Highlights of Vehicles

ISSN 2696-8347, A Peer-Reviewed Open Access Journal by Highlights of Science
https://www.hos.pub/ho/vehicles

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Cite this Article

Javid, R., Sadeghvaziri, E., & Jeihani, M. (2023). A Driving Simulator Study to Understand the Impact of Cell Phone Blocking Apps on Distraction. *Highlights of Vehicles*, *1*(1), 17–28. https://doi.org/10.54175/hveh1010002

Highlights of Science

Publisher of Peer-Reviewed Open Access Journals
https://www.hos.pub
Barcelona, Spain

Article

A Driving Simulator Study to Understand the Impact of Cell Phone Blocking Apps on Distraction

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Abstract Using cell phone blocking apps is an effective way to prevent distracted driving. This study used a high-fidelity driving simulator to examine drivers' behavior while using a cell phone blocking app. Thirty-five participants drove in a simulated network under four scenarios. Participants also completed pre- and post-survey questionnaires. The results support previous investigations regarding interactions with phones while driving. Results showed that drivers deviated from the center of the road, changed lanes significantly more often, and increased their steering velocity when drivers were interacting with a cell phone. The impacts of cell phone blocking apps were similar to the no distraction scenario while driving. This suggests that using cell phone blocking apps is one of the most effective ways to prevent distracted driving. Survey results indicated that only 23% of drivers used cell phone blocking apps before the experiment. However, 88% of the participants had a positive opinion about using these apps and indicated that they would use such apps after the experiment. These findings support the importance of cell phone blocking apps from a policy perspective and highlight the need to educate drivers about distracted driving prevention technologies.

Keywords distracted driving; cell phone blocking app; distracted driving prevention

1. Introduction

Distracted driving is one of the main causes of traffic fatalities around the world [1]. It also accounts for 40% of all crashes in the United States (U.S.). In 2020, 3142 people were killed, and 324,652 were injured in motor vehicle crashes as a result of distracted drivers in the U.S. [2]. Distractions on the road are mainly categorized into three types: manual, visual, and cognitive. Some of the top driving distractions while driving include cell phone use, being lost in thought, smoking, grooming, eating, drinking, attending to pets or objects moving inside the vehicle, and focusing on something outside the vehicle [3]. Although cell phones might help by supplying traffic data [4–6], one of the most alarming and dangerous distractions while driving is cell phone use, particularly texting while driving, which combines all three categories of distracted driving (manual, visual, cognitive) and increases the possibility of distraction [3,7,8]. According to the National Highway Traffic Safety Administration (NHTSA), drivers remove their eyes from the road for roughly five seconds when they read or type a text [3].

Previous research has identified several factors that may contribute to cell phone use while driving such as age, gender, education, etc. [9]. However, cognitive biases related to the overestimation of one's own capabilities or conspiracy beliefs about cell phone while driving could also impact cell phone use while driving [10].

The results of an online survey study related to distracted driving conducted in 2020 in the U.S. showed that 41% of all drivers texted, 32% read emails, 29% read social media, and 36% accessed the internet while driving. Compared to 2010 or 2015, more drivers reported engaging in each task in 2020 [11]. Another study from 2021 reported that, on average, 47.7% of American drivers admitted to engaging in activities with a cell phone while driving [12]. Many states in the U.S. have passed legislation that bans the use of cell phones while driving. For instance, 24 states have banned handheld cell phone use, 48 states have banned texting while driving, and 20 states have banned all cell phone interaction while driving [13]. Penalties can range from $20 to $1000 depending on the state and can even carry a misdemeanor offense in states like Alaska

Received: 7 March 2023
Accepted: 3 June 2023
Published: 8 June 2023

Academic Editors
Elżbieta Macioszek, Silesian University of Technology, Poland and Kevin Heaslip, University of Tennessee, USA

and Iowa [14]. However, the attempts to outlaw cell phone use while driving have not always been successful, and the effects of the bans frequently faded over time [15–17].

There are many ways to limit cell phone interactions while driving, and technologies like cell phone blocking apps offer possibilities for safer communication while driving. When a person is presumed to be driving, cell phone blocking apps detect how fast they are moving and will silence text and phone alerts above 15 mph. Other apps enable users to compete for the safest driving experience or receive insurance discounts for lowering their risk while driving thanks to telematics systems [14]. More advanced apps send out alerts through text or email with useful details for the parents of young drivers [18]. With the simple command, "read my text messages", most cell phones will now read texts aloud, and most keyboards now feature a voice-to-text feature that enables users to speak their texts into the cell phone rather than typing them. However, it should be kept in mind that using voice-to-text technologies while driving can still be dangerous [14]. Cell phone blocking apps may be classified into three groups, according to Albert et al. (2016): blocking apps, apps that show fewer distracting interfaces by enabling "eyes on the road; hands on the wheel" and driving feedback and coaching apps [19].

Many studies have investigated the impacts of cell phone use on drivers' crash risk [1,20–22], and many studies used driving simulators to investigate driving behaviors [23–28].

The state of the art of this study is that it evaluates the effectiveness of a specific cell phone blocking app in reducing cognitive distractions while driving. While previous studies have examined the effects of various distraction mitigation strategies, such as infotainment lockouts or interrupting non-driving tasks [29–31], our study focused specifically on the use of a cell phone blocking app and its impact on driving behavior and safety. Additionally, our study utilized a driving simulator, which allows for controlled and repeatable conditions, enabling us to gather detailed data on driving performance metrics and behavior. By doing so, this research addresses an important gap in the literature. The goal of this study is to investigate drivers' attitudes and behaviors while using a cell phone blocking app using a driving simulator. To reach this goal, four different scenarios were performed on a driving simulator to compare no distraction, texting and driving, driving while interacting with a cell phone, and driving with an activated cell phone blocking app.

2. Background

According to previous studies, distractions can occur for different reasons. Drivers can be distracted by outside objects such as roadside events [32], advertisements [33–35], digital billboards [36], the built environment [37,38], etc. Moreover, in-vehicle distractions include talking and interacting with other passengers [39], eating or drinking, radio tuning [40], and interacting with wearable devices such as Google Glass [41] and smartwatches [42,43]. Cell phone-related distractions include hands-free [20], handheld, texting, using voice messaging apps [44], social media, GPS [20,45], taxi-hailing applications [46], etc. Interacting with a cell phone remains one of the most distracting behaviors which drivers engage in [20]. There has been significant research on the association between driving safety and the use of cell phone devices. Previous studies suggest that cell phone use while driving is a deeply rooted behavior for many drivers [47]. Moreover, cell phone use while driving can cause behavioral changes, undermining vehicle control, causing drivers to move at a lower speed [48], and increasing the number of lane deviations [25,49].

There are many ways to prevent distracted driving. Laws banning the use of cell phones behind the wheel are the most common and popular solution to this problem. However, studies in this regard have shown that legal penalties have little effect on the frequency of self-reported phone use while driving. Another interesting finding from a study compared insurance claim rates in areas with and without the restrictions and found that crashes do not decrease as a result of handheld cell phone or texting bans [50,51]. These studies suggest that distracted driving prevention programs that concentrate on teen drivers, parents, and passengers are still needed. The goal of these programs is to raise awareness about the risks associated with distracted driving; offer parents, youth, and educators best practices and resources to set expectations about distracted driving; and identify the best ways to leverage different media platforms to reach the audience with messages or interventions [52,53].

Cell phone bans and distracted driving campaigns are two ways to help prevent distracted driving. Based on the findings of the previous research, however, it is clear that there is still a need for alternative methods to control cell phone use while driving. One option is to adopt technologies that prevent cell phone interactions while driving. One study proposed that cell phone blockers are a new countermeasure with the potential to limit distraction from cell phones [47]. Indeed, a variety of cell phone applications have been invented to avoid dangerous phone behaviors by drivers. A study conducted by Oviedo-Trespalacios et al. (2019) provided a review of the smartphone applications developed to prevent distracted driving. They found a total of 29 relevant applications, most of which focused on blocking specific phone functions (e.g., texting or calling). The focus of the applications was on limiting particular phone features rather than controlling workload or simplifying particular phone tasks while driving [21].

Another study investigated cell phone use among teen drivers while using cell phone blocking software. The results indicated that blocking applications could successfully mitigate novice teen drivers from calling, texting, or using other phone applications while driving [54]. In addition, a 2020 survey by Reagan and Cicchino investigated the use of cell phone blocking software while driving, and found that only 20.5% of drivers, according to their analysis, have a specific cell phone blocking program configured to activate automatically. Additionally, users of these apps were also less likely to admit to using their phones while driving [47]. Moreover, a naturalistic study with 167 young drivers found that when they installed a research-focused smartphone app and turned on “soft blocking” while driving, the average number of screen touches decreased by about 20% [55].

Other studies have looked at drivers’ perceptions of cell phone blocking software that prevents the use of cell phones while driving and becoming distracted. Some drivers were more willing than others to utilize a hands-free technology like Bluetooth to speak commands to the cell phone, and survey results showed that women were far more inclined to download and activate these types of apps [56]. Moreover, another study using a mixed-method approach examined the use of optional applications to minimize distracted driving. The results showed that using these applications significantly reduced engagement in visual-manual, cognitive-auditory, and music mobile phone experiences [57]. Furthermore, a study investigated whether cell phone blocking technology is an effective and acceptable method for reducing distracted driving among drivers of corporate fleet vehicles. The results suggested that phone blocking solutions might offer a practical way to change driving-related cell phone use behavior behind the wheel; however, the reliability and usability of the products need to improve to reach higher rates of acceptance among this cohort of drivers [50]. On the other hand, Oviedo-Trespalacios et al. (2019) also noted that cell phone blocking technology might not be attractive to drivers who view their cell phones as a necessity. Thus, some drivers are unlikely to use these voluntary cell phone apps [21].

In conclusion, the review of the literature suggests that using cell phone blocking apps is one of the most effective ways to prevent distracted driving. Results showed that using these applications significantly reduced interaction with a cell phone while driving. However, to the best knowledge of the authors, no study evaluates the impacts of the use of cell phone blocking apps on driver behavior and safety using a driving simulator.

3. Methodology

3.1. Ethics Statement

The research team conducted an IRB-approved driving task (IRB#22/09-0169). The purpose of IRB review is to assure, both in advance and by periodic review, those appropriate steps are taken to protect the rights and welfare of humans participating as subjects in the research. To determine the impacts of their experiences on their driving behaviors, participants were asked first to sign a consent form to complete a pre-survey questionnaire, drive for approximately ten minutes in various simulated scenarios, and then complete a post-survey questionnaire.

3.2. Participants

For this study, participants were recruited from Morgan State University and the Baltimore metro area via flyers containing an outline of the study’s details distributed manually and online. All participants were required to hold a valid driver’s license, drive on a regular basis, and own a smartphone. After eligibility checks, potential participants were scheduled to drive in a simulated environment. Eventually, thirty-five licensed drivers drove in the simulator under several scenarios, which will be explained in the following sections.

Table 1 shows the results of the pre-survey questionnaire. The results show that 51.4% of the participants were male, and 48.6% were female. The age group of participants was between 16 and over 65 years old, 28.6% of which were between 16 and 24 years old.

Table 1. Results of the Pre-survey.

Variable		Frequency	Percentage
Gender	Male	18	51.4%
	Female	17	48.6%
Age Group	16 to 24	10	28.6%
	25 to 34	8	22.9%
	35 to 44	8	22.9%
	45 to 54	3	8.6%
	55 to 64	2	5.7%
	More than 65	4	11.4%
Education Status	Less than high school graduate	0	0%
	High school graduate, including GED	5	14.3%
	Some college or associate degree	7	20%
	Bachelor's Degree	3	8.6%
	Graduate or professional degree	20	57.1%
Race	Black or African American	23	65.7%
	White	10	28.6%
	Asian	1	2.9%
	Hispanic or Latino	1	2.9%
	Unemployed	9	25.7%
Using any distraction prevention technologies before this experiment	Yes	8	22.9%
	No	27	77.1%

3.3. Process

The research team conducted the IRB-approved driving task. To determine the impacts of their experiences on their driving behaviors, participants were asked to complete a pre-survey questionnaire, drive for approximately ten minutes in various simulated scenarios, and then complete a post-survey questionnaire. First, the observer asked the participants to increase the volume of their cell phone's ringer volume up loud and have it nearby. The observer also made sure that the participants knew how to activate the "Do Not Disturb (DND)" while driving on their cell phone settings. The observer then gave the participants a brief description of the simulator to familiarize them with its environment. They also went through the procedure before driving. To evaluate driver performance during cell phone usage, participants completed the scenarios in a driving simulator which used three 40-inch LCD panels to exhibit the simulation. Participants sat in the driver's compartment of the simulator, which offered a view of the road and dashboard instruments such as a speedometer (Figure 1). Realistic engine noises, road noises, and passing traffic sounds were provided as well.

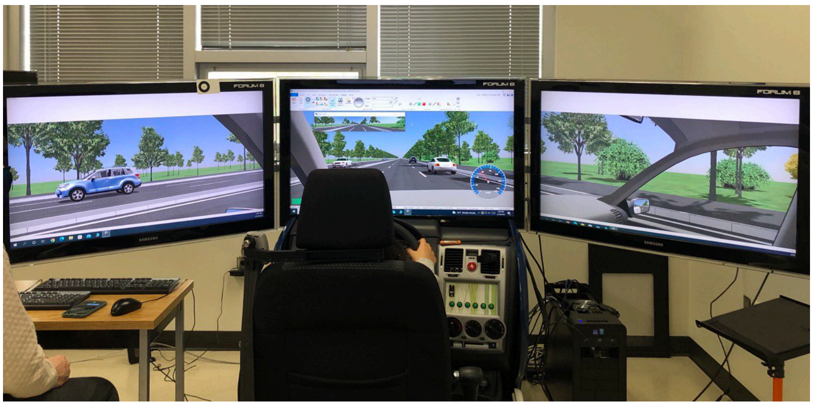


Figure 1. The driving simulator.

3.4. Simulated Scenarios

The participants drove on a six-kilometer-long network which consisted of six scenarios. A major three-lane road (three 12-foot lanes), with a speed limit of 55 mph, was designed using the VR-Studio software. A level of service B, i.e., light traffic was used in these scenarios, so that the participants do not slow down, due to high traffic which may have been the case otherwise, creating issues evaluating distracted driving. Traffic flow and density were the same in all six scenarios. The first and last scenarios, which were the first and the last kilometer, were warm-up and cool-down designed so that the participants became used to driving in the simulated environment. In the second scenario, which was from kilometer one to kilometer two, the participants drove in a base scenario with no distractions to compare normal driving behavior with distracted behavior. The third scenario (from kilometer two to kilometer three) included a distraction that occurred at exactly the same location for all participants. In this scenario, the observer texted the participants, who then needed to pick up their cell phones, read the text, and reply to the text. In the fourth scenario (from kilometer three to kilometer four), the observer asked the participants to activate their cell phone blocking app (e.g., "Do Not Disturb While Driving") on their cell phone settings. This scenario was considered as an interaction with their cell phone. In the fifth scenario (from kilometer four to kilometer five), the participants drove with their phones set to "Do Not Disturb While Driving". At the same exact location, the observer texted the driver and asked them to reply if they heard the text notification. In the fifth scenario, with the activating DND, the participant did not receive any distractions and they performed similarly to the no distraction scenario. Figure 2 shows the structure of the network of the study.

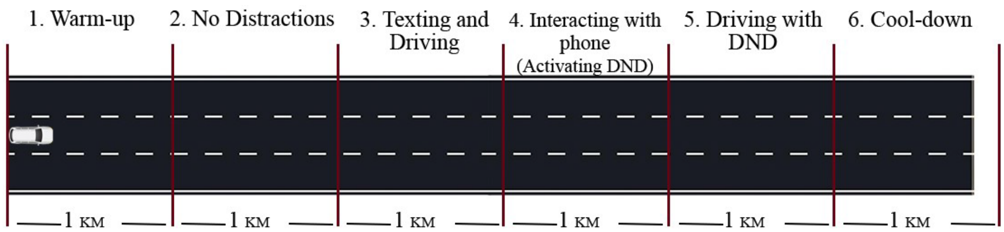


Figure 2. The Network of the Study.

3.5. Data

The pre-survey asked about the participants' demographics and real-world driving behavior prior to the driving simulator experience, while the post-survey included questions related to real-world driving behavior and the use of cell phone blocking apps following the driving simulator experience. Apart from pre-survey and post-survey data, several driving-related data were exported from the driving simulator. These variables include lateral distance, lane change, and steering velocity. Table 2 shows the variables used in this study and their descriptions.

Table 2. Variables Used in This Study.

Variable Name	Description
Lateral Distance	Lateral position of the vehicle toward the right side of the road
Lane change	Lane change frequency
Steering velocity	Rotation rate of the steering wheel (−1: Max left, 0: Middle (straight), +1: Max right)

4. Results Analysis

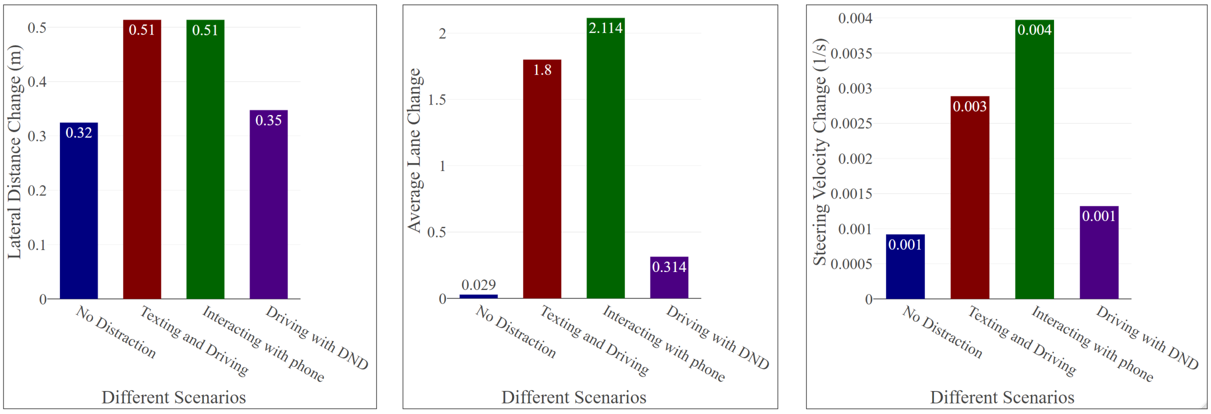
This research investigated drivers' behaviors when using cell phone blocking apps. Each section of the process is analyzed separately: pre-survey questionnaire results, driving simulator results, and post-survey questionnaire results.

4.1. Pre-survey Questionnaire Results

The results of the pre-survey questionnaire show that almost 23% of the participants used cell phone blocking technology while driving to prevent distraction. The questionnaire also asked about the type of blocking technology each participant used. The most common technology that participants used to prevent distraction was "Do Not Disturb While Driving (DND)", which is a feature on iPhone and Android cell phones designed to keep drivers safe on the road [58].

4.2. Driving Simulator Results

Many studies use statistical analysis to develop policies to improve traffic safety, investigate and forecast travel behavior, and pinpoint deficiencies in transportation policy [20,59–70]. For this study, first, a descriptive statistic was conducted to demonstrate the changes in variables in different scenarios. Figure 3 shows the lateral change, lane change, and changes in steering velocity under different scenarios.



(**a**) (**b**) (**c**)

Figure 3. (**a**) Lateral distance change, (**b**) Average lane change, and (**c**) Steering velocity change.

Moreover, we conducted ANOVA tests to compare driving behavior under different scenarios and conditions. To compare the statistical differences, a 5% significance level was used in this study. Table 3 shows the results of the analysis and reveals the significant differences between variables in different scenarios. We can conclude from the results that the lateral changes, lane changes, and changes in steering velocity differ significantly between drivers who indulged in texting or interacting with their phones while driving and those who did not. Moreover, using DND while driving produced a significant difference in lateral change, changes in steering velocity, and lane change compared to driving while texting and driving.

Table 3. ANOVA Test.

Variables		**Degrees of Freedom (Df)**	**Sums of Squares (SS)**	**Mean Squares (MS)**	**F-value**	**P-value**
Lateral Distance Change	Scenarios	4	1.147	0.2867	6.179	0.000115
	Residuals	170	7.887	0.0464	-	
Lane Change	Scenarios	4	0.0600	0.014992	6.739	4.66e-05
	Residuals	170	0.3782	0.002225	-	
Steering Velocity	Scenarios	4	0.0002453	6.133e-05	4.689	0.00129
	Residuals	170	0.0022236	1.308e-05	-	

Moreover, to show where these differences are significant, we conducted a post-hoc Tukey HSD test. Table 4 shows the results of these tests. The results show that driving with an activated cell phone blocking app scenario and the no distraction scenario were not significant, which shows the similarity of drivers' behaviors in these two scenarios. Other variables, including speed change, brake frequency, and acceleration, were also investigated in this study, none of which were significant.

Table 4. Post Hoc Tukey Test Analysis Results.

		Lateral Distance Change		**Lane Change**		**SteeringVelocity**	
Scenarios		diff	p adj	diff	p adj	diff	p adj
Texting and Driving	No Distraction	−0.189	0.003	0.039	0.013	0.002	0.160
Interacting with phone (Activating DND)	No Distraction	0.183	0.005	0.042	0.005	0.003	0.008
Driving with Activated DND	No Distraction	0.150	0.032	0.006	0.966	0.000	0.967

Table 4. (*Continued*)

Interacting with phone (Activating DND)	Texting and Driving	−0.006	0.999	0.004	0.991	0.001	0.654
Driving with Activated DND	Texting and Driving	−0.039	0.891	−0.033	0.049	−0.002	0.372
Driving with Activated DND	Interacting with phone (Activating DND)	−0.033	0.931	−0.037	0.022	−0.003	0.032

4.3. Post-survey Questionnaire Results

The post-survey questionnaire included questions about participants' experience and driving behavior after driving in the simulator. The post-survey questionnaire contained three questions. The first question asked about the participants' feelings when they drove while DND was activated. Figure 4 shows the results, which indicate that most of the participants felt safe (38%) and attentive (45%) while driving with the DND activated, 11% felt distracted, and 4% did not like it. The answer for not liking the DND was, "I did not like it because I would not know when I am getting a message".

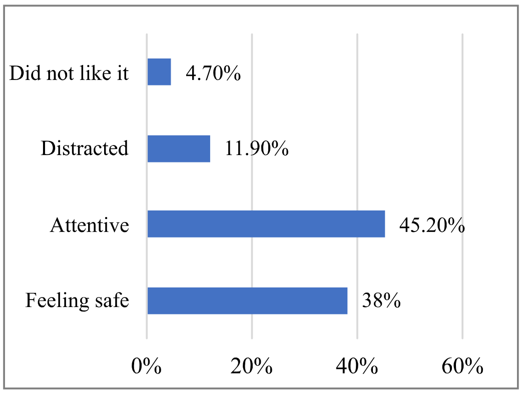


Figure 4. Participants' attitude regarding DND.

In the second question, we asked the participants whether they would use distraction prevention technologies (such as "Do not Disturb While Driving" or any other apps) in the future to drive safely after this experiment in the future. Interestingly, more than 88% of the participants answered that they would use this technology in the future.

For the third question, a description of cell phone blocking apps that pay their users not to use their phones while driving was presented to the participants. Then, participants were asked which option they preferred to prevent distracted driving. Figure 5 demonstrates that more than 51% of the participants stated that they would use their phone's built-in driving mode to prevent distracted driving, while 14% stated that they would use those mentioned apps that pay to drive safe. In addition, 11% of all participants stated that they would not use any distraction-prevention technologies while driving. Some of the reasons for not using these technologies were "I will put my phone out of reach", "I will put the phone on silent mode", and "I will use a smartwatch for important notifications".

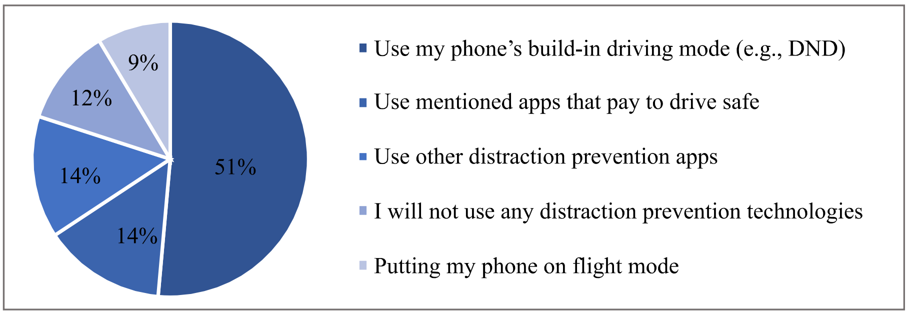


Figure 5. Participants' choice regarding distracted prevention technologies.

5. Discussion

It is crucial that researchers consider the potential effects that new technological developments may have on transportation, both from a safety and a traffic operations standpoint, as they become more widespread. Distracted driving is one of the most important safety issues associated with emerging technologies, and concerns about its effect on driver safety are increasing significantly. Previous studies have indicated that interacting with a cell phone is one of the most common behaviors contributing to distracted driving, and cell phone blocking apps are designed to prevent this type of distraction.

The results of this study support previous investigations regarding cell phone use while driving and the results are consistent with previous studies that have investigated the effects of distraction reduction strategies on driving performance which suggested that texting while driving led to more frequent and longer glances away from the road, longer reaction times to hazards, and increased lateral position variability and also the fact that an infotainment lockout system significantly reduced driving errors and increased driver attention. Our analysis shows significant changes in lateral control performance after texting or interacting with a cell phone (activating DND) while driving. Moreover, drivers changed lanes significantly more times and deviated from the center of the road when they were texting or interacting with a cell phone (activating DND).

However, our study is unique in that we evaluated the effectiveness of a cell phone blocking app in a driving simulator, which allowed us to control for confounding variables and provide a safe and controlled environment for the participants. Also, the present study, unlike others, investigated the use of cell phone blocking apps using a driving simulator. It is particularly noteworthy that the impact of cell phone blocking apps while driving was similar to that of the no distraction scenario. This research also confirmed that steering is a crucial indicator of driver response. It can provide a timely warning of distraction due to its short time constant, which only requires milliseconds of driver input. Moreover, the results of this study show that steering velocity increases significantly when interacting with a phone (activating DND) compared to using a cell phone blocking app. This suggests that the use of cell phone blocking apps is an effective way to prevent distracted driving.

The statistical analysis of this study also shows that only 23% of the drivers were using cell phone blocking apps before the experiment. After the experiment, however, more than 88% of participants stated that they had a positive opinion of cell phone blocking apps and would use one while driving in the future. The most popular type of cell phone blocking app based on the questionnaire was the built-in cell phone blocking apps on the drivers' cell phones. The results showed that 45% of the participants felt attentive, and 38% felt safe while using cell phone blocking apps. This shows that the opinion of drivers toward using this technology has been very positive.

One important contribution made by this study was to compare "no distraction" and "driving with an activated cell phone blocking app" scenarios in a driving simulator. It proposed the idea that driving while using a cell phone blocking app is similar to a situation with no distractions while driving.

5.1. Limitations and Future Studies

A limitation of this study is that it monitored driving behavior in a simulator that offered the safe, controlled setting needed rather than testing the participants' responses in various driving conditions. Therefore, future research could take a naturalistic approach to see if similar results occur in driving in actual driving situations.

Additionally, this study only examined the immediate effects of using a cell phone blocking app on driving behavior, and it did not assess the long-term effects of using these apps on driving behavior or the adoption of this technology in real-world driving settings. Furthermore, while this study examined the willingness of participants to use cell phone blocking apps, it did not assess the barriers to adoption or the factors that may influence the sustained use of these apps in real-world settings. Future research could explore these issues in more detail. Moreover, future studies could focus on other variables such as speed, braking, and acceleration to investigate whether cell phone blocking apps can impact these variables as well. Another limitation of this study is that it did not measure other outcomes that are known to be impacted by cognitive distractions, such as situation awareness and attention errors. Future research could investigate these outcomes to provide a more comprehensive understanding of the effects of cell phone blocking apps on driving performance.

6. Summary and Conclusions

Numerous research studies focused on the impacts of distracted driving on drivers' behaviors and attitudes toward cell phone blocking apps. The results of these studies showed that using these applications significantly reduced interaction with a cell phone while driving. However, to the best knowledge of the authors, no study evaluated the impacts of the use of cell phone blocking apps on driver behavior and safety using a driving simulator. Therefore, this study examined drivers' behaviors while using a cell phone blocking app and their attitudes toward this technology using a driving simulator.

Some 35 participants drove a base scenario (without distraction) and three other scenarios, including texting while driving, interacting with a cell phone while driving (activating DND), and driving with an activated cell phone blocking app on a realistic road network. The results showed that participants changed their lanes more frequently and changed their steering velocity and lateral distance more significantly while texting or interacting with a cell phone. However, the results of the t-tests for driving with activated cell phone blocking app scenarios and the no distraction scenario were not significant, which shows the similarity of drivers' behavior in these two scenarios. Attitudes toward using a cell phone blocking app were also assessed using pre- and post-trial questionnaires. The results suggested that 23% of the participants used cell phone blocking apps. After the experiment, however, 88% of the participants answered that they would use cell phone blocking apps while driving in the future.

The findings of this study support the need for more aggressive enforcement of distracted driving laws and the importance of cell phone blocking apps from a policy perspective. The research findings also support the need for driver education about distracted driving prevention technologies.

Funding

This study was financially supported by the Maryland Department of Transportation, Motor Vehicle Administration, Maryland Highway Safety Office.

Author Contributions

Study conception and design: R. J., E. S., & M. J.; Data processing: R. J., E. S., & M. J.; Analysis and interpretation of results: R. J., E. S., & M. J.; Draft manuscript preparation: R. J., E. S., & M. J. All authors reviewed the results and approved the final version of the manuscript.

Conflicts of Interest

The authors have no conflict of interest to declare.

References

1. Sajid Hasan, A., Jalayer, M., Heitmann, E., & Weiss, J. (2022). Distracted Driving Crashes: A Review on Data Collection, Analysis, and Crash Prevention Methods. *Transportation Research Record*, *2676*(8), 423–434. https://doi.org/10.1177/03611981221083917
2. NHTSA. *Distracted Driving Dangers and Statistics*. https://www.nhtsa.gov/risky-driving/distracted-driving (accessed 15 July 2022).
3. Zendrive. *How to prevent distracted driving in 2022: A comprehensive guide.* https://www.zendrive.com/blog/how-to-prevent-distracted-driving (accessed 19 July 2022).
4. Sadeghvaziri, E., Rojas, M. B., & Jin, X. (2016). Exploring the Potential of Mobile Phone Data in Travel Pattern Analysis. *Transportation Research Record*, *2594*(1), 27–34. https://doi.org/10.3141/2594-04
5. Rojas, M. B., Sadeghvaziri, E., & Jin, X. (2016). Comprehensive Review of Travel Behavior and Mobility Pattern Studies That Used Mobile Phone Data. *Transportation Research Record*, *2563*(1), 71–79. https://doi.org/10.3141/2563-11
6. Sadeghvaziri, E., & Jin, X. (14–18 May 2017). *Deriving Activity Locations Inferred from Smartphone Data*. The 16th TRB National Transportation Planning Applications Conference, Raleigh, NC, USA.
7. Children's Hospital of Philadelphia Research Institute. *Cell Phone Use and Texting While Driving Facts and Statistics.* https://www.teendriversource.org/teen-crash-risks-prevention/distracted-driving/cell-phones (accessed 19 July 2022).
8. Qi, Y., Vennu, R., & Pokhrel, R. (2020). *Distracted Driving: A Literature Review* (Research Report No. FHWA-ICT-20-004). Illinois Center for Transportation. https://doi.org/10.36501/0197-9191/20-005
9. Jeihani, M., Javid, R., & Sadeghvaziri, E. (2021) *Identifying State-Specific Distracted Driving Target Group*. Morgan State University.

10. Valero-Mora, P. M., Zacarés, J. J., Sánchez-García, M., Tormo-Lancero, M. T., & Faus, M. (2021). Conspiracy Beliefs Are Related to the Use of Smartphones behind the Wheel. *International Journal of Environmental Research and Public Health*, *18*(15), 7725. http://dx.doi.org/10.3390/ijerph18157725
11. Joyce, L. (7 May 2021). 9 of 10 Drivers Used Their Smartphone Behind the Wheel in 2020. *State Farm*. https://newsroom.statefarm.com/why-did-89-of-drivers-choose-to-engage-in-distracted-driving-behaviors-in-2020 (accessed 19 July 2022).
12. The Zebra. (2022). *Distracted Driving Statistics 2022*. https://www.thezebra.com/resources/research/distracted-driving-statistics (accessed 19 July 2022).
13. Coleman, S. (2022). *Distracted Driving Statistics 2022*. Bankrate. https://www.bankrate.com/insurance/car/distracted-driving-statistics (accessed 19 July 2022).
14. Sleight, M. (2022). *Texting and Driving Statistics 2022.* Bankrate. https://www.bankrate.com/insurance/car/texting-and-driving-statistics (accessed 19 July 2022).
15. McCartt, A. T., Braver, E. R., & Geary, L. L. (2003). Drivers' use of handheld cell phones before and after New York State's cell phone law. *Preventive Medicine*, *36*(5), 629–635. https://doi.org/10.1016/s0091-7435(03)00021-5
16. McCartt, A. T., Geary, L. L., & Berning, A. (2003). Observational study of the extent of driving while suspended for alcohol impaired driving. *Injury Prevention*, *9*(2), 133–137. https://doi.org/10.1136/ip.9.2.133
17. McCartt, A. T., Hellinga, L. A., & Geary, L. L. (2006). Effects of Washington, D.C. law on drivers' hand-held cell phone use. *Traffic Injury Prevention*, *7*(1), 1–5. https://doi.org/10.1080/15389580500412853
18. National Safety Council. *Technology Can Reduce Cell Phone Distracted Driving*. https://www.nsc.org/road/safety-topics/distracted-driving/technology-solutions (accessed 19 July 2022).
19. Albert, G., Musicant, O., Oppenheim, I., & Lotan, T. (2016). Which smartphone's apps may contribute to road safety? An AHP model to evaluate experts' opinions. *Transport Policy*, *50*, 54–62. https://doi.org/10.1016/j.tranpol.2016.06.004
20. Taherpour, A. (2023). *A Holistic Approach to Address Road Safety Issues; A Case Study of Outer Ring Road in Nairobi Kenya*. SSRN. https://doi.org/10.2139/ssrn.4387770
21. Oviedo-Trespalacios, O., King, M., Vaezipour, A., & Truelove, V. (2019). Can our phones keep us safe? A content analysis of smartphone applications to prevent mobile phone distracted driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 657–668. https://doi.org/10.1016/j.trf.2018.11.017
22. Javid, R., Sadeghvaziri, E., & Jeihani, M. (2022). The Effect of COVID-19 on Distracted Driving: A Survey Study. *MedRxiv*. https://doi.org/10.1101/2022.12.26.22283062
23. Sadeghvaziri, E., Haleem, K., Alluri, P., Fartash, H., & Gan, A. (10–14 January 2016). *Effects of Different Guide Signs on Driver Behavior at Express Lane Entrance: A Driving Simulation Study.* Transportation Research Board 95th Annual Meeting, Washington, DC, USA.
24. Ansariyar, A., Sadeghvaziri, E., & Jeihani, M. (2022). Systematic Review of Bike Simulator Studies. *Journal of Science and Cycling*, *11*(1), 5–29. https://doi.org/10.28985/1322.jsc.01
25. Papantoniou, P., Papadimitriou, E., & Yannis, G. (2015). Assessment of Driving Simulator Studies on Driver Distraction. *Advances in Transportation Studies*, *35*, 129–144.
26. Zolali, M., Mirbaha, B., & Behnood, H. R. (5–29 January 2021). *Impact of Drivers' Characteristics on Speed Choice Behavior in Adverse Weather Conditions: A Driving Simulator Study*. Transportation Research Board 100th Annual Meeting, Washington, DC, USA.
27. Ansariyar, A., Ardeshiri, A., Vaziri, E., & Jeihani, M. (8–12 January 2023). *Investigating the Traffic Behavior of Bicyclists in Interaction with Car Users on Shared Bike Lanes Without Physical Barriers*. Transportation Research Board 102nd Annual Meeting, Washington, DC, USA.
28. Zolali, M., Mirbaha, B., Layegh, M., & Behnood, H. R. (2021). A Behavioral Model of Drivers' Mean Speed Influenced by Weather Conditions, Road Geometry, and Driver Characteristics Using a Driving Simulator Study. *Advances in Civil Engineering*, *2021*, 5542905. https://doi.org/10.1155/2021/5542905
29. Köhn, T., Gottlieb, M., Schermann, M., & Krcmar, H. (2019). Improving take-over quality in automated driving by interrupting non-driving tasks. *IUI '19: Proceedings of the 24th International Conference on Intelligent User Interfaces,* 510–517. https://doi.org/10.1145/3301275.3302323
30. Donmez, B., Boyle, L. N., & Lee, J. D. (2006). The impact of distraction mitigation strategies on driving performance. *Human Factors*, *48*(4), 785–804. https://doi.org/10.1518/001872006779166415
31. Jung, T., Kaß, C., Zapf, D., & Hecht, H. (2019). Effectiveness and user acceptance of infotainment-lockouts: A driving simulator study. *Transportation Research Part F-traffic Psychology and Behaviour*, *60*, 643–656. https://doi.org/10.1016/j.trf.2018.12.001
32. Née, M., Contrand, B., Orriols, L., Gil-Jardiné, C., Galéra, C., & Lagarde, E. (2019). Road safety and distraction, results from a responsibility case-control study among a sample of road users interviewed at the emergency room. *Accident Analysis & Prevention*, *122*, 19–24. https://doi.org/10.1016/j.aap.2018.09.032
33. 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
34. 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
35. Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J., & Brown, J. (2006). Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis & Prevention*, *38*(1), 185–191. https://doi.org/10.1016/j.aap.2005.09.007
36. 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
37. Lym, Y., & Chen, Z. (2021). Influence of built environment on the severity of vehicle crashes caused by distracted driving: A multi-state comparison. *Accident Analysis & Prevention*, *150*, 105920. https://doi.org/10.1016/j.aap.2020.105920
38. Chen, Z., & Lym, Y. (2021). The influence of built environment on distracted driving related crashes in Ohio. *Transport Policy*, *101*, 34–45. https://doi.org/10.1016/j.tranpol.2020.11.011

39. Neyens, D. M., & Boyle, L. N. (2008). The influence of driver distraction on the severity of injuries sustained by teenage drivers and their passengers. *Accident Analysis & Prevention*, *40*(1), 254–259. https://doi.org/10.1016/j.aap.2007.06.005
40. Lee, J. Y., Lee, J. D., Bärgman, J., Lee, J., & Reimer, B. (2018). How safe is tuning a radio?: using the radio tuning task as a benchmark for distracted driving. *Accident Analysis & Prevention*, *110*, 29–37. https://doi.org/10.1016/j.aap.2017.10.009
41. He, J., McCarley, J. S., Crager, K., Jadliwala, M., Hua, L., & Huang, S. (2018). Does wearable device bring distraction closer to drivers? Comparing smartphones and Google Glass. *Applied Ergonomics*, *70*, 156–166. https://doi.org/10.1016/j.apergo.2018.02.022
42. Brodeur, M., Ruer, P., Léger, P.-M., & Sénécal, S. (2021). Smartwatches are more distracting than mobile phones while driving: Results from an experimental study. *Accident Analysis & Prevention, 149,* 105846. https://doi.org/10.1016/j.aap.2020.105846
43. Giang, W. C. W., Shanti, I., Chen, H.-Y. W., Zhou, A., & Donmez, B. (2015). Smartwatches vs. Smartphones: A preliminary report of driver behavior and perceived risk while responding to notifications. *AutomotiveUI '15: Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, 154–161. https://doi.org/10.1145/2799250.2799282
44. Li, J., Dou, Y., Wu, J., Su, W., & Wu, C. (2021). Distracted driving caused by voice message apps: A series of experimental studies. *Transportation Research Part F: Traffic Psychology and Behaviour, 76*, 1–13. https://doi.org/10.1016/j.trf.2020.10.008
45. Knapper, A. S., Hagenzieker, M. P., & Brookhuis, K. A. (2015). Do in-car devices affect experienced users' driving performance? *IATSS Research*, *39*, 72–78. https://doi.org/10.1016/j.iatssr.2014.10.002
46. Feng, X., Zhang, X., Zhang, Y., & Cao, L. (2019). Study on Distracted Driving Caused by Taxi-hailing Applications. *Zhongguo Jixie Gongcheng / China Mechanical Engineering*, *30*, 1776–1781. https://doi.org/10.3969/j.issn.1004-132X.2019.15.002
47. Reagan, I. J., & Cicchino, J. B. (2020). Do Not Disturb While Driving – Use of Cellphone Blockers Among Adult Drivers. *Safety Science*, *128*, 104753. https://doi.org/10.1016/j.ssci.2020.104753
48. Metz, B., Schömig, N., & Krüger, H.-P. (2011). Attention during visual secondary tasks in driving: Adaptation to the demands of the driving task. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*, 369–380. https://doi.org/10.1016/j.trf.2011.04.004
49. Svenson, O., & Patten, C. J. (2005). Mobile phones and driving: a review of contemporary research. *Cognition Technology and Work*, *7*, 182–197.
50. Ponte, G., & Baldock, M. (6–8 September 2016). *An examination of the effectiveness and acceptability of mobile phone blocking technology among drivers of corporate fleet vehicles.* The 2016 Australasian Road Safety Conference, Canberra, Australia.
51. Morton, C. C. (22 August 2012). Why Cell Phone Bans Don't Work. *Science*. https://www.science.org/content/article/why-cell-phone-bans-dont-work (accessed 20 July 2022).
52. Joseph, B., Zangbar, B., Bains, S., Kulvatunyou, N., Khalil, M., Mahmoud, D., et al. (2016). Injury Prevention Programs Against Distracted Driving: Are They Effective? *Traffic Injury Prevention*, *17*, 460–464. https://doi.org/10.1080/15389588.2015.1116042
53. Cismaru, M., & Nimegeers, K. (2017). "Keep your eyes up, don't text and drive": a review of anti-texting while driving Campaigns' recommendations. *International Review on Public and Nonprofit Marketing*, *14*, 113–135. https://doi.org/10.1007/s12208-016-0166-7
54. Creaser, J. I., Edwards, C. J., Morris, N. L., & Donath, M. (2015). Are cellular phone blocking applications effective for novice teen drivers? *Journal of Safety Research*, *54*, 75.e29–78. https://doi.org/10.1016/j.jsr.2015.06.014
55. Albert, G., & Lotan, T. (2019). Exploring the impact of "soft blocking" on smartphone usage of young drivers. *Accident Analysis & Prevention, 125*, 56–62. https://doi.org/10.1016/j.aap.2019.01.031
56. Oviedo-Trespalacios, O., Williamson, A., & King, M. (2019). User preferences and design recommendations for voluntary smartphone applications to prevent distracted driving. *Transportation Research Part F: Traffic Psychology and Behaviour,* 64, 47–57. https://doi.org/10.1016/j.trf.2019.04.018
57. Oviedo-Trespalacios, O., Truelove, V., & King, M. (2020). It is frustrating to not have control even though I know it's not legal!": A mixed-methods investigation on applications to prevent mobile phone use while driving. *Accident Analysis & Prevention, 137*, 105412. https://doi.org/10.1016/j.aap.2019.105412
58. Lynch, D. (4 December 2019). Do Not Disturb While Driving: iPhone Safety Feature Explained! *Payette Forward*. https://www.payetteforward.com/do-not-disturb-while-driving-iphone-safety-feature-explained (accessed 10 July 2022).
59. Javid, R. J., Salari, M., & Javid, R. J. (2019). Environmental and economic impacts of expanding electric vehicle public charging infrastructure in California's counties. *Transportation Research Part D: Transport and Environment*, *77*, 320–334. https://doi.org/10.1016/j.trd.2019.10.017
60. Javid, R., & Sadeghvaziri, E. (2022). Investigating the Relationship Between Access to Intercity Bus Transportation and Equity. *Transportation Research Record*, *2676*(9), 711–719. https://doi.org/10.1177/03611981221088218
61. Jeihani, M., Ansariyar, A., Sadeghvaziri, E., Ardeshiri, A., Kabir, M. M., Haghani, A., et al. (2022). *Investigating the Effect of Connected Vehicles (CV) Route Guidance on Mobility and Equity.* Morgan State University / National Transportation Center.
62. Jeihani, M., Javid, R., & Sadeghvaziri, E. (2022). *Public Education about Occupant Protection Technologies and Protecting Occupants with Disabilities.* Morgan State University / National Transportation Center.
63. Jeihani, M., Javid, R., & Sadeghvaziri, E. (2022). *Educating the Public About Distracted Driving and Evaluating Distraction-Prevention Technologies.* Morgan State University / National Transportation Center.
64. Sadeghvaziri, E., & Tawfik, A. (2017). Using the 2017 National Household Travel Survey Data to Explore the Elderly's Travel Patterns. In G. Zhang (Ed.), *International Conference on Transportation and Development 2020* (pp. 86–94). American Society of Civil Engineers. https://doi.org/10.1061/9780784483169.008
65. Javid, R., & Sadeghvaziri, E. (2023). *Assessing Gender Gaps in Citi Bike Ridership in New York City.* SSRN. https://doi.org/10.2139/ssrn.4358660
66. Javid, R. J., Xie, J., Wang, L., Yang, W., Javid, R. J., & Salari, M. (2021). High-Occupancy Vehicle (HOV) and High-Occupancy Toll (HOT) Lanes. *International Encyclopedia of Transportation*, 45–51. https://doi.org/10.1016/b978-0-08-102671-7.10292-1

67. Amini, M., & Jahanbakhsh Javid, N. (2023). A Multi-Perspective Framework Established on Diffusion of Innovation (DOI) Theory and Technology, Organization and Environment (TOE) Framework Toward Supply Chain Management System Based on Cloud Computing Technology for Small and Medium Enterprises. *International Journal of Information Technology and Innovation Adoption*, *11*, 1217–1234.
68. Javid, R., & Sadeghvaziri, E. (2023). Equity Analysis of Bikeshare Access: A Case Study of New York City. *Findings*. https://doi.org/10.32866/001c.73906
69. Sadeghvaziri, E., Javid, R., & Jeihani, M. (2023). *Investigating Walking and Biking Activities Among Low-Income African Americans*. Morgan State University.
70. Jeihani, M., Ansariyar, A., Sadeghvaziri, E., Ardeshiri, A., Rakha, H., & Fadhloun, K. (2022). *Bicyclist Longitudinal Motion Modeling* (Report No. UMEC-035). Virginia Tech / Morgan State University.