



Effect of Distracting Factors on Driving Performance: A Review

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Received 10 December 2021; Revised 18 January 2022; Accepted 26 January 2022; Published 01 February 2022

Abstract

The number of traffic accidents because of distracted driving is increasing rapidly worldwide. Hence, the main objective of the present study is to review the effects of different distracting factors on driving performance indicators. Distracting factors considered in this study are roadside advertisements (billboards), mobile use, in-built vehicle systems, and sleepiness; and driving performance indicators are lane deviation, reaction time, and speed variation. Studies from existing literature reveal that all the distracting factors distract drivers from forwarding roadways in many ways. The location and content displayed on the billboard and the use of mobile phones increase reaction time. However, the former decreases the driver's ability to control the vehicle, and the latter increases the speed variation and reduces lane-keeping capacity. Lateral vehicle control and reaction time are compromised when drivers engage in searching for songs or videos on music players. When sleepiness occurs, drivers exhibit a higher standard deviation of speed and a decreased headway distance. Nevertheless, most of the studies in this area are carried out in developed countries like the USA and European countries. Therefore, a detailed study and further research in developing countries like India, where activities like installing billboards and mobile phone use are increasing day by day due to the rapid urbanization of major cities in the country, are quite essential.

Keywords: Driving Performance; Distracting Factors; Road Safety; Billboard; Mobile Use; In-Built Vehicle System; Sleepiness.

1. Introduction

According to the World Health Organization (W.H.O) (2018) [1], road traffic crashes cause 1.35 million deaths each year, making them the eighth highest cause of mortality for individuals of all ages worldwide. Distraction while driving is considered a severe and growing concern that poses a hazard to road traffic safety (W.H.O, 2018). Distraction has been defined in several ways over the years. Still, the most widely accepted definition is a "diversion of attention away from activities critical for safe driving towards a competing activity, which may result in insufficient or no attention to activities critical for safe driving" [2]. It can deteriorate driving performance visually (not looking at the road), cognitively (not paying attention to the road), and physically (hands off the steering wheel) [3, 4]. Distracted driving occurs when the primary task (driving) is shared with a non-driving related secondary task. It was observed that the co-occurrence of distracted driving with other driving behaviors or secondary tasks increased the probability of near-crash and crash events [5]. Two general categories of the non-driving related secondary tasks are internal (such as mobile phone use, etc.) and external (e.g., looking at roadside advertising signs, etc.) [6].

Recently, there has been a great effort to research how and why road traffic accidents increase due to distracted driving. This article studies the literature on the relationship between distracting factors and driving performance.

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 <http://dx.doi.org/10.28991/CEJ-2022-08-02-014>



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However, there is a broad range of distracting factors affecting driving performance. In recent decades, many researchers have shown that distracting factors such as roadside advertisements, mobile phone use, in-built vehicle technology, and sleepiness are associated with higher crash risk [7–9]. Hence, a detailed study has been carried out on these four distracting factors.

This study presents the effect of four distracting factors (roadside advertisement, mobile use, in-built vehicle system, and sleepiness) on driving performance (lateral and longitudinal control of vehicle, eye fixation, response time, gap acceptance, and workload). In the following sections (sections 2–5), previous work on the factors mentioned above in the context of different driving performance measures is reviewed. The summary and future research directions are discussed in section six, followed by the conclusions in section seven. Finally, a summary of the studies, the data, and key findings on the four aforementioned distracting factors is presented in Tables A1 to A4 in Appendix I.

2. Roadside Advertisement/Billboard

The main aim of installing roadside advertisements along roadways is to attract the attention of the road users as much as possible. This provides a massive benefit to the advertisers [10]. In professional literature, roadside advertisements, roadside advertising signs, and billboards are used interchangeably. Billboard is defined as “any off-premises external-to-vehicle advertising sign that is permanently constructed along a roadway and conveys visual information” [11]. Roadside advertisements/billboards and external distractors are being employed more than ever before due to improved technology and the significance of commercials in society. However, billboards, more than other external elements, can endanger traffic safety because of their enticing character [12]. In other words, these billboards can influence a variety of driving performances, such as response time, vehicle lateral control, and situation awareness, posing a risk to road safety [13]. Specifically, these billboards may divert driver attention away from the road ahead, hinder visibility at intersections, pose a physical hazard to the vehicle that deviates from the route, or obstruct attention to formal traffic signs [14].

Billboard presence demonstrated a detrimental effect on numerous driving performance measures and increased the risk of a crash [15–17]. Young et al. (2009) [18] studied the effect of billboards on driving performance under three different roadway conditions: rural, urban, and motorways. The results revealed that vehicle lateral control decreased significantly in the presence of billboards for motorways and rural roads. Similarly, Bendak and Al-Saleh (2010) [15] also observed that roadways with billboards induced more lateral deviations and instances of carelessly crossing risky junctions when compared to road stretches without billboards. Edquist et al. (2011) [19] used ISO standardized Lane Change Test to investigate the level of distraction induced by billboards, and they reported that billboards distracted drivers' eyes away from the road ahead and caused a 0.5 to 1-second delay in responding to traffic signs, increasing the incidence of driver errors. According to Herrstedt et al. (2013) [16], billboards captured drivers' attention to the point where they affect driving performance measures and road traffic safety. They reported that the safety buffer (the time required by the driver to respond to a sudden dangerous situation that requires immediate action to avoid an accident) to the vehicle ahead is less than 2 seconds for about 25% of the glances and less than 1.5 seconds for 20% of the advertising glances. Belyusar et al. (2016) [7] observed that drivers were distracted by the presence of digital billboards because they spent a significantly larger portion of time staring off-road when digital billboards were visible. The results of the study reported that several glances in the direction of billboards lasted longer than 2 seconds. This could increase the chance of crash occurrence, as past research found that off-road glance time longer than 2 seconds doubled the likelihood of near-collisions and crashes [20]. Recently, Meuleners et al. (2020) [8] found that the vehicle's lane position and speed were more variable in a roadway with a billboard when compared to a street without a billboard. Furthermore, drivers in the vicinity of billboard spent more time in high-risk headways of 2 seconds and very high-risk headways of 0.25 seconds than in an area without billboard, front, suggesting that billboard may increase crash risk.

The previous studies found that the impact of billboards on driving performance varies depending on the billboards' and drivers' characteristics [6, 21, 22]. Characteristics of the billboard include the type of display [11, 23, 24], the content of the display [25–28], and the level of illumination [29, 30]. Driver characteristics includes age [31–33], and gender [31, 32, 34]. The impact can also vary with respect to the placement/locations of billboards [8, 17, 21] and environmental conditions [32, 35].

2.1. Types of Display

Static and digital (also known as electronic) billboards were commonly used in the literature [6] for studying their effect on driving performance. Static billboards convey a single image and are passive in nature. On the other hand, digital billboards display numerous images that alter at specified times and are active in nature [11]. Other types of advertising signs are less commonly included in the literature, like video-based signs, Light Emitting Diode (LED) signs, 3D signs, etc. Recently, the use of business-logo signs on highways has been increasing, which has captured the attention of scientific researchers. Generally, these signs do not seem to affect driver visual behaviors [36, 37], though speed is reduced while viewing nine-panel signs in comparison to six-panels [38].

When comparing the effects of static and digital billboards on driving performance, it was observed that digital billboards caused drivers to be more distracted than static billboards [39–41]. In a naturalistic study, Beijer et al. (2004) [23] focused on the glance behavior of twenty drivers at different billboards along a Toronto expressway in Canada. They observed that the number of glances for digital billboards was significantly higher than static billboards. The number of average glance durations for digital billboards was also higher than for static billboards. In another naturalistic study, Dukic et al. (2013) [35] looked at gaze patterns of forty-one Swedish drivers considering four digital billboards, seven traffic signs, and one traditional billboard. When compared to other road signs, the authors found that digital billboards caused drivers to become more distracted by garnering more and longer stares. During the day, drivers spent an average of 2.25 seconds fixating on electronic billboards, compared to 0.87 seconds for other traffic signs. In a simulation study, Stavrinou et al. (2016) [24] investigated the visual behavior of drivers using two types of digital billboards (250-foot and 500-foot digital billboards) and traditional billboards. They observed that digital billboards took drivers' eyes more away from the roadway when compared to traditional billboards. It was also observed that the 500-foot digital billboards took more driver's attention than the other types of billboards. In a similar study, Milloy and Caird (2011) [40] found that more collisions occurred in the presence of video billboards than in the presence of static billboards or the absence of billboards. When drivers saw video billboards, they were reported to take longer to apply the lead vehicle brake, compared with that while crossing static billboards or no billboard at all.

2.2. Content of Billboard

The emotional and arousal content of the billboards can influence driver behavior. For example, Megías et al. (2011) [42] looked into the impact of billboard emotional content on the alteration of driver attention in a high-risk driving situation. Negative and positive emotional commercials were found to evoke more fixations and total fixation time than neutral advertisements. Furthermore, drivers took a long time to gaze in case of negative billboards when compared to positive and neutral billboards, resulting in more glances away from the road as a result of this attentional catch. Trick et al. (2012) [27] displayed images on a dashboard-embedded screen, and participants were made to respond (using a button press) as to whether the image was positive or negative in valence. They observed that positive contents were linked to better vehicle steering control than negative contents, especially when both arousal levels were low. Chan & Singhal (2013) [25] explored the ability of emotional content on billboards to distract drivers and found that the presence of bad emotional phrases reduced the speed of the vehicle and slowed reaction times in comparison with positive emotional phrases. In another simulation research, the same authors reported that emotion-related auditory distraction can affect driver focus whether the emotional content is negative or positive. On comparison to distractions due to positive and neutral content on billboards, negative distractions had more detrimental effects on lateral control and speed of the vehicle [26]. Recently, Walker & Trick (2019) [28] observed that the driver could be distracted by the emotional content of roadside images displayed on billboards, even if drivers were not compelled to look at the images. It was reported that the emotional (positive high-arousal and negative low-arousal) content of the billboard caused the greatest variation in steering in the 50-meter period following a billboard. Maliszewski et al. (2019) [43] conducted three studies in which drivers were generally found to be very sensitive in the presence of erotic content billboards. The results of study I (nationwide survey) revealed that Polish drivers considered sexual information on roadside advertising to be distracting and perilous. According to the Attentional-Network test (study-II), response time was extended in cognitive tasks due to the presence of sexual information on roadside advertisements. In the simulation study (Study-III), the authors observed driving fluency being disrupted in the presence of a roadside advertisement containing sexual content. The reason for this could be that drivers' attention was diverted away from the road due to the presence of such advertisement, resulting in the driver losing lateral control and speed of the vehicle.

Some studies showed increased reaction time and reduced cognitive resources when participants were presented with digital billboards that display longer slogans. Harasimczuk et al. (2021) [44] observed that participants' driving performance was found to be lower in the case of longer slogan condition when compared to short-slogan one. Additionally, Schieber et al. (2014) [45] found that drivers experienced greater variation in steering and longer gaze durations when they were presented with eight or more words in digital billboards.

2.3. Level of Illumination

Despite limited research connecting illumination levels to impaired driving performance, Zalesinska (2018) [30] reported that those billboard surfaces with a size of over $0.58 \times 0.38\text{m}$ and brightness of more than 400 cd/m^2 were negatively related to the visual performance of drivers. Domke et al. (2011) [46] affirmed the presence of high luminance billboard surfaces in the presence of low luminance in the vicinity of billboards. The presence of such billboards distracted drivers and impaired driving performance. High luminance of LED billboards against a low background luminance and high contrast of dynamically changing images were found to increase driver gaze duration and affect the visual perfection of the driver.

Recently, Tomczuk et al. (2020) [29] conducted pilot field studies to determine whether excessive brightness of media is a problem in Poland country and what percentage of media is affected. The light parameters (carrier luminance,

background luminance, and contrast) and geometric dimensions of 227 billboards' surfaces were measured. The study revealed that the permissible brightness levels were frequently exceeded in LED billboards. It was reported that the light coming from billboards (TVs with LED light sources with high illuminance values of 4000 to 7000 cd/m² and 1000 to 4000 cd/m² for 15 media and 19 media respectively) becomes brighter, causing higher distraction and posing a potential threat to the drivers. This negative effect was multiplied when digital billboards were installed. To avoid distraction, they also suggested that the medium's brightness should be adjusted to match the brightness of the environment where it was used.

2.4. Location/Placement of Billboard

Wallace (2003) [22] suggested that there were two specific situations where billboards could function as distractors: at junctions and on long monotonous roads (such as motorways). The billboards on curves were particularly problematic because they had the potential to be distracting in a situation where the cognitive load was high [47], and the billboards should be avoided at dangerous bends and intersections (or nearby) [15, 48]. According to Mollu et al. (2018) [17], installing digital billboard signs near already attention-demanding locations, such as pedestrian crossings should be avoided. They found that in a retail zone roadway, there were more eye glances than in a built-up area roadway. Sheykhfard & Haghighi (2019) [32] found that having a long sight distance to view digital billboards and having digital billboards installed at road intersections and verges increased the likelihood of driver distraction.

Crundall et al. (2006) [21] used driving videos to compare two different billboard types placed in different locations and investigated the glance and gaze behaviors of drivers. SLB (short level billboard) and RLB (3m raised level billboard) were the two types of billboards. The authors observed that SLBs received the highest number of fixations when drivers were only looking for threats and the fewest number of fixations when they were instructed to look for billboards. In addition, SLBs had longer fixations than RLBs. Beijer et al. (2004) [23] found that billboard placed in the centerline of view attracts more attention, no matter how far their distance from the road. Targosiński (2017) [49] confirmed this finding, observing that if the billboard was close to the centerline of the driver's view - and if it was appealing to drivers - it was watched more frequently. Herrstedt et al. (2017) [39] observed that billboards, which were placed in such a way that they appear centrally in the visual field of the drivers, drew more attention. The results of the study carried out by Meulenens et al. (2020) [8] revealed an unexpected finding: drivers were less distracted by billboards on the edge of the road than by billboards immediately above the road. Billboards directly above the road are thought to be less distracting because they do not force the driver to glance away from the street ahead.

2.5. Driver Characteristics (Age and Gender)

Many researchers examined the relationship between driver characteristics (age and gender) and the effect of billboards [11], and most of the studies had shown mixed results. According to some studies, the presence of billboards had a negative impact on younger drivers. For example, in an early review study, Farbry et al. (2001) [50] observed that young drivers took a longer time to detect hazards, especially if the hazard is distant or emerging, in the presence of billboards. Stavrinou et al. (2016) [24] revealed that compared to both middle (35-55 years) and older (≥ 65 years) age groups, young drivers (16-19 years) had more and longer glances at all billboard types. Older drivers, on the other hand, spent more time looking at static billboards than they did at other types of billboards. Olejniczak-serowiec et al. (2017) [51] found that a higher level of distraction due to billboards was found among novice drivers. Sheykhfard & Haghighi (2019) [32] found that young and novice drivers (≤ 30 years) have a higher distraction in the presence of digital billboards than older drivers (≥ 60 years). In contrast, Edquist et al. (2011) [19] observed that old age drivers exhibited more lane change errors when compared to young-aged (18-25 years) and middle-aged (26-55 years) drivers, especially in the presence of billboards. Topolšek et al. (2016) [33] observed that drivers' age was not associated with the detection of the number of static billboards.

Olejniczak-serowiec et al. (2017) [31] reported that males get more distracted than females in the presence of billboards with sexual content. Sheykhfard and Haghighi (2019) [32] found that male drivers get more distractions due to digital billboards than female drivers. The underestimation of the hazardous effect of distraction on the likelihood of driving errors and higher risk-related behaviors among male drivers could be one explanation. In contrast, Misokefalou et al. (2016) [34] indicated that gender differences were not statistically significant.

2.6. Environmental Conditions

Some researchers have investigated the effect of billboards on drivers' visual performance under different environmental conditions. For example, Sheykhfard & Haghighi (2019) [32] conducted a naturalistic study to examine drivers' distraction behavior due to the presence of digital billboards in day and night environments. They observed that drivers were found to be more distracted at night and during foggy, snowy, cloudy, and rainy weather than during the day and when the weather was clear. The light from billboards becomes more visible in low-visibility conditions, causing drivers more distraction (more staring). However, Dukic et al. (2013) [35] showed no significant differences between daytime and night-time driving to digital billboards.

3. Mobile Phone Use

Ferdinand and Menachemi (2014) [52] observed that driving performance had a destructive relationship with secondary tasks like the use of the mobile phone. Recently, it was observed that the mere presence of mobile distracted drivers, especially those who were highly dependent on their mobile phones [53]. Distracted drivers exhibited significantly more driving errors, such as speeding and collision than those in the phone absent condition, irrespective of proximity to the phone and whether it was on or off [53]. The use of a cell phone while driving is one of the most distracting elements that can impair driving performance and raise the likelihood of a severe car crash [54–56]. In addition to talking, messaging, and searching for information, mobile phone use nowadays encompasses a wide range of activities, such as emailing, gaming, surfing social media, and listening to music. Chinese drivers' five most common tasks were surfing, talking, messaging, changing phone positions, and phone in hand [57]. The impact of all of these phone tasks on driving performance has resulted in varying degrees of driver distraction. Therefore, a deeper understanding of secondary phone tasks (such as texting, browsing, etc.) and their impacts on driver behaviors and driving performance is required. The review analysis of how driving performance measures (such as speed, lane change, headway) are affected by the use of secondary phone tasks (such as texting, dialing, conversing, etc.), demographic variables (such as age, gender, and driving experience), and driving context (such as road type and weather) is outlined below.

3.1. Various Types of Secondary Phone Tasks

3.1.1. Conversation

Benedetto et al. (2012) [58] used a simulation study to examine the effect of three types of phone handset use (Hand-held, hands-free, and hands-free voice) on driving performance measures (reaction time and longitudinal distance) under various road conditions (urban, rural, and motorway). They found that the reaction time of drivers increased while conversing, regardless of the handset types and urban roadway curvature. However, on rural roads, the reaction times did not alter considerably. In some situations (Hand-held along tangent and Hands-free voice along curve), they decreased whereas, on motorways, reaction times recorded in all types of mobiles were very similar to that of the control scenario for the tangent case while increasing for curve geometry. These results corroborated the findings of some studies [59–61]. Törnros and Bolling (2006) [61] observed that conversing drivers while driving on a rural roadway with a speed limit of 90km/h took longer to react than those driving on a low-complexity urban road with a 50km/h speed limit. After reviewing the findings of numerous studies, Caird et al. (2008) [59] observed that talking on a mobile while driving increased the reaction time of the drivers. They reported that the standard deviation exhibited variation from 0.17 to 0.31 seconds, and the mean increase in reaction time was slightly more than 0.2 seconds. In another simulation study, Haque and Washington (2014) [62] observed that drivers involved in a phone call lowered the vehicle speed faster and more promptly than the drivers who were not involved. Recently, the statistical results showed that secondary tasks such as mobile conversing, texting, and handling children, caused drivers to reduce their speed significantly, compared to the non-distracted condition [63].

Briggs et al. (2011) [64] observed that the degree of detrimental in driving performance depended on the type of conversation the drivers were having. The results reported that drivers who engaged in emotional conversation had a much higher cognitive task, made more driving errors, and had a considerable decrease in the range of their eye fixations, indicating a visual tunneling pattern. In a similar type of study, Dula et al. (2011) [65] observed that mobile phone use has a more detrimental effect on driving performance measures: an increase in the number of centerline crossings and speeding incidents, especially when the mobile conversation is emotionally intense and thus posing more dangerous driving. However, the study results of Garrison & Williams (2013) [66] and Reimer et al. (2014) [67] revealed that mobile-distracted drivers have less lane variation while conversing compared to non-distracted drivers. Some studies have shown that the change in lane position between phone and no phone conditions is insignificant (e.g., [68, 69]).

Choudhary and Velaga (2017) [70] investigated and modeled the effects of mobile talking and texting on Indian drivers' driving performance in terms of average speed and ability to avoid accidents. The authors found that while engaged in talking and texting tasks on the phone, drivers reduced their average speed by 2.62 m/s and 5.29 m/s, respectively, to compensate for the increased workload. It was also reported that talking on the phone or texting while driving increased the risk of a crash by three and four times, respectively [70].

Wang et al. (2020) [57] investigated the effect of mobile use on various driving performance measures in a naturalistic study. The authors found that during phone periods, the standard deviation of three performance measures (speed, lane offset, and headway) was considerably lower than during baseline periods. These results indicated the mobile-use drivers had less fluctuation in their driving when compared to non-use drivers. The finding on headway from this study was consistent with Metz et al. (2015) [71], who found an increase in headway while talking on the mobile phone.

3.1.2. Texting

Mobile texting had been the worst driving condition [72] because mobile texting required more visual demands than a mobile conversation [73]. Drivers involved in texting while driving were associated with more crashes than drivers not engaged in texting [74–76]. Kim et al. (2013) [77] conducted a simulation study in which drivers were asked to drive for 2 minutes with a constant distance and speed (80 km/h or 100 km/h). Drivers only drove for the first minute. For a further minute, drivers just drove or performed an activity (driving + SMS) while driving. They found that, even for very experienced taxi drivers over the age of 50, performing extra tasks in unforeseen scenarios reduced the smoothness or skill of the driving action and increased braking time response, affecting thus safe driving performance. The authors found that the braking reaction time of drivers while texting was significantly longer than that of drivers who drove only for both driving speeds. The 100 km/h braking time was considerably longer than the 80 km/h condition. Similarly, Drews et al. (2009) reported that drivers were 0.2 s slower to respond to brake application while driving + texting than under driving conditions only. He et al. (2014) [78] also observed that the braking reaction time of drivers who drove only was considerably shorter than that under the condition of handheld mobile phone use.

Alosco et al. (2012) [74] found that the drivers' texting group exhibited more middle line crossings than the drivers without texting. Also, more road edge excursion was observed in the drivers' texting group when compared to the eating group and control group. Stavrinou et al. (2013) [76] revealed that distracted drivers, particularly texting, exhibited more lane deviations and greater fluctuation in speed, affecting traffic flow. He et al. (2014) [78] found that lane deviation under the drive-only condition was considerably smaller than driving with mobile phone use condition. Rumschlag et al. (2015) [79] found that mobile texting significantly increased lane deviation in a driving simulator.

He et al. (2014) [78] observed that drivers exhibited a significantly higher standard deviation of speed while texting. Recently, Morgenstern et al. (2020) [80] found that drivers reduced vehicle speed by 2 km/h when sending messages and picked up speed after completing the messaging task. This finding is consistent with the conclusion of Schneiderei et al. (2017) [81], who observed that drivers lowered their driving speed by about 0.50 km/h after starting messaging and increased their driving speed by about 1 km/h after they finished messaging.

Drews et al. (2009) [75] found that texting drivers exhibited larger variation in the following distance when compared to single-task drivers (driving only condition). The drivers involved in texting while driving sometimes increased their following distance and drove at a lower minimum following distance as compared to single-task drivers. In a simulation study conducted by Hosking et al. (2009) [82], drivers' variability in following distances to lead vehicles increased by up to 150 percent when they were texting messages while driving. Similarly, Choi et al. (2013) [83] also found that mobile phone use (e.g., messaging and searching direction) decreased the smoothness or skill of driving movement and increased vehicle's anterior-posterior and medio-lateral variability, impairing driving performance. Kim et al. (2013) [77] found that highly experienced taxi drivers exhibited increased horizontal variability of the vehicle while carrying out secondary tasks during unseen situations, resulting in more rear-end collisions with cars ahead. The results showed that the lateral variation in the driving with texting condition was considerably larger than that of the driving-only condition for both driving speeds. He et al. (2014) [78] observed that the standard deviation of gap distance for handheld phone use while driving was considerably more than that for hands-free phone use and drive-only conditions.

3.1.3. Answering

In a controlled laboratory experiment, Schattler et al. (2006) [60] found that the distractions produced by answering a call and conversing on a mobile phone considerably reduced driving performance. The findings revealed that when drivers used their cellphones while driving, average speeds were much slower, proportions of improper lateral placement were significantly greater, and the number of traffic crashes increased dramatically. Pouyakian et al. (2013) [84] observed that speed and headway were essential factors in deciding whether or not to accept or reject a phone call. When the headway distance was larger than 25 m, drivers were observed to receive phone calls more regularly than when the headway distance was 5 m and 15 m, respectively.

3.1.4. Browsing

Basacik et al. (2011) [85] observed that smartphone use for sending and receiving messages on social media increased reaction time by about 30%. It was also reported that drivers were unable to keep the vehicle at the centerline of the lane while browsing social media. Furthermore, it was also reported that the drivers drove at a more variable time headway because their ability to respond as rapidly to a leading car gradually altering speed decreased when browsing. McNabb & Gray (2016) [86] also observed that messaging and surfing social networking sites on mobile have an adverse effect on driving performance. They observed that brake reaction times and time headway were significantly greater in the texting conditions as compared to both the social media browsing (Facebook, Snapchat, Instagram) conditions and the baseline. Similarly, Hashash et al. (2019) [87] observed that texting took longer reaction times than browsing social media. The authors showed no significant influence of texting and browsing on average lane position variation, contrary to Basacik et al. (2011) [85].

3.1.5. Dialing and Emailing

Xiong et al. (2015) [88] observed that drivers drove slower under sparse traffic conditions while involving visual-manual tasks like emailing and dialing compared to baseline conditions; however, the maximum speed of the distracted drivers was slightly higher in dense traffic conditions.

These tasks (such as reading, texting, conversation, browsing, and emailing) influence the driver's visual and manual distraction level. Visual distractions, commonly found in most drivers, are distractions that pull the driver's eyes and focus off from the roadway, even if just for a few seconds. Visual distraction is measured by eyes-off-road duration time (EORT), frequency of eyes-off-road glance (EORG), and total eyes-off-road time (TEORT). EORT is the portion of time in which driver's eyes are away from the road in front of them, and TEORT is total measurement. Manual distraction [89] is when a driver becomes busy while operating a mobile phone with one or both hands during driving.

In a quasi-naturalistic study, Owens et al. (2011) [90] observed that handheld texting diverted drivers' attention away from the road more regularly and for longer durations of time, compromising vehicle control when compared to the baseline condition. McKeever et al. (2013) [91] illustrated that time required for mobile texting (118s) was almost twice the time taken by radio tuning tasks (the 60s) in a simulation study. It was reported that drivers get distracted for longer durations while messaging than when listening to the radio. Furthermore, a longer duration was observed in both 2-words and 5-words text messages, thus indicating an increased risk of distracted driving when texting. In another simulation study, Hashash et al. (2019) [87] found that secondary tasks such as messaging and surfing social networking sites significantly lowered visual focus on the road. Based on the number of fixations on the street, the results showed that drivers glanced away more from the road when surfing social media and much more when texting. Compared to no mobile use condition, a lower average fixation time during both texting and surfing indicated drivers had been no longer cognitively processing the surroundings and what's occurring in it as profoundly or very well during both conditions [87]. The results of a case-cohort approach by Simons-Morton et al. (2014) [92] revealed that driver's eye glance away from the forward roadway while using phone operations (like talking, texting, dialing, reaching, etc.) increased the likelihood of a crash and near-crash occurrence.

In a naturalistic study, Fitch et al. (2015) [93] found that drivers' mean percentage of TEORT increased while using a hand-held phone for texting and decreased while using the same phone for conversation, demonstrating that drivers checked out the forward roadway extra frequently. Through a driving simulator experiment, Jeong & Liu (2019) [94] found that drivers exhibited longer and more frequent eyes-off-road behaviors (i.e., higher % EORG and % EORT) on curved roads while performing secondary tasks. The authors reported that the drivers on sharper curved roads while performing non-driving-related tasks gave more and longer attention to the forward streets. According to Wang et al. (2020) [57], surfing, talking, messaging, changing phone location, and phone in hand were accounted for 98.8 percent of all secondary phone tasks in the study. These tasks affected the performance of drivers visually and manually. With 5662 incidents of eyes-off-road and an average EORT of 3.16 s, which is comparable to 22.82 m of driving recklessly at a speed of 26 km/h, phone use increased visual distraction to a higher level. This distraction was exacerbated by manual distraction because 17 percent of mobile use time was spent with both hands [57].

Christoph et al. (2013) [95] observed that the average duration of a manually distracted driver while using a mobile phone (31.0 s, SD=15.5) was substantially longer than that of the drivers who used a navigation system (20.9 s, SD=9.6). Kujala & Mäkelä (2018) [89] assessed how many times the drivers touched their phones in an hour and found that the average speed varied depending on the number of touches and the type of road.

3.2. Types of Mobile Phone Handsets

Törnros & Bolling (2006) [61] found that conversation via handsfree phones was not safer than conversation via handheld phones. It was reported that drivers reduced driving speed in all situations while having a handheld phone conversation. However, handsfree phone conversations slowed them down only in rural 90 and urban complex scenarios. This finding was in line with the results of Burns et al. (2002) [96] and Patten et al. (2004) [97] studies, who observed that driving speed reduced more when conversing with a handheld phone. One possible explanation is that drivers start underestimating the risk involved with a phone conversation when using a hands-free phone and thus do not adjust as much by reducing speed as they do when using a handheld phone. This finding was substantiated to some extent with the results of Benedetto et al. (2012) [58], who observed that minimum longitudinal distance (headway) between vehicles decreased under different types of roads (urban, rural, and motorways), especially if the mobile phone used was a hands-free type.

When a driver conversed with hands-free mobile, Saifuzzaman et al. (2015) [98] noticed a 0.33s increase in time headway and a 0.75s increase when a driver spoke with a handed phone. He et al. (2014) [78] found that driving performance was more impaired in the handheld texting condition when compared to speech-based texting condition. They found that handheld texting increased braking reaction time and large fluctuation in lane position and gap distance. Drivers who texted with a hand-held phone followed longer distances to the vehicle ahead and drove closer to the left

side of the lane boundary. Soccolich et al. (2014) [99] observed that drivers preferred to use handheld phones for conversation than hands-free phones because the drivers found hands-free phones to be less handy for secondary tasks like messaging and dialing. However, Ishigami & Klein (2009) [100] and Lipovac et al. (2017) [101] observed that performance measures while using a hands-free mobile were not notably better than those while using a handheld mobile. Similarly, Haque & Washington (2015) [62] observed insignificant variations in braking behavior between handed and hands-free mobile conditions. When approaching a pedestrian crossing, drivers who were distracted by handed mobile conversations required roughly 8% less time to reduce their starting speed to 20 km/h than drivers conversing with hands-free phones [62].

Fitch et al. (2013) [102] found that the drivers who used the handed phone while driving had more crash risk ($RR = 1.73$) than those drivers who used portable ($RR = 1.06$) or integrated ($RR = 0.57$) hands-free phones in on-road driving research. Li et al. (2019) [103] illustrated that drivers who used handheld mobiles took longer to apply brakes than those who used hands-free phones. They were also likely to be involved in a high crash risk group.

Some previous studies showed the effect of different mobile input interfaces on driving performance [67, 69, 104]. Reimer et al. (2014) [67] found that mobile with a keyboard interface had less influence on driving performance because tactile pushbuttons necessitate fewer looks away from the road. It was observed that the average number of looks longer than 1.6 seconds on the iPhone was 2.1 times that of the flip phone. Furthermore, it was found that the lane deviation was more significant when dialing the flip phone than when dialing the iPhone. Yannis et al. (2014) [104] found that crash probability increased for the drivers involved in texting with touch screen mobile phones while driving at a speed higher than the mean speed. However, Young et al. (2014) [69] observed that performance deteriorations were identical for both numeric keypad and touch screen phones.

3.3. Characteristics of Drivers (Age, Gender, and Driving Experience)

3.3.1. Age

Gras et al. (2007) [105] observed that younger drivers were involved more than older drivers in sending messages while driving. Lipovac et al. (2017) [101] conducted a literature review and found that younger male drivers used their mobiles more regularly while driving than women and older males. Tractinsky et al. (2013) [106] observed that experienced and older drivers initiated fewer phone calls when compared to young drivers because experienced drivers and older drivers were both sensitive to road type when initiating calls and to the context of the calls (incoming vs. outgoing). In contrast, Asbridge et al. (2013) [107] observed that mobile tasks less influenced younger drivers in terms of brake response time and cognitive deficiencies than older drivers. Compared to more experienced drivers, adolescent drivers were much less affected by texting distraction [79]. Liu & Ou (2011) [108] found that using hands-free mobile had a considerably significant impact on older drivers' performance (such as accuracy, reaction time, etc.) than younger drivers. Recently, it was observed that compared to the old group, distracted young drivers tend to drive comparatively faster and with smaller headway, consequently possessing a higher risk of an accident [63].

3.3.2. Gender and driving experience

Gender and driving experience were identified as significant driving performance indicators [76, 103, and 109]. In a field study, Hallett et al. (2012) [109] found that the average number of text messages sent by males while driving was higher than the numbers sent by female drivers. Compared to male drivers, Reimer et al. (2014) [67] observed that female drivers, who used flip phones, looked most of the time on the road and had a minimum probability of demonstrating long-duration off-road glances. Li et al. (2019) [103] observed that female and non-professional drivers had a higher probability of engaging in unsafe driving behavior than male drivers and professional drivers. However, the study carried out by Stavrinou et al. (2013) [76] revealed no significant variations in driving experience when involved in mobile phone use while driving. Rumschlag et al. (2015) observed that driver gender was not substantially connected with lane deviations while mobile texting.

3.4. Road Conditions and Environment

The impact of road and environmental factors on various driving performance measures was studied under different scenarios. The typical road conditions considered were urban roads, rural roads, and motorways, and environmental conditions were daytime and nighttime driving under clear and rainy weather. Yannis et al. (2014) [104] observed that mobile texting has an adverse effect on the driver's reaction time and speed of the vehicle on both urban and rural roadways in various weather situations. It was reported that speed reduction was higher on urban roads, and higher increased reaction time was on rural roads under all different environmental conditions (good weather, rainy condition, and night driving). Furthermore, compared to free driving, the risk of a crash was 2.9 times higher when reading the message and 8.3 times higher when writing a message on urban roadways. The respective crash probabilities for reading and writing messages were 1.4 and 1.5 times higher in the case of rural roads. Xiong et al. (2015) [88] observed that drivers were involved in fast driving during the day than at night, and they drove slower in medium traffic than in

scattered traffic scenarios when they were on the phone. Kujala & Mäkelä (2018) [89] observed that drivers' mean speeds on highways were proportionately greater than that on major, minor, and urban roads when they were using their phones. Christoph et al. (2019) [110] found that the duration of mobile phone use was substantially longer on motorways than that on rural roadways. It was also revealed that when a passenger was present, drivers utilized their cellphones less.

4. In-Built Vehicle System

The automobile has seen significant improvements in recent years. Many in-car technologies, such as vehicle navigation systems, wireless Internet capability, wireless messaging, and audio systems, have been implemented by vehicle manufacturers. Although the expansion of new in-vehicle technologies is undoubtedly concerning, several studies have shown that these facilities simultaneously distract drivers and degrade driving performance [e.g., 111-113]. Drivers get distracted while driving and are involved simultaneously in the operation of in-vehicle devices such as radio/audio systems [114-116], video/navigation systems [115], and wireless internet systems [113].

It was observed that drivers performed different secondary tasks due to many in-vehicle devices, and they were related to either visual, auditory, manual, or cognitive distraction [117–120]. Eye glance is one of the most often utilized indicators to analyze the distraction effect of in-vehicle secondary tasks, as eye glance data offers crucial information for better comprehension of the mechanism of driver attention associated with distraction [121–123]. Glance distractions demand a driver temporarily divert their focus from the road and do some auxiliary tasks at this time [116]. Young et al. (2012) [124] investigated the effects of music tasks on driving performance using eye glance behavior. They observed that doing music searches while driving caused drivers to glance away from the road for longer periods. This finding was substantiated to some extent to the results of [125], who found that distractions were frequently linked to poor driving performance as evaluated by eyes directed inside rather than outside the car. Similarly, Xian & Jin (2015) [113] found that receiving and sending an e-mail on iPad4 while driving caused drivers to glance away from the road for longer periods and reduced the ability of the drivers to keep a steady lane position. Recently, Li et al. (2019) [103] used Eco-Safe Human-Machine-Interface in a simulation study to explore drivers' gaze behaviors as measures of the distraction of drivers. The results demonstrated that such a driving system increased the eco-safe driving behaviors of the drivers while causing no visual distraction.

Young et al. (2012) [124] observed that using an iPod touch screen interface to search for music reduced lateral vehicle control (111 percent more lane excursions and 27 percent higher standard deviation of lane position). In a driving simulator study conducted in California, Salvucci et al. (2007) [126] observed a higher lateral lane deviation while engaged on music player tasks (like watching a video, selecting an item). However, the authors also reported no effect on lane position or vehicle speed while listening to songs. In a similar study, Crisler et al. (2008) [127] observed that the drivers struggled to keep their vehicles in proper lane position while controlling an iPod during driving. However, this iPod task caused significant variation in driving speed.

Furthermore, Chisholm et al. (2008) [128] found that the drivers had more substantial amounts of steering angle variability in the difficult iPod condition than in the baseline. This variation mainly occurred on freeways, followed by residential and urban roadways. Finally, Ma et al. (2018) [115] concluded that when driving task demands are high, all in-vehicle information systems, particularly the operation of visualized navigation systems and portable audio players, should be prohibited to reduce driver distraction. This is because the study's findings showed that if the visual scan range of the driver moves away from the road beyond a certain threshold, indicators of distraction, such as lane position deviation, lane departure, brake time, increase. Furthermore, they also concluded that in-vehicle distraction from 67% of the in-vehicle facilities was avoidable.

Choudhary & Velaga (2019b) [111] conducted a simulation study to examine the distracting effects of using a phone and a music player at unsignalized junctions to assess Indian drivers' driving performance. They observed that drivers' gap acceptance behavior deteriorated significantly due to the music player activities and that the results could be even worse because the drivers were unaware of the increased risk connected with the music player operation and did not compensate for the workload.

5. Sleepiness

Sleepiness/drowsiness is a typical symptom of sleep loss, which can be caused by acute or chronic, total or partial sleep deprivation, or interrupted sleep. Sleep deprivation has been linked to increased dangerous behavior, impaired decision-making, a decreased ability to adapt behavior quickly to changing environmental demands, and increased driver distraction during tedious work [129]. Sleepiness while driving increased the probability of a crash by 2.51 times [130]. Many researchers have examined the impact of the sleepiness factor on different aspects of driving performance, including Lateral position [131–133]; Speed [134–136]; Brake reaction time [137–139], and Time headway [140-142].

5.1. Lateral Position

Gillberg et al. (1996) [143] observed that professional drivers exhibited more fluctuation in lane position during night driving. Similarly, Lenné et al. (1998) [144] found that both professional and non-professional drivers' lateral positions of vehicles may be destabilized when they are drowsy. Sleepiness or fatigue increased to a higher level while driving on long monotonous roads/ long 'boring' stretches of road (such as motorways) [22]. Thiffault & Bergeron (2003) [132] used a steering wheel movement (SWM) analysis approach to analyze the effect of the monotony of roadside visual stimulation in a driving simulator study. They concluded that sleepiness caused drivers to respond slower to lane position deviations and with larger steering wheel movements. A similar finding was found in the study of Loon et al. (2015) [145], who used a high-fidelity driving simulator with a monotonous (night time) driving task. The authors observed that drivers resorted to more severe steering wheel angles for higher levels of sleepiness when the lateral position deviated further from the driver's mean. Recently, it was observed that the standard deviation of lateral position was increased when drivers were sleepy and after sleep compared to when drivers were alert [146].

Philip et al. (2005) [147] found that sleep restriction impaired driving performance (vehicle lateral control) even though 8 hours of wakefulness and 105 minutes of driving times were both quite short. After sleep restriction, overall line crossing increased from 66 to 535 crossings (Incidence Rate Ratio = 8.1). Anderson & Horne (2013) [131] conducted a pilot study whereby participants were instructed to drive in a driving simulator for two h during the diurnal afternoon drive after a previous night's sleep restriction of 5h. They observed that driving in the afternoon after a previous night's sleep restriction of 5h increased distraction level, resulting in more driving mishaps with at least two wheels off the carriageway. Jackson et al. (2013) [138] investigated the effect of 27h total sleep deprivation on different aspects of driving performance. Subjects were instructed to drive in the middle of the left-hand lane for 30 minutes with a speed of 60 to 80 km/h on a continuous 2-lane highway with a series of straight and curvy highways in the AusEd driving simulation test. The study found that when compared to regular sleep, lateral lane deviation was significantly impaired after 27h sleep deprivation. The percentage increase in lateral lane deviation was 25% in the sleep deprivation condition. In another simulation study, Howard et al. (2014) [137] observed a continuous and considerable increase in lateral lane position after subjects had been awake for 17 to 24 hours. The lateral lane position fluctuated throughout the day, with more alteration in the early afternoon and a gradual decline after midnight. Professional and non-professional drivers showed no differences in performance changes. Williamson et al. (2014) [133] observed that sleepy drivers were more than 9 times more likely to cross a centerline than those who evaluated themselves as an alert. The result of Pack et al. (2006) [148] showed that short sleep duration impaired commercial drivers' driving skills (lateral vehicle control). In contrast, Miyata et al. (2010) [139] found insignificant differences in the standard deviation of lane position for the road-tracking test and coefficient of variation of the car-following test between insufficient (<4h sleep) and sufficient sleep (> 8h sleep) conditions.

5.2. Speed

Jackson et al. (2013) [138] observed that speed variability was greatly affected following sleep deprivation compared to regular sleep in a simulation study. The percentage increase in speed variability was 43.4% after 27h sleep deprivation. The study results by Howard et al. (2014) [137] revealed a considerable increase in speed variability on a simulated driving task after subjects had been awake for 17 to 24 hours. The speed of the vehicle fluctuated throughout the day. There was a steady increase in speed variation after 17h of extended awake, with a 24.9 percent increase after 23h of awake compared to the first one. Professional and non-professional drivers showed no differences in performance changes. This finding was corroborated by Lenné et al. (1998) [144]. They observed that 36 hours of sleep deprivation severely impaired both inexperienced and experienced drivers' ability to keep a constant speed. The authors reported an increase in the standard deviation of the running speed when sleepiness occurred.

Aidman et al. (2018) [134] examined the effect of caffeine on the link between driving performance and sleepiness over a 50-hour sleep deprivation period. Subjects were asked to execute fifteen identical 40-minute driving assignments over the course of 50 hours and were advised to drive in the left lane at an average speed of 80 kilometers per hour. Subjects were randomly divided into the caffeine group (who received four dosages of caffeine chewing gum every two hours) and the placebo group (who received no caffeine chewing gum). Driver's sleepiness level was measured through Johns Drowsiness Scale (JDS) score. They found that in the placebo group, speed variability (km/h) increased with increasing sleepiness level and that while the same pattern was observed initially (up to JDS= 5) in the caffeine group, the rate of speed variability was noticeably lower than in the placebo group, with a paradoxical decline in speed variability observed above JDS =5.

5.3. Reaction Time

In a simulation study, Lenné et al. (1998) [144] observed that when compared to experienced drivers, inexperienced drivers took a longer time to apply vehicle break-ins in both sleep-deprived and non-sleep-deprived conditions. Philip et al. (2005) [147] conducted a naturalistic study on an open French highway, in which 22 healthy French males were

instructed to drive five identical 200 km sessions with a constant speed of 130 km/h on separated lanes motorway for 105 minutes (each session). It was reported that sleepiness (sleep restriction) combined with fatigue increased the reaction time of drivers, which might increase distractibility and driving incidents. This finding was validated in Jackson et al. (2013) [138]. When participants were sleep-deprived, they were considerably slower to brake in reaction to approaching trucks. Miyata et al. (2010) [139] investigated the impact of insufficient sleep (less than 4 hours) on driving performance in nineteen healthy Japanese adults. They observed that in the harsh-braking test, the brake reaction time was considerably longer after insufficient sleep (less than 8 hours of sleep) than it was after sufficient sleep (> 8 hours of sleep). Furthermore, the authors reported that one night of insufficient sleep harmed the subjects' daily cognitive function and driving performance. Howard et al. (2014) [137] observed that drivers' response time to apply break increased in the Psychomotor Vigilance Task test after subjects had been awake for 17 to 24 hours.

5.4. Time Headway

In an epidemiological study, Åkerstedt et al. (2001) [141] described that rear-end accidents occurred when the distance between two vehicles deteriorated due to falling asleep. The same result was found in a study conducted by Abe et al. (2010) [140]. Zhang et al. (2016) [142] investigated the performance of a driver's car-following behavior when drivers were under the influence of sleepiness or fatigue. They found that sleepy driving significantly affected performance measure time headway. The study results indicated that at high fatigue levels, drivers decreased headway distance, i.e., drivers followed the leading vehicle at a lower time headway, and the minimum time headway maintained during car following was also closer to the leading vehicle.

5.5. Duration of Driving Time

The duration of driving time was associated with impaired driving performance, leading to traffic accidents. Ting et al. (2008) [136] conducted a 90-minute simulator driving test in which participants were instructed to keep a constant speed of 100 km/h and car-following distance by 50 meters. The results of the study indicated that progressive increase in sleepiness due to long driving duration made the vehicular operation more unstable which, in turn, adversely affected driver control of steering and speed regulation. Further, the performance index score decreased over time, indicating that prolonged driving increased the likelihood of a crash. Furthermore, the authors observed that 80 minutes of monotonous highway driving was the safe limit. Sagaspe et al. (2008) [149] found that self-rated sleepiness score was positively connected with driving impairment in four hours and eight hours sessions in an actual driving experiment. Inappropriate line crossings, in particular, increased with time as a result of continual actual driving. In another simulator study, Davenne et al. (2012) [150] concluded that inappropriate line crossing increased with the increasing duration of driving. In other words, the drivers had difficulty maintaining the vehicle in the right lane when sleepiness increased, mainly at the end of the 8-h driving session. Aidman et al. (2018) [134] found that in the placebo group, performance measures (lane keeping and speed maintenance) decreased with each subsequent drive, with a faster reduction within each drive. Compared to the placebo group, the caffeine group had a smaller decrease in lane maintaining and speed maintenance ability (both between and within drives).

Many previous studies had illustrated that sleep-related-driving causes deteriorations comparable to those caused by prescribed blood alcohol levels [151-153]. Dawson & Reid (1997) [152], using a tracking task, established equivalences between decrements in performance produced by alcohol and by sustained wakefulness (sleep deprivation). They found that 17 hours of sleep deprivation resulted in cognitive, psychomotor performance (CPP) impairments comparable to those seen in 0.05 percent blood alcohol concentrations (BAC). CPP performance decreased to the same level as that of a 0.10 percent BAC after 24 hours of awake. Subsequent studies using psychomotor tests [155, 156], driving simulators [151], and closed-course driving [154] had confirmed these findings. Williamson & Feyer (2000) [155] observed how sleep deprivation and alcohol affected driving performance. Sleep deprivation of 17 to 19 hours had an impact on the performance that was comparable to or worse than when the blood alcohol level was 0.05 percent. Respondents who had consumed alcohol responded 50 percent slower, and accuracy was also worse. This finding revealed that driving performance, like speed, could be impaired by sleep deprivation. Arnedt et al. (2000) [151] observed that 20 hours awake and 0.08 percent BAC alcohol drinking resulted in identical magnitudes of impairment in simulated driving performance. It was also observed that combining prolonged wakefulness with alcohol use resulted in higher impairments in simulated driving ability than either condition on its own. Powell et al. (2001) [154] compared the risks of drowsy driving and alcohol-impaired performance. Although the study's overall findings could not be extrapolated, the model revealed that driving while sleepy poses a threat that was at least as harmful as driving while intoxicated. Falleti et al. (2003) [157] investigated cognitive impairment after 24 hours awake and a blood alcohol concentration of 0.05%. They found that fatigue from sleep (24 hours of sustained wakefulness) had a greater impact on the speed of continuous attention, memory, and learning and the accuracy of complex matching than alcohol. These findings were in line with those of Lamond & Dawson (1999) [158], who found that exhausted drivers (those who had been awake for more than 22 hours) had a slower rate of continuous attention than those with a BAC of less than 0.05 percent.

6. Summary and Future Research Direction

Except for Megías et al. (2011) [42], who reported that static billboards with negative valence impaired the reaction time of motorcycle riders, all studies investigated the effect of different types of billboards on various driving performance measures using only one type of vehicle, namely, car. Therefore, further studies may be conducted on a variety of road users, such as motorcycle riders and pedestrians and their relationships. Further research can also be carried out considering environmental conditions and driver gender, as the results of available limited studies have shown conflicting results. Sheykhfard & Haghighi (2019) [32] observed that drivers were found to be more distracted at night and when the weather was not clear than during the day and when the weather was clear. Whereas the results of Dukic et al. (2013)'s [35] study showed minor variations between daylight and nighttime driving in the presence of digital billboards. Olejniczak-serowiec et al. (2017) [31] showed that men get more distracted than women in the presence of billboards with sexual content. In contrast, the results of Misokefalou et al. (2016)'s [34] study indicated that gender differences were not statistically significant.

Mobile-related tasks include conversation, texting, dialing, navigation, checking email, browsing social media, and playing music. Most of the studies focus mainly on conversation and texting tasks. The effects of ringing, browsing/internet, navigating, and dialing tasks on driving performance have received little attention. Further study is needed on the lateral lane position parameter of driving performance because most of the literature has shown conflicting and inconsistent results in the case of a phone conversation task. For example, some studies have shown less standard deviation of lane position [66, 67], some studies show more lane deviation [64, 65], and some results have shown a negligible difference in lane position [68, 69]. Due to the lack of consistent results and limited research on demographic variables (such as age, gender, and driving experience), there is an obvious need for more in-depth research considering various secondary tasks of mobile use. Although many studies have been conducted to investigate the impact of different road environments (such as rural, urban, freeway, day and night driving, clear and rainy weather) on distracted driving due to mobile phone use, specific driving contexts such as intersections need further research.

The results of many studies based on distracted driving due to in-built vehicle systems have shown consistent trends in terms of lane deviation, eye glance behavior, and reaction time. However, most of the studies considered in this review study have adopted the simulation (laboratory) approach. Despite its popularity in distraction-related research, the simulation study has some drawbacks in terms of ecological validity and driver arrangement. Therefore, it is suggested to carry out more research using the data collected through naturalistic studies to overcome these limitations. Furthermore, while some research has focused on the effects on some driving performance measures (like reaction time and lateral control) [115, 124], research on other driving performance measures, such as headway and speed, is lacking. This is an area that could be investigated further in the future.

The majority of previous studies have looked at the impact of distracted driving due to sleepiness factors on various driving performance parameters such as lane position, speed, time headway, and reaction time and have shown consistent results. But none of these studies considered in this review had examined the effect of the sleepiness factor on performance measures like gap acceptance and duration of eye closure. Therefore, considering these parameters using a naturalistic approach, further research can be conducted. Notably, more study is needed to evaluate the full effect of sleepiness on driving performance. In addition, the investigation may include a broader range of participants.

From the literature review, it is evident that many studies are from developed countries like the USA and European countries. It is yet to examine thoroughly the effect of these four distracting factors on driving performance in developing countries like India, where activities like installing billboards and mobile phone use population are increasing day by day due to the rapid urbanization of major cities of the country. Therefore, the studies may be carried out in this direction also. In addition to the above-mentioned distracting factors, other factors such as passengers' presence, alcohol, and drug consumption also need to be examined and reviewed.

7. Conclusions

Some of the key findings of this study are outlined below:

- Billboards' presence along roadways causes visual distraction to drivers, affecting driving performance. The drivers spent significantly more time staring off-road when the billboards were visible. Digital billboards cause drivers to be more distracted than static billboards. The location and content display on the billboard increase reaction time and decrease the driver's ability to control the vehicle. In addition, the driver's visibility decreases with an increase in the illumination level of the billboard.
- Mobile phone use while driving (especially mobile texting tasks) causes cognitive distraction and visual-manual distraction for drivers, impairing driving performance, such as increased reaction time, reduced lane-keeping capacity, and higher speed variation. Generally, drivers reduce driving speed while performing any secondary tasks (texting, answering, browsing, dialing, etc.) using mobile and increase headway to compensate for the workload imposed by these tasks.

- While performing in-built vehicle system tasks (such as searching for songs, listening to songs, and watching videos), drivers are involved in auditory distraction and manual distraction, which force them to glance away from the road for longer periods. Lateral vehicle control is compromised when drivers engage in searching for songs or videos on music players. The driver's gap acceptance behavior deteriorated significantly as a result of the music player's activities.
- Sleepiness causes drivers to respond slower to lane position deviations and larger steering wheel movements. Drivers exhibited a higher standard deviation of speed and decreased headway distance when sleepiness occurred. Further, the impact of sleepiness on driving performance is comparable to the decrements in performance produced by alcohol.

Overall, it is concluded that these distracting factors have a detrimental effect on driving performance.

8. Declarations

8.1. Author Contributions

Conceptualization, N.G.S.; methodology, N.G.S.; writing—original draft preparation, N.G.S.; writing—review and editing, D.P.; supervision, D.P. All authors have read and agreed to the published version of the manuscript.

8.2. Data Availability Statement

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

8.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

8.4. Conflicts of Interest

The authors declare no conflict of interest.

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Appendix I

Table A1. Summary of studies on the effect of Billboards on driving performance

Author and Country	Study	Participants	Considered Parameters	Key findings
Smiley et al. (2005) [159], Canada	Naturalistic	16 drivers (age 25-50)	Glance behavior, Headway	Compared to static billboards, glances at video signs were related to a longer headway.
Lee et al. (2007) [160], USA	Naturalistic	36 drivers (18 male, 18 female) [younger age:18-35 and older age:50-75]	Glance behavior, Speed, Lane deviations	Longer looks in the direction of electronic billboards. Higher speed variation due to billboards. More lane deviations due to the presence of digital and static billboards,
Dukic et al. (2013) [35], Sweden	Naturalistic	41 drivers (Age 35-55)	Gaze behavior	Electronic billboards attracted more glances than road signs.
Belyusar et al. (2016) [7], USA	Naturalistic	123 drivers (younger age: 20-29 and older age:60-69)	Glance behavior	Numerous glances towards Digital billboards had a duration greater than 2 sec.
Stavrinos et al. (2016) [24], USA	Simulation	66 drivers (Young: 16-19; Middle: 35-55, Older: ≥ 65)	Glance behavior	It was confirmed that billboards did not affect glance pattern activity.
Young et al. (2017) [13], Australia	Naturalistic	19 drivers (12 male, 7 female) [age:22-47]	Situation Awareness	Static billboards had little effect on the structure or content of drivers' situation awareness.
Mollu et al. (2018) [17], Belgium	Simulation	35 drivers (19 male, 16 female) [age 22-66]	Glance behavior, speed, reaction time	More eye glances in brief billboard message display times. In the presence of a digital billboard, brake reaction time increased by 1.5 times.
Meuleners et al. (2020) [8], Australia	Simulation	96 drivers (Age 18-76)	Speed, lane deviation, headway, gaze fixation	Complex content with short dwell time impaired driving performance
(Sheykhfard & Haghighi (2019) [32], Iran	Naturalistic	78 drivers (42 male, 36 female) [age 15-65]	Distraction	Drivers were more distracted during the weekend than on weekdays.

Table A2. Summary of studies on the effect of Mobile phone use on driving performance

Author and Country	Study	Participants	Considered Parameters	Key findings
Alm & Nilsson, (1995) [161], Sweden	Simulation	40 drivers, (30 male, 10 female)	Reaction time, headway, lateral position	Older drivers took a longer reaction time than younger drivers when they used mobile while driving.
Patten et al. (2004) [97], Sweden	Naturalistic	40 drivers (32 male; 8 female) [Age: 21-60]	Reaction time	The driver's reaction time increased considerably when engaged in a phone conversation while driving.
Tornros & Bolling (2005) [162], Sweden	Simulation	48 drivers (Age: 24-54)	Lateral position	higher lane deviation while dialing and less lane deviation while conversing
Yannis et al. (2010) [163], Greece	On-Road	37 drivers (26 male; 11 female) [Age:18-25]	Speed and headway	Speed reduced, and headway increased during phone use
Backer-grøndahl & Sagberg (2011) [164], Norway	Survey	9314 drivers	Crash risk	Drivers had a higher probability of crash when using a handheld phone than that of hands-free one.
Owens et al. (2011) [90], USA	On-Road	20 drivers (Age: 19-51)	Reaction time, glance	Older drivers spent more time texting on their phones and looked inside for longer periods.
Al-darrab et al. (2009) [165], Saudi Arabia	Naturalistic	27 drivers (Age:22-24)	Reaction time	The driver took a long time to apply the vehicle brake when they spent more time on a phone conversation.
Negulescu et al. (2012) [166], Canada	On-Road	12 participants (8 male, 4 female) [22-36]	Total Eyes of Road Time (TEORT)	While texting, TEORT increased four times.
Rudin-Brown et al. (2013) [167], Australia	Simulation	24 drivers (Age: 25-50)	Speed, lane position	Speed reduced and lane deviation increased in tunnel compared to the freeway while performing texting task
Haque & Washington (2013) [168], Australia	Simulation	32 drivers (Age: 21-26)	Reaction time,	The driver's reaction time was increased more than 40% when distracted.
Klauer et al. (2014) [114], USA	Naturalistic	151 drivers (86 male, 65 female) [Age: 16-72]	Crash risk	While performing secondary tasks in mobile, the danger of crashing increased.
Tivesten & Dozza (2014) [169], Sweden	Naturalistic	49 drivers	Speed, glance behavior	While performing visual-manual phone tasks (texting, dialing, reading), drivers had longer off-road glances.
Young et al. (2014) [69], Australia	Simulation	24 drivers, (12 male; 12 female) [Age: 25-50]	Speed, lane deviation, eyes-off-road time	Drivers spent 29% less time looking at forwarding roadway while mobile texting
Yannis et al. (2014) [104], Greece	Simulation	34 drivers (19 male; 15 female) [Age: 18-28]	Speed, reaction time	Decreased mean speed and increased mean reaction time due to mobile texting led to an increased crash probability.
Stavrinos et al. (2015) [170], USA	Simulation	22 drivers (11 male, 11 female) [Age: 16-18]	Lane position	Texting while driving increased variability of lane position.
Thapa et al. (2015) [73], USA	Simulation	36 drivers (30 male; 6 female)	Speed, lane deviation	Considerable lateral lane deviations from texting persisted for an average of 3.38 seconds after texting was stopped.
Papadakaki et al. (2016) [171], Greece	Simulation	50 drivers	Steering position, lateral lane position	Text-message reading and messaging had a considerable impact on steering position.
Choudhary & Velaga (2017b) [172], India	Simulation	100 drivers	Reaction time	Mobile conversation and texting increased drivers' reaction time in both pedestrian and rod crossing events.
Yan et al. (2018) [173], China	Simulation	30 drivers, (19 males and 11 female) [Age: 22-33]	Reaction time, speed, time headway	With an increase in the complexity of the mathematical computation task in mobile, the driver's brake reaction time increased.

Jeong & Liu (2019) [94], USA	Simulation	24 drivers (16 male, 8 female) (Age: 19-31)	Lane keeping, eye movement	Drivers could not keep a steady lateral lane position on severe bend roads when distracted by a mobile phone.
Zhang et al. (2019) [174], China	Naturalistic	60 drivers (Age: 35-50)	Lane deviation, Speed	Drivers exhibited higher lane deviation while texting. Drivers slowed down the vehicle while answering and dialing.
Kreusslein et al. (2020) [175], Germany	Naturalistic	3500 drivers	Eye glance behavior	Longer means off-road glances due to mobile dialing and searching for contacts tasks.

Table A3. Summary of studies on the effect of in-built vehicle system on driving performance

Author and Country	Study	Participants	Considered Parameters	Key findings
Sodhi et al. (2002) [116], Spain	Naturalistic	25 drivers (16 male, 9 female)	Gaze behavior	Longer off-road fixation durations were reported in radio tuning and rear-view mirror checking activities.
Stutts et al. (2005) [125], USA	Naturalistic	70 drivers (35 male, 35 female)	Steering wheel, eye glance, lateral vehicle control	A higher percentage of drivers did not have their hands on the steering wheel while handling in-built vehicle systems. While operating in-built vehicle systems, more eyes glance inside the car rather than on the road, and lanes change frequently.
Chisholm et al. (2008) [128], Canada	Simulation	19 drivers (10 male, 9 female) [age 18-22]	Glance behavior	Difficult iPod tasks (those requiring more than two steps) were linked to increases in the car's duration and the number of glances.
Young et al. (2012) [124], Australia	Simulation	37 drivers (age-18-48)	Eye fixation, Lateral vehicle control, headway	While looking for songs, drivers spent 2.5 times longer looking away from the road. An increment of 0.4s was observed in the standard deviation of time headway while engaged in the iPod tasks.
Klauer et al. (2014) [114], USA	Naturalistic	151 drivers, (86 male, 65 female) [age 18-72]	Crash risk	Compared to experienced drivers, novice drivers exhibited a higher probability of crash while engaged in the adjustment of radio and HVAC.
Xian & Jin (2014) [113], China	Simulation	18 drivers (20-31)	Eye fixation, vehicle control, completion time	Drivers spent 2.41 times longer looking away from the road when engaged in e-mail tasks.
Dingus et al. (2016) [112], USA	Naturalistic	3542 drivers (age 16-98)	Crash risk	The chance of crash increased when dealing with in-built vehicle systems (the radio, music player, and air conditioning).
Choudhary & Velaga, (2019a) [176], India	Simulation	74 drivers (age-18-53)	Drivers' stop/cross decisions at signalized intersections.	The probability of crossing an intersection was lower while performing the music player tasks than while conversing on the phone.
Choudhary & Velaga (2019b) [111], India	Simulation	81 drivers	Gap acceptance, accepted lag, maneuver completion time.	The use of a music player while driving increased the gap acceptance rate while not influencing the acceptable lag or maneuver completion time, implying a higher crash risk.

Table A4. Summary of studies on the effect of Sleepiness on driving performance

Author and Country	Study	Participants	Considered Parameters	Key findings
Gillberg et al. (1996) [143], Sweden	Simulation	9 drivers	Speed, lane position, reaction time	Night driving was slower with higher speed variability
Arnedt et al. (2001) [177], Canada	Simulation	18 drivers (Male, Age-19-35)	Lane position, speed, off-road occurrence	Driving performance dropped to the same level as that of a BAC of 0.05 percent and 0.08 percent after 18.5 and 21 hours of awake, respectively.
Hack et al. (2001) [153], UK	Simulation	50 drivers	Reaction time, off-road event	Impairment degree of steering performance by 24 h without sleep and blood alcohol levels was same.
Akerstedt et al. (2005) [178], Sweden	Simulation	10 drivers (5 male, 5 female)	Lane position	Deviation of the lateral position of the vehicle increased from 18 to 43 cm when driving home from a night shift.
Anderson & Horne (2006) [179], Australia	Simulation	16 drivers (8 male, 8 female) [Age:21-25]	Reaction time	Sleepiness (5h sleep restriction) enhanced distraction during a Monotonous Task.
Vakulin et al. (2007) [180], Australia	Simulation	21 drivers (age:18-30)	Steering deviation, breaking reaction time	When 4 hours of sleep deprivation was paired with a 0.035g/dL dose of alcohol, steering deviation increased considerably.
Jackson et al. (2008) [181], Australia	Simulation	19 drivers (18 male, 1 female)	Reaction time, driving errors	Professional drivers took longer reaction time and increased errors of emission after 27h sleep deprivation.
Abe et al. (2010) [140], Japan	In-depth crash investigation	1772 drivers	Headway, driving duration	The likelihood of a rear-end collision was substantially linked to a sleep duration of fewer than 6 hours and an increase in driving spells.
Anderson & Horne (2013) [131], Australia	Simulation	8 drivers, (age: 20-26)	Lane drift	A five-hour sleep the night before an afternoon drive increased long distractions by 4 times.
Aidman et al. (2018) [134], Australia	Simulation	11 drivers (6male, 5female; Age:18-28)	Lane position, speed	Over 50 hours of sleep deprivation, drivers in both the placebo and caffeine groups (up to JDS=5) reported significant fluctuation in lateral lane position.
Anund et al. (2018) [182], Sweden	Naturalistic	18 drivers, (9 male, 9 female)	Reaction time	The Psychomotor Vigilance Task response time increased with split shift working.
Caponecchia & Williamson (2018) [183], Australia	Simulation	45 drivers	Lane deviation, percent of the time spent speeding	Performance impairments were most evident in the morning for those with 2h sleep deprivation