Research Article

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Looking behavior to vertical road signs on rural roads

Abstract

In this study visual fixations at vertical road signs was tested in15 participants who drove a rural road of 15 km. Drivers gaze was assessed by mobile eye tracking glasses and vehicle performances were measured by VBOX PRO device. The route was the same for all participants and included a total of 277 vertical road signs. The results shown that only 24% of vertical signs were looked. The results were explained in terms of signs' type, road environment conditions, traffic conditions and gender.

Keywords: eye-tracking, traffic sign, road safety, conditions, crashes

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Introduction

Improving safety on roads is regarded as being a challenging task. This is because crashes and causalities tend to be widespread across these networks.[1] More than 1.2 million people die on the world's roads every year, and as many as 50 million others are injured.[2] Generally, there are three main components that control the safety of any transportation network: the first one is related to the infrastructure design and maintenance, the second one to the vehicle safety and the third one to road users.[3–5] The reliability of the road-vehicle-drivers' system is determined by numerous and complex factors. Statistics show user behavior to be the main cause of accidents (around 90%), making it the main element to focus attention on.[5] Road traffic signs are considered as one of the most important elements for road safety purposes. Their inspection is typically included in the road management systems.[3] They are considered as a link between traffic engineer and road users, which in turn help the drivers to anticipate the road ahead in order to make driving more safe and convenient by providing useful information.[6] The identification of any road sign is achieved through two main stages: detection and recognition.[7] Driver's read-and-respond time is about 2.5 s. This means that signs should be separated by at least 70 m on a road with an average speed of 100 km/h.[8]

The road signs generally fall under the following groups:

a. Vertical signs;

b. Horizontal signs;

c. Signal lights;

d. Signals and complementary equipment.

The vertical signs can be subsequently divided into three main categories:

a. Warning signs, used to express a warning of hazard or dangerous places on the road ahead of the drivers;

b. Prescription signs: obligations, prohibitions and restrictions which road users must comply with;

c. Instruction signs, used to provide information to the driver about the facilities available ahead such as identification of locations, routes, services and systems.

The typical design of traffic sign is composed of a visual/symbolic language about the road ahead that can be interpreted easily by drivers.[9] They are designed in fixed 2-D shapes like triangles, circles, octagons, or rectangles. Their colors are chosen with high contrast to the surrounding environment, so they can be detected easily by the drivers. The signs are located in well-defined locations with respect to the road, so that the driver can, more or less, expect the location of these signs. The location of any traffic sign should be chosen far enough in advance to the situation in order to give sufficient time for the driver to take an appropriate reaction and act accordingly. The factors which determine the location of any sign include the size of the sign, the number of information to be scanned, the lateral distance of the sign from the edge of carriageway and the speed of the approaching vehicle.[10-11]

Despite the critical role played by vertical road signs in tra□c safety and driver's behavior regulation, there is a conspicuous amount of evidence that they are often unattended. Costa et al.,[11] for example, have investigated visual fixations to vertical road signs in an ecological setting. The results showed that only 25.06% of vertical signs were fixated by drivers. Milosevic et al.,[12] moreover, have obtained levels of sign recall of 2–20%for single signs and 34% for serially repeated signs.[13] Cole et al.[13] have found that the conspicuity of traffic signs and signals was generally quite low, on the basis of only 15–20% of driver reports, and as few as 10% of the traffic signs present were reported.[14–16] In this study visual fixations at vertical road signs was tested in15 participants who drove a route of 15 km on a rural road. Gaze was assessed by mobile eye tracking glasses and vehicle performances were assessed by VBOX PRO.

Methods

Sample

Fifteen drivers, 10 men (mean age=27.67 years±13.74) and 5 women (mean age=19.4 years±0.89), have participated in the experiments. All drivers had normal vision and none of them wore glasses, in order to avoid artifacts to the eye movement recording system. The participants did not have any idea about the experiment aim and nobody was paid. Participants have a regular driving license (class B for cars). Their mean driving experience was 6.7 years±11.76. The average number of kilometers driven per year was 5300±5728. None of the participants had any previous experience of the route used in this study. One of them had caused one accident and another one had caused three accidents.

Measurements

The experiments have been conducted in the municipality of Imola (Italy) along the road SP 610 "Selice-Montanara", in the section between Imola and Fontanelice. The entire route took place on a single carriage way secondary road, with one lane in each direction. It can be subdivided into urban sections (Linaro, Ponticelli, Fabbrica, Casalfiumanese, Borgo Tossignano, Fontanelice), and suburban ones. The total length of the route is about 15 km. In order to avoid participants feeling disoriented and paying too attention to directional signs, the route was planned in very simple orientation terms. The drivers started and ended at the same intersection; half-way along the route, they reached another specified intersection and then returned along the opposite way to the starting point. Data collection was carried out along three days during morning (from 9.30 to 12.00), to avoid intense brightness by the sun which can cause unreliable results due to tracking loss of the eye movement recording system. Each participant has driven the same vehicle along the road SP 610: a BMW, model Series 1, Diesel supplied, with manual gear. The car has been supplied with the device VBOX PRO to record the accelerations, decelerations, the speeds and the progressive position (through the coordinates that has been given by a GPS system) of the vehicle. The drivers were wearing the device ASL Mobile Eye-XG equipment which consists of two digital high-resolution cameras attached to lightweight eyeglasses (Figure 1). The first camera was able to track and record the movement of the right eye, while the other was used to record the scene image. Data was recorded at a speed of 30 Hz with an accuracy of 0.5–1 °. A calibration procedure was carried out for each participant in order to get a good accuracy of the eye-movement recorder. The process took place in a parking lot with the car being stationary, and involved asking participants to look at least 10 visual points spread across the whole scene. Calibration points were chosen between vertexes and centers of small objects present at the scene. Once that the calibration was done, the participant started their driving experience on the SP 610. An initial trial distance (about 600 meters) has been added to the whole effective path, in order to allow the user get used to the Mobile Eye device. The eye tracking equipment along with a computer and the VBOX PRO equipment were kept on the back seat and were monitored by one of the experimenters, who was instructed not to talk to the driver except for giving instructions as to direction and if there was a request for assistance.

Figure 1 The ASL Mobile Eye-XG.

By processing the recorded videos, it was possible for each participant to identify which traffic signs have been seen and which ones have been ignored. This procedure has led to a preliminary analysis in terms of percentage of what has been detected. ASL software was used to create a video for each participant, in which eye-fixations were showed by a cross at the intersection between vertical and horizontal red lines. The frequency of each video is 30 frames per second (1 frame = 33.33 ms). These lines were superimposed to the video of the driver's scene allowing researchers to detect each movement and which specific point of the scene was being seen by the participant. The procedure to determine if a sign has been seen or not is the following: if the red cursor (that indicates the point of look), is superimposed to a sign (or it is very close to it) that is already entered in the visual field of the participant, the PC user considers the sign as "seen". If this does not happen, the PC users consider the sign as "not seen". In the case of "tracking loss" by the device, the sign is not considered in the analysis (Figure 2). After each trial, all participants had answered some questions such as name, gender, age, driving license category and its date of issue, kilometers driven per year, number of accidents caused by the participant since the driving license issue date, self-evaluation of the own driving skills (very good, good, average, poor, very poor) and knowledge of the road. Driving ability was evaluated as very-good by one participant (6.7%), good by ten participants (66.7%) and on average by four participants (26.6%). None of them have evaluated their driving ability as poor or very-poor.

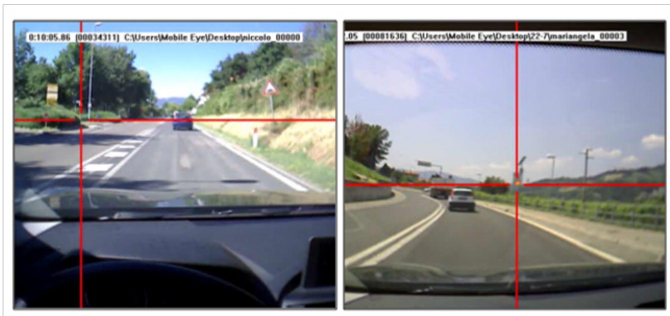

Figure 2 The sign on the left was considered as 'non-seen', the sign on the right was considered as 'seen'.

Results

On the driving route, there were a total of 277 traffic signs (warning, mandatory, prohibition and information signs). All the vertical signs that drivers encountered are listed in Tables 1-4, together with their symbols. The third fourth column lists the absolute frequency for each sign along the whole route. According to Costa et al.,[12] this study clearly shows how poorly vertical road signs are looked at by drivers. The mean probability of looking at signs was only 24% for all signs (Figure 3). On average, only one in four signs was seen by drivers. This data is even more significant considering that participants wore eye tracking glasses, drove an unfamiliar car and knew that their driving behavior was being studied. One can assume that their driving style was more careful and thorough than under real-life conditions, when the quantity of their looking behavior to signs can be expected to be reduce further. Assuming that the primary role of vertical traffic signs is to trigger drivers into being aware of some particular situation, the signs failed on average in 76% of the cases, which is very high.

According to Costa et al.,[12] one possible explanation of this low occurrence is that vertical signs are not particularly easy to be seen because they are set at an angle from the direct eye-fixation area of

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the driver (ahead). The angular distance increases with poor visibility, since the sign is seen at a shorter distance. This results is confirmed by the results about the middle-island signs, which percentage of looking was 96%. They are a directional signs, fixed at an island located at the middle of the road in order to separate between the opposite driving lanes. They are placed on the plane directly in front of the driver and they are more effective in influencing driver behavior, considering that driver's fix their eyes mostly on the center of the road (Figure 4). These results confirm Yuan et al.[15] that found, for all drivers, the percentage of eye-fixations on the center of the road exceeded 60%, mainly on areas to the left and close to the front of the vehicle.

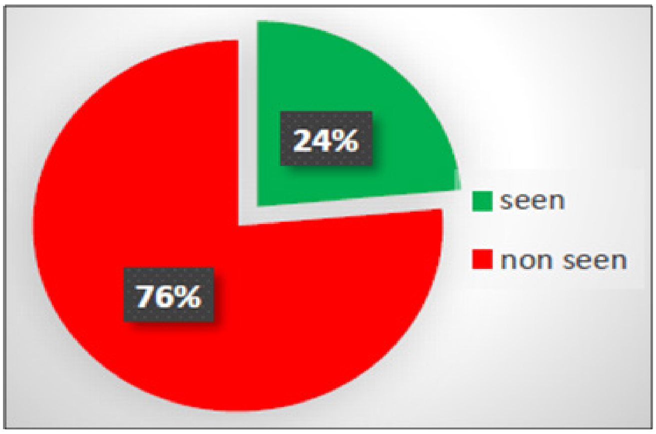

Figure 3 Fixation frequency expressed in percentage for all signs.

Fixations to vertical road signs increased passing from suburban areas (30%) to urban ones (33%) (Figure 5). This is probably explained by a change in the driver's visual search strategy mediated by speed. At low speed (urban area) the driver tends to visually monitor the near environment, whereas when increasing speed the driver tend to explore more farther away, detecting less critical elements of the visual scene. Passing from traffic conditions and free flow conditions, moreover, the fixations to vertical road signs slightly decreases because, even if the driver in the first case drives at lower speed and he looks with more attention the road, he stares at the vehicle in front of his car (Figure 6). The mean probability of looking at signs for men was 22% for all signs, while for women was about 24% (Figure 7). Women gave more attention to vertical signs and in general they adopted safer driving behavior. The results of the current study have very important implications in assessing the role of vertical traffic signs in influencing driving. Vertical traffic signs play a critical role and, in many cases, are considered the only way of influencing drivers' behavior. Since they are looked at only in a low number of cases (24%), it seems important to promote improvements to make vertical traffic signs more conspicuous.

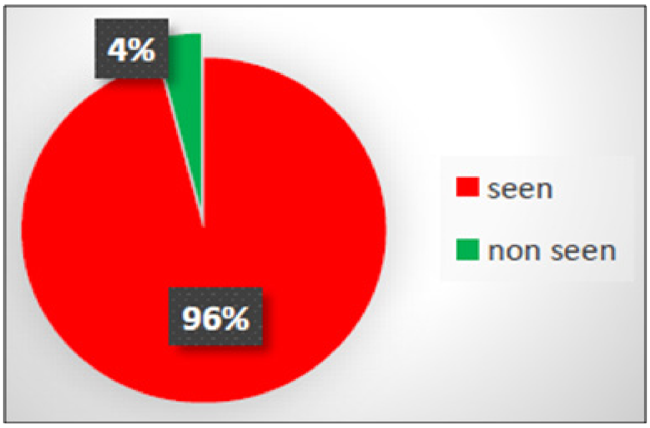

Figure 4 Fixation frequency expressed in percentage for middle-island signs (on the right).

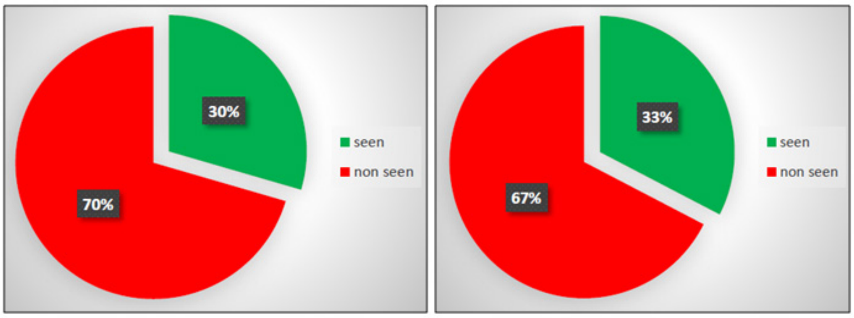

Figure 5 Fixation frequency expressed in percentage for suburban areas (on the left) and for urban areas (on the right).

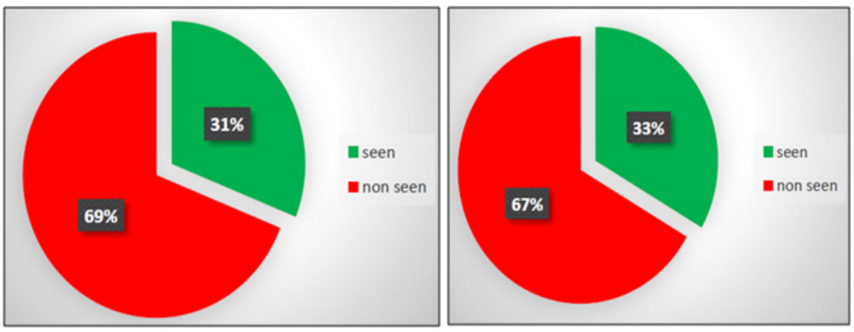

Figure 6 Fixation frequency expressed in percentage for traffic conditions (on the left) and for free flow conditions (on the right).

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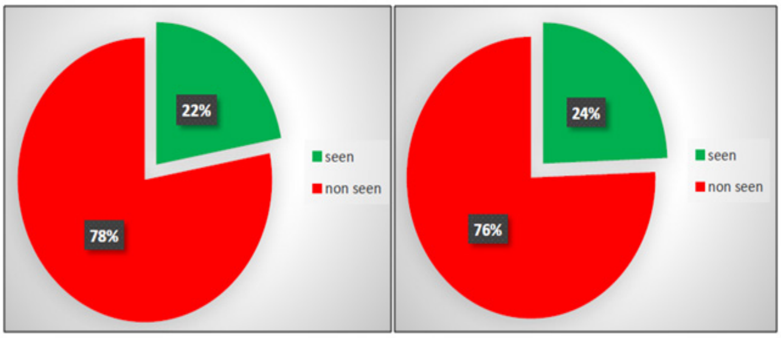

Figure 7 Fixation frequency expressed in percentage for men (on the left) and for women (on the right).

Table 1 Warning road signs encountered in the route used in the study

Icon	Meaning	Category	Frequency
	Wild animals	Warning	15
	Slippery road	Warning	13
	Bend to the right	Warning	17
	Bend to the left	Warning	17
	Double bend, the first to the right	Warning	2
	T-intersection to the left	Warning	11
	T-intersection to the right	Warning	6
	Cross roads with minor road	Warning	21
	Road hump	Warning	11
	Pedestrian crossing	Warning	6
	Children	Warning	1
	Other danger	Warning	3

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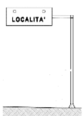
Table 2 Mandatory road signs encountered in the route used in the study

Icon	Meaning	Category	Frequency
	Keep left	Mandatory	7
	Obligatory to the right	Mandatory	1
	Middle-island sign	Mandatory	44
	Chevron	Mandatory	20

Table 3 Prohibition road signs encountered in the route used in the study

Icon	Meaning	Category	Frequency
	Speed limit	Prohibition	35
	End of speed limit	Prohibition	4
	No stopping	Prohibition	3
	No parking	Prohibition	5
	No overtaking	Prohibition	2

Table 4 Information road signs encountered in the route used in the study

Icon	Meaning	Category	Frequency
	Pedestrian crossing	Information	11
	Portal sign	Information	22

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Conflict of interest

The authors declare no conflict of interest.

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