Road Signs Perception: Eye Tracking Case Study in Real Road Traffic

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Abstract: This study investigates driver visual perception of road traffic signs under real road conditions. Using mobile eye tracking technology, we analyzed glance behavior toward various traffic signs and advertisements along urban and highway routes during daytime and nighttime conditions. Results showed significant differences in glance duration and frequency based on sign type, environmental conditions, and the presence of advertisements. Drivers primarily focused on speed limit and directional signs, while advertisements attracted longer glance durations despite their lower frequency of detection. Nighttime conditions generally led to increased glance durations and higher frequencies for most traffic sign types. These findings highlight the importance of optimizing road signage design and placement to improve driver attention and road safety, especially in environments with high visual clutter. Limitations include the exclusion of peripheral vision effects and potential biases introduced by experimental settings.

1 INTRODUCTION

Road sign perception is a prerequisite to receiving information on that sign and anticipating it in the driver's behavior, so knowledge and perception of traffic signs is necessary for safe driving and subsequently traffic safety. Traffic signs play important role in driver – road infrastructure interaction as they provide important information about traffic rules, warn before danger or relevant changes in road environment.

There has been a number of realized research focused on the road sign perception mainly visual detection in real road traffic sometimes also in combination with verbal reports while driving or after driving (e.g. Topolšek et al., 2016; Costa, 2014; Inman et al. , 2012) and simulator studies which used ability to recall a sign after passing it to analyze perception (e.g. Kuniyoshi, et al., 2021). The Kapitaniak et al. (2020) based on literature review concluded that eye tracking currently belongs among the most frequent methods for the study of cognitive strategies, mainly visual strategies and enable a quantitative assessment of objective parameters under different experimental conditions.

The driver behavior including perception in road traffic is influenced by various factors such as age (e.g. Donmez and Liu, 2015; Topolšek and Dragan, 2016), gender (e.g. Cui et al., 2023), location or type of roadside elements (e.g. Crundall et al., 2006; Bucsuházy et al., 2018), weather condition or daytime period (Mohamed et al., 2013). However, the conclusions of studies focusing on behavior in different situations or the visual perception of different elements in road traffic often differ with regard to the definition of influencing factors.

Topolšek et al. (2016) also point out that drivers could have difficulties differentiating relevant and irrelevant information for safe driving such as traffic signs and advertisements. Hudák and Madleňák (2016) also shows that the driver missed 60% of traffic signs. The advertisements do not provide any relevant information for the safe driving so negatively affect driver attention, increase mental workload and reduce ability to safe driving (Edquist et al., 2011; Salaheddine et al., 2010; Bucsuházy et al., 2018; Smiley, 2005). Some of the previous studies (e.g. Seppelt et al., 2017; Hudák and Madleňák, 2017; Dingus et al., 1989) also emphasize that off road glances longer than 2 second can lead to critical situations.

In previous studies, the authors focused on the glancing towards billboards (e.g. Bucsuházy et al., 2019). Elements near the road attract the driver's attention and their correct and timely understanding

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and interpretation are important for road safety. A complex and not entirely clear combination of multiple traffic signs can be confusing and potentially lead to traffic accidents.

The recommendations for countermeasures to increase road safety, as described by Nordqvist et al. (2023), also include removing superfluous signs and consolidating the existing signs to reduce visual clutter and improve driver attention.

Our study investigates how different types of signs and environmental conditions affect visual attention. The study aimed to analyse driver visual perception of vertical traffic signs under real traffic conditions focusing on:

- Analysis of glances towards different types of road signage.
- Comparison of visual attention focused on traffic signs and advertisements (mainly billboards).
- Analysis of visual attention during daytime and nighttime conditions.

Based on the literature review was assumed that:

- The glances toward vertical traffic signs are influenced by the type of traffic sign.
- The visual perception of advertisements and road signs differ significantly.
- Drivers perceive differently in nighttime and day-time conditions.

2 METHODS

2.1 Experiment

The study was conducted in real road traffic. The analysis included one test route in city of Brno and one test route around city of Vyškov (including highway section and city of Vyškov). The first test route (in the Brno city) was 16 km length, and second test route (highway and Vyškov city) was 75 km length. Both test routes include variety of driving situations. Measurements were carried out under similar weather conditions (without rain or fog) during daytime and nighttime condition.

The study included men drivers (n=16) aged from 20 to 50 years, who are active drivers. Drivers were selected among volunteers that responded to the participation invitation. All participants were free of medical or cognitive disabilities (including visual or auditory disabilities, due to eye tracking limitations, drivers suffering eye disease were excluded from the dataset). Every participant drove for two driving tests – first during day and second during night in the same city. The drivers were not familiar with the aim of the study and test track itself. The participants were distributed on two test tracks – in the city of Brno, and in the city of Vyškov and its surroundings. Two drives need to be excluded due to the eye tracking technical issues and data losts. Drivers were instructed to drive on predeterminated route using navigation system with audio-visual feedback. Both experiments were realized with instrumented vehicle of IFE BUT – BMW 5 equipped with modern safety systems.

All participants completed provided written informed consent. Before the experiment, the safety procedure and basic instructions including the information about the equipment and also the vehicle itself was introduced to all participants. All participants were accompanied by 3 researchers – one researcher at vehicle front seat ensured the safety and researchers at back seat control the experiment (make notes and ensure system function).

2.2 Eye Tracking

The analysis of visual behavior was realized using mobile eye-tracking. The video-based mobile eye tracker Dikablis Glasses 3 was used. Dikablis Glasses 3 (Ergoneers) eye tracker is binocular with eye cameras tracking frequency 60 Hz and resolution 648 x 488 pixels. The scene camera resolution is 1920 x 1080 with tracking frequency 30 fps (manual Dikablis Glasses). The Dikablis Glasses are connected directly to the recording computer during drive, the data were observed by accompanying researcher in the vehicle during driving.

The glance behavior analysis was conducted using D-Lab software. Each video was analysed frame by frame to assess if the participant visually detected the sign (respectively advertisement) and also to analyse the length of the glance if the element was visually perceived.

2.3 Road Sign Classification

The Vienna Convention on Road Signs and Signals (United Nations Economic & Social Council, 1968) presented main categories of road signs: danger warning signs, regulatory signs including priority signs; prohibitory or restrictive signs; mandatory signs; special regulation signs and informative signs including information, facilities or service signs; direction, position or indication signs and additional pannels. In Czechia, the regulation 294/2015 described among others vertical traffic signs and its classification in Czechia: warning sign (mainly

triangular), yield signs, prohibitory signs (mainly circular), mandatory signs and informative signs.

Based on these categories were classified existing road signs on test tracks with respect to its frequency on analysed track, so following categories were analysed:

- Warning sign (mainly triangular)
- Yield signs divided to main road sign and stop/give way signs
- Prohibitory signs (mainly circular) divided to speed limit signs and other prohibitory signs
- Mandatory signs mainly direction signs
- Informative signs divided to direction signs, zebra crossing sign and other information signs

The road signage perception was compared with the perception of advertisements on test track (including all types of advertisements such as billboards, bigboards, megaboards).

2.4 Visual Perception of Vertical Road Signs

Three main objectives were studied in the experiment – visual perception of road signs, comparison of visual perception towards vertical traffic signs and advertisements and comparison of visual perception during daytime and nighttime conditions. The analysis was focused on glances towards signage which included glance shift off the road toward the vertical traffic sign and its visual fixation.

The descriptives confirmed the hypothesis that the length of glances towards vertical traffic signs are influenced by the type of traffic sign. The differences are also confirmed by statistical analysis (Kruskal-Walis non-parametric test).

With respect to frequency, drivers predominantly glanced towards speed limit signs (21%), informative signs such as direction signs (22%), and main road yield signs (19%). The percentage of fixations on various types of traffic signs ranges between 9% and 22%. However, the results should be interpreted concerning the eye-tracking method limitation. The method does not allow a comprehensive analysis of peripheral vision and object detection using peripheral vision.

Histogram (Figure 1) also illustrates the higher frequency of glances within the length in the interval 0.4-0.6 s related to mandatory signs and advertisements. The longest glances are related mainly to the perception of informative signs namely direction signs.

The statistical analysis also confirmed the second hypothesis, that the visual perception of advertisements and road signs differ significantly. The pair-wise comparison shows not statistically significant differences among the advertisement and informative signs (direction and other types), mandatory signs and yield signs. The glance length was statistically significantly different in case of comparison of advertisement with yield sign – main road, informative signs – zebra crossing, warning signs and prohibitory signs (see Figure 2). Although

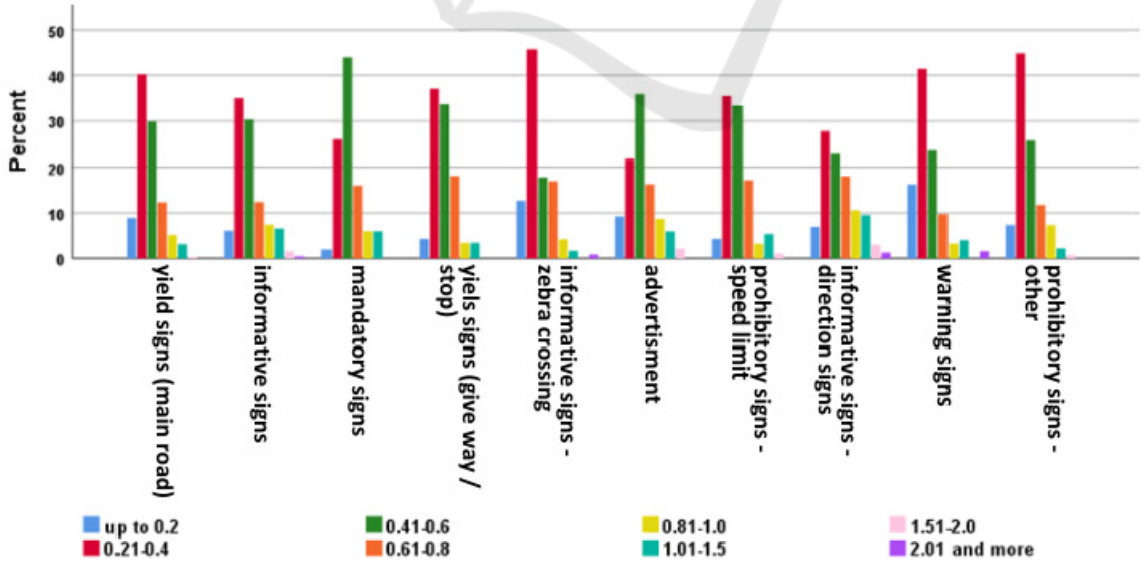

Figure 1: Visual perception of vertical traffic signs and advertisements (author).

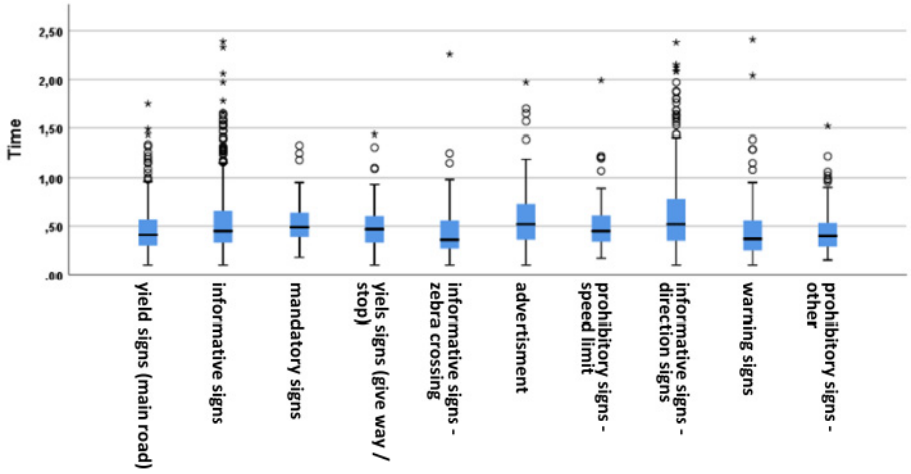

Figure 2: Visual perception of vertical traffic signs and advertisements (author).

Table 1: Visual perception of vertical traffic signs (author).

Type of signs	Mean (s)	Median (s)	Min (s)	Max (s)	N
Yield signs (main road)	0.46	0.41	0.10	1.75	348
Informative signs	0.54	0.45	0.10	2.39	685
Mandatory signs	0.54	0.49	0.18	1.33	50
Yield signs (five way / stop)	0.50	0.47	0.10	1.44	116
Informative signs - zebra crossing	0.44	0.36	0.10	2.26	118
Advertisement	0.56	0.52	0.10	1.97	184
Prohibitory signs – speed limit	0.51	0.45	0.17	1.99	93
Informative signs – direction signs	0.63	0.52	0.10	2.38	461
Warning signs	0.45	0.37	0.10	2.41	123

the advertisements rank among the longer off-road glances, in terms of the frequency, drivers perceived only about 4% of advertisements on the route. However, the data may be influenced by the fact that the drivers drove the borrowed vehicle and were more aware as they were informed about being monitored.

Visual perception of traffic signage during the daytime and nighttime conditions is also statistically significantly different (p-value 0.01) as expected. Descriptives demonstrate that mean and median glance lengths on vertical traffic signs were longer at nighttime conditions. Differences in the perception of different types of vertical traffic signage are also more noticeable at night than during the day (Figure 3). In comparison to the daytime drives, at night are apparent statistically significant differences in the case of comparison of advertisement with zebra crossing sign perception, and also informative and prohibitory signs, mandatory and warning signs, speed limit signs and warning signs, and the difference among yield sign – the main road in comparison to the warning signs and also prohibitory signs. In the daytime conditions, these described differences were not statistically significant.

3 DISCUSSION AND CONCLUSION

One of the crash causes could be the high density of information which affect the ability to detect relevant information in road traffic, even potential risk. Road signs are one of key elements to ensure road safety and anticipate safe behavior, so we aimed to analyse visual perception of road signs in real road traffic and selected factors which could influenced it perception such as type or daytime. The results could be beneficial for road infrastructure design and identification of potential risks in road traffic related to insufficient perception of a certain type of road sings by drivers.

The frequency of road signs' visual perception was surprisingly relatively low - ranging between 10 and 30% perceived road signs. Similarly, Costa (2014) and Inman (2012) state that visual fixations to vertical road signs are low. The results obtained in our study may be influenced by the usage of a navigation system that draws attention to several traffic signs. However, the navigation was chosen to ensure the

Table 2: Daytime vs. nighttime visual perception of vertical traffic signs (author).

Type of signs	Daytime					Nighttime				
	Mean (s)	Median (s)	Min (s)	Max (s)	N	Mean (s)	Median (s)	Min (s)	Max (s)	N
Yield signs (main road)	0.43	0.40	0.10	1.44	116	0.48	0.42	0.11	1.75	232
Informative signs	0.52	0.44	0.10	2.06	306	0.55	0.47	0.10	2.39	379
Mandatory signs	0.51	0.49	0.18	1.18	25	0.56	0.47	0.22	1.33	25
Yield signs (give way / stop)	0.44	0.39	0.10	0.93	49	0.55	0.49	0.15	1.44	67
Informative signs – zebra crossing	0.41	0.36	0.11	1.15	46	0.46	0.36	0.10	2.26	72
Advertisements	0.54	0.49	0.10	1.70	116	0.60	0.54	0.17	1.97	68
Prohibitory signs – speed limit	0.50	0.42	0.18	1.22	29	0.52	0.47	0.17	1.99	64
Informative signs – direction signs	0.59	0.51	0.10	2.12	188	0.65	0.52	0.10	2.38	273
Warning signs	0.48	0.34	0.10	2.41	57	0.43	0.37	0.10	2.04	66

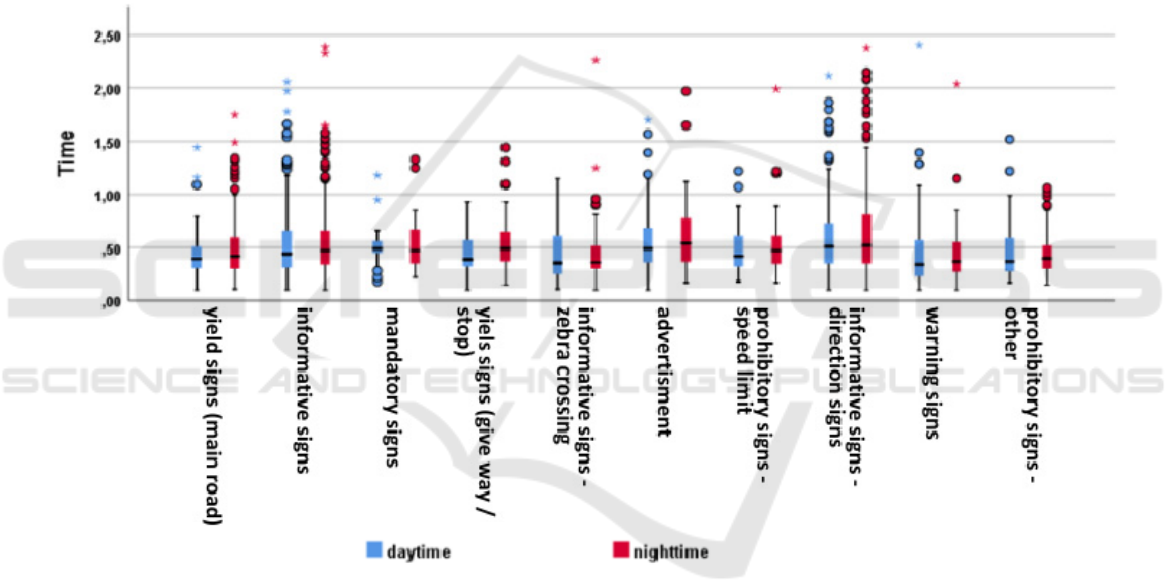

Figure 3: Visual perception of vertical traffic signs and advertisements in daytime/nighttime conditions (author).

comparability of the driving and the instructions given by the driver during the movement on the set route.

Costa (2014) also concluded that visual fixations to vertical road signs are very short (154 ms). Our study shows that the mean average glance at traffic signs was around 0.5 s. The significantly higher values cannot be caused only by the comparison of different variables - glances (which included not only fixations but also glance shifts) analyzed in our study and fixations analyzed by Costa (2014). Longer visual fixation on traffic signs (300 ms) in comparison to Costa (2014) was also described by Sprenger et al. (1999).

The mean glance duration on advertisements in the road surrounding was 0.6 s in daytime condition and 0.7 s in nighttime conditions. Previous studies reported mean glance distraction between 0.4-0.9 s (Bucsuházy et al., 2014; Smiley et al., 2005; Misokefalou et al., 2015). In general, drivers perceived less advertisements – the frequency of advertisements visual perception was lower in comparison to the perception of road signs. However, when drivers look at the advertisements, the glance length was usually longer in comparison to the perception of road signs. In contrast, Smiley (2005) concluded that average glances on advertisements were similar as those found in studies of traffic signs (0.5 s). However, Smiley (2005) similarly as number

of previous studies did not distinguish between the types of traffic signs and daytime conditions.

The driver's perception differed concerning the type of traffic sign and daytime. At nighttime conditions, traffic sign glances were longer and more frequent in the case of most types of traffic signs. While during the daytime drivers glanced at 10-20% of traffic signs, at nighttime conditions the frequency of watching traffic signs was higher (between 20-30% for majority of traffic sign types). In contrast, Madleňák (2018) reported that drivers followed 21% of road signs at night and 35% during the day. The results could be influenced not only by the road sign type but also by retroreflexivity of road sign, which was not distinguished in this study. Similarly to what Madleňák (2018) describes, our results show a lower frequency of visual attention toward advertisements during daytime conditions.

The results could be affected by the identical road track for both experiments, so also identical advertisements in both conditions (see also limitations). Also, peripheral vision plays a role in road sign perception as evidenced by Costa et al. (2018). However, the eye-tracking method does not allow a comprehensive analysis of peripheral vision and object detection using peripheral vision. The limitation of the eye-tracking method could be also seen in the fact that seeing does not necessarily lead to perception. The interpretation of the results needs to consider the limitation of the eye-tracking method.

Except for the limits resulting from the method used, the study faced several limitations:

- The drivers were aware of monitoring of their visual behavior
- Some of the factors such as locality, the change of driving behavior following the road sign perception, age, gender, etc. were not subjected to this study.
- Future studies should also include a control group, which allows for analysis if the results are not distorted by the realization on the same test track at nighttime and daytime conditions. Future studies should also reflect the representativeness of the driver population (including age, gender, different type of road users).
- The combination of visual perception analysis with verbal reports while driving or after driving could be used to increase the validity of the results, but it should be also analyzed how these combinations affect results and driving behavior itself.

High-clutter environments, such as urban areas with dense roadside advertising and excessive traffic signage, often overwhelm drivers with competing visual stimuli (see Fig 4). This visual overload can lead to delayed or missed recognition of critical traffic signs, resulting in unsafe driving behavior and an increased risk of accidents. Additionally, the overabundance of traffic signs may cause drivers to omit or overlook relevant information, further compromising road safety.

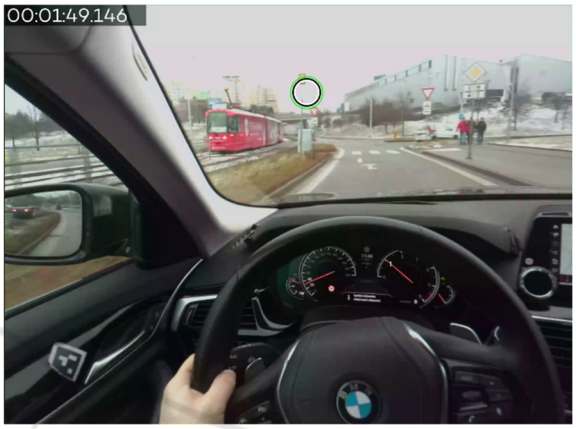

Figure 4: Eye tracking record of a driver's gaze at a dangerous intersection (location of frequent crashes) (author)

To address these issues, findings suggest that redesigning the placement of traffic signs in high-clutter environments could significantly improve driver attention. Consolidating traffic signs is essential to reduce their density and visual complexity. A thorough revision of existing traffic signs is necessary to identify and eliminate redundancy, ensuring that only essential information is conveyed. Furthermore, minimizing or removing advertisements in the vicinity of roads can help reduce distractions and improve the overall visibility of traffic signs. By optimizing the placement and content of traffic signs, along with addressing visual distractions in the road environment, it is possible to create a more navigable and less overwhelming road traffic infrastructure.

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