ACCIDENT RESPONSE ANALYSIS OF SIX DIFFERENT TYPES OF DISTRACTED DRIVING

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Resume

The study analysed the driving performance and visual impairment of 92 participants under six different distraction scenarios. Using a car simulator and by simulating two real-world roads, a variety of data was collected, including driver behavior and vehicle-related data. According to a statistical analysis conducted during and before the distraction on road 1, females significantly increased speed more than males when using a hand-held call (=scenario #3), hands-free call (=scenario #4), text (=scenario #6), and voice command text (=scenario #7). The Kruskal-Wallis H test was performed on gender, age, vehicle speed, throttle, and offset from the center of the road subcategories, while selecting the more correlated variable with each type of distraction. Finally, the generalized linear regression model was used to provide a significant relationship between the frequency of distraction and highly correlated independent variables.

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1 Introduction

Driving while distracted is anything that diverts the driver's attention from the main task of driving, which is one of the most important factors leading to crashes and fatalities [1]. The 2010 to 2019 U.S. crash data showed nearly 3,000 people died each year in crashes associated with distracted driving [2-4]. Different studies have indicated that talking to passengers, using a cell phone, eating, drinking, and taking off or putting on clothes can distract drivers behind the wheel and lead to accidents and fatalities [5-7]. Although several activities are referred to as the source of distraction in multiple studies, cell phone related activities (calling and texting both hands-free and hand-held) are the riskiest task that may result in distraction for drivers [8-11].

This study aims to investigate six different distractions commonly associated with driving including "eat and drink", "hand-held calls", "hands-free call", "taking off and putting on clothes", "texting", and "voice command text" on drivers' performance and visual impairment. The behavior of 92 participants before, during, and after the distraction was studied using a real-world network including two types of roads (a freeway and an urban arterial road). As a part of the first step of data collection, the gender, age, speed of the vehicle, number of brakes, throttle, offset from the center of the road, acceleration, and deceleration, pushing severity during acceleration, and eye gaze movement from on the road to the out-of-the-road were collected. Using Pearson correlation [12] and factor analysis [13] tests, the highly correlated variables were identified in the second step. For the final step, a new statistical method in the state-of-the-art (Kruskal-Wallis H test) was applied to find the key variable affecting distraction.

The findings of this study can provide insight into policymaking, legislation, education and training, safety guidelines, and car manufacturing standards. The remainder of this article is structured as follows: Section 2: Literature Review, Section 3: Research Methodology, Section 4: Data Analysis, Section 5: Statistical Model Analysis and Discussion, Section 6: Conclusion, and Section 7: References.

2 Literature review

Urban traffic congestion and the probability of incidents are increasing at alarming rates due to an increase in vehicles [14]. Engaging in distractions while driving is the act of diverting the driver's attention from the driving duties. Activities may include communicating or interacting with passengers, texting, browsing the web, eating, drinking, and reaching for devices are prevalent types of driving distractions. Human error causes 94% of all traffic accidents, according to a report by the National Highway Traffic Safety Administration (NHTSA) [15]. Distracted driving is among the most important factors contributing to crashes every year [16]. According to the published report by NHTSA [3], approximately 9% of fatal crashes, 15% of injury crashes, and 15% of crashes reported by the police are caused by distracted driving. In addition, a total of 3142 people were killed and 424,000 people were injured in motor vehicle crashes caused by distracted driving. Cell phone usage is a common distraction for motor vehicle drivers [17]. According to the NHTSA data from 2017, about 5.3% of drivers use their cell phones while driving [18] and among different age groups, younger drivers are more likely to use cell phone while driving [19] since a significant percentage of this group of drivers are interested in texting while driving [20]. Driving while using a cell phone (e.g., to talk, send text messages, or watch videos) can impact many aspects of driving performance, such as reaction time, speed, and decision-making [21-22]. Additionally, using a cell phone while driving can lead to missing enough distances to the front vehicle, braking, headway adaption, missing lane changes, lane position variability, and can lead to a lack of appropriate perception reaction time [23-25]. Cell phone-related crashes in the U.S. killed 385 people and injured 3300 people in 2018 [26]. Additionally, a recent study during the Covid-19 pandemic highlighted that hands-free cell phone use (64 %), GPS use (75 %), and eating and drinking were the most reported distracting behaviors among drivers [27].

The causes and consequences of distractions have been studied in a variety of studies [28-30]. From different types of distraction, hand-held calls, hands-free calls, texting, and voice message text were taken into account as key reasons of distraction since drivers had a reduction in their awareness of the situation [31] and cause more road edge excursions [32]. The study conducted by Harbluk et al. [7] showed that drivers pay less attention to traffic lights at intersections when using mobile phones. Drews et al. [33] showed that in the secondary task condition, drivers react more slowly to the braking lights and demonstrate less control of a vehicle in forward and lateral movements. Owens et al. [34] indicated that sending and receiving text messages while driving lead to increase the time in which eyes are off the road, increase in the mental demand, and steering measures degradation. In another study, He et al. [35] investigated the texting while driving, and the scholars found that texting behind the wheel leads to higher workloads for drivers and more lane excursions. Furthermore, they [35] demonstrated that the impact of vocal texting on driving performance was less than that of manual texting, but it still impaired drivers compared to undistracted driving.

In terms of hand-held calls distraction, Knapper et al. [36] indicated that this secondary task can lead to a significant decrease in vehicle speed. Moreover, holding a phone and entering directions lead to more time eyes off the road and reduced lateral control. Haque and Washington [37] investigated the braking behavior of young drivers in hand-held calls. The results of their study revealed that participants reduced their speed faster and more abruptly.

In terms of hands-free calls distraction, Yan et al. [38] investigated the effects of hands-free calling on braking reaction time, speed variation, the fluctuation of car-following distance, and car-following headway. The results revealed that hands-free calling impaired driving performance considerably. In another study, Alosco et al. [32] demonstrated that hands-free calls impaired driving performance at the same level as eating. The scholars found that when participants were distracted by hands-free calls, they crossed more center lines, were involved in more crashes, and were involved in more pedestrian strikes when compared to when participants were not distracted. Zhao et al. [39] highlighted that drivers who frequently use hands-free calls behind the wheel change their speed more quickly and accelerate at a faster rate. Their braking maneuvers were also harder and they spent more time in the left lane.

In terms of eating and drinking distractions, Alosco et al. [32] found that distracted drivers were more likely to miss the stop signs when eating. Irwin et al. [40] discovered that eating had significant negative effects on Standard Deviation of Lane Positioning (SDLP), lane departure from the road center, and auditory reaction time. Wang et al. [25] specified that high speed has a negative effect on SDLP and trajectory offset (TO), so when speed was increased, SDLP and TO increased.

In terms of putting on or taking off clothing while driving, Bailey et al. [41] found that putting on or taking off clothes distraction is very risky for 57.7% of their research sample size, and it is somewhat risky for 29.6% of the sample. In another research, Honowski [42] specified that putting on or taking off clothing while driving can negatively affect a driver's reaction time.

The state-of-the-art highlighted the negative impact of different types of distracted driving on driver's behavior. In the same line with previous studies, the aim of our study is to examine six different types of distractions integrally and to identify the highly correlated independent variables (driver behavior or vehicle characteristics) with the percentage of distractions using a new statistical test (Kruskal-Wallis H test).

Figure 1 *Morgan State University's driving simulator (a) and Tobii Pro Glasses2 eye-tracking system (b)*

3 Research methodology

3.1 Data collection

A driving simulator (FORUM8 Company's fixed driving simulator with three 40-inch monitors) was used to collect driving performance data from a simulated network of the Baltimore Metropolitan Area (BMA) in Maryland, USA. A real-world network, including two freeway and urban arterial roads, were simulated. I-695 is a 51.46-mile full beltway that extends around Baltimore, Maryland. A portion of I-695 with 3.3 miles (=5.31 km), with four lanes and a 55 mph speed limit was studied so that this section is one of the crowded sections of I-695 in Baltimore city. Total of 92 participants were recruited via flyers distributed manually, online, and through social media at Morgan State University and in the Baltimore metro area. The flyer included contact information, a summary of the study requirements, and details about the monetary compensation for driving the simulator. A valid driver's license was required for participants, and they received $15 an hour for their participation. During the pre-drive interview, we asked the participants whether they wore eyeglasses or if they used hands-free devices in general. As a part of the driving experience, participants were also asked to wear a hands-free device and a jacket or sweater to simulate different distractions. Water and candy were provided to distract them while drinking and eating. After filling out a pre-survey questionnaire, participants drove for about two hours in different simulated scenarios, and then submitted a post-survey questionnaire afterward. As a way of determining the drivers' general behavior, we asked them whether they multitask while driving or not. The results showed that 96% of participants prefer to concentrate on only driving rather than doing anything else. The participants were instructed to adjust their cell phone's volume to a loud ringer before beginning each scenario and to have it handy at all times. In addition, a graphical "Collision" text and a special sound of collision were displayed on the screen when a collision occurred between the vehicles. An eye-tracking system (Tobii Pro Glasses2) was worn by participants to capture gaze frequency and duration. The eye-tracking system can record eye movement by using two sensors mounted on the glasses and is equipped with one central camera which records events in the driving process. Then, by using the Tobii Analyzer tools, all recordings were analyzed. Figure 1 shows the driving simulator and Tobii Pro Galsses eye-tracking system used in this study.

In pre-survey questionnaire, the personal information of a participant, including gender, age, ethnicity, type of driving license (lerner's permit, class A, and class C), and driving experience, were asked and made sure all the questions were answered correctly by all participants. Furthermore, using different technologies e.g., social media during driving, they were asked to specify the general behavior of participants while driving. After filling out the pre-survey form, the participants were asked to drive 7 scenarios including "without distraction (basic scenario)", and six scenarios with distraction including "eating and drink", "hand-held calls", "hands-free call", "taking off and putting on clothes", "texting", and "voice command text". Each distraction scenario was performed at a specific distance from the initial position of the network. The participants had no clue what "hand-held calls", "hands-free calls", "texting", or "voice command texts" were about. To minimize the error of data collection, all participants drove in the simulated network to get familiar with the driving simulator and the network (base scenario - without distraction). The driving simulator and eye tracking system recorded participants' driving performance and eye movement per second for behavioral and gaze analysis. In road 1 (freeway), the distraction was done in km 00+880 from the initial position of the network. In road 2 (urban arterial), the distraction was done in km 00+480 from the initial position of the network. On both roads, distraction points have been identified based on the presence of the real-world natural barriers that cause drivers to be distracted. It is worth mentioning that there were no differences in the content of distractions between the two routes. Detailed descriptions of each scenario are provided in Table 1.

***Table 1** The description of the scenarios*

Scenario ID	Description
1 (Basic scenario)	Without Distraction: driving in the normal condition
2	Eat and Drink: The participant should drink water and eat candy
3	Hand-Held Calls: During the data collection, the observer called the participant's phone number, which the participant had to answer by keeping the phone near his or her ear. A 20-second phone call was taken.
4	Hands-Free Call: During the data collection, the observer called the participant's phone number, which the participant had to answer by hands-free device. A 20-second phone call was taken.
5	Taking off and on putting Clothes: During the data collection, the observer asked the participant to take off and put on his/her jacket
6	Texting: An observer sent a short message by SMS during the data collection, and participants were required to read it, then respond by typing a text. It is recommended that 20 seconds be allowed for viewing, reading, and responding. However, the time interval of viewing, reading and responding is different between participants.
7	Voice Command Text: An observer sent a message by SMS during the data collection, and participants were required to respond by sending a voice command text. In scenario #7, to record and send a voice message, participants had to unlock their cell phones, press the record icon, and press the send icon.

***Figure 2** Simulated network with different road classes and distraction locations*

Every participant experienced different types of distractions randomly without any special order or learning effect. It is worth mentioning that in both phone calls and text distractions, the same content and context were used. During the phone call, participants were asked about their first and family names, as well as their dates of birth. Participants in the text distraction scenario were asked to respond with the name of their high school. Based on the recorded data, variables related to the participants' driving performance were selected for this study, including speed, throttle, brake, offset from road center, steering wheel velocity, and lane changing. Additionally, during the data collection the participant's behavior with a secondary task, which engaged their attention physically, visually, and cognitively that can affect their driving behavior, was monitored. Figure 2 shows the simulated network and 2 distraction points in the simulated network.

3.2 Pre-survey data analysis

Descriptive analysis of pre-survey data reveals that about 43 % of participants were female, and 57 % of participants were male. Based on the "age" group of the participants, 16 % between 18 to 20 years old, 45 %

Table 2 *Distraction experience of the participant in the Pre-survey*

	Talk on the phone (hand-held or hands-free), %	Facebook %	Snapchat %	Twitter %	Instagram %	Other Social media (Whats app, Telegram, etc.), %
Never	23	75	63	84	63	87
Rarely	24	15	15	9	15	9
Sometimes	43	8	18	4	15	3
Always	10	2	3	3	7	1

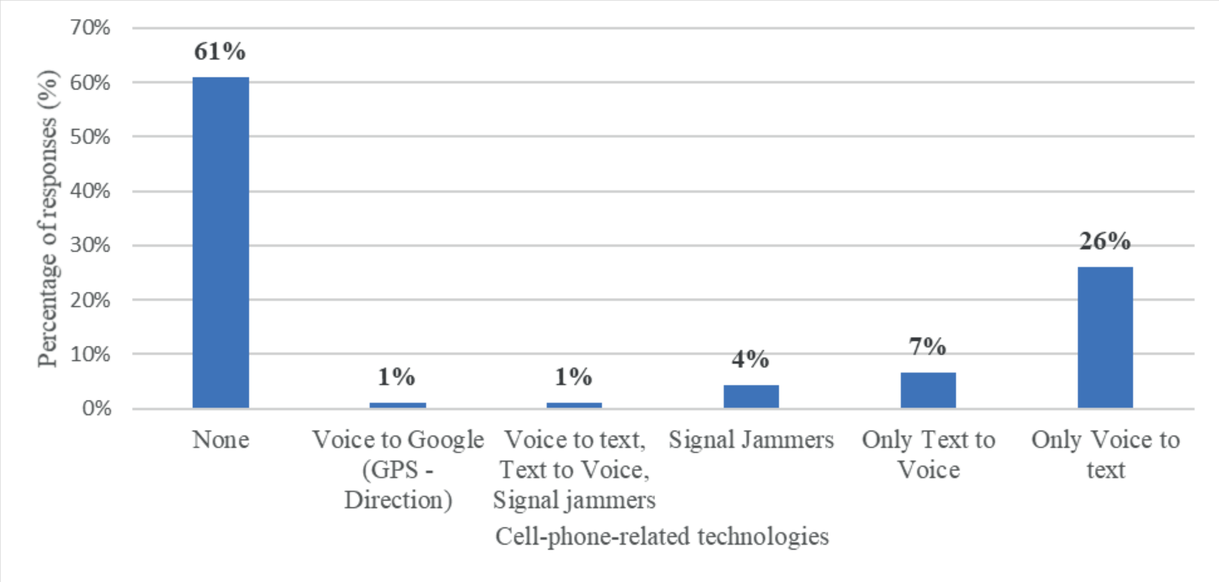


Figure 3 *Cell-phone-related technologies declared by participants*

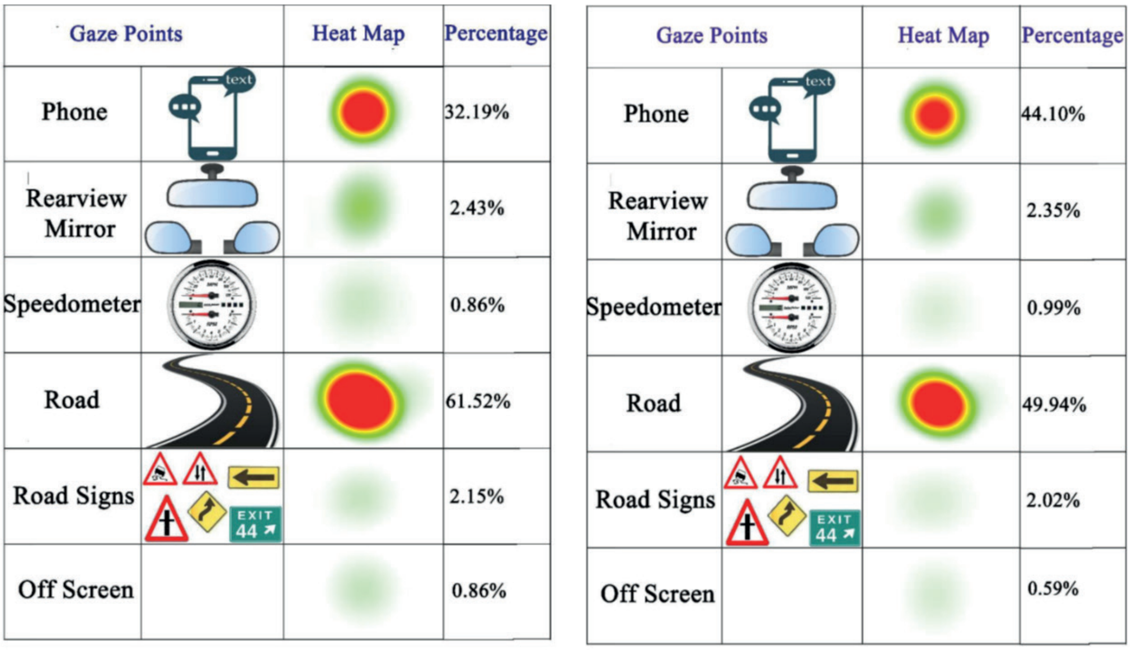
between 21 to 25 years old, 16% between 26 to 30 years old, 10% between 31 to 35 years old, 3% between 35 to 45 years old, 9% between 36 to 40 years old, and 1% more than 40 years old.

The "ethnicity" of the participants specified that 13% Asian/Pacific Islander, 59% black of African American, 2% Hispanic or Latino, 1% native American or American Indian, 12% White, and 13% from the other races.

Participants with previous driving experience were invited to participate in the study. The "driving experience" specified that 6% of participants with learner's permit, 3% of participants with commercial vehicles license (class A), and 90% of the participants with permanent license for all regular vehicles (class C). Furthermore, to designate the milage of driving by participants in the real world, the participants were asked to declare the approximate mileage of driving. The results of driving mileage highlighted that 48% of participants drove a car less than 100 miles, 25% of participants with 100 to 200 miles, 11% of participants with 201 to 300 miles, 10% of participants with 301 to 400 miles, and 7% of participants with more than 400 miles. The 92 participants were selected randomly, so that they can represent a significant percentage of society's behavior. As a goal of this study, the distraction experience of participants was asked by talking to phone (hand-held or hands-free), checking Facebook during driving, checking Snapchat during driving, checking Twitter during driving, checking Instagram during driving, or checking the other social media e.g., Whats app or Telegram during driving. The results of the pre-survey questionnaire on distraction experience are shown in Table 2.

In addition, participants were asked about different cell-phone-related technologies they usually use. Cell-phone-related technologies declared by participants are shown in Figure 3.

A previous comprehensive analysis of distraction dataset [43] indicated that there was a meaningful difference between %driving performance such as speed, throttle, brake, steering wheel velocity, offset from the center of the road, and lane change in the majority of distraction scenarios compared to the base scenario (no distraction). On the same line with the state-of-the-art, our research collected more than 60 variables, including vehicle characteristics, driver characteristics, and road characteristics. Then, Pearson correlation test [44] and factor analysis [13, 45] were used to specify the highly correlated variables to distraction driving. Finally, the highly correlated variables were utilized for statistical analysis of distraction driving. It is worth mentioning that %SPSS software was used for statistical analysis.



a: voice command to text scenario

b: typing a text message scenario

Figure 4 *Heat maps in gaze fixations analysis- a: voice messaging scenario (Scenario #7), b: texting scenario (=Scenario #6)*

3.3 Eye-tracking analysis

By using an eye-tracking system, the gaze fixations of participants were analyzed when they were exposed to text distraction scenarios (=scenarios #6 and #7). The heat maps of these two scenarios are presented in Figure 4, with red being the scenario with the highest gaze fixations and green being the scenario with the lowest gaze fixations.

Eye-tracker data analysis as shown in Figure 4 revealed that in the voice messaging scenario (=scenario #7), about 62% of gaze fixations were on the road and approximately 32% of gaze fixations were on the phone while recording a voice message. On the other hand, in the typing text message scenario (=scenario #6), the gaze fixations on the road were about 50% and roughly 44% of all gaze fixations were on the phone while driving. This is an alarming change of behaviour with 37% more gaze fixations on the phone than the voice messaging scenario that can easily result in a collision. Since texting and voice command messages are two of the most frequently used types of distraction, the paper did not use eye-tracking analysis in scenarios #2 to #5. Moreover, the limitation of cloud space for recording eye-tracking videos forced the authors to exclude eye-tracking from the remaining scenarios.

3.4 Hypotheses

After collecting the data and identifying the personal information of participants, a Pearson correlation test and factor analysis were used to identify the variables highly correlated with different types of distractions. Hereupon, the variables including age, gender, ethnicity, household income, driving experience, number of vehicles in the household, mileage of driving, speed of vehicle, throttle, offset from the center of the road, and the number of brakes were investigated. A Pearson correlation test and factor analysis specified that age, gender, speed of the vehicle, throttle, and offset of a vehicle from the road center are highly correlated with different types of distraction. Hence, three following hypotheses were provided to investigate speed, throttle, and offset before, during, and after the distraction.

Hypothesis #1, Vehicle Speed: Different studies investigated the speed changes of distracted drivers [46-50]. Trespalacios et al. [46] considered as an average 30 s for speed adaptation behaviour of distracted drivers. Strayer et al. [47] suggested, compared to single-task conditions (i.e., driving only), when drivers use cell phones, their reactions are 18% slower, their following distance is 12% greater, and they take 17% longer to recover lost speed after braking than when they do not use cell phones. Based on observations of 2 million seconds in 7394 baselines (no events), 1237 near crashes, and 617 crashes, Arvin and Khattak [48] suggested a 15-second interval as the time interval during which the distracted driving occurs. Arvin and Khattak also proposed the time interval of 6.66 seconds in crash/near crash events (CNC), and 4.74 seconds in no events for cellphone-oriented distractions, an average of 3.19 seconds and 2.17 seconds in CNC and no events for object-oriented distractions, and an average of 5.51 seconds and 4.42 seconds in CNC and no events for Activity-oriented distractions, respectively. Caird et al.

[49] found that drivers on the phone were distracted for an average of 27 seconds, which was significantly longer than the average distraction time of 19 seconds for drivers who were not on the phone. Finally, Wu and Xu [50] suggested cell phone distractions take 6.63 seconds to detect, talking or singing distractions take 4.90 seconds, focusing on objects takes 3.53 seconds, eating or drinking distracts for 8.67 seconds, changing devices in vehicles distracts for 3.59 seconds, and other distractions take 1.67 seconds. According to the state-of-the-art proposed time intervals for speed and to increase the accuracy of study, a 15 second time interval for before distraction, a 15 second time interval for during the distraction, and a 15 second time interval for after distraction were investigated.

Hypothesis #2, Throttle: The throttle is defined as an input on the accelerator pedal. For a more accurate throttle analysis, similar to the study by Jeihani et al. [51], a 16 second time interval for before distraction, 16 seconds during the distraction, and 16 seconds after distraction were evaluated.

Hypothesis #3, Offset from the road center: Offset from the road center is defined as the distance between the vehicle's position and the center of the road. Wang et al. [25] after examining 1200 distracted driving segments determined that an 8.27-second average trajectory offset was appropriate. In another study, Peng et al. [52] suggested 4 to 5 seconds for analyzing the longitudinal and lateral offsets. Hereupon, based on in-person observing the behavior of participants during the data collection and to increase the accuracy of analysis, similar to throttle analysis, 16 seconds before distraction, 16 seconds during the distraction, and 16 seconds after distraction were analyzed.

After identifying the variables that are highly correlated, the Kruskal-Wallis H test was used to identify the independent variables representative of each distraction type.

4 Data analysis

4.1 Road 1 (freeway road)

A 3.3-mile stretch of I-695 from Exit 27 to the Exit 3 corridor was considered as road #1. The I-695 is a 51.46-mile full beltway that extends around Baltimore, Maryland. Road 1 includes a two-way road with four lanes in each direction. A distraction was done in road 1 at km 0+880 from the network's initial position.

The analysis includes the "weighted average" so that the three weighted average values of all the data records per second, including before, during, and after distraction were obtained. That means one average value for before distraction, one average value for during distraction, and one average value for after distraction were calculated.

To accurately assess participants' driving behavior in all seven scenarios, they were categorized by gender and age. That means the speed, throttle, and offset from the road center were evaluated for male and female participants and based on their age groups. To report the changes of speed, throttle, and offset, two comparison sets including "during distraction with before distraction (during-before)", and "after distraction with during distraction (after-during)" were designed. If the weighted average value in during distraction was higher than before distraction, it means the speed, throttle, and offset were increased in the "during-before" set. Similarly, if the weighted average value in after distraction was higher than during distraction, it means the speed, throttle, and offset were increased in the "after-during" set. Table 3 shows the percentage of increasing or decreasing speed, throttle, and offset for male participants in "during-before" set.

As shown in Table 3, for instance in "eat and drink" scenario (=scenario #2), 100% of male participants preferred to increase the speed during the distraction toward before distraction. Furthermore, 13% and 30% of male participants preferred to increase throttle and offset from the center of the road, respectively, in scenario #2. As an average for 7 scenarios, 96%, 13%, and 19% of male participants increased the speed, throttle, and offset, respectively. According to the results of male participants, although a significant percentage of male participants increased speed during distractions, however, 87% and 81% decreased throttle and offset, respectively. It means that during the distraction, increasing speed cannot enhance pushing harder on accelerator of male participants' distance from the center of the road. Table 4 shows the percentage of increasing or decreasing speed, throttle, and offset for male participants in "after-during" set.

As shown in Table 4, male participants behaved completely different after distraction. The throttle and offset were increased on average across seven scenarios, while the speed after distraction increased less than during-before set. By using the same methodology of male participants, Table 5 shows the percentage of increasing or decreasing speed, throttle, and offset for female participants in the "during-before" set.

As can be seen in Table 5 and as a comparison with the results of Table 3, female participants increased their speed in scenarios #3, #4, #6, and #7 more than male participants. The throttle was increased more in scenarios #2, #3, #4, and #5 towards the male participants. The offset from the road center for female participants was increased more in scenario #3. Table 6 shows the percentage (%) of female participant in "after-during" distraction set.

As can be seen in Table 6, in scenarios #2, #3, #4, and #5, female participants' speed increased towards the male participants after distraction. The throttle was increased in scenarios #2, #3, and #4 towards the male participants after distraction. Additionally, female participants preferred to increase the distance from the

Table 3 *The percentage (%) of male participant in "during-before" distraction set on road #1*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	100	0	9	91	9	91
Eat and Drink (#2)	100	0	13	87	30	70
Hands held call (#3)	95	5	19	81	16	84
Hands-free call (#4)	95	5	16	84	16	84
Take off and on clothes (#5)	91	9	9	91	18	82
Text (#6)	93	7	7	93	24	76
Voice Commands text (#7)	98	2	17	83	19	81
Average of 7 scenarios	96.0	4.0	12.9	87.1	18.9	81.1

Table 4 *The percentage (%) of male participant in "after-during" distraction set on road #1*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	53	47	84	16	80	20
Eat and Drink (#2)	57	43	78	22	78	22
Hands held call (#3)	51	49	74	26	60	40
Hands-free call (#4)	56	44	77	23	63	37
Take off and on clothes (#5)	59	41	86	14	86	14
Text (#6)	71	29	95	5	57	43
Voice Commands text (#7)	64	36	76	24	67	33
Average of 7 scenarios	58.7	41.3	81.4	18.6	70.1	29.9

Table 5 *The percentage (%) of female participant in "during-before" distraction set on road #1*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	100	0	3	97	5	95
Eat and Drink (#2)	100	0	15	85	20	80
Hands held call (#3)	100	0	22	78	19	81
Hands-free call (#4)	100	0	21	79	16	84
Take off and on clothes (#5)	75	25	15	85	10	90
Text (#6)	100	0	0	100	14	86
Voice Commands text (#7)	100	0	14	86	14	86
Average of 7 scenarios	96.4	3.6	12.9	87.1	14.0	86.0

center of the road after distraction in scenarios #2, #3, and #6 towards the male participants. As a conclusion of male and female participants on road 1 before, during, and after distraction, the following results are obtained.

A comparison of the "during-before" distraction set among females and males participants revealed the following consequences: Female participants increased the speed more than male participants in hand-held call (=scenario #3), hands-free call (=scenario #4), text (=scenario #6), and voice command text (=scenario #7). Throttle results showed that the value of throttle was increased more for female participants in scenarios eat and drink (=scenario #2), hand-held call (=scenario #3), hands-free call (=scenario #4), and take off and put on clothes (=scenario #5). In addition, female participants increased the offset from the center of the road in scenario hand-held call (=scenario #3) toward the male participants.

Table 6 The percentage (%) of female participant in "after-during" distraction set on road #1

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	54	46	82	18	69	31
Eat and Drink (#2)	65	35	85	15	80	20
Hands held call (#3)	65	35	81	19	65	35
Hands-free call (#4)	61	39	82	18	63	37
Take off and on clothes (#5)	60	40	65	35	65	35
Text (#6)	49	51	74	26	71	29
Voice Commands text (#7)	57	43	60	40	66	34
Average of 7 scenarios	58.7	41.3	75.6	24.4	68.4	31.6

Table 7 The percentage (%) of male participants in "during-before" distraction set on road #2

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	49	51	20	80	40	60
Eat and Drink (#2)	30	70	9	91	35	65
Hands held call (#3)	30	70	26	74	47	53
Hands-free call (#4)	44	56	40	60	37	63
Take off and on clothes (#5)	9	91	5	95	59	41
Text (#6)	45	55	21	79	50	50
Voice Commands text (#7)	51	49	28	72	51	49
Average of 7 scenarios	36.9	63.1	21.3	78.7	45.6	54.4

A comparison of the "after-during" distraction set among females and males participants revealed the following consequences: Female participants increased the speed more than male participants in without distraction (=scenario #1), eat and drink (=scenario #2), hand-held call (=scenario #3), hands-free call (=scenario #4), take off and put on clothes (=scenario #5). Throttle results showed that the value of throttle was increased more for female participants in scenarios eat and drink (=scenario #2), hand-held call (=scenario #3), and hands-free call (=scenario #4). In addition, female participants increased the offset from the center of the road in scenarios eat and drink (=scenario #2), hand-held call (=scenario #3), and text (=scenario #6) toward the male participants.

Based on a comparison of "age" and considering that 45% of male and female participants were between the ages of 21 and 25, 43% of female participants with age group 21-25 years old in without distraction (=scenario #1), 45% in eat and drink scenario (=scenario #2), 43% in hand-held call (=scenario #3), 44% in hands-free call (=scenario #4), 45% in take off and put on clothes (=scenario #5), 43% in text (=scenario #6), and 43% in voice commands text (=scenario #7) increased the vehicle speed. In terms of throttle, 15% of female participants with age group 21-25 years old increased throttle in eat and drink scenario (=scenario #2), 8% in hand-held call (=scenario #3), 10% in hands-free call (=scenario #4), 5% in take off and on clothes (=scenario #5). In terms of offset, 5% of female participants with age group 21-25 years old preferred to keep distance from the center of the road in without distraction (=scenario #1), 5% in eat and drink scenario (=scenario #2), 11% in hand-held call (=scenario #3), 5% in hands-free call (=scenario #4), 10% in take off and on clothes (=scenario #5), 6% in text (=scenario #6), and 9% in voice commands text (=scenario #7).

4.2 Road 2 (urban arterial road)

An urban arterial road including three lanes in each direction was simulated as shown in Figure 2. In accordance with the real-world road characteristics with 3.8 miles (=6.11 km), a 35 mph speed limit was simulated. Furthermore, the distraction was done at km 0+480 from the road's initial position. The same methodology as explained for road 1 was applied to study the behavior of male and female participants before, during, and after the distraction. To report the

***Table 8** The percentage (%) of male participants in "after-during" distraction set on road #2*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	38	62	87	13	78	22
Eat and Drink (#2)	39	61	91	9	65	35
Hands held call (#3)	40	60	88	12	63	37
Hands-free call (#4)	47	53	84	16	70	30
Take off and on clothes (#5)	59	41	91	9	55	45
Text (#6)	40	60	88	12	64	36
Voice Commands text (#7)	42	58	86	14	65	35
Average of 7 scenarios	43.6	56.4	87.9	12.1	65.7	34.3

***Table 9** The percentage (%) of female participants in "during-before" distraction set on road #2*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	62	38	20	80	42	58
Eat and Drink (#2)	50	50	20	80	30	70
Hands held call (#3)	58	42	45	55	53	47
Hands-free call (#4)	45	55	37	63	39	61
Take off and on clothes (#5)	40	60	15	85	55	45
Text (#6)	49	51	29	71	43	57
Voice Commands text (#7)	54	46	34	66	46	54
Average of 7 scenarios	51.1	48.9	28.6	71.4	44.0	56.0

***Table 10** The percentage (%) of female participants in "after-during" distraction set on road #2*

Scenario/Variable	Speed		Throttle		Offset from the center of road	
	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)	Increase (+)	Decrease (-)
No distraction (#1)	32	68	92	8	85	15
Eat and Drink (#2)	25	75	85	15	80	20
Hands held call (#3)	22	78	89	11	74	26
Hands-free call (#4)	47	53	89	11	66	34
Take off and on clothes (#5)	40	60	85	15	75	25
Text (#6)	23	77	94	6	63	37
Voice Commands text (#7)	23	77	80	20	71	29
Average of 7 scenarios	30.3	69.7	87.7	12.3	73.4	26.6

changes of speed, throttle, and offset, two comparison sets including "during distraction with before distraction (during-before)", and "after distraction with during distraction (after-during)" were designed. Table 7 shows the percentage of increasing or decreasing speed, throttle, and offset for male participants in "during-before" set.

According to Table 7, male participants preferred to decrease the vehicle speed in scenarios #2, #3, #4, #5, and #6. In most scenarios, including scenarios #2, #3, #4, #5, #6, and #7, the throttle was decreased. While the male participants increased their speed, the offset was decreased in scenarios #2, #3, and #4, which indicated that they could control the vehicle. Table 8 shows the behavior of male participants in "after-during" set on road 2.

As can be seen in Table 8, a significant percentage of male participants decreased the speed, increased the throttle, and increased the offset after distraction. To analyze the behavior of female participants, Tables 9 and 10 show the percentage (%) of female participants in “during-before” and “after-during” sets, respectively.

Table 9 shows that female participants decreased their speed during the distraction more than the male participants. In terms of throttle and offset, female participants exhibited the same behavior as male participants in “during-before” set. Table 10 shows the percentage of female participants in “after-during” distraction set on road #2.

According to Table 10, female participants decreased their speed more than male participants after distraction. Additionally, female participants increased the offset more than male participants. In regards to the throttle after distraction, the same behavior was observed as in the case of male participants.

As a conclusion of male and female participants on road 2 before, during, and after the distraction, the following results are obtained.

During distraction, in scenarios #2, #3, #4, #5, #6, and #7, female participants increased their speed more than male participants. In scenarios #2, #3, #5, #6, and #7, female participants increased throttle more than male participants. Moreover, female participants keep their distance from the center of the road when distracted with a hand-held call (=scenario #3) or a hands-free call (=scenario #4).

Female participants exhibited conservative driving behavior after distractions, as they did not increase vehicle speed in all the distraction scenarios. In scenarios #3, #4, and #6, female participants increased the throttle more than male participants. Additionally, female participants in scenarios #2, #3, #5, and #7 kept a greater distance from the center of the road than male participants.

Based on a comparison of “age” and considering that 45% of male and female participants were between the ages of 21 and 25, 25% of female participants with age group 21-25 years old in without distraction (=scenario #1), 25% in eat and drink scenario (=scenario #2), 24% in hand-held call (=scenario #3), 24% in hands-free call (=scenario #4), 20% in take off and on clothes (=scenario #5), 23% in text (=scenario #6), and 23% in voice commands text (=scenario #7) preferred to increase the speed. In terms of throttle, 5% of female participants with age group 21-25 years old increased throttle in eat and drink scenario (=scenario #2), 21% in hand-held call (=scenario #3), 16% in hands-free call (=scenario #4), 10% in take off and on clothes (=scenario #5), 17% in text message (=scenario #6), and 9% in voice command text message (=scenario #7). In terms of offset, 15% of female participants with age group 21-25 years old preferred to keep the distance from the center of the road in without distraction (=scenario #1), 20% in eat and drink scenario (=scenario #2), 21% in hand-held call (=scenario #3), 13% in hands-free call (=scenario #4), 15% in take off and on clothes (=scenario #5), 17% in text (=scenario #6), and 20% in voice commands text (=scenario #7).

5 Statistical model analysis and discussion

To determine if highly correlated variables (gender, age, speed, throttle, and offset) influence different types of distraction, the Kruskal-Wallis H test [53] was used. As a rank-based nonparametric test, the Kruskal-Wallis H test can be used to determine if there is a statistically significant difference between the two or more groups of an independent variable on a continuous or ordinal dependent variable [54]. The distraction of the participant is a dependent variable in our research that includes Likert scales (e.g., distracted, somewhat distracted, not distracted). In the context of distracted, the participant is completely distracted by those six types of distraction. Participants that were somewhat distracted were able to control their vehicles vigilantly despite distractions. A participant who was not distracted was completely attentive during the distraction. Each participant’s distraction level was measured by how long they spent distracted from the road to the off-road. It is important to note that the Kruskal-Wallis H test is only reported for scenarios #2 through #7 when the participants were distracted during the roads.

Generally, four hypotheses are investigated for Kruskal-Wallis H test [55] including: 1) The dependent variable should be measured on an ordinal or continuous scale; 2) Independent variables should consist of two or more categorical groups (in this paper age and gender categories for speed, throttle, and offset); 3) Observations should be independent, which means there should be no relationship between observations within and between groups; 4) The distributions in each group have the same shape, which means they are also equally variable. According to the fourth hypothesis, the Kruskal-Wallis H test is used to compare the medians of dependent variables when distributions have the same shape. In the case of different distribution shapes, the Kruskal-Wallis H test can be used to compare the mean ranks.

5.1 Scenario #2 (=eat and drink) on “road 1” and “road 2”

The results of Kruskal-Wallis H test for eat and drink type of distraction showed “offset” variable can reject the null hypothesis (=the mean ranks of the groups are the same). Hereupon, offset from the road center is the best variable for eat-and-drink distractions on the road 1. According to the Kruskal-Wallis H test results for eat-and-drink distraction on road 2, “age” is the best variable to reject the null hypothesis.

***Table 11** The result of Kruskal-Wallis H test on road 1 and road 2*

Type of distraction	Independent-Samples Kruskal-Wallis Test Summary		
		Road 1 (Offset)	Road 2 (Age)
Eat and drink distraction	Total N	92	92
	Test Statistic	8.97	11.06
	Asymptotic Sig.(2-sided test)	.034	.0293
		Road 1 (Offset)	Road 2 (Offset)
Hand-held call distraction	Total N	92	92
	Test Statistic	6.743	4.746
	Asymptotic Sig.(2-sided test)	.009	.029
		Road 1 (Offset)	Road 2 (Throttle)
Hands-free call distraction	Total N	92	92
	Test Statistic	4.884	13.824
	Asymptotic Sig.(2-sided test)	.027	.0403
		Road 1 (Age)	Road 2 (Speed)
Take off and put on clothes distraction	Total N	92	92
	Test Statistic	12.27	11.63
	Asymptotic Sig.(2-sided test)	.0131	.0281
		Road 1 (Offset)	Road 2 (Offset)
Text distraction	Total N	92	92
	Test Statistic	15.221	17.785
	Asymptotic Sig.(2-sided test)	.000	.002

***Table 12** The result of Kruskal-Wallis H test for voice command distraction on road 1 and road 2*

Independent-Samples Kruskal-Wallis Test Summary			
	Road 1		Road 2 (Offset)
	(Throttle)	(Offset)	
Total N	92	92	92
Test Statistic	6.323	12.456	12.723
Asymptotic Sig.(2-sided test)	.012	.001	.002

5.2 Scenario #3 (=hand-held call) on "road 1" and "road 2"

According to Kruskal-Wallis H test results for hand-held call distraction on road 1 and road 2, "offset" is the best variable to reject the null hypothesis.

5.3 Scenario #4 (=hands-free call) on "road 1" and "road 2"

The results of Kruskal-Wallis H test for hands-free call distraction on road 1 highlighted that "offset" is the best variable to reject the null hypothesis. The results of Kruskal-Wallis H test for hands-free call distraction on road 2 specified that "throttle" is the best variable to reject the null hypothesis.

5.4 Scenario #5 (=take off and put on clothes) on "road 1" and "road 2"

Based on the Kruskal-Wallis H test results for take off and put on clothes distraction on road 1, "age" was deemed the best variable for rejecting the null hypothesis. Furthermore, "speed" was selected as the best independent variable to reject the null hypothesis on road 2.

5.5 Scenario #6 (=text) on "road 1" and "road 2"

Based on the Kruskal-Wallis H test results for text distraction on road 1, "offset" was identified the best variable for rejecting the null hypothesis. A value of zero for the offset error on road 1 was obtained.

Table 13 *The highly correlated independent variables from Kruskal-Wallis H test*

Scenario	Description of the scenario	Road 1	Road 2
#2	Eat and drink	Offset	Age
#3	Hand-held call	Offset	Offset
#4	Hands-free call	Offset	Throttle
#5	Take off and on clothes	Age	Speed
#6	Text message	Offset	Offset
#7	Voice command text	Throttle, Offset	Offset

Table 14 *The generalized linear regression models for the frequency of distracted participants*

Scenario	Road #1	Road #2
#2	Frequency of distraction = 200.85 -0.032*Speed + 58.54*Offset -0.092*Throttle + 11.55*Gender + 4.43*Age	Frequency of distraction = 74.22 +1.34*Speed + 3.45*Offset +45.88*Throttle + 8.67*Gender + 3.39*Age
#3	Frequency of distraction = 103.54 +0.16*Speed + 84.13*Offset +17.55*Throttle + 6.03*Gender -1.88*Age	Frequency of distraction = 44.51 +1.05*Speed + 54.03*Offset +1.42*Throttle + 7.05*Gender + 2.46*Age
#4	Frequency of distraction = 50.78 +1.96*Speed + 15.84*Offset -6.09*Throttle + 9.17*Gender -0.302*Age	Frequency of distraction = 42.96 +1.05*Speed + 1.51*Offset +55.25*Throttle + 7.5*Gender +2.52*Age
#5	Frequency of distraction = 119.53 +1.91*Speed + 1.76*Offset +90.15*Throttle + 0.84*Gender +5.21*Age	Frequency of distraction = 87.67 +1.69*Speed + 3.46*Offset +61.95*Throttle + 9.03*Gender +3.81*Age
#6	Frequency of distraction = 156.67 -0.115*Speed + 16.22*Offset +1.89*Throttle + 0.27*Gender -3.33*Age	Frequency of distraction = 42.97 +1.008*Speed + 54.42*Offset +1.39*Throttle + 7.51*Gender +2.55*Age
#7	Frequency of distraction = 143.002 +0.261*Speed + 15.88*Offset +22.69*Throttle + 1.08*Gender -1.87*Age	Frequency of distraction = 50.16 +1.23*Speed + 66.96*Offset +1.51*Throttle + 7.53*Gender +2.51*Age

Accordingly, the variable offset on road 1 can reject the null hypothesis with a great accuracy. Similarly, the “offset” variable was selected as the best independent variable to reject the null hypothesis on road 2.

5.6 Scenario #7 (=voice command text) on “road 1” and “road 2”

According to Kruskal-Wallis H test results on road 1, two independent variables including “throttle and offset” were capable of rejecting the null hypothesis. In road 2, the variable “offset” was considered as an independent variable that could reject the null hypothesis.

Asymptotic Significant error in Tables 11 and 12 shows the error value of the test that should be less than 5% confidence interval. Table 11 shows that the significant error is always less than the confidence interval, indicating that the statistical analysis is highly accurate. Considering the two highly correlated independent variables for voice command distraction on road 1, this type of distraction was not mentioned in Table 11. The results of voice command distraction are shown in Table 12.

As a discussion of the statistical analysis and for different categories of distraction, Table 13 shows highly correlated independent variables from the Kruskal-Wallis H test.

To identify a statistical relationship between the distraction type (distracted, somewhat distracted, and not distracted) and the highly correlated independent variables, the generalized linear regression models were developed. The model with the lowest significant error (< 5%) was reported for all independent variables. Table 14 shows twelve linear regression models on roads #1 and #2.

6 Conclusions

Public safety is at risk due to distracted driving. Since 2005, the distracted driving fatalities have increased dramatically due to the dramatic rise in texting volume. As technology advances, motor vehicle drivers are increasingly exposed to distractions. Injuries and fatalities may occur when the driver’s attention is diverted from on the road to out-of-the road. Cell phone use is one of the most common distractions for motor vehicle drivers. In addition to the cell phone use, other distractions e.g., eating or drinking, taking off or putting on clothes, reading, using a navigation system, grooming while driving, distractions from kids or other passengers, distraction by pets, adjusting climate control while driving, playing with the radio, reaching driver’s wallet while driving, and looking at a traffic accident or an eye-catching billboard (rubbernecking) were taken into account as the major distraction ways of vehicle drivers. In this study, a real-world network, including the two different roads (a freeway and an urban arterial), was simulated to examine the behavior of vehicle drivers during distraction. After in-person monitoring of both roads and based on the location of physical barriers on the road, the location of billboards and the points with a high probability of crashes, one point on each road were considered to distract the drivers. A car simulator was used to model the network, and 92 participants from inside and outside of the university were recruited to drive 7 scenarios including without distraction, distraction by eating and drinking, distraction by hand-held call, distraction by hands-free call, distraction by taking off or putting on clothes, distraction by texting a message, and distraction by sending a voice command text. Various age groups of participants were invited to address different driving behaviors. In addition, participants with prior driving experience were invited. Participants were asked to complete a pre-survey questionnaire before starting the scenarios. Participant's personal information was collected in a pre-survey questionnaire. The participants then drove the scenarios in each 2 hours' sessions. Participants were asked to complete a post-survey questionnaire after completing the scenarios to identify their experience with the car simulator. An initial database was collected from the car simulator and highly correlated distracted driving variables were identified using the Pearson correlation and factor analysis tests. Using the Pearson correlation and factor analysis tests, variables such as gender, age, vehicle speed, throttle, and vehicle offset from the center of the road were identified as highly correlated variables.

After reviewing the state-of-the-art, three hypotheses were developed to analyze speed, throttle, and offset before, during, and after the distraction. Literature review and personal observation of participants' behavior during the distraction on the road led to the time intervals for before, during, and after distraction. In the state-of-the-art, Kruskal-Wallis H tests has been less used. Hereupon, this gap in the literature was addressed in our research. This paper presents the following findings and contributions:

As a conclusion of male and female participants on road 1 in "during-before" distraction sets, females significantly increased speed more than males when using a hand-held call (=scenario #3), hands-free call (=scenario #4), text (=scenario #6), and voice command text (=scenario #7). Among the scenarios, there was an increase in throttle value for female participants in eat and drink (=scenario #2), hand-held call (=scenario #3), hands-free call (=scenario #4), and taking off and on clothes (=scenario #5). Female participants also increased their offset from the center of the road in scenario hand-held call (=scenario #3) compared to male participants. In "after-during" distraction sets, in the scenarios without distraction (=scenario #1), eating or drinking (=scenario #2), hand-held calling (=scenario #3), hands-free calling (=scenario #4), and taking off and putting on clothes (=scenario #5), female participants increased their speed more than male participants. In scenarios eat and drink (=scenario #2), hand-held call (=scenario #3), and hands-free call (=scenario #4), throttle value increased more for female participants. Additionally, female participants increased the offset from the center of the road in scenarios eat and drink (=scenario #2), hand-held call (=scenario #3), and text (=scenario #6).

As a conclusion of male and female participants on road 2 in "during-before" distraction sets, Female participants increased their speed more than male participants in scenarios #2, #3, #4, #5, #6, and #7. Female participants increased throttle more than male participants in scenarios #2, #3, #5, #6, and #7. In addition, female participants keep their distance from the center of the road when distracted by a hand-held call (=scenario #3) or a hands-free call (=scenario #4). In "after-during" distraction sets, female participants drove conservatively, not increasing vehicle speed after distractions. Female participants increased the throttle more than male participants in scenarios #3, #4, and #6. Furthermore, female participants in scenarios #2, #3, #5, and #7 keep a greater distance from the center of the road than male participants.

The highly correlated variable for each type of distraction was specified by Kruskal-Wallis H test analysis. As shown in Table 13, In scenarios #2, #3, #4, #6, and #7, "offset" was identified as a highly correlated variable when the participant drove on a freeway road (road 1). Likewise, age and throttle were found in scenarios #5 and #7 respectively as highly correlated variables when the participant drove on a freeway road (road 1). On road 2 (an urban arterial road), age (in scenario #2), offset (in scenarios #3, #6, and #7), throttle (in scenario #4), and speed (in scenario #5) were specified as highly correlated variables with distracted driving. Additionally, the statistical relationship of distracted participants in terms of highly correlated independent variables were specified by using linear regression models.

Sending a text, eating or drinking, applying makeup, working with a cell phone, texting, and using hand-held calls are all of these tasks that negatively affect the quality of driving. Drivers are responsible for keeping themselves, their passengers, and other road users safe by concentrating on the road. Visual distractions (eyes off the road), manual distractions (hands off the wheel), and cognitive distractions (mental diversion) are all main activities that lead to distracted driving. Legislation, public awareness campaigns, and technological solutions have all been implemented to combat distracted driving. Many jurisdictions prohibit handheld phone use and texting while driving. Public campaigns aim to raise awareness about distraction dangers. As well as alerting drivers to potential hazards, advanced driver assistance systems (ADAS) also provide safety features. Evaluating the efficacy of these interventions provides insights into their limitations and potential for improvement. Advancements in technology offer practical ways for mitigating distracted driving including driver-monitoring systems that use cameras and sensors to detect signs of distraction. These systems provide issue warnings or intervene if a driver appears distracted. Additionally, improved voice recognition and gesture control interfaces can reduce manual interactions and lead to traffic safety. Education programs and cognitive training can enhance drivers' ability and attention on driving tasks. These interventions aim to foster safer driving behaviors by cultivating a sense of responsibility and self-regulation. Incorporating human-centered design principles in vehicle and interface design can play a fundamental role in minimizing distraction. Providing the user-friendly interfaces can efficiently reduce the cognitive load on drivers, allowing them to focus on the road, and enhance traffic safety. By analyzing patterns of distraction and identifying high-risk situations, interventions can be tailored to specific contexts and individual behaviors. Stricter and rigorous implementation of regulations addressing distracted driving, combined with elevated fines and penalties, can be an enforcement tool to reduce the distracted driving. However, stricter, and rigorous distracted driving laws should be investigated based on the equity concepts so that this approach takes into account the equitable demands of the community. As a practical solution to eliminate the negative consequences of distracted driving, efficient approaches are suggested, including providing comprehensive education, integrating road safety modules into school curricula and driver education programs, and addressing the safe driving habits. These programs can extremely foster an environment where distraction is socially unacceptable. To improve the situation and eliminate weak points that lead to crashes caused by distracted driving, a multifaceted approach should be implemented. By combining the legislative efforts, technological innovations, and education, a holistic strategy can be developed to create safer road environments. Pulling over for a few seconds in cases if the driver plans to eat or drink, implementing navigation systems e.g., GPS before heading to the destination, familiarizing with the vehicle's controls especially any infotainment system with touch screens, setting up the radio stations or streaming music before start the vehicle, pulling over in the cases of taking a call, sounding off the notifications that distract driver's attention while driving, and limit the time looking away from the road or taking the hands off the wheel are practical ways that improve traffic safety while driving.

Some limitations of the study worth mentioning are including more distraction ways, different types of weather condition, more participants and developing models such as distracted prediction or recognition, machine or deep learning models, multilevel models, or hierarchical models. Policymaking, legislation, education, training, safety guidelines, and car manufacturing standards can benefit from the findings of this study. In the U.S., the distracted driving laws have been enacted in many states. Teen drivers should be prohibited from texting while driving, hands-free laws should be implemented, and passengers under the age of 18 should not be allowed to ride along with them. A graduated driver licensing system (GDL) provides new drivers with lower-risk driving experience by gradually granting them driving privileges. Various states have installed rumble strips on highways to alert drowsy, distracted, or otherwise inattentive drivers. Certain types of crashes can be reduced by these rumble strips.

As a future work, the authors are interested in working on machine or deep learning models, k-means clustering, and logistic regression.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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