# Eye Tracking Study of Visual Pollution in the City of Zilina

**Radovan Madleňák, Lucia Madleňáková, Margita Majerčáková, Roman Chinoracký**

University of Zilina, Univerzitna 8215/1, 01026 Zilina, Slovakia; e-mail: radovan.madlenak@uniza.sk; lucia.madlenakova@uniza.sk; margita.majercakova@uniza.sk; roman.chinoracky@uniza.sk

*Abstract: This paper examines the issue of visual pollution in the city of Žilina, focusing specifically on outdoor advertising. A quantitative study was conducted to investigate the density of outdoor advertising on major roads in the town, as well as the topics of the advertisements. The research data collected provides pertinent information for policymakers and marketing firms to consider when forming policies concerning transportation, the environment, and outdoor advertising. This study is essential to comprehend the effects of visual pollution on the cognitive mobility of drivers navigating city roads. The findings of this study suggest that outdoor advertising has a pretty limited impact on how drivers perceive their environment and interact with it. Consequently, the results of this research can be used to create more effective policies related to outdoor advertising and traffic safety.*

*Keywords: visual pollution; eye tracking study; outdoor advertising; road safety*

## 1 Introduction

The turn of the third millennium has seen mobility become a fundamental pillar of our society. The rapid advancements in technology have enabled us to enhance our cognitive capacity in a variety of fields; mobility is one of the most significantly impacted. Mobility has become a multifaceted concept in our understanding; its relevance in transportation has also manifested in the digital realm and other areas. Consequently, the potential of mobility has become increasingly visible in its ability to bring about positive changes in our society, as highlighted by [1].

The concept of mobility is inherently related to the notion of taking initiative. Decisions are integral to mobility, as they determine whether an activity is mobile or not and can be taken multiple times throughout. The type of device or vehicle used, and the quality of such, heavily influences the decision making process, resource requirements, and ultimate outcome of the mobility. Furthermore, in addition to the infrastructure needed, mobility also necessitates a variety of resources such as money, time, and energy. The human-machine interface plays a vital role and offers a broad spectrum of options, including smartphones, smart maps, web-tracking interfaces, and simulation software, as noted by [2].

Decision making is extremely important not only for increasingly automated vehicles, but also for driver support. Intensive research is under way in this area to investigate the implications of cognitive memory for decision making in traffic. One excellent example is continuous, dynamic route re-design through the inclusion of cognitive variables, which has been found to significantly reduce error rates. This suggests that vehicles are capable of learning from cognitive variables, opening the possibility of unsupervised learning to make sensible traffic decisions. According to [2], it is worth mentioning that the cognitive process involved in vehicle-related decision making bears resemblance to that of the human mind, where event classification is linked to patterns that have been previously processed.

The decision making of drivers in real-world conditions is often impacted by a range of external stimuli. These can include the physical environment and the objects which populate it. According to research [3], analyzing and detecting patterns of driver behavior under real-world conditions can provide valuable data for autonomous vehicle decision making, by understanding the interplay between humans, machines, and the environment.

A specific example of objects found in the vicinity of the vehicle are outdoor advertising objects. This illustrates the importance of external stimuli when determining driver behavior and could have important implications for autonomous vehicle decision making. Outdoor advertising, alternatively termed out-of-home (OOH) advertising is a form of media, which is intended to reach consumers who are away from their dwellings. This includes billboards, signs, placards, and other forms of advertising which are situated in public spaces such as thoroughfares, sidewalks, and public transit systems. From an outlook of road safety, outdoor advertising contributes to visual pollution and can have a negative impact on the safety of drivers and pedestrians. Recent research of Abdullah and Sipos [4], Pečeliūnas *et al.* [5] and Čubranić-Dobrodolac *et al.* have focused on analyzing drivers' behavior and predicting the likelihood of traffic accidents using statistical models. Their research shows that the abundance of outdoor advertising has the potential to cause distraction and cognitive impairment, which can increase the risk of accidents. Therefore, it is important to consider the effect of outdoor advertising on road safety when designing and implementing an advertising campaign.

The term "visual pollution" was initially used by William H. Whyte in his 1980 publication The Social Life of Small Urban Spaces [7] to describe the adverse impacts of the visual environment on human perception. Outdoor advertising is a major contributor to this phenomenon, as it can be seen from a distance and often covers large public areas, making it difficult to ignore. The use of bright colors, shapes, and fonts in outdoor advertising can be overwhelming and distracting, thus disrupting the natural aesthetic of a landscape or urban skyline. The presence of outdoor advertising in elevated areas can lead to an increase in light pollution.

The presence of aesthetically displeasing objects and structures along transportation routes constitutes visual pollution in transportation. This includes, but is not limited to billboards and other forms of advertising, litter, derelict vehicles, and other signs of urban decline. Madlenak and Madlenakova [8] conducted a study on visual pollution in road infrastructure, highlighting the negative impact of excessive advertising and visual clutter. Toros [9] analyzed the issue of visual pollution caused by advertising signboards in Ankara, emphasizing the need for regulations and guidelines to manage outdoor advertising. Liu and Liu [10] conducted a positioning analysis of urban outdoor advertising and suggested the importance of location in maximizing the effectiveness of advertising. These studies provide insight into the impact of outdoor advertising on visual pollution and the need for regulations and strategic placement of ads. Visual pollution in transport can have deleterious consequences on the mental health and well-being of individuals and on the quality of life within a community. Mohamed *et al.* [11] studied the effects of visual pollution on the people of Saudi Arabia, highlighting its manifestations and negative consequences. Lopez and Custodio [12] discussed the legal framework for addressing "forgotten" pollution, including noise, smells, and visual impacts, in Mexico. Latypova *et al.* [13] conducted a study on visual garbage from a visual ecology perspective, providing insights into its impact on the environment. Moreover, visual pollution can be a source of distraction for drivers and could be a contributory factor to traffic accidents.

Visual pollution in transportation plays a detrimental role in the environment and people's ability to enjoy the area, as it is both distracting and an eyesore. Visual pollution has a negative impact on the environment and the enjoyment of public spaces. Allahyari *et al.* [14] evaluated visual pollution in urban squares using SWOT, AHP, and QSPM techniques. Chmielewski [15] proposed a 3D Isovist and Voxel approach for the assessment of visual impact of advertisement billboards, while Chmielewski [16] used tangential view landscape metrics to measure visual pollution. Chmielewski *et al.* [17] conducted intervisibility analysis and public surveys to measure the visual pollution caused by outdoor advertisements in urban streets. Such pollution can also reduce air quality, obstruct views, and distract drivers, thus leading to dangerous road conditions. Codato [18] discusses the troubled relationship between visual pollution and noise, highlighting the negative effects of these pollutants on the environment and society. Correa and Mejia [19] examine the impact of visual pollution on the population, emphasizing how it can reduce air quality and obstruct views. Madlenak and Hudak [12] focus on the visual pollution of road infrastructure in Slovakia and highlight the negative impact of visual pollution on drivers, leading to dangerous road conditions. The studies collectively suggest that visual pollution can lead to harmful consequences for both the environment and society. As argued by Rodrigue, Comtois, and Slack [21], reducing visual pollution in transport systems is crucial to promote a safe environment, enhance the aesthetic quality of the area, and prevent road accidents. It is imperative to prioritize strategies that reduce visual pollution in transport infrastructure. Rodrigue, Comtois, and Slack [22] describe that transport systems are vital components of modern societies, consisting of networks of infrastructure and vehicles that enable the movement of people and goods between different locations. These systems encompass a wide range of modes (in city and rural condition), including roads, railways, waterways, airports, and various types of public transportation such as buses and taxis as it is described in Gaal, Horváth, Török, and Csete's article [23]. The efficient functioning of transport systems is crucial for economic development, social integration, and environmental sustainability. However, the negative impact of transport systems, such as visual pollution, noise pollution, and carbon emissions, cannot be overlooked.

Visual pollution is known to have detrimental effects on transport systems by reducing visibility, increasing the probability of accidents, and creating a hostile environment for pedestrians and cyclists. It can also result in a decrease in the aesthetic value of the surroundings, thus reducing the attractiveness of public transport and pedestrian-friendly modes of transport, and negatively affecting the tourism industry. Stoma *et al.* [24] have suggested that autonomous vehicles may provide a solution to the issue of visual pollution in transport by reducing the risk of accidents and potentially creating a more pleasing environment for pedestrians and cyclists. This development could lead to increased safety and improved quality of life for all commuters, which would result in a more efficient transportation system. In addition, visual pollution may obscure road signs, leading to confusion and further risks to safety.

Visual pollution can also increase noise levels, as it can reflect sound waves and amplify noise in the area. This can be especially problematic in urban areas, where noise pollution is already high. Additionally, visual pollution can reduce the amount of sunlight that is allowed to reach a given area, which can lead to decreased air circulation and higher temperatures, making it less comfortable for people to travel in the area.

Visual pollution can have diverse effects on the surrounding environment and the economy. Apart from its negative impact on the aesthetic and functional aspects of transportation, it may reduce property values, and in turn, influence businesses and individuals. Chuang *et al.* [25] revealed that visual pollution may decrease the value of a place and lower the effectiveness of advertising. Additionally, visual pollution may induce littering and various forms of environmental degradation, leading to the deterioration of the area's natural resources.

Visual pollution refers to the presence of intrusive or distracting visual stimuli in the environment, which can negatively affect individuals' well-being and cognitive processes. Tarkowski *et al.* [26] investigated the potential influence of driver distraction on the extension of reaction time. Through their research, the authors found that visual distractions, particularly those related to smartphones, can significantly increase drivers' reaction time. This increase in reaction time poses a higher risk of accidents, as delayed responses can lead to compromised driving performance and reduced overall safety. Salisu and Oyesiku [27] conducted a traffic survey analysis in Nigeria to identify traffic patterns and inform road transport planning. Their study revealed that traffic congestion and inadequate infrastructure are major challenges that impede the efficient movement of people and goods in Nigeria. The presence of visual pollution, such as poorly designed road signage or excessive billboards, can contribute to traffic congestion by diverting drivers' attention and increasing cognitive load.

Ližbetin and Stopka [28] proposed a roundabout solution for a particular traffic operation to reduce congestion and increase safety. The study demonstrated that the implementation of a well-designed roundabout can effectively alleviate traffic delays and increase the capacity of the intersection. By reducing visual clutter, such as confusing signage or excessive road markings, drivers can navigate intersections more easily, enhancing their driving experience and minimizing the potential for accidents. Słomiński and Sobaszek [29] developed a dynamic autonomous identification and intelligent lighting system for moving objects with discomfort glare limitation. Their research aimed to minimize discomfort glare, which can occur when drivers are exposed to bright lights or reflections. The study showed that the implemented system effectively reduced discomfort glare while improving visibility of moving objects. By mitigating visual pollution caused by excessive or poorly directed lighting, drivers can maintain better focus and reaction time, contributing to safer driving conditions.

Wang *et al.* [30] investigated the effect of particulate iron on tracking indoor PM2.5 of outdoor origin in a case study conducted in Nanjing, China. Their findings revealed that particulate iron can serve as an important tracer for indoor PM2.5 originating from outdoor sources. This knowledge can inform indoor air quality management, allowing for the development of strategies to reduce visual pollution caused by outdoor particulate matter, which may obscure visibility and affect drivers' respiratory health. Rybicka *et al.* [31] applied an emission standard methodology to compare a specific railway line with parallel road transport. Their research demonstrated that railway transport emits fewer pollutants compared to road transport, suggesting that it can be an effective alternative for reducing emissions. By reducing the visual pollution associated with vehicle emissions, such as smog or exhaust fumes, railway transport can contribute to improved air quality and a more pleasant driving environment. Frej *et al.* [32] discussed the importance of alternative drive vehicles in road transport, specifically in Poland and the European Union. The authors highlighted the potential benefits of alternative drive vehicles, including reduced emissions and increased energy efficiency. Policy incentives were identified as crucial in promoting the adoption of these vehicles, which can contribute to a decrease in visual pollution caused by conventional vehicles, such as smoke or noise pollution.

In conclusion, the reviewed literature demonstrates that visual pollution can have significant implications for drivers. Factors such as distractions, traffic congestion, poorly designed infrastructure, discomfort glare, and vehicle emissions all contribute to visual pollution and can negatively impact driver performance, safety, and overall driving experience. Strategies aimed at reducing visual pollution, such as improved road design, intelligent lighting systems, and the adoption of alternative drive vehicles, are essential for creating a safer and more sustainable transportation environment.

# 2 Methodology

The city of Žilina, located in Northern Slovakia, was chosen as the site for a comprehensive research project which aimed to assess the influence of visual smog on drivers in the city. Visual pollution, in the form of large-format outdoor advertising, was the primary focus of the study. To this end, two routes within the city limits of Žilina were selected for an empirical analysis. The study adopted a scientific approach, utilizing eye-tracking technology to measure the effects of visual smog on drivers. The results of the study are expected to provide valuable insights into the impact of visual pollution on drivers in Žilina, as well as in other cities with similar characteristics.

The individual routes and the advertisements that are placed on them are meticulously processed and registered in the developed Google Maps application (see Figure 1). This interactive mapping application serves as a comprehensive repository of all registered advertisements, including their geographic location, distribution, and other pertinent indicators. The collected data encompasses the proprietor of the advertising medium, the type of medium and the content of the advertisement. For large-scale advertising, the data recorded also includes the advertiser, the precise advertisement (e.g., logo, product, service) and a visual representation of the advertisement.

Following the analysis of visual pollution, the impact of outdoor advertising on car drivers was measured using HMI equipment - SMI's eye-tracking glasses. The same type of equipment was used in a study by Pavlenko and Shamanina [33] on eye tracking in the study of cognitive processes. This technology allowed for the quantification of the effects of outdoor advertising on car driver behavior as demonstrated in the study conducted by Bozomitu, Păsărică, Tărniceriu, and Rotariu [34] in the development of an eye tracking-based human-computer interface for real-time applications.

The SMI ETG 2W head-mounted eye-tracking glasses, in conjunction with the iViewETG version 2.8 software, were chosen as the primary tool for data acquisition. This specific device was designed to monitor the real-time visual behavior of subjects and capture relevant data. It consists of three high-speed cameras, two of which are infrared cameras utilized to track and record the movement and positioning of the subjects' pupils in both eyes.


Routes and outdoor advertising placement in selected routes in Zilina

The third camera is a high-definition scene camera with a resolution of 1280 × 960 p @24 fps, capturing the surrounding environment. The use of this equipment has been previously employed by the authors [35] in a study on experimental testing of vehicle-driver interaction through eye-tracking technology in laboratory conditions.

Additionally, a notebook was connected to the glasses to facilitate data recording (see Fig. 2). The SMI ETG 2W is capable of providing a highly accurate and reliable eye tracking data set with a sampling frequency of 60 Hz that is extended throughout the entire field of view. This eye tracking system has been specifically designed to ensure a tracking range of 80° horizontal and 60° vertical with a gaze tracking accuracy that does not vary over distance, achieving an impressive 0.5° accuracy.

The SensoMotoric Instruments (SMI) BeGaze software version 3.7.59 was utilized for a comprehensive analysis of the data collected by the SMI ETG 2W.

The 11 drivers, composed of 6 females and 5 males aged between twenty-one and thirty-seven years, completed test drives across two measurement days. To ensure the accuracy of the research, five measurements were taken on Route 1 (the inner circle – orange marks) and six measurements were taken on Route 2 (the bypass route – yellow marks). The test drives were conducted under various conditions, such as weather and traffic, to produce a comprehensive overview of the results. These conditions included clear, cloudy, and rainy weather, as well as both with and without traffic.

Figure 2
Measurement using an eye tracker in Zilina

# 3 Results

In the eye-tracking research, the primary objective was to evaluate the influence of visual smog on the attentional processes of motor vehicle drivers while driving. To do this, we analyzed a variety of physiological variables, including the number of fixations, saccades, and blinks as it was stated in study Przepiorka *et al.* [36]. This provided us with a comprehensive understanding of how cognitive processes are used by drivers while they are behind the wheel. Additionally, this study also sought to investigate the ability of drivers to notice an advertising area close to the road in order to discover the effects of visual smog on their attention as it was mentioned in the study Kainz *et al.* [37]. The term 'saccade', derived from the French verb for 'jerk', was used for the first time to describe eye movements by Javal in the 1880s. It is used to designate the rapid, conjugate (with both eyes performing the same action) movements we make when re-orienting our foveal region to a new spatial location; the average rate of saccades is three per second. Saccades are normally identified as 'ballistic' movements, implying that the trajectory cannot be altered once initiated. Additionally, it is often asserted that during saccades, we become 'effectively blind'. Saccades, characterized by rapid eye movements, are commonly preceded and followed by fixations, which represent periods of relative stillness during which visual information is processed. The differentiation between fixations and saccades involves complex rules and algorithms employed by researchers and eye-tracking software (Feng *et al.* [38]; Hu *et al.* [39] and Xuguang & Jianping, [40]). The duration of fixations usually ranges from 200 to 300 milliseconds but can be either shorter or longer. Additionally, the average fixation duration is contingent upon the context in which it is observed; for example, fixations tend to be of shorter duration when reading than when viewing scenes. During the analysis stage, fixations are of particular interest to researchers, especially if gaze is being used as a proxy for ‘attention’.

Blinks, although not actual movements of the eye itself, play a crucial role in effective eye tracking due to several reasons. One of these reasons, as mentioned in the study by Snegireva *et al.*, [41], is that gaze cannot be monitored if the eye is not visible. In their validity study utilizing eye tracking in male youth and adult athletes of selected contact sports, the authors found that blink duration is increased in concussed youth athletes. Blinks can disrupt fixations, leading to the appearance of two separate fixations within the same area in the eye-tracking data. Although this may not pose a significant issue in many scenarios, the length and position of the fixations are crucial factors to consider.

## 3.1 Route 1 – Inner Circle

Route 1 of the city of Žilina is an ideal choice to conduct analysis due to its location in the center of the city and its length of approximately 3,300 meters. The route is known to experience heavy traffic during peak hours, such as the morning and afternoon rush hours. Furthermore, three flat sections exist along the route, providing adequate visibility for drivers. Not only this, but there is no need to be vigilant of intersections without traffic signals as the route follows the main road. In total, seven traffic lights can be found along this route.

From the perspective of the driver, it is imperative to exercise heightened caution when traversing Route 1, due to the presence of various intersections, crossings, and bus stops that can significantly impede the flow of traffic. Moreover, the conditions of Route 1 vary according to the day of the week and time of day; thus, the driver must be prepared to adjust to the conditions accordingly. All in all, Route 1 serves as a potential driving route that requires one to be constantly adjusting to changing conditions.

The main thoroughfare of Route 1 boasts a total of one hundred and thirty-nine advertising displays that are visible to motorists. The strategic positioning of the advertising carriers along this route is beneficial to both the proprietors of the carriers and the companies advertising their wares, as a significant number of cars, pedestrians and cyclists traverse the route on a daily basis.

Despite being located in a highly populated urban area, Route 1 has been found to have a significantly higher than average concentration of billboards and bigboards. This is especially evident when surveying strategic locations such as buildings and intersections, where drivers can more easily perceive the advertisements due to their conspicuous placement. As much as 20% of all the advertisements recorded in this area are in the form of billboards and bigboards.

Table 1
Route 1 – Physiological characteristics of the drivers

| | Number of fixations [per minute] | Number of saccades [per minute] | Number of blinks [per minute] | Drive durations [min.] |
|---|---|---|---|---|
| Driver 1 | 171 | 156 | 13 | 9:19 |
| Driver 2 | 82 | 49 | 7 | 9:34 |
| Driver 3 | 96 | 88 | 5 | 10:08 |
| Driver 4 | 163 | 146 | 15 | 9:39 |
| Driver 5 | 166 | 156 | 6 | 9:38 |
| Average | 135,6 | 119 | 9,2 | 9:40 |

Data in the table represents a comparison of driving characteristics between five different drivers on the route 1. Driver 1 has the highest number of fixations and saccadic movements, and the highest number of blinks per minute. Driver 2 has the lowest number of fixations and saccadic movements, and the lowest number of blinks per minute. Driver 3 and Driver 5 have similar numbers of fixations and saccadic movements, but Driver 5 has fewer blinks. Driver 4 has the second highest numbers of fixations and saccadic movements, and the second highest number of blinks. All five drivers have similar driving durations.

Conceptually, Driver 1 obtained the most beneficial outcomes. Nevertheless, it is essential to be aware that an excessive amount of fixations or saccades can induce feelings of anxiety or unease whilst driving. The average number of fixations per minute for the drivers that took part in the study was 135.6, with the average value of saccades being 119, equaling approximately two fixations and saccades for each driver per second.

## 3.2 Route 2 – Outer Bypass

Route 2 was the second route under consideration for analysis. The outer loop route was determined to be more advantageous as it provided longer and more even stretches of roadway, frequently with two lanes in each direction. Moreover, the route was composed of three extended straight stretches, which cumulatively accounted for approximately 80 % of the total length of the route.

From the driver's point of view, the number of pedestrian crossings and intersections is roughly the same. In comparison to Route 1, the driver is not required to pay as much attention while driving. On Route 2, the most important points are where the lanes diverge or converge into one. There are long stretches of flat road which give the driver the opportunity to drive in a more leisurely manner. The positioning of the billboards is strategically advantageous, and with only a few exceptions, they are clearly visible. Drivers who encounter billboards located on the opposite side of the road may, however, experience a slight decrease in visibility.

Analysis of Route 2 yielded the highest number of advertisements of the four routes studied, totaling up to 166. The majority of these advertisements were brand-related, with billboards and bigboards making up the second and third-most numerous categories, respectively.

Driver 1 has the highest number of fixations (183 per minute), the second highest number of saccadic movements (167 per minute) and the second lowest number of blinks (15 per minute). Driver 2 has the second lowest number of fixations (142 per minute), the second lowest number of saccadic movements (115 per minute) and the highest number of blinks (21 per minute). Driver 3 has the third highest number of fixations (150 per minute), the third highest number of saccadic movements (128 per minute) and the second highest number of blinks (21 per minute). Driver 4 has the second highest number of fixations (178 per minute), the fourth highest number of saccadic movements (155 per minute) and the third highest number of blinks (22 per minute). Driver 5 has the fourth highest number of fixations (159 per minute), the fifth highest number of saccadic movements (148 per minute) and the fourth highest number of blinks (23 per minute). Driver 6 has the lowest number of fixations (132 per minute), the lowest number of saccadic movements (109 per minute) and the second lowest number of blinks (18 per minute).

Table 2

Route 2 – Physiological characteristics of the drivers

| | Number of fixations [per minute] | Number of saccades [per minute] | Number of blinks [per minute] | Drive durations [min.] |
|---|---|---|---|---|
| Driver 1 | 183 | 167 | 15 | 19:47 |
| Driver 2 | 142 | 115 | 21 | 26:48 |
| Driver 3 | 150 | 128 | 21 | 23:55 |
| Driver 4 | 178 | 155 | 22 | 21:52 |
| Driver 5 | 159 | 148 | 23 | 21:19 |
| Driver 6 | 132 | 109 | 18 | 21:42 |
| Average | 157,3 | 137 | 20 | 22:34 |

Driver 1 demonstrated the most noteworthy results on the subsequent course, yet this may be an indication of his uneasiness during the run. On average, the members of the driving group exhibited 157.3 fixations per minute and 137 saccadic movements. This yields to a greater mean of fixations and saccadic movements per second of the drivers during the course in comparison to route 1.

## 3.3 Visibility of Outdoor Advertising by Driver

The most essential information obtained from the measurement was the fixation of drivers' eyes on the external ads (see Fig. 3). An eye-tracker was utilized to assess gazes directed at large-format promotional surfaces located within the driver's visual range.

Figure 3
Driver fixation for large format advertising on Route 2

Table 3
Route 1 – Visibility of Outdoor ads formats by drivers

| Route 1 | Number of Outdoor ads | Outdoor ads seen | Ads seen to total ads ratio |
|---|---|---|---|
| Driver 1 | 25 | 3 | 12% |
| Driver 2 | 25 | 0 | 0% |
| Driver 3 | 25 | 2 | 8% |
| Driver 4 | 25 | 0 | 0% |
| Driver 5 | 25 | 1 | 4% |

An aggregate of 25 large-format advertisements were evaluated on Route 1 and 137 on Route 2. Drivers on these two routes rarely focused their attention on the ads. Route 1 had only 6 fixations in total, equating to 5% of the total possible ad views (See Table 3). Route 2 was more compelling, with 108 fixations observed, making up 13% of the overall ad views (see Table 4).

The final stage of the research sought to ascertain whether drivers are consciously aware of visual smog (outdoor advertising) while driving. The objective was to determine whether drivers perceive outdoor advertising while driving.

Table 4
Route 2 – Visibility of Outdoor ads formats by drivers

| Route 2 | Number of Outdoor ads | Outdoor ads seen | Ads seen to total ads ratio |
|---|---|---|---|
| Driver 1 | 137 | 24 | 18% |
| Driver 2 | 137 | 9 | 7% |
| Driver 3 | 137 | 7 | 5% |
| Driver 4 | 137 | 22 | 16% |
| Driver 5 | 137 | 26 | 19% |
| Driver 6 | 137 | 20 | 15% |

Advertising spaces included billboards and bigboards, but also banners, tarpaulins and other signs located near the road. Out of the eleven participants in the survey, nine reported being aware of various forms of visual smog while driving, indicating that up to 82% of respondents are consciously aware of outdoor advertising (see Fig. 4).

This finding is in contrast with the results of the eye-tracking experiment, which demonstrated that out of 959 outdoor advertising spaces, only 114 (11.9%) were observed by drivers. This discrepancy between the conscious and subconscious perceptions of outdoor advertising spaces near the road is noteworthy. In this case, conscious perception is based on the responses from the questionnaire survey, while subconscious perception is inferred from the eye-tracking data.

It is important to note that the outcome of the experiment could be affected by the amount of traffic during the measurement, as well as by the general conditions of the road in question.

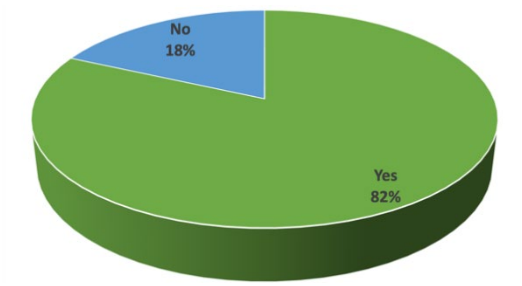


Figure 4
Overall perception of outdoor advertising during the driving

The findings of this research have far-reaching implications for the effectiveness of outdoor advertising. It can be argued that the discrepancy between the conscious and subconscious perception of outdoor advertising spaces near the road could be due to the fact that drivers are often preoccupied with other tasks and may not be able to devote their full attention to outdoor advertising. Therefore, it is possible that outdoor advertising needs to be more eye-catching, or placed in more visible locations, in order to be more effective. Additionally, further research should be conducted to determine whether the conscious perception of visual smog is affected by factors such as the driver's age or the type of vehicle being driven. By doing so, it may be possible to develop more effective strategies for targeting outdoor advertising.

## Discussion

The study aimed to investigate the influence of visual smog, specifically outdoor advertising, on the attentional processes of motor vehicle drivers, with a focus on the role of cognitive mobility. Cognitive Mobility is an inclusive approach that considers both artificial and natural cognitive features of the driver in understanding mobility comprehensively. In order to assess this influence, the researchers analyzed physiological variables such as fixations, saccades, and blinks to understand how drivers allocate their attention while driving.

To conduct the investigation, eye-tracking research was performed on two routes, Route 1 and Route 2, to examine the drivers' perception of outdoor advertising. Route 1, situated in the city center with heavy traffic and numerous intersections, exhibited a higher concentration of billboards and bigboards compared to Route 2, which offered longer and more evenly distributed stretches of roadway. Among all the drivers, drivers on Route 1 displayed the highest number of fixations, saccades, and blinks per minute, indicating heightened cognitive processing. It is worth noting that excessive fixations and saccades may induce feelings of anxiety or unease while driving. On Route 2, drivers exhibited a higher mean of fixations and saccades per second in comparison to Route 1. This route had a greater number of advertisements, and drivers demonstrated higher fixation rates on the ads compared to Route 1. The overall fixation rates on outdoor ads remained relatively low on both routes. Interestingly, a discrepancy emerged between conscious perception, as reported by respondents, and subconscious perception, as indicated by eye-tracking data, of outdoor advertising. While 82% of the respondents reported being aware of visual smog, the eye-tracking experiment revealed that only 11.9% of outdoor advertising spaces were observed by drivers. This finding suggests that drivers may not fully attend to outdoor advertising due to the presence of other tasks and distractions while driving.

The results imply that outdoor advertising may need to be more eye-catching or positioned in more visible locations to be effective. It is crucial to consider factors such as driver age and vehicle type in understanding the conscious perception of visual smog. Based on the results of this study, there is a need to develop basic recommendations for decision-makers on the placement of advertisements with a focus on ensuring the safety of both drivers and pedestrians on the roads, which will be the subject of our further research. Additionally, future research should delve into these factors and develop more effective strategies for targeting outdoor advertising.

## Conclusions

In conclusion, this study highlights the ineffectiveness of placing outdoor advertising, also known as visual smog, in downtown areas for targeting motorists. Empirical evidence indicates that these advertisements have an insignificant impact on their target audience, providing a rational basis for advertising agencies to reconsider the practice of creating large-scale visual smog in densely populated urban areas. Moreover, the findings suggest that outdoor advertising does not significantly influence the decision making process of drivers. Therefore, it is crucial to consider the concept of cognitive mobility, which emphasizes the importance of drivers' cognitive capabilities in response to changing environmental and situational factors. Understanding and integrating cognitive mobility into the design and implementation of outdoor advertising campaigns can lead to more effective and impactful strategies in targeting drivers.

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