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Laboratory test of the impact of the area of an LED billboard on drivers' visual performance

***Abstract**. The driver's visual performance is affected, to a large degree, by the distributions of luminance present in the driver's field of view. Placing LED billboards near roads makes drivers uncomfortable and distracts them when driving. In order to determine the impact of LED billboards on the visual performance of drivers, a vehicle driving simulator was built. The simulator served to conduct research on the impact of the size of LED billboards on visual performance of a selected group of observers. The article describes the testing procedure and tests results.*

***Streszczenie.** Na wydolność wzrokową kierowcy mają istotny wpływ rozkłady luminancji występujące w jego polu widzenia. Lokalizowanie reklam LED blisko drogi powoduje dyskomfort i przeszkadza w kierowaniu pojazdem. W celu ustalenia wpływu reklam elektronicznych na wydolność wzrokową kierowców zbudowano symulator jazdy samochodem. Na symulatorze wykonano badania wpływu wielkości reklamy LED na wydolność wzrokową wybranej grupy obserwatorów. W artykule przedstawiono procedurę badawczą oraz wyniki badań (**Badania laboratoryjne wpływu wielkości powierzchni reklamy LED na wydolność wzrokową kierowców**).*

Keywords: visual performance, driving simulator, LED billboard, electronic billboard.
Słowa kluczowe: wydolność wzrokowa, symulator jazdy, reklama LED, reklama elektroniczna

Introduction

In urban traffic, the driver's visual task performed while driving is not limited to observing the road right in front of the car and, given the specific nature of urban traffic, three levels of performing the visual task should be applied to its investigation: the position level, the situational level and the navigational level. The position level applies to maintaining the desired position and the correct course in a traffic lane. The situational level is connected to making maneuvers in the road and maintaining and adjusting the vehicle's speed. The navigational level is related to orientation in the surroundings and selection of the road to be covered. Each of the above levels requires special kind of information from the visual analysis of the road and its vicinity, that allows correct execution of a specific task.

For a horizontal visual task it is important to visually recognize changes in the roadway such as traffic lane lines, curbs, shoulders, etc. and to spot the relative movement of the surroundings. Visual tasks at the situational level are related to assessing the current position and speed in relation to other traffic participants. It is necessary to have visual information indicating the need to adjust the speed, driving direction or position in the road. The driver must recognize typical features of a given situation, relying, to a large extent, on previously gathered experience and knowledge and, if necessary, must make the right maneuver. Visual tasks at the navigational level are connected with finding and processing information from the direct or non-direct vicinity of the road - simple and quick recognition of characteristic points in the surroundings, traffic signs, information boards, street names and parcel numbers, etc., required to make decisions on the choice of the continued route. In this situation, the distribution of illumination in the area adjacent to the road is important, since the driver's vision is also directed outside the road. After dusk, the driver's field of vision may cover objects whose luminance greatly differs from the luminance of the road and whose brightness may cause discomfort and hinder the execution of normal tasks related to driving a car. LED billboards (electronic billboards) may be such objects. Such billboards are potential sources of glare because it often happens that their luminance is measured in several thousand cd/m^2 [1] and they display content that attracts the attention of drivers and distracts them. Consequently, they pose a threat to road traffic safety.

So far, the requirements and normative recommendations related to limiting the danger posed by LED billboards have not been defined. Although the reference literature includes various requirements and recommendations related to the use of such devices, most of them fail to address to requirements covering the billboards' photometric qualities, the angular size and location of billboards in relation to the observer.

Purpose of the study

In connection with the lack of unambiguous requirements concerning the photometric and geometric qualities of LED billboards, studies on the impact of such billboards on the drivers' visual performance have been conducted in the Poznan University of Technology. During the realization of grants [1, 2], the basic properties of LED billboards installed in Poznan were studied, subjective tests on a group of selected observers were done and guidelines for the permissible levels of luminance were elaborated.

Currently, studies aiming to formulate guidelines on the location of billboards in relation to observers and their angular size are under way. The completed studies aimed to assess the impact of LED billboard size on drivers' visual performance and attempted to formulate guidelines on the use of maximum areas of LED billboards close to roads.

A car driving simulator was used since the drivers' reactions were tested in potentially dangerous situations. Figure 1 presents the test bed. The description of the driving simulator and the method of calibration were presented in literature [3, 4, 5, 6].

Fig. 1. The view of the test bed for examining drivers' visual performance in the car driving simulator

Preparation of the experiment and description of the measurement procedure

The impact of the area of an LED billboard on drivers' visual performance was tested on a properly set up laboratory test bed. The visual performance was assessed on the basis of the observer's reaction time to the emergence of an obstacle in a driving lane, in a situation where on the shoulder of the road there was an illuminated LED billboard with a specific luminance L and a non-illuminated LED billboard (L = 0 cd/m^2).

Each time, the task of the test participants was to drive, without collisions and observing traffic regulations, through a virtual town in the direction of Poznan. Obstacles were emerging in the road during the trip. The obstacles could be a human, a dog or a ball. In order to force the driver to make decisions instantaneously, thus eliminating the reaction time needed to make a decision from the measured time, the obstacles would emerge in the lane suddenly, a short distance in front of the car. The driver's reaction to the obstacles was pressing the brake pedal or turning the steering wheel. The time was measured with 1 ms accuracy.

Figure 2 presents an example of an obstacle emerging in the driving lane while an LED billboard is illuminated and without an illuminated billboard.

a)

b)

Fig. 2. An example of an obstacle emerging in the driving lane
a) when a billboard was illuminated at specific luminance
b) without an illuminated billboard on the shoulder of the road

For the purpose of conducting the experiment, five routes through a virtual town were prepared. These included a training route, to allow the observer to learn the simulator's driving abilities and the method of moving around the virtual town, and four proper routes in which obstacles would emerge in places where an LED billboard was not illuminated in the shoulder of the road - one route, and three routes with illuminated LED billboards with specific luminances of the displayed images. The average luminances of the billboard along individual routes were: 400 cd/m^2, 800 cd/m^2 and 1600 cd/m^2. Each route always displayed billboards of identical luminance.

Figure 3 shows the distribution of luminance on the surface of a billboard serving as an example.

In order to maintain identical conditions for evaluating the impact of luminance of billboards on the tested person's reaction time, the routes were designed to have the same number of turns, intersections and straight sections projected exactly in the same order, but with different scenery (different appearance of buildings). The location of LED billboards, the place of appearance of obstacles and their type were exactly the same in each of the four routes.

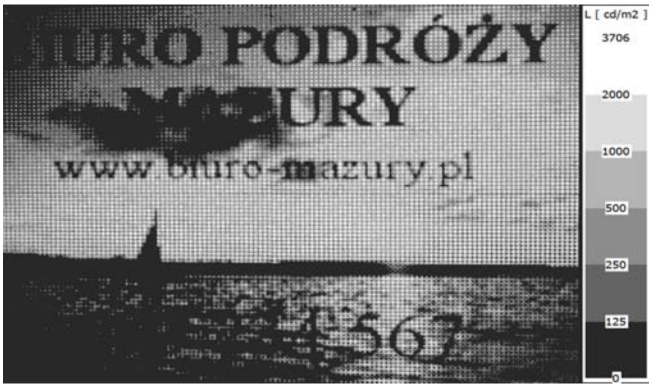

Fig. 3. The distribution of luminance on the surface of a billboard serving as an example

All observers were divided into four groups. The first group encountered advertisements displayed across the entire LED billboard area (1.54 m x 1.05 m), the second group - advertisements taking up about 50% (1.05 m x 0.77 m) of the screen's total area, the third group - about 25% (0.77 m x 0.53 m), the fourth group - about 12.5% (0.53 m x 0.38 m). Figure 4 shows an example of an advertisement in various sizes, displayed on an LED screen.

100 % area of LED screen

50 % area of LED screen

25 % area of LED screen

12,5 % area of LED screen

Fig. 4. Advertisement in various sizes displayed on an LED screen

In the beginning, each observer was informed about the objective and method of conducting the test and about the possibility of resigning from continued participation in the study at any time. To make sure the most objective nature of the test was maintained and the same amount of information was given, all information was read aloud to the observers by the person in charge of the experiment. Upon completion of the preparatory stage, the test route was taken, followed by the proper routes.

To eliminate the impact of the order of routes on the results of measurement, the test participants drove along the proper routes according to a different schedule each time.

Following the completed measurement stage in the car simulator, the observers filled in personal data forms with basic demographic information and a study-related survey.

Characteristics of test participants

The visual performance examination was done in laboratory conditions, on a group of 16 volunteers. 13 of the tested persons failed to complete a full cycle of tests. The observers were diagnosed with symptoms of simulator sickness. The description of typical symptoms of simulator sickness are covered in literature [7, 8].

The majority of observers were young people. The average age of the tested individuals was 23 years. All test subjects were holders of at least category B driving licenses. Most of them have had driving license for 4 or 5 years and declared good passenger car driving skills.

Test results and analysis of the obtained results

The study of the impact of the area of an LED billboard on drivers' visual performance was held according to the previously described procedure.

The obtained results were used to determine average (t_{av}) reaction times for the tested group of observers. Standard deviation for average reaction times of the observers was calculated, along with confidence interval for confidence limit of P = 95 % (significance level □ = 0.05). The determined parameters are shown in Table 2.

The relation of the observers' reaction times on the level of luminance of an LED billboard for the examined areas of advertisements displayed in the LED screen is shown in Figure 5.

Table 2. Average times of reaction of drivers to sudden appearance of an obstacle in the road t_{av}, standard deviation □ and confidence interval p depending on the luminance of the billboard and the area of the displayed image

Billboard's luminance L [cd/m^2]	Drivers' reaction time, standard deviation, confidence interval	Area occupied by the image displayed on the LED screen			
		100 %	50 %	25 %	12,5 %
0	t_{av} [ms]	739	756	746	742
	σ[ms]	78	78	75	69
	p [ms]	28	28	27	25
400	t_{av} [ms]	826	796	794	769
	σ [ms]	154	115	134	124
	p [ms]	56	42	49	45
800	t_{av} [ms]	854	861	792	773
	σ [ms]	129	121	147	131
	p [ms]	47	44	53	48
1600	t_{av} [ms]	829	827	804	793
	σ [ms]	219	130	136	126
	p [ms]	80	47	50	46

The conducted study confirmed the negative impact of the area of the image displayed in the LED screen on the drivers' visual performance. The drivers' reaction times to a sudden appearance of an obstacle in the road extended in comparison to situations when these obstacles would appear in locations without active billboards in the shoulder of the road, practically for all considered areas and luminances. The differences in reaction times ranged from several to dozen percent. The differences were smaller in case of billboards covering 12,5% and 25% of the LED screen. Also, for these areas, a lower impact of the billboard's luminance on average reaction times, and consequently on the observers' visual performance, was determined. The analysis of the variability of curves $t_{av} = f(L)$ for 12,5% and 25% of the area of illuminated LED screen, allows a conclusion that these curves are of similar nature. The results of the conducted tests also suggest a certain convergence of the curves of dependence of average reaction times of the observer's on the luminance of the LED billboard for 50% and 100% of the area of the displayed image. For these areas the reaction time of the observers extends, consequently leading to a reduction in visual performance for billboards with luminance of 400 cd/m^2 and 800 cd/m^2, followed by a characteristic improvement in visual performance (reduced reaction time) for the luminance of 1600 cd/m^2 almost to the level measured for the luminance of 400 cd/m^2. The author believes that the results obtained in these cases were additionally affected by factors not related directly to the luminance of the billboards, e.g. psychological factor related to the appearance of a highly bright billboard that may suggest imminent appearance of an obstacle in the road (increased vigilance).

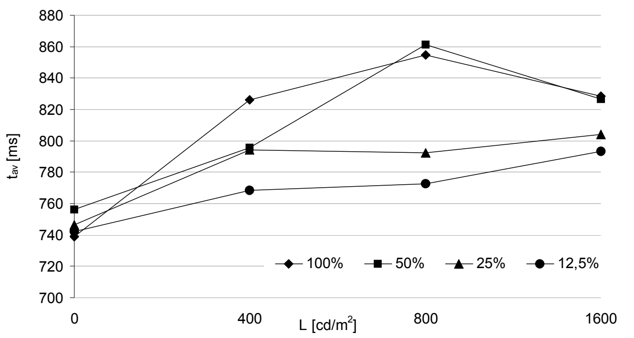

Fig. 5. The relation of the observers' average reaction time and the luminance of the LED billboard for the examined areas of the displayed image

The completed studies were aimed to assess the impact of LED billboard size on drivers' visual performance and attempted to formulate guidelines on the use of maximum areas of LED billboards installed close to roads. Previous studies [2, 9] served to formulate recommendations, among else pertaining to the illumination of LED billboards. It was determined that the maximum luminance of an LED billboard should not exceed 400 cd/m^2. With this recommendation applied and having analyzed the results of the conducted studies, a conclusion may be formulated that the maximum area of the displayed image that has not significant impact on the drivers' visual performance in the examined conditions is 25% of the LED screen area.

For the purpose of building the test bed an LED billboard module was purchased, whose dimensions, in the designed location in the laboratory, are the equivalent of dimensions of a real-life billboard whose size is approximately 5 m x 6 m. Thus, it can be assumed that the studies were conducted for billboard areas that match real areas of approximately 30 m^2, 15 m^2, 7,5 m^2 and 3,8 m^2, observed from a distance of around 20 m. Consequently, the maximum LED billboard area, with luminance limited to 400 cd/m^2 [2], should not exceed 7,5 m^2 for billboard located in close vicinity to roads.

The maximum area of LED billboards was determined for a location of the billboard in relation to the observer and the road that, specifically determined in laboratory conditions. The change of location of the billboard in relation to the driver's viewing direction may significantly affect the results. Therefore, studies that also take into account the change of location of the LED billboard to the viewing direction of the road should be conducted.

During the analysis of the test results, answers to the questions in the survey filled in by the test participants and the observations from the experiment, it was found that certain modifications, especially with regard to the design of the route, must be implemented. In order to limit the observers' certainty as to the appearance of an obstacle in the road while an LED billboard is active, additional advertisements were placed along the route, but no obstacles would appear in the road while these were illuminated. The author believes that for further studies the number of such advertisements should be increased and the same luminance, as for the billboards whose impact on visual performance was tested, should be used. It will be especially important to introduce this modification for routes with billboards whose luminance is 1600 cd/m^2.

Summary

A decision was made to use a car driving simulator for the purpose of evaluation of the impact of LED billboards on the drivers' visual performance. Although such devices will never replace natural driving conditions, they can be used to conduct tests, often in pre-accident conditions.

Despite the use of routes with different designs, the conducted studies showed significant convergence with the results of previous studies [2, 9] that concerned the impact of luminance of billboards, when the displayed image occupied 100% of the LED screen, on the drivers' visual performance. This fact supports the possibility of application of driving simulators to test drivers' visual performance in various illumination conditions in the road and its direct vicinity. Continued studies regarding the impact of LED billboards on the drivers' visual performance will allow to formulate specific requirements for the area of LED billboards.

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