts and/or stops the engine is in a position which makes it possible for the engine to operate. In the same way, the daytime running lamp shall switch OFF automatically when the headlamps are switched ON, except when the latter are used to give intermittent luminous warnings at short intervals. DRLs in USA are regulated by FMVSS 108 [3] and SAE J2087 [4] and they are forbidden in Japan.

Given the variety of "other means of signaling during daytime" and the current convergence towards the use of specific DRLs, that are mandatory in ECE countries, this study will be focused on the last ones. Their entry into force and subsequent increase on the roads in the next future encourage us to look for answers to questions that maybe are not well understood yet.

This entry into force is based in a large amount of scientific evidences that highlight the importance of DRL to avoid accidents during daytime [5-9], especially knocks to pedestrians and cyclists. However, given that the addition of new lights like DRL to headlamps could lead to visual masking, a deep research on this potential masking and it effect on visual reaction time (VRT) [10] of road users seems to have of a critical importance. This is the target of this study.

2. Materials and method

The target of this experiment was to obtain some conclusions from the reaction time of several observers in the presence of a Turn Indicator that is suddenly and randomly switched on at different distances from a Daytime Running Lamp. With the results obtained we pretend to infer whether the distance between DRL and Turn Indicator has influence on the perception of this last. We also pretend to know which colour of DRL (white or amber) makes the perception of the vehicle easier for pedestrians.

For this last reason, and besides the measurements of reaction times, the participants in the experiment answered to two subjective questions about the colour of DRL. The first one asked the participants whether they consider that one amber DRL is more easily perceptible than a white one by a pedestrian. The second one asks whether any kind of confusion could arise because if both DRL and Turn Indicator were amber.

2.1. Participants

148 participants (50 women and 98 men) participated in this experiment. They were between 18 and 26 years old and the mean age was 20.0. The standard deviation for the age was 1.37. The mean height was 1.75 m with extreme values of 1.52 and 1.91 m and standard deviation of 0.09.

2.2. Experimental Device

The headlamp containing a DRL was set on a stand that reproduces the conditions in the vehicle at a mounting height of 900 mm on the ground. Low and high beam remained switched off all the time. The module hosting the Turn Indicator, which was independent from the main headlamp, was fitted to the same stand and placed under the headlamp. It could be sliced up and down through a bar that allowed us to change its mounting height with no angular deviation of its optical axis.

The DRL used a P21W bulb when it was white and a PY21W when amber, both at 13.5V. For the Turn Indicator, we used a H21W bulb. All these bulbs are approved according to Regulation ECE 37 [11].

In order to accurately distribute the light, the DRL is performed by a concave reflector of circular shape made of small mirrors that direct the beams. The reflector of Turn Indicator is similar to but its shape is rectangular and it includes a piece of polycarbonate with optical grooves (fresnel) to help re-direction of light by reflection. Inside the module there is a Position Lamp (bulb and reflector) but it remained off during the whole experiment.

2.3. Experiment

The experiment was carried out in a closed street during daytime in a very sunny day (Illuminance on the ground: 80.000 lux). We took measures when the optical axis of both observer and headlamp formed angles of 0º and 20º (outer side of the vehicle). In both cases the distance between participants and experimental device was 25m.

Although in real conditions Turn Indicators flash with a frequency between 60 and 120 per minute, in this experiment they did not flash once they were switched on. We have done it in order to reduce the high number of variables. In future experiments flashing turn signal will be introduced.

From a line at 25 m, participants looked towards the DRL, which remained ON, and did a signal as soon as they have detected the activation of Turn Indicator. In order to better reproduce the conditions of circulation of pedestrians on the street, they have looked at an object located on the axis of the headlamp but far away and above it during their walk.

After some training and control trials, the sequence of measurements has been the following:

- Turn indicator 5 cm below white DRL. Participants aligned with the axis of the set.
- Turn indicator 5 cm below white DRL. 20º between experimental set and participants visual line.
- Turn indicator 50 cm below white DRL. Participants aligned with the axis of the set.
- Turn indicator 50 cm below white DRL. 20º between experimental set and participants visual line.
- Turn indicator 5 cm below amber DRL. Participants aligned with the axis of the set.
- Turn indicator 5 cm below amber DRL. 20º between experimental set and participants visual line.
- Turn indicator 50 cm below amber DRL. Participants aligned with the axis of the set.
- Turn indicator 50 cm below amber DRL. 20º between experimental set and participants visual line.

In each measurement, the time between activation of the Turn Indicator and reaction of the participant is denominated “visual reaction time” (VRT).

3. Results

Tables 1 and 2 below show the mean values of reaction times in this experiment depending on the observation angle between observer and the experimental device:

Table 1. Results obtained for front observation. Figures in seconds.

	AMBER DRL - 5 CM DIST.	AMBER DRL - 50 CM DIST.	WHITE DRL - 5 CM DIST.	WHITE DRL - 50 CM DIST.
Average value	0,98	0,95	0,93	0,97
Standard dev.	0,25	0,14	0,13	0,18

Table 2. Results obtained for observation at 20º. Figures in seconds.

	AMBER DRL - 5 CM DIST.	AMBER DRL - 50 CM DIST.	WHITE DRL - 5 CM DIST.	WHITE DRL - 50 CM DIST.
Average value	1,04	1,05	0,99	0,95
Standard dev.	0,34	0,86	0,27	0,14

As seen, VRT are much higher for observation angles of 20º and, in general terms, when the colour of the light emitted by the DRL is amber. This has been confirmed by the ANOVA analysis carried out in [12].

In addition, a deeper analysis based on decision trees and a generalized linear model (GLM), showed higher VRT for women and lower VRT for myopic participants.

4. Conclusions

Several immediate conclusions can be deduced from the measures collected in tables 1 and 2:

(1) When the colour of DRL is amber, average VRT is higher if compared with white DRL. It proves that, when both functions have the same colour, visual performance of Turn Indicators is diminished..

This conclusion also agrees with the feelings of the participants after the experiment. Thus, when asked whether, to their understanding, amber DRLs difficult Turn Indicator detection, 70% of participants answered that amber DRLs make detection of Turn Indicators more difficult.

(2) For observation angles of 20º, average VRT is higher than for observation angles of 0º (frontal observation). This result, must be seriously considered because most knocks downs to pedestrian and cyclists take place under notable angles between directions of cars and victims.

(3) Women have remarkably longer visual reaction times than men. The long distance between observers and experimental device, which makes the small difference in height between the genders neglectable, excludes a geometrical explanation of this fact, which could be hormonal.

(4) Myopic subjects with correction (glasses) have lower visual reaction times than the rest of the sample..

Conclusions above, demonstrate that white DRLs are much more effectively discriminated from Turn Indicators. Thus, given that the vast majority of cars incorporate Turn Indicators and DRLs in the same lamp (that is, they are quite near), we suggest that regulations allowing amber DRLs should deeply consider the effects on their interaction with Turn Indicators. Concerning the survey, results have been quite uniform if we consider that the majority of participants did not know what a DRL is. As mentioned above, 100% of them confirmed that amber DRLs make confusion with Turn Indicator easy. Concerning their preferences about the colour, 80% stated that, in spite of their answer to question number 1, vehicles would be more easily detectable during daytime if DRLs were amber.

The evidences found also encourage us to suggest that constrains on mutual distance between both functions must be deeply studied before being introduced in Regulations. In summary, the positive experience and the logic of the results obtained, evidence the necessity of carrying out more experiments on the mutual interaction between different automotive lights in order to harmonize the different regulations with the target of improving safety on the road. Future research on this topic will consider different conditions and will involve or change different variables.

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