

## The Impact of Road Familiarity on the Perception of Traffic Signs – Eye Tracking Case Study

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**Abstract.** Traffic sign visual information provides road users with the basic instructions regarding route selection, safety at intersections, warnings on physical obstacles on the road and safe route marking. The use of sophisticated eye tracking systems is an efficient way to analyse the influence of traffic signs on drivers' behaviour. In this paper, the drivers' perception of traffic signs has been analysed using such a system. The aim of this paper is to determine how the perception of traffic signs changes according to the frequency of driving on a specific route or according to the route familiarity. The results show that the drivers' perception of traffic signs declines as they get familiar with the route and road conditions. In addition, older drivers having more driving experience perceive fewer signs and elements from the environment because they are often led by their own experience and knowledge, so they do not need the same amount of information as compared to younger drivers.

**Keywords:** traffic signs, perception, eye tracking, traffic safety.

**Conference topic:** Roads and railways.

### Introduction

To enable smooth and safe traffic flow, special attention should be paid to the transfer of information between traffic signalization and road users. Traffic sign visual information provides road users with the basic instructions regarding route selection, safety at intersections, warnings on physical obstacles on the road and safe route marking. Generally, the visibility of a target depends on its size, contrast and background luminance and visual factors surrounding the target (Goodspeed, Rea 1999). A number of factors affect the visibility, and thus the perception of traffic signs, apart from the subjective characteristics of the driver and the surroundings, among which the most important are their legibility and optical characteristics or retroreflective properties (Pašagić *et al.* 2000).

Numerous scientific studies have been conducted with an aim to understand the impact of traffic signs on the drivers' perception and attention. By researching the drivers' awareness of road signs, Johansson and Rumar (1966) found that drivers remember 17% of pedestrian crossing signs and 78% of speed limit warning signs. Johansson and Backlund (1970) concluded that the drivers' awareness of road signs is between 25% and 75%, Milosevic and Gajic (1986) between 2% and 20%, Macdonald and Hoffmann (1991) 26% and 39% depending on the driver's experience, while Drory and Shinar (1982) reported recall levels of less than 10% during the day and 16.5% at night.

Additionally, different types of signs affect the driver's perception in different ways, thus signs with logos attract more attention and take slightly longer to process than guide signs. However, this does not correlate to the driver's vehicle control, since driving operations are worse in the presence of guide signs in comparison to logo signs and even worse in an environment with no signs (Kaber *et al.* 2015). On the other hand, Sun *et al.* (2011) find that fixation, acceleration and offset distance increase with the accrual of information content on traffic signs, meaning that the more information a traffic sign includes, the more complexity it presents to driving operations.

Uneven and relatively low percentages of traffic sign awareness recorded in previous studies suggest the dominance of motivational factors in determining whether or not a sign is “noticed”. However, motivation was not the only significant factor: physical properties of both the sign and its environment were also found to affect the perception of signs (Macdonald, Hoffmann 1991). Likewise, many aspects of driving become automated with practice (Ranney 1994) and while driving experienced drivers enter a state in which they have no active attention for the driving task and perform on “autopilot” (Charlton, Starkey 2011). The lack of driver's active attention and automation of the driving process entail a risk and it is precisely the failures in this automatic mode of driving that appear to be the cause and the most common crash scenarios (Iden, Shappell 2006; Stanton, Salmon 2009).

From the foregoing, it can be concluded that due to the limitation of the human perception process to the certain amount of information, it is important that drivers only detect traffic signs and that their perception is not disturbed by various commercial elements located in the direct traffic environment (Jamson *et al.* 2005).

The purpose of the research conducted in this paper is to analyse how the familiarity of certain routes influences the perception of traffic signs, using the eye tracking system. The aim is to determine how the perception of traffic signs changes according to the frequency of driving on a particular route, or according to the familiarity with the route, as well as to determine how drivers perceive traffic signs.

## Research methodology

A sophisticated eye tracking system Tobii Pro was used for the purposes of this research. In general, the eye tracking method is used to measure the motion of the eye with respect to the head. It provides real, objective and deep insight into human visual behaviour in real environment, by capturing the eye movement and view. Its purpose is to fixate objects in the field of vision, in the area of sharp vision or foveal region (Topolšek *et al.* 2016).

The mentioned eye tracking system is very simple and non-invasive, enabling precise and accurate data collection in all weather and traffic conditions, and for all driver categories, regardless of age, sex and driving experience. The system consists of Tobii Pro Glasses (Fig. 1), a device for video recording and a computer equipped with management and data processing software, and is based on cameras located in the middle of the bridge and in the lower part of the frame which record eye movement.



Fig. 1 Tobii Pro Glasses (source: <http://www.tobii.com/product-listing/tobii-pro-glasses-2/#Components>)

The research was conducted on a section of DC30 state road in the City of Velika Gorica, Zagreb County, Republic of Croatia. The length of the state road section is 9 kilometres. Most of the section passes through an uninhabited area, while a smaller part of the road is located in populated area. Fig. 2 below shows the examined area.

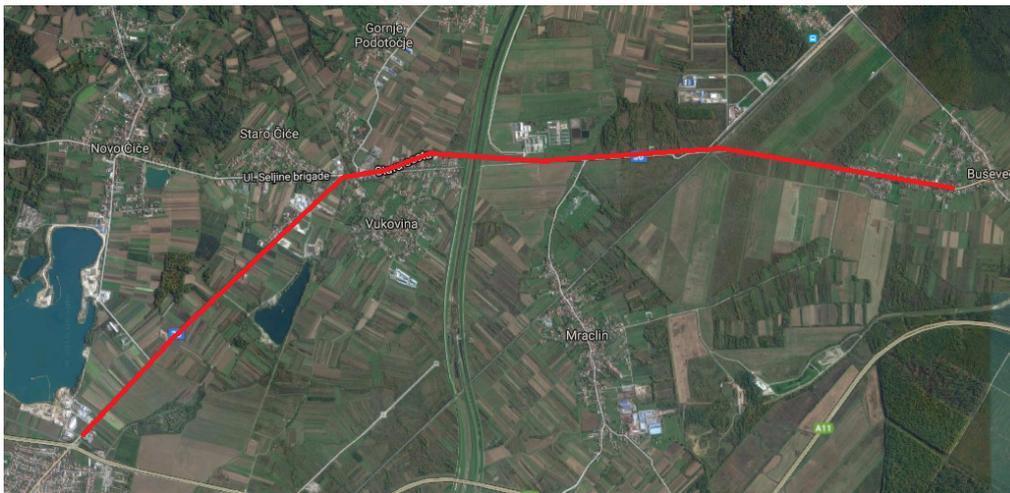


Fig. 2. The examined state road section

The tested road section comprises a total of 143 traffic signs, 71 sign in one direction and 72 in the opposite direction. Of a total of 143 traffic signs, 34 (23.78%) are warning signs, 40 (27.97%) are mandatory signs, 55 (38.46%) are information signs, 9 (6.29%) are directional signs and 5 (3.50%) are additional plates (additional signs), as shown in Fig. 3.

The study included ten participants (five male and five female) of different age and driving experience. The majority of participants were between 25 and 30 years old with 5–10 years driving experience. Before the test, the participants were introduced to the Tobii Pro system and the driving route, but the purpose of the research was not revealed to avoid affecting the results. Furthermore, the system was calibrated for each participant before each ride to ensure the accuracy of results. Each participant was driving on the same road section, in the same vehicle (Mercedes Citan), five times during the day in normal weather conditions at intervals of several days. Participants were asked to drive an average speed limit on the specified section, which was set at 60 km/h prior to conducting the study.

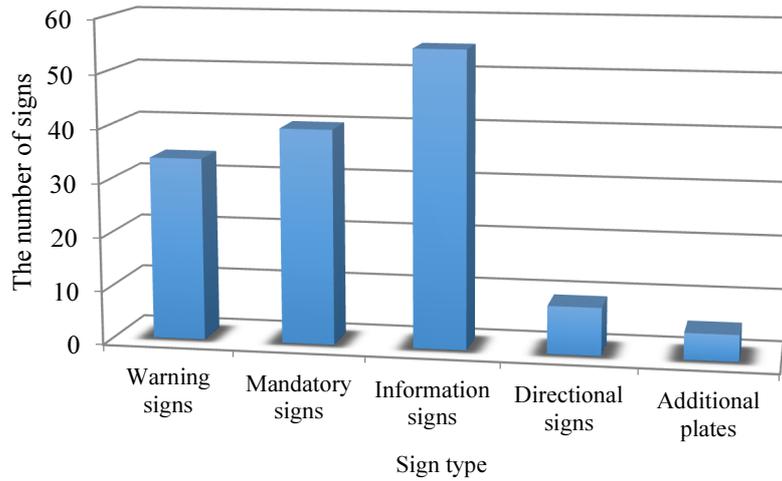


Fig. 3. Signs on the tested section according to their meaning

The data were processed by using the software Tobii Pro Analyzer, as shown in Fig. 4. This software provided the video review of all participants' rides and enabled to determine the number of perceived signs for each participant. The circle represents the direction of the driver's view, showing the exact direction in which the participant was looking at a particular time of driving, which allowed to accurately determine which signs were perceived by the participants, and which were not.

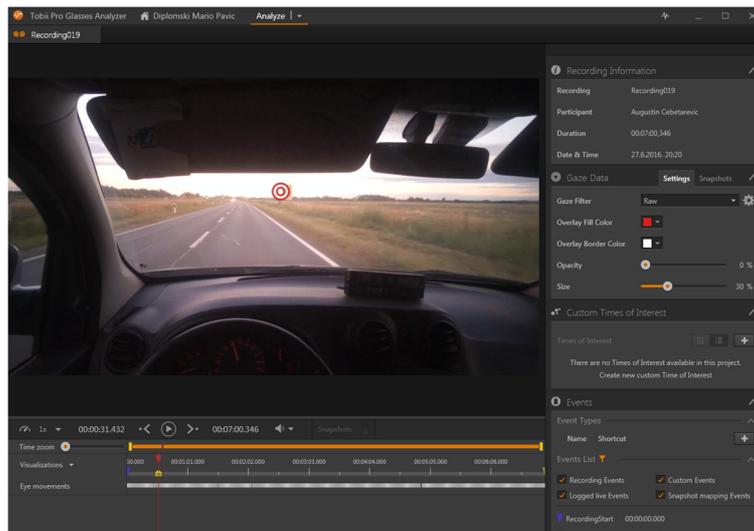


Fig. 4 Data analysis in Tobii Pro Analyzer

## Results

As stated in the previous section, there was a total of 143 signs on the examined road section, 71 in one direction and 72 in the opposite direction. The above mentioned shows that the maximum number of signs that a participant could notice within five rides was 715 signs. Table 1 below shows the results of sign perception for each participant per each drive.

The results show that all drivers perceived the greatest number of signs during the first drive, an average of 91.2 signs (63.78% of the total number of signs) and that this number is then reduced during the following rides. In the final drive, the average number of perceived signs was 57.1 or 39.93% of the total number of signs which, compared to the first drive, shows a decline of 59.72%. This is due to the fact that the road section was unknown to participants during the first drive, and they concentrated on the environment in order to get as much information as possible to continue safe driving. As they conducted more drives, and thus got to know the environment and the situation on the road, they gained more confidence and perceived less traffic signs. These results confirm the hypothesis suggested by Martens

and Fox (2007) that drivers are less attentive to road signs and more susceptible to incidental stimuli, meaning that there is a possibility of overlooking significant changes in road signage if they are familiar with the driving route.

Fig. 5 shows the total number of signs perceived per each direction and each ride.

Table 1. The total number of signs perceived by participants per ride

| Participant | Number of perceived signs |         |         |         |         | Total | Age   | Experience |
|-------------|---------------------------|---------|---------|---------|---------|-------|-------|------------|
|             | Drive 1                   | Drive 2 | Drive 3 | Drive 4 | Drive 5 |       |       |            |
| 1           | 106                       | 89      | 71      | 53      | 40      | 359   | 25–30 | 5–10       |
| 2           | 99                        | 101     | 86      | 83      | 62      | 431   | 25–30 | 5–10       |
| 3           | 70                        | 60      | 56      | 43      | 38      | 267   | >60   | >20        |
| 4           | 93                        | 85      | 82      | 77      | 69      | 406   | 18–25 | 1–5        |
| 5           | 84                        | 76      | 75      | 67      | 59      | 361   | 18–25 | 1–5        |
| 6           | 98                        | 89      | 89      | 77      | 73      | 426   | 25–30 | 5–10       |
| 7           | 81                        | 74      | 65      | 62      | 53      | 335   | >60   | >20        |
| 8           | 95                        | 87      | 75      | 64      | 56      | 377   | 25–30 | 5–10       |
| 9           | 92                        | 87      | 80      | 70      | 60      | 389   | 30–40 | 10–20      |
| 10          | 94                        | 86      | 80      | 71      | 61      | 392   | 30–40 | 10–20      |
| Total       | 912                       | 834     | 759     | 667     | 571     |       |       |            |

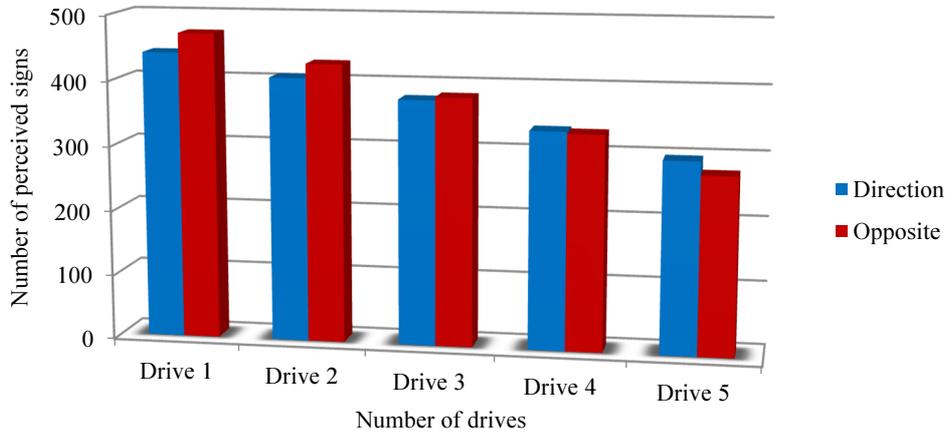


Fig. 5. The total number of signs perceived per each direction and each ride

By examining the correlation between the drivers’ age and their driving experience with a number of perceived traffic signs, it can be concluded that both variables have a significant negative impact on sign perception. As shown in Table 2, driving experience has a significant impact on the perception of signs (Spearman’s correlation coefficient was  $-0.594$ ), while the drivers’ age is a less influential factor, but still significant (Spearman  $-0.467$ ). The obtained results are in line with the current knowledge (Macdonald, Hoffmann 1991; Summala, Naatanen 1974). Given that experienced drivers have a smaller, more centrally-focused pattern of fixations, directed further down the road ahead of the vehicle, compared to inexperienced drivers (Mourant, Rockwell 1972), they rely more on experience and instinct while driving, perceiving fewer elements from the environment, including signs, to relieve their perceptual system and make the ride more comfortable and less “stressful”. On the other hand, younger drivers with less driving experience scan the environment more actively while driving, trying to get as much information as possible in order to perceive the traffic situation more accurately and to ensure safe driving.

Table 2. Analysis of correlation between traffic sign perception, age and driving experience

|                |                 | Age                     | Experience |          |
|----------------|-----------------|-------------------------|------------|----------|
| Spearman’s rho | Number of signs | Correlation Coefficient | $-0.467$   | $-0.594$ |
|                |                 | Sig. (2-tailed)         | 0.173      | 0.070    |
|                |                 | Number of samples       | 10         | 10       |

During the five rides, each participant could have perceived a total of 715 signs. Given that the research included ten people, the total possible number of perceived signs by all participants is 7150. Of the total number of possibly perceived signs, participants perceived a total of 3743 signs, which represents 52.35% of all the signs. On the other hand, the participants did not perceive almost half of the signs (3407 or 47.65%) located in the test section. Compared to previous studies, the percentage of perceived signs is somewhat higher in this study, which may be explained by more sophisticated data collection methodology, where the eye tracking system has been used. Specifically, due to lack of adequate data collection technologies, in most of the previous research the sign perception was measured based on the driver remembering the signs after driving, which is why this percentage is lower. However, certain authors (Johansson, Backlund 1970) concluded that the maximum percentage of perceived signs is around 50%, as confirmed by this study.

When it comes to the unperceived traffic signs, most were information signs, 1489 i.e. 43.70% from all unperceived signs, followed by warning signs (849 or 24.92%), mandatory signs (771 or 22.63%), directional signs (128 or 3.76%) and additional signs (170 or 4.99%), as shown in Fig. 6.

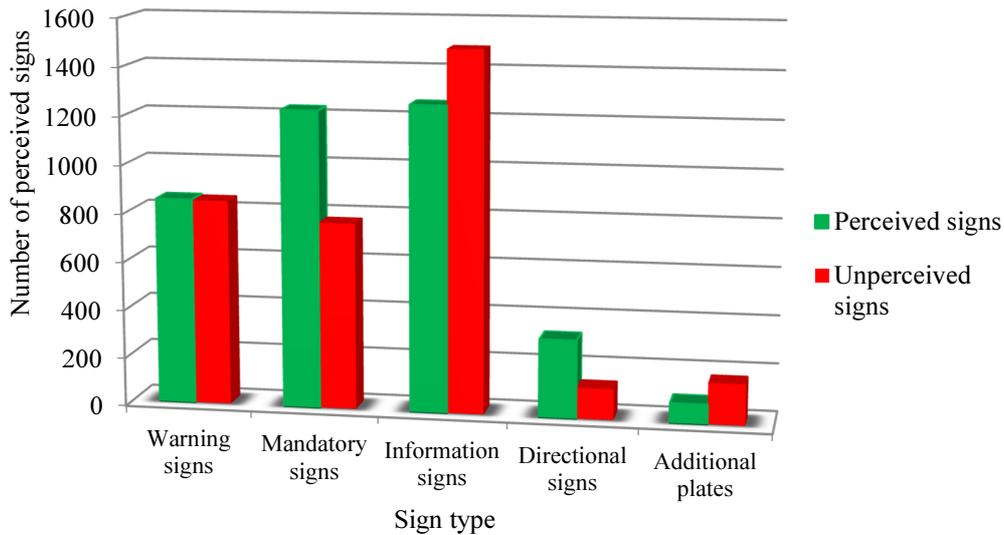


Fig. 6. The ratio of perceived and unperceived traffic signs with respect to the traffic sign type

According to these results, the information signs were least perceived by the participants. However, it should be noted that most of the signs on the observed road section were information signs. Therefore, each sign type was separately analysed in order to obtain reliable results. After having observed the results in this way, there are 849 unperceived warning signs or 49.94%, 771 mandatory signs (38.55%), 1489 information signs (54.15%), 128 directional signs (28.44%) and 170 additional signs (68.00%), as shown in Table 3.

Table 3. Perceived and unperceived signs according to sign type

| Sign type         | Total number of signs | Number of perceived signs | Number of unperceived signs | Percentage of unperceived signs in total number of signs |
|-------------------|-----------------------|---------------------------|-----------------------------|--|
| Warning signs     | 1700                  | 851                       | 849                         | 49.94%   |
| Mandatory signs   | 2000                  | 1229                      | 771                         | 38.55%   |
| Information signs | 2750                  | 1261                      | 1489                        | 54.14%   |
| Directional signs | 450                   | 322                       | 128                         | 28.44%   |
| Additional signs  | 250                   | 80                        | 170                         | 68.00%   |
| Total             | 7150                  | 3743                      | 3407                        |  |

The results in Table 3 clearly show that additional panels and information signs were least perceived by the participants, while the most perceived were mandatory signs. This is due to the fact that certain notifications and additional information on the signs were not crucial for the participants in order to continue safe driving, which is why they showed no interest in them. On the other hand, mandatory signs carry, for the driver's safety, important messages which is why they were perceived the most.

The least perceived were information signs indicating the section of state road and signs indicating a bus stop. The information sign indicating road section is relatively small in size (generally 23×17 cm) and is placed relatively low (approx. 70 cm above the ground) with respect to other traffic signs. Furthermore, the road section sign and bus stop sign have little relevance to the current state of the road and they did not represent essential information for the driver for the further course of driving at the given moment, which explains the minimum number of eye fixation on them.

Participants most often perceived information signs indicating names of towns and pedestrian crossings. Signs indicating names of towns are large in size (120×50 cm), which is why they were frequently perceived, although not very important for drivers at a given moment. On the other hand, pedestrian crossing information signs provide extremely important information for the safety of all road users, which is why the participants paid attention to them.

## Discussion

Previous scientific research focused at studying the impact of traffic signs on the drivers' perception and attention measured the sign perception based on the driver remembering the signs after driving due to the lack of adequate data collection technologies, which is why the results were uneven and varied considerably.

The aim of this research is to examine how the drivers' perception of traffic signs changes according to the frequency of driving on a particular route or according to route familiarity.

The main research findings show that there is a significant difference in the perception of traffic signs when the driver is familiar with the driving route. The results show that all participants perceived the highest number of signs (63.78% of the total number of signs) in the first ride on the test route and that this number then declined during the following rides. In the final ride, the participants perceived 39.93% of the total number of signs which, compared to the first ride, represents a decrease of 59.72%. These results confirm the hypothesis suggested by Martens and Fox (2007), stating that drivers are less attentive to road signs and more susceptible to incidental stimuli, meaning that there is a possibility of overlooking significant changes in road signage if they are familiar with the driving route. In other words, during the first ride, the participants found the route unfamiliar, which caused greater attention to the road elements, i.e. they actively scanned the environment looking for as much information as necessary to continue safe driving. As they drove more rides, and thus got to know the environment and the situation on the road, they gained more confidence and the number of perceived signs decreased.

Furthermore, it was determined that the drivers' age and their driving experience have a significant negative impact on the sign perception. Driving experience, for which Spearman's correlation coefficient was  $-0.594$ , has a significant impact on sign perception, while the drivers' age presents a less influential, but still important, factor (Spearman  $-0.467$ ), which is consistent with previous findings (Macdonald, Hoffmann 1991; Summala, Naatanen 1974). Given that experienced drivers have a smaller, more centrally-focused pattern of fixations, directed further down the road ahead of the vehicle, compared to inexperienced drivers (Mourant, Rockwell 1972), while driving, they rely more on experience and instinct, perceiving fewer elements from the environment, including the signs, in order to relieve their perceptual system and make the ride more comfortable and less "stressful". On the other hand, younger drivers with less driving experience more actively scan the environment while driving, trying to get as much information as possible in order to perceive the traffic situation in which they are located as accurately as possible, and to ensure continued safe driving.

Compared to previous studies, the percentage of perceived signs is somewhat higher in this study (52.35% of the total number of signs), which can be explained by more sophisticated data collection methodology using the eye tracking system. Most of the previous research, due to the lack of adequate data collection technologies, measured the sign perception based on the driver remembering signs after driving, which is why the percentage was lower.

By examining specific types of signs, it is evident that participants least perceived additional panels and information signs. This is because the participants were not interested in these signs while driving, since the information on the signs was not crucial to continue safe driving. The most perceived were mandatory signs which carry, for the driver's safety, important messages.

This study was conducted on a relatively small sample and with limited sample and driving conditions diversity. Additional research with a higher number of participants and higher diversity of traffic signs should be conducted before reliable conclusions are to be accepted and implemented in the wide context of traffic safety. Furthermore, future research should be aimed at studying the impact of different levels of traffic sign retroreflection and various retroreflective materials used for making traffic signs on the drivers' perception, since retroreflection is crucial for sign perception at night and in low visibility conditions.

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