The influence of digital out-of-home media on driver perception and driving: an integrative literature review

A influência da mídia exterior digital na percepção do motorista e na condução: uma revisão integrativa da literatura

Lara Lima Felisberto, Vanessa Casarin

out-of-home media, roadside advertising, digital advertising

Out-of-home Media is constantly changing, incorporating new technologies, such as digital technology; this media is advancing faster than the research on the effects of it on consumers and the government in regulating it. In this sense, in order to contribute to advances in research and production within Information Design, we sought to investigate the influence of digital out-of-home (DOOH) media on driver perception and driving, striving to answer three main questions: What is the influence of DOOH Media on driving? What guidelines may be found in the scientific literature for managing these media in the landscape? What are the suggestions for future studies in this field? Research procedures involved an integrative literature review to uncover research and advances in the field of digital out-of-home (DOOH) media indexed in recognized databases which resulted in the full text analysis and synthesis of 32 studies, considering papers in scientific journals, conference papers, PhD thesis and research reports. The results pointed out that digital advertisements, especially animated ones, catch the attention of drivers and may compromise road safety. The distraction level may be affected depending on the luminance, brightness, and contrast levels and the number of words on the screen. Also, it was observed that young and senior drivers are more susceptible, and gender differences influence the perception and attention to the advertisements, although they are inconclusive. Studies recommend limiting words, controlling luminance, and adequately placing the advertisements for regulation.

mídia exterior, publicidade em estradas, publicidade digital

A mídia exterior está em constante mudança, incorporando novas tecnologias, como a tecnologia digital; essa mídia está avançando mais rápido do que a pesquisa sobre seus efeitos nos consumidores e a regulação governamental sobre ela. Nesse sentido, para contribuir com os avanços da pesquisa e da produção no campo do Design da Informação, buscamos investigar a influência da mídia exterior digital (DOOH) na percepção do motorista e na condução, com o objetivo de responder a três questões principais: qual é a influência da Mídia DOOH na condução? Quais diretrizes podem ser encontradas na literatura científica para o gerenciamento dessa mídia na paisagem urbana? Quais são as sugestões para futuros estudos nessa área? Os procedimentos de pesquisa envolveram uma revisão integrativa da literatura para identificar pesquisas e avanços no campo da mídia exterior digital (DOOH), indexados em bases de dados reconhecidas, o que resultou na análise e síntese de 32 estudos, considerando artigos em periódicos científicos, artigos de conferências, teses de doutorado e relatórios de pesquisa. Os resultados apontaram que

os anúncios digitais, especialmente os animados, atraem a atenção dos motoristas e podem comprometer a segurança nas estradas. O nível de distração pode ser afetado dependendo da luminância, brilho, contraste e do número de palavras na tela. Além disso, observou-se que motoristas jovens e idosos são mais suscetíveis, e diferenças de gênero influenciam a percepção e a atenção aos anúncios, embora de forma inconclusiva. Os estudos recomendam limitar o número de palavras, controlar a luminância e posicionar adequadamente os anúncios para fins de regulamentação.

1 Introduction

Urban growth and the consequent concentration of people in metropolises have stimulated the interest of brands in promoting the exposure of their products in the urban landscape. The media for advertisement exposure in the urban landscape is evolving rapidly.

Out-of-home (OOH) media or out-of-home (OOH) advertising, as it is called the media found in public spaces outside of the home, is constantly changing, incorporating new technologies, such as digital technology. This media is advancing faster than the research on the effects of it on consumers and the government in regulating it.

In the case of billboards, the printed ones still coexist in landscape with digital panels; the last ones capable, not only of incorporating movement and lighting, but also countless digital effects capable of attracting the attention of passers-by. In contrast to out-of-home media, digital out-of-home (DOOH) media is being considered outdoor advertising 2.0. DOOH media is dynamic, data-driven, permits the display of numerous messages in a short period of time and can deliver measurable impact for advertisers.

From the point of view of the design of the information contained in such advertisements, the application of lighting and movement in out-of-home media products is not new. However, with technological evolution, the appearance of large-format digital panels with effects and animation in city landscapes is increasingly frequent, especially those that do not have standards for their regulation.

In the landscape of cities with less restrictive control on out-of-home media, it is common to see the replacement of a conventional billboard by large digital panel, whose operating dynamics and interference in the surroundings are quite different.

Although this practice aims to increase the visibility and reach of advertising messages, its application may lead to interference in vehicle driving, thus exposing the need to investigate the possible consequences of these facts.

Outdoor media is a fundamental element in the composition of the urban landscape. According to Cullen (2020), advertisements are a part of city life, with just a need for regulation and appropriate integration. The author also pointed out that urban planners neglect the positive contribution of advertisements in the landscape, minimizing the importance of their regulation.

This highlights the need to consider public safety issues and the implementation of more effective regulation of advertisements, particularly those that use digital technologies. In this context, there is also a need to understand how the distribution of these elements in the landscape interferes with driving.

Thus, an integrative literature review was proposed with the aim of identifying the state of the art on the influence of digital out-of-home (DOOH) media on driver perception and driving, answering three main questions: What is the influence of digital media on driving? What guidelines may be found in the scientific literature for managing these media in the landscape? What are the suggestions for future studies in this field?

So, this paper aims to contribute to both, mechanisms for control – presenting the state of the art on the influence of outdoor media on driving and in guidelines for controlling this kind of media in the landscape – and to research in the field of study itself, bringing to light possibilities for future studies.

2 Methodological procedures

This article is an Integrative Literature Review (IRL). This type of review consists of a method to compile the existing literature on a given subject, covering studies with various experimental and non-experimental methodologies, maintaining the rigor characteristic of systematic literature reviews (Whittemore & Knafl, 2005).

The search was conducted in the following databases: Google Scholar, the Brazilian Digital Library of Theses and Dissertations, Web of Science, the CAPES Journals Portal, Scopus, Scielo, the Library System of Congress, USP/Unicamp/UFSCar Databases, and the JISC Library.

In the review process. at first, 25,900 studies were identified by the databases considering the research string[1] addressing the topics, in the Identification Phase (Figure 1). No studies addressing the research topic were found in Scielo, the Library System of Congress, USP/Unicamp/UFSCar Databases, and the JISC Library databases. The management of the collected articles was carried out using the EndNote Online® software.

1 The following search strings were employed in the databases: ((Landscape OR "Urban Landscape" OR Roadside OR highway OR roadway OR freeway OR interstate OR scenery OR scene OR view OR visual OR panorama OR street OR way OR avenue OR boulevard OR "side road" OR thoroughfare) AND (driv*) AND (advertising OR "outdoor advertising" OR "billboard" OR "luminous media" OR "out of home media" OR "out of home advertising" OR "outdoor media" OR frontlight OR backlight OR "OOH media" OR "OOH advertising" OR "digital media" OR "digital advertising" OR "electronic media" or "electronic advertising")) and ((Paisagem OR "Paisagem Urbana" OR "Rodovia" OR "Via" OR "Visual" OR "Cena" OR "Cenário" OR "Avenida" OR "Rua" OR "Estrada" OR "Caminho" OR "Autoestrada" OR "Autopista" OR "Autovia" OR "Via Expressa") AND (motorista*) AND (anúncio* OR "anúncio luminoso" OR "Midia exterior" OR "mídia externa" OR "mídia digital" OR "anúncio digital" OR "publicidade externa" OR "publicidade exterior" OR "publicidade digital" OR "mídia eletrônica" OR "anúncio eletrônico"))

In the second phase, the Selection Phase, 403 studies which fitted in the research scope were selected by reading the title. These 403 studies were selected for abstract reading in the third phase of the review process, the Eligibility Phase. Of these, duplicates were excluded, leaving 336 articles for abstract reading.

After excluding out-of-scope abstracts, 154 articles remained for full reading. Of the 154, those that did not respond specifically to the requested scope, the combination of the digital media topic + drivers, were excluded. Thus, 32 articles remained for the final synthesis, in the Inclusion Phase.

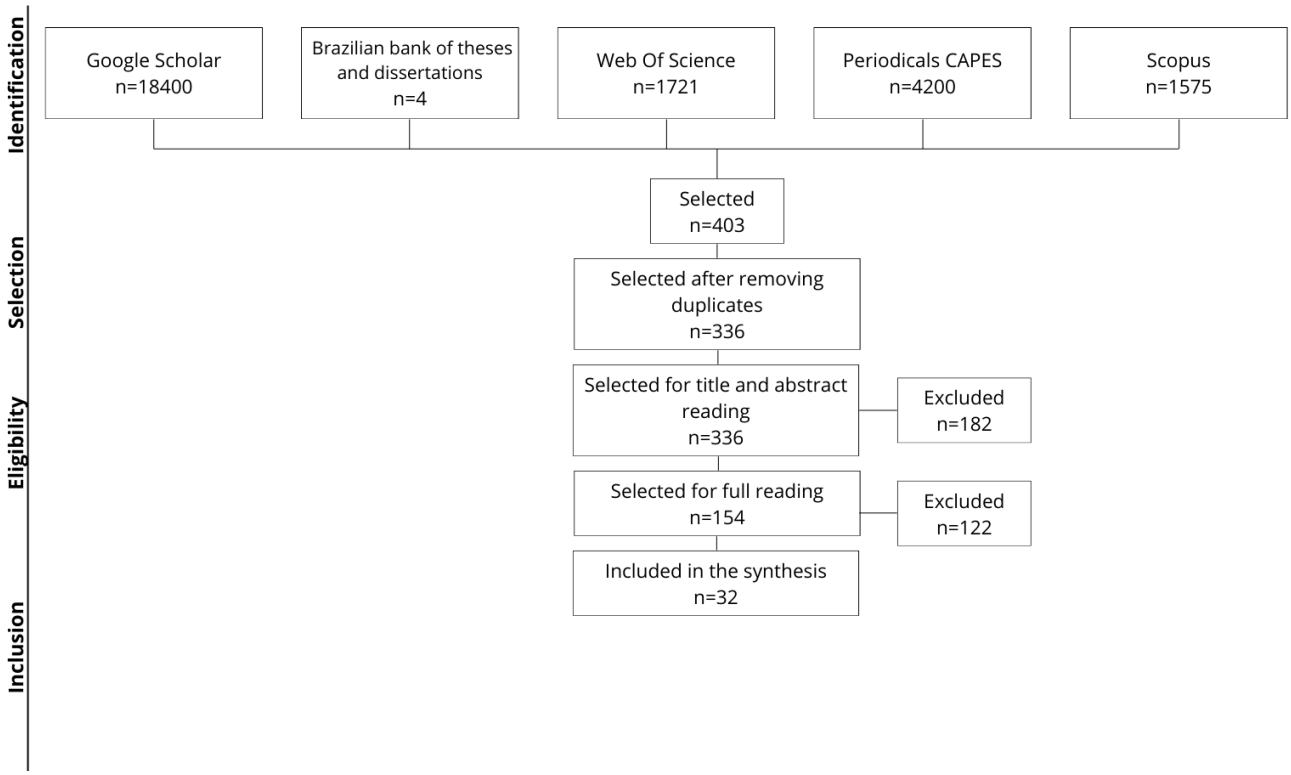

Figure 1 Search synthesis. Source: Prepared by the authors.

Of the 32 selected studies, 10 are articles published in annals of international events and 16 in journals, in addition to one master's thesis and five research reports, as listed in Table 1.

3 Results

It was possible to observe that among the selected indexed studies, research regarding the topic started around 2007. Studies were developed mainly in Europe, with special attention in Poland, followed by USA, and Australia, between others.

Table 1 Synthesis of the collected studies. Source: Prepared by the authors. (continued)

Original title	Author/year	Study location	Kind of publication
Digital billboard recommendations and comparisons to conventional billboards	(Lewin, s/n)	Arizona, USA	Report
Driving performance and digital billboards	Lee, Mcelheny, & Gibbons (2007)	Virginia, USA	Report
Are roadside electronic static displays a threat to safety	Friswell et al. (2011)	—	Conference Paper
Large-sized digital billboards hazard	Domke et al. (2012)	Poland	Paper in Scientific Journal
Designing evidence-based guidelines for the safe use of digital billboard installations: Experience and results from Australia	Roberts (2013)	Australia	Conference Paper
Effects of electronic billboards on driver distraction	Dukic et. al. (2013)	Sweden	Paper in Scientific Journal
Evaluation of the visual demands of digital billboards using a hybrid driving simulator	Schieber et al. (2014)	South Dakota, USA	Conference Paper
A comprehensive assessment of possible links between digital advertising billboards and traffic safety	Islam (2015)	Alabama, USA	Master's Thesis
Survey on applications of multimedia technology to examine impact of roadside advertising on drivers	CzyzewskI et al. (2015)	Poland	Conference Paper
The impact of billboards on driver visual behavior: A systematic literature review	Decker et al. (2015)	Alabama, USA	Paper in Scientific Journal
Visual behavior differences in drivers across the lifespan: A digital billboard simulator study	Stavrinos et al. (2016)	Alabama, USA	Paper in Scientific Journal
A field study on the effects of digital billboards on glance behavior during highway driving	Belyusar et al. (2016)	Massachusetts, USA	Paper in Scientific Journal
Exposure and perception on distraction towards roadside digital advertisements	Yellappan et al. (2016)	Malaysia	Report
Research on the parameters of light emitting advertising media	Chrzanowicz & Tomczuk (2017)	Poland	Conference Paper
Influence of roadside illuminated advertising on drivers' behavior	Sendek-Matysiak (2017)	Poland	Paper in Scientific Journal
The safety effects of (digital) roadside advertising: an overview of the literature	Vlakveld & Helman (2017)	—	Report
Photometric and geometrical characteristics of advertising media installed in the road environment	Tomczuk & Chrzanowicz (2018)	Poland	Conference Paper
Digital billboards dynamic luminance measurements	Tomczuk & Wytrykowska (2018)	Poland	Conference Paper
Analysis of results of emission parameters of advertising media in field conditions	Chrzanowicz & Jaskowski (2018)	Poland	Conference Paper
The impact of the luminance, size and location of led billboards on drivers' visual performance—laboratory tests	Zalesinska (2018)	Poland	Paper in Scientific Journal
Driving simulator study on the influence of digital illuminated billboards near pedestrian crossings	Mollu et al. (2018)	Belgium	Paper in Scientific Journal
Driver's visual attention to different categories of roadside advertising signs	Costa et al. (2019)	Italy	Paper in Scientific Journal

Table 1 Synthesis of the collected studies. Source: Prepared by the authors. (conclusion)

Original title	Author/year	Study location	Kind of publication
The impact of road advertising signs on driver behaviour and implications for road safety: A critical systematic review	Oviedo-Trespalacios et al. (2019)	Australia	Paper in Scientific Journal
Driver distraction by digital billboards? Structural equation modeling based on naturalistic driving study data: A case study of Iran	Sheykhfard & Haghighi (2020)	Iran	Paper in Scientific Journal
Identifying the distracting aspects of electronic advertising billboards: A driving simulation study	Meuleners, Roberts, & Fraser (2020)	Australia	Paper in Scientific Journal
Compendium of a decade's worth of research studies on distraction from digital billboards	Wachtel (2020)	California, USA	Report
Perceived and real impacts of digital advertising billboards on driving performance	Sisiopiku et al. (2021)	Alabama, USA	Conference Paper
The effect of display brightness on visual function for young and old drivers	Ikaunieks et al. (2021)	Latvia	Conference Paper
Influence of coloured light projected from night-time excessive luminance outdoor led display screens on vehicle driving safety along urban roads	He et.al. (2021)	China	Paper in Scientific Journal
Roadside digital billboard advertisements: Effects of static, transitioning, and animated designs on drivers' performance and attention	Brome, Awad, & Moacdieh (2021)	Lebanon	Paper in Scientific Journal
A novel conceptual framework investigating the relationship between roadside advertising and road safety: The driver behaviour and roadside advertising conceptual framework	Hinton, Watson, & Oviedo-Trespalacios (2022)	Australia	Paper in Scientific Journal
Procedure for measuring the luminance of roadway billboards and preliminary results	Tomczuk, Chrzanowicz, & Jaskowski (2022)	Poland	Paper in Scientific Journal

The results obtained by reading the texts were categorized according to the research questions: the interference of digital out-of-home media in driving (subdivided into the following: attention, distraction, animation, and gaze fixation; driver performance and age; road safety; the impact of luminance; and driver performance and gender), the guidelines suggested by the studies, and suggestions for future studies, as follows.

3.1 The interference of digital out-of-home (DOOH) media in driving

3.1.1 Attention, distraction, animation, and gaze fixation

The main consensus among the studies is that digital advertisements strongly interfere with the attention of vehicle drivers (Friswell et al., 2011). The analyzed factors contributing to this interference include animation and changes in luminance, which involuntarily catch the attention of drivers. This attention is evidenced by the more significant fixation time that drivers devote to digital advertisements compared to other types, with digital LED

advertisements being the leading causes of this distraction (Lee et al., 2007; Dukic et al., 2013; Roberts, 2013; Decker et al., 2015; Belyusar et al., 2016; Yellapan et al., 2016; Oviedo-Tresplacios et al., 2019; Wachtel, 2020; Brome et al., 2021). However, Costa et al. (2019) found that conventional billboards are more distracting than LED advertisements.

Empirical research with driving simulators has observed that participants performed less overtaking in the presence of billboards, which may be explained by the catching of their attention and the consequent reduction in speed (Sisiopiku et al., 2014; Vlakveld & Helman, 2017; Meuleners et al., 2020). In addition to the speed reduction, variability in lane position and gaze fixations outside the field of vision of the road were also detected, demonstrating a negative impact (Meuleners et al., 2020; Hinton et al., 2022).

Among other factors related to distraction, Schieber et al. (2014) found that driver performance may decline when reading advertisements with eight or more words. Moreover, it was found that shorter message display times result in longer gazes in the direction of the billboards (Mollu et al., 2018). Stavrinos et al. (2016) demonstrated that the percentage of time spent looking at advertisements increased as the transition time did.

Sheykfhard and Haghighi (2021) found that installing advertisements near intersections and roundabouts increases the risk of driver distraction. They also highlighted environmental factors that amplify this risk, such as nighttime and adverse weather conditions (rain, fog, and snow).

3.1.2 Driver performance and age

Regarding driver age and distraction, young people (aged 20 to 25 years) agree that digital advertisements are more distracting than static ones and claim not to use the information they read in such advertisements (Sisiopiku et al., 2014). Although the effects do not always vary with age, Belyusar et al. (2016) and Stavrinos et al. (2016) found that the behavior of fixing one's gaze on an advertisement may be particularly affected among senior drivers.

As for age groups, Iakuners et al. (2021) found no differences in advertisement screen brightness preferences between different age groups. In addition, Wachtel (2020) found that young drivers are the most prone to distraction but also the most agile in responding to traffic emergencies.

3.1.3 Road safety

The studies did not find strong connections between advertisements and traffic accidents. However, Sendek and Matysiak (2017) found that most drivers involved in accidents or head-on collisions indicated in their research that advertisements often affected their attention. Among the drivers who reported being frequently distracted by illuminated advertisements, one in four were responsible for a traffic collision.

3.1.4 The impact of luminance

Regarding advertisement illumination, Chrzanowicz and Tomzuck (2017, 2018, 2022) and Tomzuck and Wytrykowska (2018) found that the impact of the illumination on drivers is directly related to the observation angle. Their study concluded that LED panels have luminance values that are more harmful to drivers. In another study, Chrzanowicz and Jaskowski (2018) found that the nuisance caused by the advertisement luminance is also related to the high contrast between the advertisement luminance and the background, especially in dark environments, in addition to the angle of advertisement placement.

Regarding the illumination differences, He et al. (2021) found that colored light from advertisements affects road safety the most.

The studies by Domke et al. (2012) and Zalesinska (2018) measured the luminance of advertisements placed in Poland and found that most had values over 400 cd/m², exceeding the limits allowed by the legislation of that country. Tomzuck et al. (2018) corroborated such results, observing that LED advertisements in Poland often exceed luminance levels allowed by local legislation.

3.1.5 Driver performance and gender

He et al. (2021) found that women recognize advertisements better than men in nighttime environments. In addition, they found that novice and male drivers are the most distracted in traffic (Sheykfhard & Haghighi, 2021). However, none of the studies could find a plausible reason for the difference between genders.

So, considering the influence of digital out-of-home media in driving, in general, findings revealed that the attention of drivers is caught primarily by the speed of transition (moviment), number of words, and luminance levels of advertisements. These factors lead to more prolonged driver gaze fixation on digital advertisements. There is still no consensus on the effects of message content on catching attention. The studies concerning the age groups also did not reach a consensus, but distraction peculiarities were found among young drivers (aged 20 and 25 years) and senior citizens (over 60 years old). In view of the findings, it is important to highlight the guidelines for regulating this kind of media which were found in the literature.

3.2 Guidelines suggested by the studies

Considering guidelines for the regulation of digital advertisements in landscape, Roberts (2013) has one of the most complete studies. He proposed that:

- Digital devices must not contain animation, changes in luminance, or any effects that create the illusion of motion;
- They must not contain flashing, rotating, pulsating, or intermittent lights;

- The authors verified a calculation for image dwell time: Dwell Time = VD (m) ÷ {SE (km/h) × 0.28 × PD, where VD is the maximum distance of the sign at which the face becomes visible to drivers, SE is the speed environment, and PD is the proportion of drivers;
- The advertisement transition must be instantaneous, with no fading, zooming, or white screen effects between messages;
- There must be no message sequencing;
- Calculation of the amount of information shown in advertisements: Number of Words < LD (m) ÷ {SE (km/h) × 0.28} × CR (sec), with Number of Words < CR (sec) × 2 and LD being the legibility distance, SE the speed environment, and CR the compression rate (approximately three words per second).
- The message color must not be similar to a traffic sign or traffic light colors (green, red, yellow);
- The devices must also not imitate traffic control devices or contain words such as "stop", "turn left", etc.;
- The devices must not present emotional, threatening, or anxiety-provoking content;
- The luminance levels must not exceed those of static signs in ambient light conditions;
- The dimensions must not be the same as official traffic signs/devices;
- They must not be placed at intersections, crosswalks, or bus stops and must not have more than one advertisement visible at the same time; Placement decisions is also a worry in Schieber et al. (2014) study.
- The visibility distance must correspond to the legibility distance;
- The installations must consider the overall risk profile of the environment (based on accident history, traffic volume, speed, complexity, and disorder).

Subsequent studies, such as from Schieber et al. (2014) suggested that digital advertisements display no more than eight words on low-speed roads and no more than four on high-speed roads. Also, study from Islam (2015) recommended that advertisements not be installed near places with high numbers of traffic accidents. Zalesinska (2018) predicted that the optimal angle of illuminated panels not to impair driver performance is 6.3° horizontally and 4.3° vertically.

3.3 Suggestions for future studies

The studies suggested a more in-depth investigation of the connection between image dwell time and driver attention, as Friswell et al. (2011).

Decker et al. (2015) highlighted that future research should emphasize the complexities of the driving task and understand the effects of digital billboard designs.

Chrzanowicz and Tomczuck (2016) and Chrzanowicz and Jaskowski (2018) suggested that future research could check the value of the maximum luminance limit and the adequate placement of advertisements relative to

the viewing angle of drivers, in addition to investigating contrasts with other elements of the urban landscape.

Oviedo-Tresplacios et al. (2019) pointed out that there is a gap in studies on animated and illuminated advertisements, considering that they are emerging technologies, thus indicating the need for more research in this field.

Brome et al. (2021) suggested that future regulations be divided into three categories: photometric parameters, content, and placement.

Hinton et al. (2022) emphasized the importance of investigating how or when the involvement of a driver with an advertisement sign extends beyond the initial exposure.

We believe that all these previous suggestion needs further studies, since they are addressing topics which has influence in driving. Including Iakunieks et al. (2021) that recommended that their study method, which involved exposure to LED screens in laboratory tests, could be replicated with larger samples and different age groups, since in their study sample were limited.

We believe that these studies should be conducted especially *in loco*, and by night, because it is a critical situation considering digital out-of-home (DOOH) media.

4 Conclusions and final considerations

This study identified relevant aspects of the influence of digital media on driving. The results showed that digital advertisements, particularly animated ones and those with high luminance, catch the attention of drivers, thus affecting their driving behavior and potentially compromising road safety.

The results also indicated that factors such as the transition speed, number of words, brightness, and digital screen contrast of advertisements are determinants for the level of distraction of drivers. It was observed that young and senior drivers are particularly susceptible to distraction, while gender differences also have some influence on the perception and attention to advertisements despite not being thoroughly investigated or proven.

Although there is no consensus on the direct relationship between digital advertisements and the incidence of accidents, the perception of drivers and empirical findings suggest a correlation, especially in low-visibility conditions or critical locations such as intersections and roundabouts. The guidelines suggested by the studies, such as limiting the number of words, controlling luminance, and adequately placing the advertisements, are some recommendations for regulations.

So digital resources incorporated into out-of-home media can influence both; the design of the information, and the way in which the target interacts with these means of communication. However, research that focuses on the effects of this kind of media is limited, and mechanisms to control it seem to be, always, one step behind.

Thus, the relevance of the addressed topic is made evident, indicating the need to review existing regulations and implement them where they are not yet present, favoring road safety and driving in general.

Acknowledgment

The authors would like to thank Fapesc (Fundação de Amparo à Pesquisa e Inovação de Santa Catarina) for funding the research.

References

Belyusar, D., Reimer, B., Mehler, B., & Coughlin, J. F. (2016). A field study on the effects of digital billboards on glance behavior during highway driving. *Accident Analysis and Prevention*, *88*, 88–96. https://doi.org/10.1016/j.aap.2015.12.014

Brome, R., Awad, M., & Moacdieh, N. M. (2021). Roadside digital billboard advertisements: Effects of static, transitioning, and animated designs on drivers' performance and attention. *Transportation Research Part F-Traffic Psychology and Behaviour*, *83*, 226–237. https://doi.org/10.1016/j.trf.2021.10.013

Chrzanowicz, M., & Jaskowski, P. (2018). Analysis of results of emission parameters of advertising media in field conditions [Conference paper]. In *12th International Road Safety Conference GAMBIT 2018 – "Road Innovations for Safety – The National and Regional Perspective"*, MATEC Web of Conferences, 231.

Chrzanowicz, M., & Tomczuk, P. (2017). Research on the parameters of light emitting advertising media [Conference paper]. In *XI International Road Safety Seminar GAMBIT 2016*, MATEC Web of Conferences, 122.

Costa, M., Bonetti, L., Vignali, V., Bichicchi, A., Lantieri, C., & Simone, A. (2019). Driver's visual attention to different categories of roadside advertising signs. *Applied Ergonomics*, *78*, 127–136. https://doi.org/10.1016/j.apergo.2019.03.001

Cullen, G. (2020). *Paisagem urbana*. Edições 70.

Czyzewski, A., Korzeniewski, A., Odya, P., Szczuko, P., & Kostek, B. (2015). Survey on applications of multimedia technology to examine impact of roadside advertising on drivers communications [Conference Paper]. In *8th International Conference on Multimedia Communications, Services and Security (MCSS)*, Krakow, Poland.

Decker, J. S., Stannard, S. J., McManus, B., Wittig, S. M. O., Sisiopiku, V. P., & Stavrinos, D. (2015). The impact of billboards on driver visual behavior: A systematic literature review. *Traffic Injury Prevention*, *16*(3), 234–239. https://doi.org/10.1080/15389588.2014.936407

Domke, K., Wandachowicz, K., Zalesi, M., Mroczkowska, S., & Skrzypczak, P. (2012). Large-sized digital billboards hazard. *International Journalof Design & Nature and Ecodynamics*, *7*(4), 367–380.

Dukic, T., Ahlstrom, C., Patten, C., Kettwich, C., & Kircher, K. (2013). Effects of electronic billboards on driver distraction. *Traffic Injury Prevention*, *14*(5), 469–476. https://doi.org/10.1080/15389588.2012.731546

Friswell, R., Vecellio, E., Grzebieta, R., Hatfield, J., Mooren, L., Cleaver, M., & De Roos, M. (2011). *Are roadside electronic static displays a threat to safety?* [Report] Australasian Road Safety Research, Policing and Education Conference. http://acrs.org.au/publications/conference-papers/database

He, Y., Zhang, X., Quan, L., Mi, R., Cui, Y., Xu, J., & Tian, Z. (2021). Influence of coloured light projected from night-time excessive luminance outdoor LED display screens on vehicle driving safety along urban roads. *Building and Environment*, *188*, 107448. https://doi.org/https://doi.org/10.1016/j.buildenv.2020.107448

Hinton, J., Watson, B., & Oviedo-Trespalacios, O. (2022). A novel conceptual framework investigating the relationship between roadside advertising and road safety: The driver behaviour and roadside advertising conceptual framework. *Transportation Research Part F-Traffic Psychology and Behaviour*, *85*, 221–235. https://doi.org/10.1016/j.trf.2021.12.002

Ikaunieks, G., Krumina, G., Volberga, L., & Naumovs, L. (2021). The effect of display brightness on visual function for young and old drivers. IOP conference series. *Materials Science and Engineering*, *1202*(1), 12036. https://doi.org/10.1088/1757-899X/1202/1/012036

Islam, M. M. (2015). *A comprehensive assessment of possible links between digital advertising billboard sand traffic safety* [Masters Dissertation]. University of Alabama at Birminghan. Birgmingham, Alabama.

Lee, S. E., McElheny, M. J., & Gibbons, R. (2007). *Driving performance and digital billboards* [Report]. Center for Automotive Safety Research, Issue.

Lewin, I. (n.d.). *Digital billboard recommendations and comparisons to convention* [Report]. https://www.polcouncil.org/polc2/DigitalBillboardsIanLewin.pdf

Meuleners, L., Roberts, P., & Fraser, M. (2020). Identifying the distracting aspects of electronic advertising billboards: A driving simulation study. *Accident Analysis and Prevention*, *145*, Article 105710. https://doi.org/10.1016/j.aap.2020

Mollu, K., Cornu, J., Brijs, K., Pirdavani, A., & Brijs, T. (2018). Driving simulator study on the influence of digital illuminated billboards near pedestrian crossings. *Transportation Research Part F-Traffic Psychology and Behaviour*, *59*, 45–56. https://doi.org/10.1016/j.trf.2018.08.013

Oviedo-Trespalacios, O., Truelove, V., Watson, B., & Hinton, J. A. (2019). The impact of road advertising signs on driver behaviour and implications for road safety: A critical systematic review. *Transportation Research Part a-Policy and Practice*, *122*, 85–98. https://doi.org/10.1016/j.tra.2019.01.012

Roberts, P. (2013). Designing evidence-based guidelines for the safe use of digital billboard installations: Experience and results from Australia [Conference Paper]. In *16th Road Safety on Four Continents Conference*, Beijing, China.

Schieber, F., Limrick, K.J., McCall, R., & Beck, A. (2014). Evaluation of the visual demands of digital billboards using a hybrid driving simulator [Conference Paper]. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 58, 2214–2218.

Sendek-Matysiak, E. (2017). Influence of roadside illuminated advertising on drivers' behaviour. *Archiwum Motoryzacji*, *77*(3).

Sheykhfard, A., & Haghighi, F. (2020). Driver distraction by digital billboards? Structural equation modeling based on naturalistic driving study data: A case study of Iran. *Journal of safety research*, *72*, 1–8. https://doi.org/10.1016/j.jsr.2019.11.002

Sisiopiku, V., Islam, M., Wittig, S., Welburn, S., Stavrinos, D. (2021). Perceived and real impacts of digital advertising billboards on driving performance. In N. Stanton, S. Landry, G. Di Bucchianico, & A. Vallicelli (Eds.), *Advances in Human Aspects of Transportation: Part II. AHFE (2021) International Conference*. AHFE Open Access, vol 16. AHFE International, USA.

Stavrinos, D., Mosley, P. R., Wittig, S. M., Johnson, H. D., Decker, J. S., Sisiopiku, V. P., & Welburn, S. C. (2016). Visual behavior differences in drivers across the lifespan: A digital billboard simulator study. *Transportation research. Part F, Traffic psychology and behaviour*, *41*(A), 19–28. https://doi.org/10.1016/j.trf.2016.06.001

Tomczuk, P., & Chrzanowicz, M. (2018). Photometric and geometrical characteristics of advertising media installed in the road environment. In *12th International Road Safety Conference GAMBIT 2018 – "Road Innovations for Safety – The National and Regional Perspective"*, MATEC Web of Conferences, 231.

Tomczuk, P., Chrzanowicz, M., & Jaskowski, P. (2022). Procedure for measuring the luminance of roadway billboards and preliminary results. *Leukos*, *18*(1), 2–20. https://doi.org/10.1080/15502724.2020.1803752

Tomczuk, P., & Wytrykowska, A. (2018). Digital billboards dynamic luminance measurements. In *12th International Road Safety Conference GAMBIT 2018 – "Road Innovations for Safety – The National and Regional Perspective"*, MATEC Web of Conferences, 231.

Vlakveld, W., & Helman, S. (2017). *The effects of (digital) roadside advertising: An overview of the literature* [Report]. ADVERTS Assessing Sistraction of Vehicle divers in Europe from Roadside Technology-based Signage.

Wachtel, J. (2020). *Compendium of a decade's worth of research studies on distraction from digital billboards (commercial electronic variable message signs)* [Report]. Veridian Group, Berkeley, California.

Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. *Journal of Advanced Nursing*, *52*, 546–553. https://doi.org/10.1111/j.1365-2648.2005.03621.x

Yellappan, K., Ghani, Y., Musa, M., Siam, M. F. M., & Yeap, T. C. (2016). *Exposure and perceptionon distraction towards roadside digital advertisements* [Report]. MIROS – Malaysian Institute of Road Safety Research.

Zalesinska, M. (2018). The impact of the luminance, size and location of LED billboards on drivers' visual performance-Laboratory tests. *Accident Analysis and Prevention*, *117*, 439–448. https://doi.org/10.1016/j.aap.2018.02.005

About the authors

Lara Lima Felisberto
laralimafelisberto@gmail.com
Universidade Federal de Santa Catarina
Florianópolis, SC

Vanessa Casarin
vanessa.casarin@ufsc.br
Universidade Federal de Santa Catarina
Florianópolis, SC

Submission date/*Artigo recebido em*: 19/7/2024
Approvement date/*Artigo aprovado em*: 3/12/2024