Final Report

Investigating the Impact of Distracted Driving among Different Socio-Demographic Groups

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ABSTRACT

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Contents

INTRODUCTION

Distracted drivers are involved in about 9% of all crash fatalities, accounting for 3,166 deaths, including 497 pedestrians in 2017 [1]. With the prevalence of cell phones and their various uses, these numbers may potentially rise. Therefore, more in-depth knowledge of accepted safe driving behaviors is needed.

Driving safely consists of performing a collection of visual-motor tasks involving a vehicle and in which the tasks vary as a function of time, place, and speed [2]. Driver distraction occurs when a driver "is delayed in recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to include the driver's shifting attention away from the driving task," and is the major cause of driver inattention [3]. Simply being "lost in thought" is another category of inattention which is distinguished from extrinsic distraction [3].

Driver distractions can be further divided into driving environment complexity effects, such as roadside advertisements, and in-vehicle effects including talking with other passengers, eating/drinking, radio tuning, or, more recently, cell phone usage [4]. Some researchers use tuning the radio as a benchmark for distracted driving [5]. Numerous studies show that cell phone usage compromises drivers' attention [6]–[11]. However, not all usages of the phone have similar distracting effects. Texting has been found to be more distracting [12], [13], perhaps because it has both a cognitive demand and a physical constraint in comparison with conversing over the phone [14]. However, other studies suggest that even using text-to-speech technology still impairs drivers' reaction time and attention span [15], [16].

In a report published by AT&T, about 97% of teenagers admitted knowing the dangers of texting and driving; however, 43% reported that they still text sometimes. About 75% of the respondents have described texting or emailing while driving as "common" among their friends and peers. More than 90% of the participants agreed that a severe legal action (license suspension or a $500 ticket) would be the most preventive method [17]. The results from similar penalties support these survey findings. For instance, Liu et. al have investigated the effectiveness of California's 2008 ban on handheld phones while driving. Their results show the effectiveness of these regulations and support a full ban on cell phone usage, not just hand-held devices [18]. Other researchers explored the willingness of drivers to use applications that limit some phone usage such as texting but allow access to other applications like GPS in order to reduce exposure to high-risk behaviors while driving [19].

The three types of research involving cell phones and other driving distractions are: epidemiological studies, field studies, and recent research conducted using simulators [10]. Törnros et al. investigated the effects of hand-held and hands-free phones on driving performance using a simulator and found that while hands-free usage of a phone improved lateral driving control during the conversation period, distraction measurements during dialing and other activities were no different when compared to hand-held usage [20]. Another study compared talking on a cell phone to talking to a passenger and found that phone conversations caused a greater deceleration in response time and thereby posed a higher collision hazard [6]. Lateral performance measures during distracted driving were investigated by Choudhary et. al in 2017 on 100 drivers, and the results indicated a significant decrease in performance during the texting and driving task. They suggest in-vehicle monitoring devices for driver distraction measurements [11].

LITERATURE REVIEW

One of the most significant traffic safety problems is driver distraction. According to the National Highway Traffic Safety Administration (NHTSA), 9% of all 37,133 crash fatalities are attributed to driver distraction which involved 2,994 distracted drivers in 2017 [21]. The distraction problem is getting worse due to the increasing use of in-vehicle information systems such as GPS navigation systems, cell phones, and satellite radios [22], [23]. Modern vehicles are filled with driver-assistance technology such as a navigator, multimedia displays, climate control, parking radar, and many more. Although drivers benefit from such modern driving assistance technologies [24], [25], it is still critical for drivers to avoid distraction and pay suitable attention to the road.

It was shown previously that wireless devices, conversation with a passenger, and in-vehicle distraction are the major sources of incidences [6]. In addition, the growing use of mobile phones while driving, which takes the driver's attention away from the primary task of driving, has increased the number of traffic incidences and crashes. According to the NHTSA, about 5.3% of drivers used either hands-free or hand-held phones while driving at a typical daylight moment in 2017 [21].

Driver distraction happens when an object or event attracts a person's attention away from the driving task. Distraction deteriorates driving performance by diverting the driver's eyes from the road (visual distraction) like adjusting the GPS [26] or taking away driver's mind off the driving task (cognitive distraction) like conversing on a hands-free cell phone [27]. Besides talking on the phone or to a passenger and interacting with in-vehicle information technologies like a navigation system, other distracting activities are adjusting the radio, shopping online, applying makeup, eating, and drinking. Several researchers investigated the impact of different types of distraction on driving behavior including interacting with a phone [28]–[30], reading (text message and email) [28], navigation tasks [28], [31], interacting with a music player [28], [29], memory tasks, and classifying sentences [32], [33]. In addition to the type of distraction, the impact of different distracting tasks depends on several other factors such as experience [34], fatigue [35], road conditions (e.g., curves, turns, crossings, and heaviness of traffic) [36], and age [33], [37]. All the aforementioned studies confirmed the detrimental effect of different types of distraction on driving performance such as lane changing [38], [39], [31]; reduced anticipation of the need to brake and shortened time to collision [40]; and reduced car following performance [29], [39], [41].

Driving behavior with and without each distraction should be compared to detect the pure effect of driver distraction. Visual and cognitive distractions represent the two main types of distraction [42]. A visual distraction that involves the driver's eyes off the road can be determined by temporary changes of drivers' eye glances. Detecting cognitive distraction, in which the mind is off the road, is more complex than detecting visual distraction because the symptom of cognitive distraction is generally not apparent and can differ among drivers. Quantifying the complex relationship between drivers' cognitive states and distraction indicators is a big challenge.

Distracted driving is defined as diverting the driver's attention from driving to other behaviors, tasks, or situations that lessen the driver's ability to sustain awareness and be in full control of the vehicle [50]. Distracted driving may have different causes such as eating, drinking, manipulating dashboard controls, visual deviations like looking at a smartphone screen, or cognitive activities like talking on the phone that take attention away from driving. Some activities such as texting can include all different types of distractions. For example, texting while driving includes physical, visual, and cognitive distractions. Distracted driving is a safety threat as it takes drivers' eyes off the road, hands off the steering wheel, and thoughts elsewhere. Also, the probability of a crash happening is high among distracted drivers [51], [52]. Distracted driving is one of the core contributors to crashes in the U.S.; Distracted driving is responsible for almost 40% of all crashes happening on roadways [53].

The advent of in-vehicle technologies and smartphones, which result in distracted driving, prompted concern about driving safety and inspired researchers to conduct more studies on distraction. Although in-vehicle systems such as adaptive cruise control systems and navigation are designed to advance safety and convenience [24], [25], working with in-vehicle systems occasionally diverts a driver's attention from the main driving tasks [54]–[56]. For example, talking on the phone while driving is a distracting behavior, even with hands-free systems [57], [58]. The subject of the conversation results in more distracted driving than does the technique of phone conversation [58]. The driver's attention diverts from the driving task to the conversation, which depreciates driving performance. Over time, with improvements in technology, new forms of distraction, including voice command text [59] and personalized phone-based digital assistance [60] cause distraction as well.

Several researchers have studied the influence of distracted driving on road safety [4], [61]–[64]. Different types of distracted driving contain a combination of manual, visual, auditory and cognitive components, each of which can negatively impact drivers' ability to keep lane position, speed, and their eyes on the road [65], [66]. Drivers whose eyes are away from the road because of a distracting activity for prolonged periods of time cannot safely control their vehicles [67], [68]. Driving is mainly a combination of visual, spatial, and manual tasks. Hand-held phones diverted visual attention away from the roadway when dialing a number or picking up a call, and one hand was taken off the steering wheel to hold the phone to the ear. Texting not only diverted visual attention away from the roadway but also took both hands off the wheel. Studies show that distracted driving has a tremendous effect on traffic safety. Some studies concluded that distracted driving increases crash risk by increasing the reaction time and response time of drivers [66], [69], [70]. Distracted drivers have a tendency toward unsafe driving behavior that increases the probability of a crash happening. The probability of using the phone while driving among younger and male drivers is higher when compared to older and female drivers based on the survey collected from 834 licensed drivers. The survey also revealed that the longer the drive is, the more likely the driver is to use a cell phone. [71]. The young driver may be more vulnerable to a distraction-related crash as they are among the strongest users of cell phones [72].

Distracted driving may also reduce the proficiency of the traffic network by increasing the headway between vehicles unreasonably [73]. Studies about distracted driving showed that talking on a hand-held cell phone while driving harms the drivers' capability to sustain their speed and location on the road [14], [74]; texting while driving increases reaction times to push the brake and increases the variability of lane changing with no change in speed [58], [67]. Reading texts while driving is the most distracting activity for youthful drivers [75].

Studies indicated that the use of cell phones among all drivers increases the risk of a crash by a factor of four [67], [76]. Similarly, another study using a simulator involving adolescent drivers showed that texting while driving increases the frequency of deviations in a lane in relation to the position from the centerline [77].

Talking and driving each requires different levels of an individual's attention, and the more attention-demanding the activity is, the less successful the performance of each individual task will be [78]. As a result of cell phone use while driving, less visual information is processed by drivers in the driving scene [79], drivers do not stop completely at stop signs [80], braking response time increases [81] and more rear-end collisions occur [80]. Several studies used machine-learning techniques to recognize visual and cognitive distractions for in-vehicle distraction mitigation systems [65], [82]–[86]. Nevertheless, while there is not an absolute correlation between distractive driving and motor vehicle accidents, the probability of a crash happening is high, based on the driving patterns displayed by distracted drivers. Usually, the speed of distracted drivers using cell phones tends to be low [79], their following distance is high [87], [88], and the frequency of lane changing is less, all of which can result in disturbances in traffic flow and increased congestion.

Previous questionnaire-based research with 20 questions regarding distraction caused by billboards in Lahore, Pakistan, was conducted with 1,000 randomly selected respondents [89]. The results indicated that 70.1% of respondents read billboard contents at least once during their trip. Some 85.8% claimed they were distracted by billboards while driving, and 86% divulged they were distracted by billboards even though they were not driving. According to Hassan [89], billboard advertisements are, to a great extent, a traffic safety threat, taking drivers' attention away from the road.

Dukic et al. [90] recruited 41 drivers between 35 and 55 with at least 5,000 Km/year driving experience using an instrumented vehicle, and a head-mounted eye-tracking system. They indicated that billboards seem to have effects on gaze behavior due to longer glances than common road signs. They concluded that to determine whether billboards are a dangerous distraction, more research should be done where the environment is controlled in a better way. This control can be done on-road, considering tactical maneuvering and conflicts and not just speed, lateral position data, and gaze behavior [90].

Commercial Electronic Variable Message Signs (CEVMS) seem to distract drivers more than do standard billboards. According to an FHWA study [91], participants looked more often at CEVMS than standard billboards (63% CEVMS to 37% Standard) on arterials, while they looked more at standard billboards than CEVMS (67% Standard to 33% CVEMS) on freeways. Furthermore, drivers gazed at CEVMS more than standard billboards at night (71% CEVMS to 29% Standard) compared to 52% and 48% percent at CEVMS and standard billboards during daytime, respectively [91].

Among drivers, teenagers are the age group most exposed to visual driving distractions due to their high utilization of cell phones or engagement in other secondary tasks. According to recent research based on real-world driving data from Virginia [92], 41% of crashes occurred due to cell phone usage, and 10% because of reaching for objects while driving. Hence, there is a direct relation between engaging in distractions, visual or manual, and the crash risk, which is higher among teenagers [93].

Visual behavior of drivers when distracted by billboards has been the subject of several types of research. Decker et al. [94] revealed that billboards do not affect glance pattern activity, and the distraction caused by billboards is minor. Therefore, the suggestion for future research is to understand the effects of driver characteristics, billboard design, and road and traffic context [94].

During the past decades, several studies have been done to examine the correlation between the presence of an out-of-vehicle visual distraction and driving performance, especially concerning lateral control. Some of these studies found a connection between these two parameters [94], [95] and some others had a contrasting result [96]. However, billboards were not the main subjects of this research. Billboards play a vital role in drivers' visual and cognitive distraction. They are highly visually demanding objects. Therefore, the size, type, and the content of the billboard can have a high impact on distraction [97].

In the current study, a driving simulator is used to investigate the effects of six different scenarios of in-vehicle distractions including usage of a cell phone with and without hands-free capability on different types of roads (rural collector, freeway, urban arterial, and local road in a school zone). Drivers were given a survey before and after their driving experience. The goal of this research is to investigate the driver's behavior in the presence of different types of distractions on different types of roads.

METHODOLOGY

Ninety-two young participants were recruited from Morgan State University and the Baltimore metro area via flyers distributed manually, online, and through social media. Flyer content included contact information, a summary of the requirements for the study, and an explanation of the monetary compensation for driving the simulator. Subsequently, prospective participants were screened for eligibility and scheduled to drive in the simulator environment.

Participants were required to possess a valid driver's license and were compensated at $15 per hour for their study participation. In addition, participants were asked to use their own cell phone during the driving experience and brought a hands-free device and a jacket/sweater with them for different distracting experiences. We provided them with water and candy for drinking and eating distractions.

Under the supervision of an advisor, a team of undergraduate and graduate student research assistants observed the IRB-approved driving tasks, and questionnaire. Participants were asked to fill out a pre-survey questionnaire, then drive for about two hours in different simulated scenarios, and then fill out the post-survey questionnaire after driving to find the effect of their experience on driver behavior.

The observer made sure that the participants' cell phones worked properly. They instructed the participants to drive briefly to familiarize themselves with the simulator environment and explained the procedure before each scenario. Participants were instructed to adjust their cell phone to a loud ringer volume and have it handy before beginning each scenario.

The participants started driving in a base scenario with no distraction to compare that driving behavior with other types of distractions. Participants then drove six different in-vehicle distraction scenarios – including hands-free call, hand-held call, voice commands text, text, taking off or on clothing, and eating or drinking and one out-of-vehicle distraction, billboards –

on a 36 Km^2 road network north of the Baltimore metropolitan area that includes four different road classes (rural collector, freeway, urban arterial, and local road in a school zone) with various numbers of lanes and speed limits (Figure 1).

There was one type of in-vehicle distraction in each scenario, and the distraction happened exactly at the same location (red circles in Figure 1). The questions involved were similar in cognitive load (but different in content) for a fair comparison between different distractions. Participants were instructed to answer a phone call, respond to a text message upon receiving it, take off or on clothing, and drink or eat during the simulated drive. Participants did not know the questions they would receive as a call or text during any given scenario so that they would not exhibit anticipatory behavior that would have influenced their driving behavior. Additionally, there were three billboards in the freeway in all scenarios as presented in Figure 1 (Blue Diamonds).

For out-of-vehicle distractions, the focus is on a 3-mile stretch of I-695 from Exit 27 to the Exit 3 corridor, where the billboards are located. I-695 is a 51.46-mile full beltway extending around Baltimore, Maryland, in the United States operating since 1958. The portion of I-695 in our study contains four lanes and the speed limit is 55 mph. As shown in Figure 1, there are three static billboards (posters) with a distance of 1,720 meters between the first and last one. The second billboard was placed 1,000 meters after the first, and 720 meters before the last billboard. The first billboard was placed in the straight part of the highway, the second billboard was placed after, and the last one was placed right after a corner, and visibility of it was restricted by trees. Contents of the billboards varied from the Morgan State University logo for the first one, a longer text with numbers for the second one, and the SABA center logo for the last billboard.

During each driving scenario, participants were instructed to drive as they typically would on a real road for approximately 15 min and comply with the speed limit. The virtual roads environment featured one lane with a 30 mph speed limit for the rural collector, three lanes with 55 mph for the freeway, two lanes with 45 mph for the urban arterial, and one lane with 30 mph for the local road. The daytime scenery closely matched driving situations in the Baltimore metropolitan area. Traffic flow and density were the same in all seven scenarios. The driving experience in each scenario progresses from rural to freeway, then to urban and finally to a local road, and participants received the distraction in the same location in each scenario (Figure 1).

Figure 1: Study Network, distraction with cell phone (Red Circles) and billboard locations (Blue Diamonds)

The observers used a script that required participants to respond to various open-ended questions with a similar cognitive load. Typical questions were "What comes to your mind when you hear the word 'America'?" or "What's your No. 1 vacation destination?" and "How many of your friends have names beginning with 'F'?". The participants were distracted five times during each scenario, including once in a rural area, twice on the freeway, and once each in the urban and local area at exactly the same position.

The questionnaires involved completing demographic information and questions about real driving behavior before the driving simulator experience (pre-survey) and driving behavior after driving the simulator (post-survey). Observers gave participants the option of completing the questionnaire on their own or with the assistance of the observer.

Participants drove about 10 miles in each scenario in a high-fidelity driving simulator to provide a measure of driving performance under different distracting tasks [98]. The simulation was displayed on three, 40-inch LCD screens. Participants sat within the simulator's driver compartment, which provided a view of the roadway and dashboard instruments, including a speedometer (Figure 2). Naturalistic engine sounds, road noise, and sounds of passing traffic were provided to simulate the real world. Simulated vehicles with varying speed and volume were randomly programmed with assigned low traffic volume to represent off-peak conditions in the area. Researchers could safely assess the impact of distracted driving by comparing drivers' behavior under different types of distractions with no distraction.

Figure 2: Driving Simulator

The gaze frequency and duration were captured using the Tobii Pro glasses 2 head-mounted Mobile eye-tracking system [99] which captures eye movement using two sensors for each eye and one central camera that records the main event. The recordings were analyzed using the Tobii analyzer by defining areas of interest for each billboard as the out-of-vehicle distraction and cell phones in voice-command and texting distraction scenarios. AOIs (areas of interest) were carefully set to capture gaze fixations as precisely as possible.

Different information about the driver's behavior including speed, throttle, brake, steering velocity, offset from road center, and lane change was calculated for the distraction condition. For example, offset from the road center, which was reported as the deviated distance from the road center toward the right or left side, was calculated and saved as an indicator of impaired driving performance. Greater within-lane deviation indicated poorer driving precision. Average driving speed within the distraction area (the distraction area was different for each road) was calculated based on the speed of the vehicle and time of distraction and computed as the degree to which drivers changed their speed for each scenario. Lane change frequency was used as an indicator and defined as the number of times the driver changed lanes. The brake force and throttle which are indicators of distraction, are compared with no distraction scenario. The severe force of a brake demonstrates inattention to the road and taking the mind off the road.

Descriptive statistics were obtained on pre-survey questionnaire data regarding participant characteristics. Some 56.52% of participants were male and 43.48% were female. The age group of participants was between 18 to 40 years old; 44.57% of which were in the age group of 21 to 25 years (Table 1).

Table 1: Sociodemographic Analysis, with intentions to balance gender

Variable		Frequency	Percent
Gender	Female	40	43.48
	Male	52	56.52
Age	18 to 20	15	16.30
	21 to 25	41	44.57
	26 to 30	15	16.30
	31 to 35	9	9.78
	36 to 40	12	13.04
Education Status	Associate degree	7	7.61
	College graduate	14	15.22
	College student	50	54.35
	High School or less	15	16.30
	Postgraduate	6	6.52
Employment Status	No	44	47.83
	Full time	18	19.57
	Part time	30	32.61
	Total	92	100.00
Household Annual Income	$20K to $30K	18	19.57
	$30K to $50K	19	20.65
	$50K to $75K	11	11.96
	$75K to $100K	2	2.17
	Less than $20K	27	29.35
	More than $100K	15	16.30
Household Size	1	23	25.00
	2	23	25.00
	3	18	19.57
	4 or more	28	30.43

RESULTS AND DISCUSSION

Pre-Survey Analyzing

According to the pre-simulation survey, 85.8% of the participants always or sometimes follow GPS while driving. Interestingly, 8.7% of participants never follow GPS when they are behind the wheel (Figure 3). Some 62% of participants entered an address (always or sometimes) to the GPS while driving, which is similar to texting.

Based on the pre-simulation questionnaire, the most common phone-related activity while driving was hands-free talking; 53.3% of participants always or sometimes do it. Reading/updating social media was the least favorite activity with 73.9% of participants stating they never use their phone to check/update their social media and only 1.1% admitted using their cell phone while driving for this activity (Figure 4). Interestingly, while 44.6% of the participants never did hand-held calling while driving, only 37% never texted while driving.

Among non-cell phone/technology-related distractive activities, eating/drinking is the most popular, with 83.7% having eaten/drunk while driving (Figure 5).

Figure 6 shows some 33.7% of participants have experienced a near-crash incident while using their cell phone in the past three years. Yet 21.7% of participants were confident about using their cellphone when driving, while only 2.2 % were very doubtful about it. Approximately 7.6% of participants have experienced a crash due to using their cell phone while driving. However, some 28.3% of participants have friends or family members who were involved in a crash while using their electronic devices while driving. Interestingly, only 4.3% of participants said they would never reply to text messages when they are driving, and the rest stated they would answer right away, wait for a safer situation to answer, or stop on the shoulder of the road and answer the text.

Pursuant to participants' response to the post-simulation survey (Figure 7), 10.9% of participants find dynamic message signs distractive. Yet most of them do not consider billboards and dynamic message signs as serious distractions. Regarding the technologies used while driving, only 4.3% use signal jammers and 1.1% use headphones while 31.5% use the text to voice / voice to text features of their device. Nevertheless, 63% of participants don't use any of the mentioned technologies while driving.

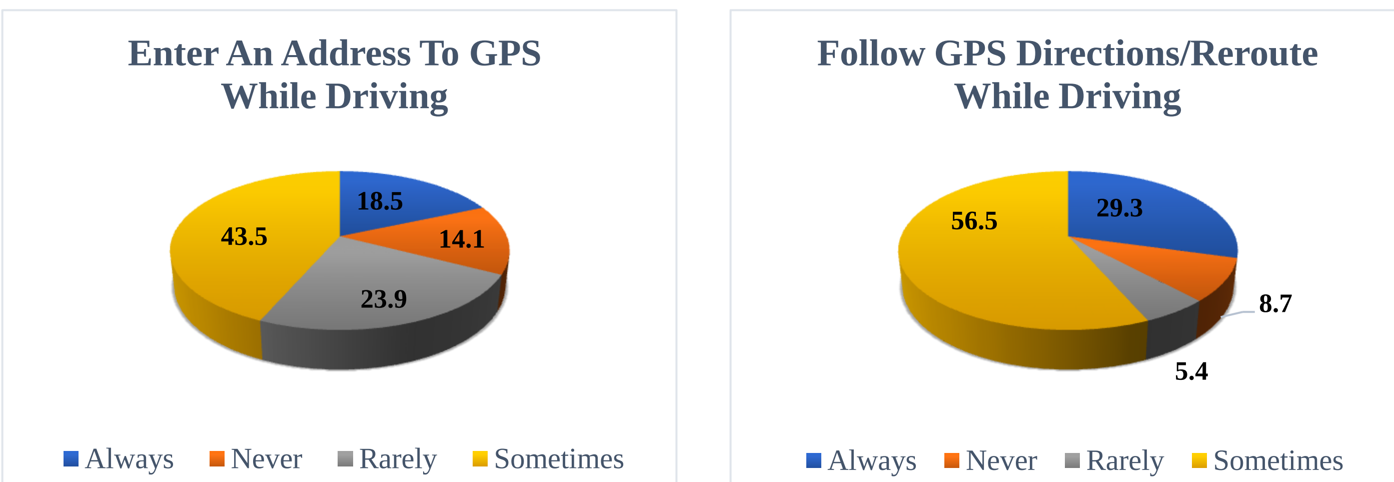


Figure 3: Pre-simulation survey, GPS-related distractions

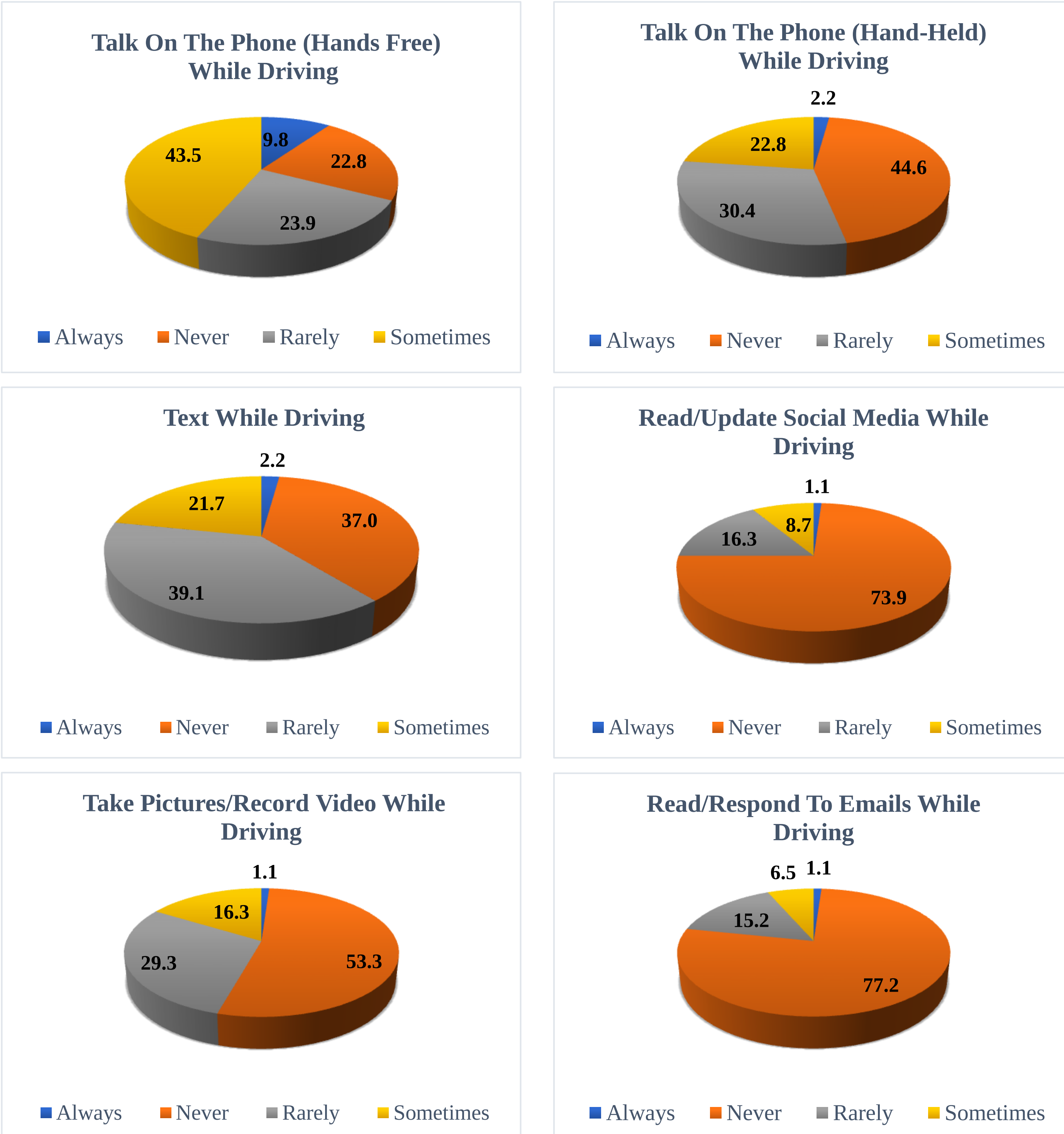


Figure 4: Pre-Simulation survey, Cell phone-related distractions excluding GPS and route selection

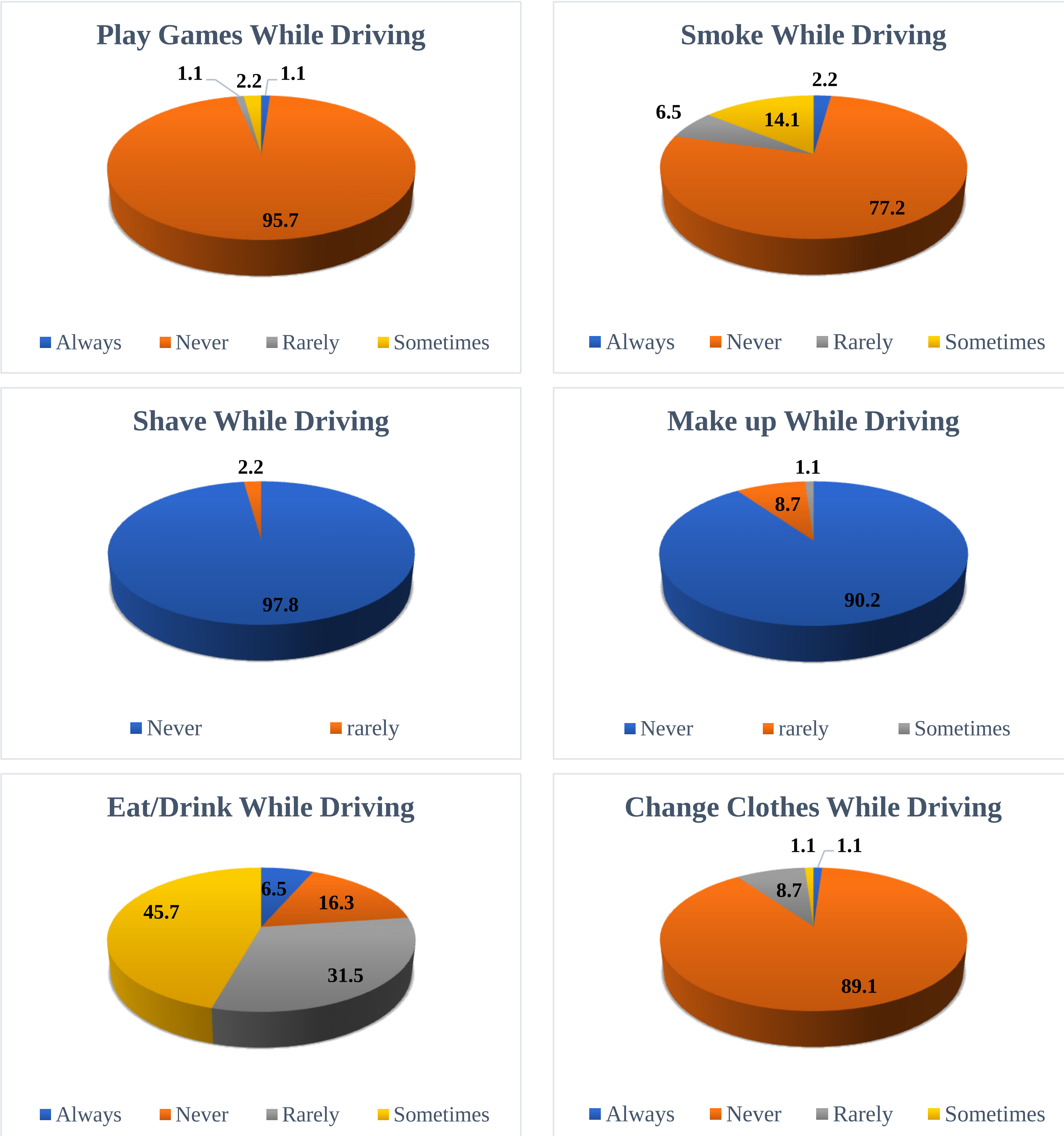


Figure 5: Pre-simulation survey, other types of distractions

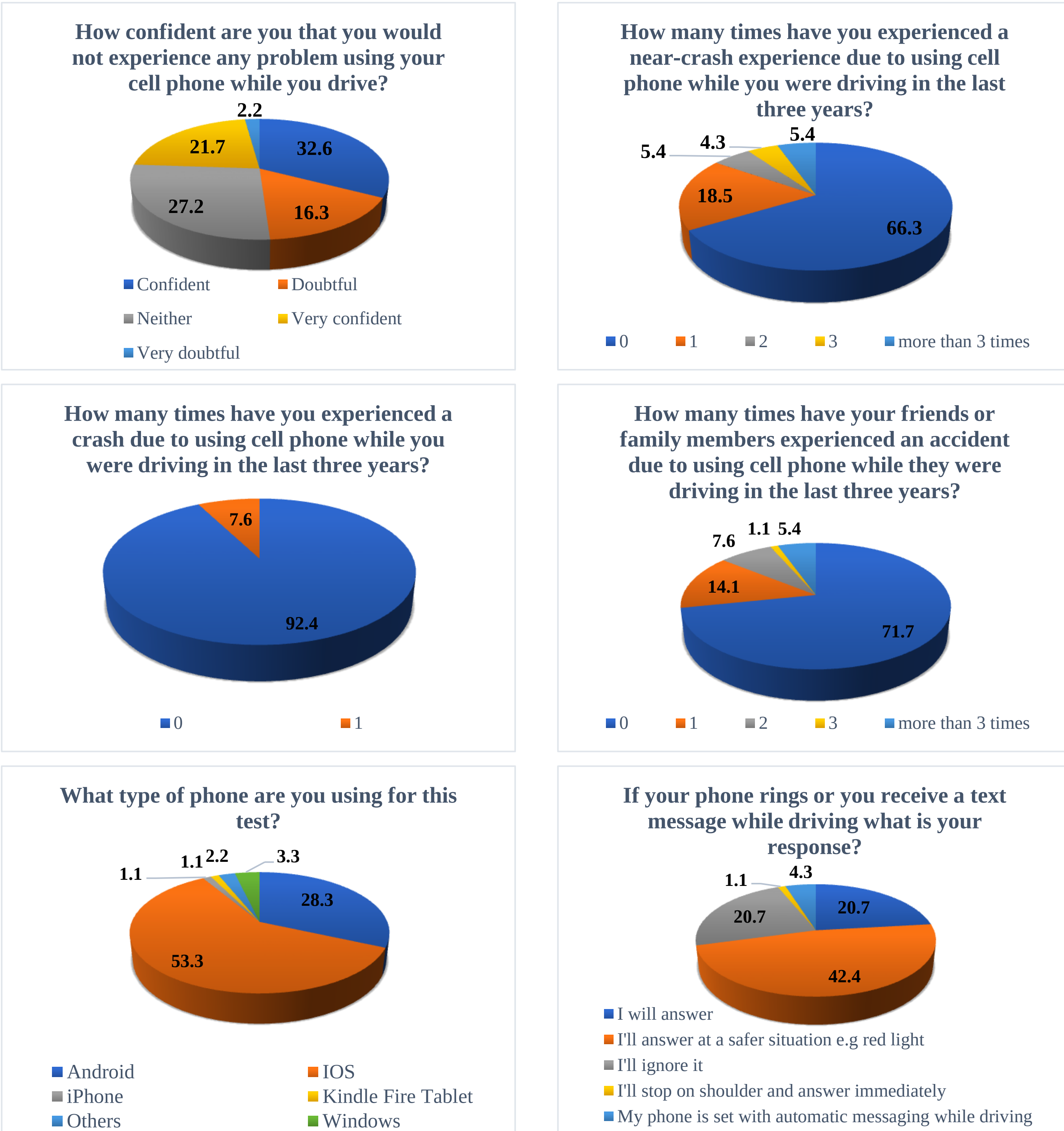


Figure 6: pre-simulation survey responses

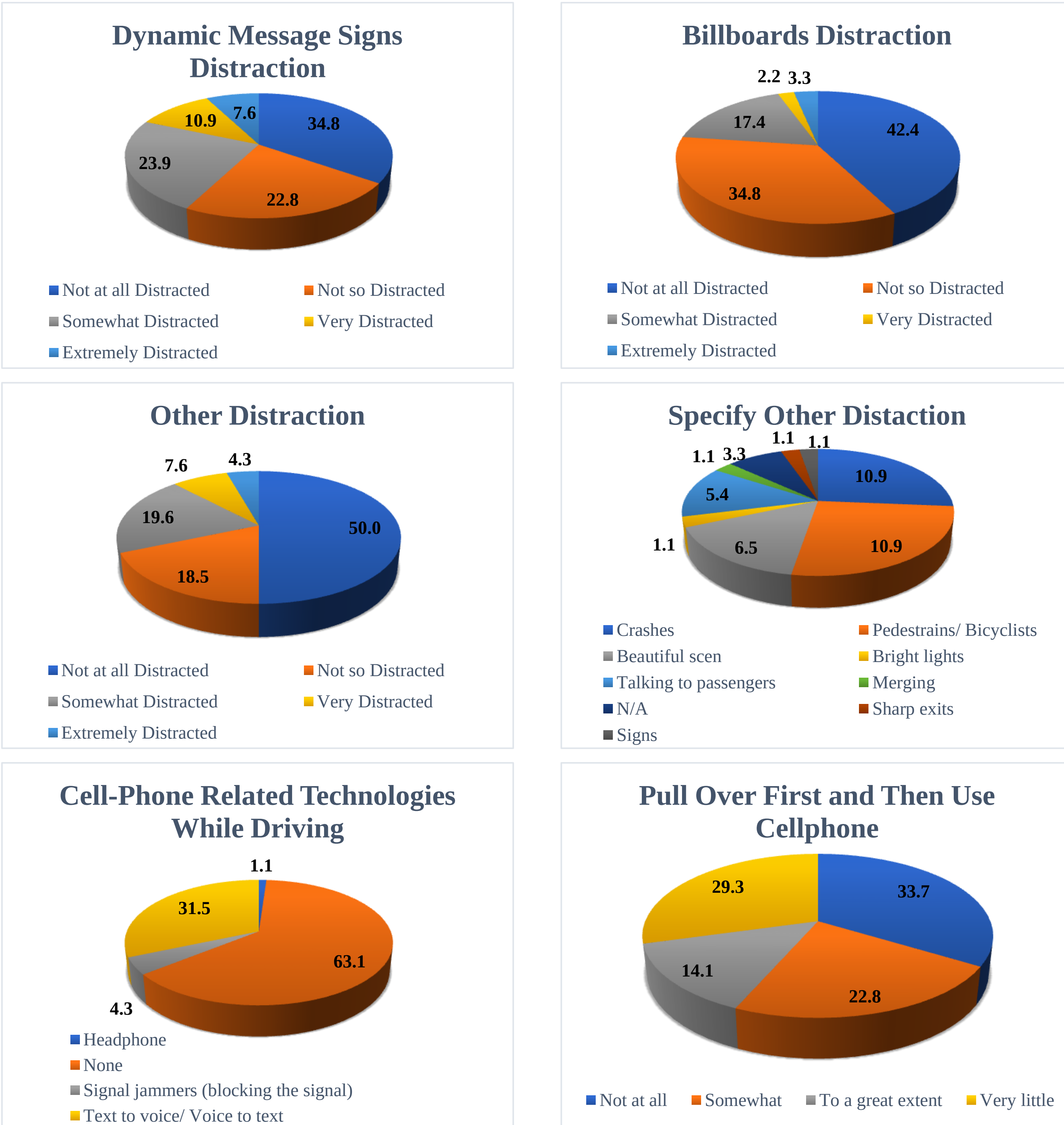
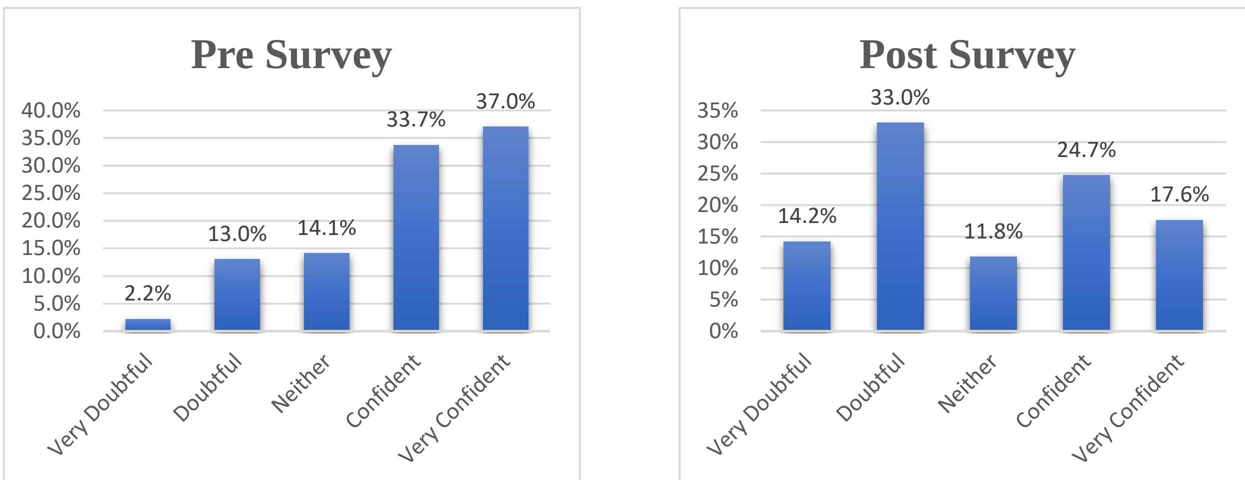


Figure 7: Pre-simulation survey responses regarding other types of distractions and driver reaction to distractions

Post-Survey Analyzing

The results of the post-survey questionnaire show a great change in the attitude of drivers after being involved in such a study. Some 36.5% of the participants stated that the driving simulator experience encouraged them to reduce cell phone use while driving. And 47.2% were doubtful about using technologies while driving for safety's sake, compared to only 15.2% who were doubtful in the pre-survey questionnaire. After driving, 51.8% expressed doubt about their ability to use cell phones freely and not make any driving mistakes; 26% had stated they were doubtful in the pre-survey (Figure 8).

To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.? [Technologies such as voice to text]



To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.? [No cell phone while driving]

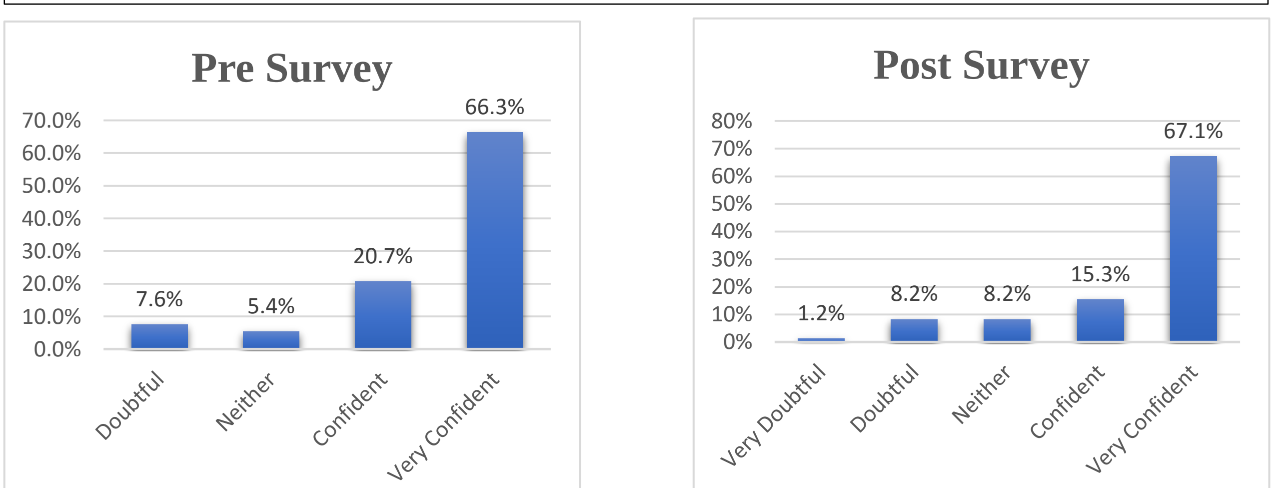
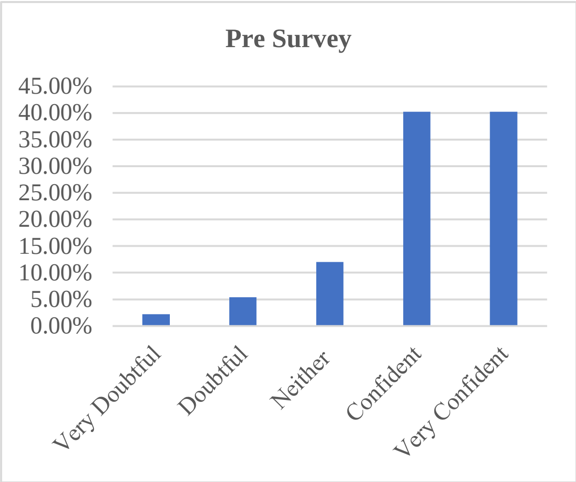
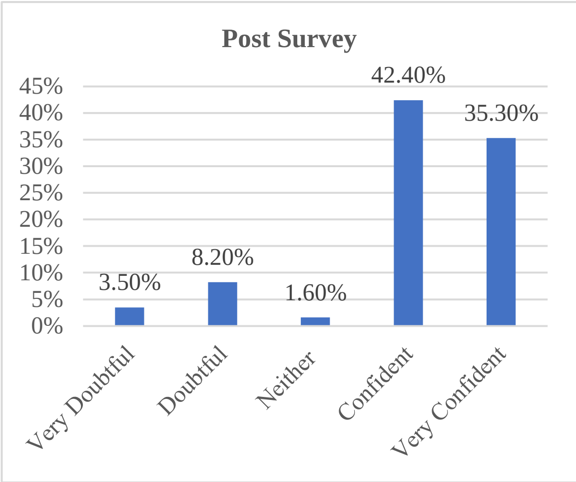


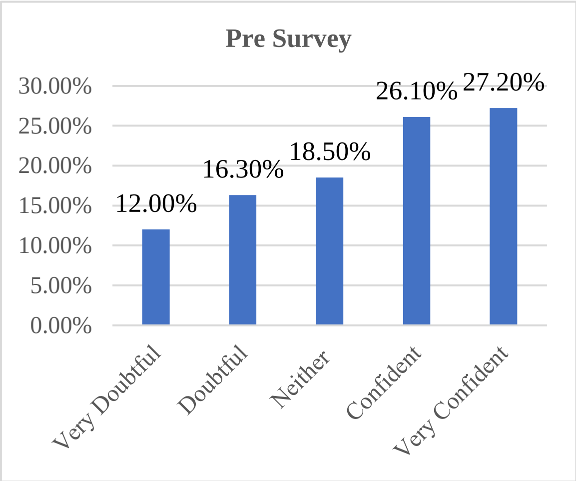
Figure 8: Participants' confidence using distracting devices before and after simulation

To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.? [<u>Using accessories such as headsets</u>]





To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.? [<u>Hand-held cell phone, while driving</u>]



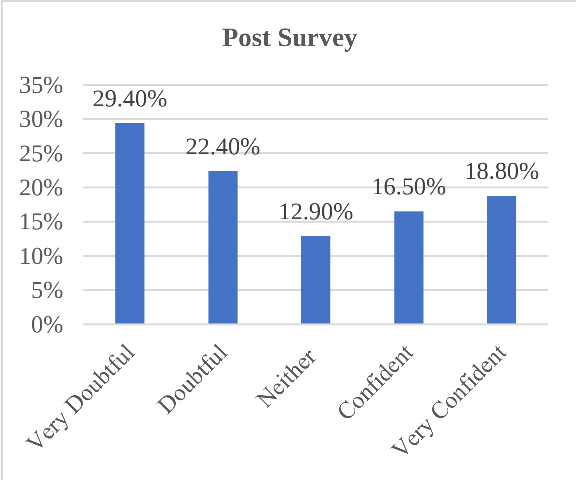


Figure 8: Participants' confidence using distracting devices before and after simulation

Driving Simulator Analysis

In-Vehicle Distractions

Several Analysis of Variance (ANOVA) were conducted to compare the driving behavior (speed, throttle, brake, steering velocity, offset from road center, and lane change) under different types of distractions (no distraction, hands-free call, hands-held call, voice commands text, text, taking off or on clothing, and eating or drinking) on different road classes. The results (Table 2) revealed significant differences in speed, throttle, brake, steering velocity, offset from road center, and lane change when comparing different types of distractions to no distraction.

Table 2: Descriptive and ANOVA Analysis

Variables		N	Mean	Std. Deviation	F	N	Mean	Std. Deviation	F	N	Mean	Std. Deviation	F	N	Mean	Std. Deviation	F
DV	IV (Type of Distraction)	Type of Road															
		Rural Collector				Freeway				Urban Arterial				Local Road in a School Zone			
Speed	No Distraction	78	70.31	19.15		156	83.16	9.67		78	52.22	14.55		66	35.72	11.32	
	Hands-Free Call	81	55.41	14.40		162	74.55	8.25		81	44.95	7.38		64	31.37	10.82	
	Hand-Held Call	81	55.00	14.94		160	73.94	7.09		79	45.60	8.55		70	30.59	8.98	
	Voice Commands Text	78	56.62	14.63	8.14*	154	72.71	8.10	37.64*	77	43.69	9.77	8.53*	69	27.68	10.68	6.62*
	Text	77	60.07	13.95		154	72.90	8.37		77	43.58	9.65		70	27.89	9.64	
	Taking off or on Clothing	42	53.66	16.60		84	69.40	6.99		42	41.68	9.44		38	22.59	11.31	
	Eating or Drinking	43	58.45	15.47		86	69.83	7.00		43	40.57	10.28		40	28.49	11.54	
Trottle	No Distraction	78	0.37	0.19		156	0.33	0.15		78	0.29	0.16		66	0.12	0.07	
	Hands-Free Call	81	0.25	0.12		162	0.29	0.13		81	0.23	0.10		64	0.10	0.07	
	Hand-Held Call	81	0.27	0.15		160	0.29	0.13		79	0.24	0.11		70	0.11	0.08	
	Voice Commands Text	78	0.26	0.12	8.45*	154	0.29	0.12	13.01*	77	0.25	0.10	1.83	69	0.09	0.06	2.59*
	Text	77	0.33	0.15		154	0.30	0.15		77	0.27	0.15		70	0.11	0.05	
	Taking off or on Clothing	42	0.38	0.15		84	0.26	0.11		42	0.25	0.15		38	0.12	0.06	
	Eating or Drinking	43	0.39	0.19		86	0.28	0.13		43	0.26	0.16		40	0.12	0.07	
Brake	No Distraction	78	0.01	0.01		156	0.01	0.01		78	0.01	0.01		66	0.10	0.09	
	Hands-Free Call	81	0.00	0.01		162	0.01	0.01		81	0.01	0.01		64	0.10	0.10	
	Hand-Held Call	81	0.01	0.01		160	0.01	0.01		79	0.01	0.01		70	0.09	0.08	
	Voice Commands Text	78	0.00	0.01	2.01*	154	0.01	0.01	3.50*	77	0.01	0.01	0.63	69	0.09	0.07	2.09
	Text	77	0.00	0.01		154	0.01	0.01		77	0.01	0.01		70	0.09	0.07	
	Taking off or on Clothing	42	0.01	0.02		84	0.01	0.01		42	0.01	0.01		38	0.12	0.09	
	Eating or Drinking	43	0.00	0.01		86	0.01	0.01		43	0.01	0.01		40	0.13	0.11	
Steering Velocity	No Distraction	78	0.02	0.01		156	0.04	0.03		78	0.02	0.01		66	0.03	0.02	
	Hands-Free Call	81	0.02	0.01		162	0.04	0.03		81	0.02	0.01		64	0.03	0.05	
	Hand-Held Call	81	0.02	0.01		160	0.04	0.03		79	0.02	0.01		70	0.02	0.02	
	Voice Commands Text	78	0.02	0.01	3.75	154	0.04	0.04	0.94	77	0.02	0.01	4.03*	69	0.02	0.02	3.04*
	Text	77	0.02	0.01		154	0.05	0.04		77	0.02	0.01		70	0.03	0.02	
	Taking off or on Clothing	42	0.02	0.01		84	0.06	0.04		42	0.03	0.01		38	0.03	0.01	
	Eating or Drinking	43	0.02	0.01		86	0.05	0.04		43	0.02	0.01		40	0.03	0.02	
Offset From Road Center	No Distraction	78	0.97	0.63		156	3.73	3.25		78	2.50	2.22		66	0.61	0.37	
	Hands-Free Call	81	0.96	0.65		162	3.37	3.06		81	2.48	2.34		64	0.61	0.39	
	Hand-Held Call	81	0.93	0.64		160	3.53	3.11		79	2.30	2.24		70	0.61	0.39	
	Voice Commands Text	78	0.97	0.64	8.87	154	3.59	3.23	6.27*	77	2.41	2.21	4.43*	69	0.58	0.33	5.97*
	Text	77	0.95	0.62		154	3.65	3.17		77	2.36	2.21		70	0.65	0.37	
	Taking off or on Clothing	42	1.49	0.26		84	6.28	1.76		42	3.91	1.57		38	0.90	0.31	
	Eating or Drinking	43	1.53	0.27		86	6.32	1.55		43	3.81	1.61		40	0.88	0.34	
Brake Light	No Distraction	78	0.09	0.46		156	0.26	0.98		78	0.60	1.42		66	2.32	3.06	
	Hands-Free Call	81	0.06	0.29		162	0.35	1.14		81	0.44	1.14		64	2.08	2.97	
	Hand-Held Call	81	0.23	0.69		160	0.46	1.44		79	0.65	1.72		70	2.17	2.72	
	Voice Commands Text	78	0.10	0.44	1.68	154	0.31	0.99	2.75*	77	0.35	1.12	2.37	69	2.04	2.71	7.27*
	Text	77	0.13	0.52		154	0.27	0.97		77	0.32	0.94		70	2.23	2.98	
	Taking off or on Clothing	42	0.00	0.00		84	0.00	0.00		42	0.00	0.00		38	0.00	0.00	
	Eating or Drinking	43	0.00	0.00		86	0.00	0.00		43	0.00	0.00		40	0.00	0.00	

Description: Speed: Unit: miles per hour. Throttle: input on the acceleration pedal. It is a ratio with a value between 0 (no Throttle) and 1 (Full Throttle). Brake: input on the brake pedal. It is a ratio with a value between 0 (no Brake Force) and 1 (Full Brake Force). Steering velocity**:** rotation rate of the steering wheel, Unit: 1/second. Offset From Road Center: distance between the center of the car and the center of the road. Brake Light: number of times the brake has been applied.

Table 3 shows the result of the post hoc Tukey, which reveals the significant difference of independent variables when comparing each type of distraction with no distraction. Steering velocity and brake did not change among different distractions. This result shows a negative

Table 3: Post Hoc Tukey Analysis

Variables			Mean Difference (I-J)	Std. Error	Mean Difference (I-J)	Std. Error	Mean Difference (I-J)	Std. Error	Mean Difference (I-J)	Std. Error
DV	IV (Type of Distraction)		Type of Road							
			Rural Collector		Freeway		Urban Arterial		Local Road	
Speed	**No Distraction**	**Hands-Free Call**	14.28*	2.50	8.92*	0.89	7.37*	1.58	7.97*	1.84
		Hand-Held Call	15.58*	2.50	8.97*	0.90	6.88*	1.59	9.43*	1.80
		Voice Commands Text	16.25*	2.52	9.36*	0.90	8.90*	1.60	11.93*	1.81
		Text	14.53*	2.53	9.81*	0.90	7.05*	1.60	10.42*	1.80
		Taking off or on Clothing	20.69*	3.01	13.37*	1.08	7.88*	1.90	17.76*	2.13
		Eating or Drinking	14.96*	2.99	12.80*	1.07	10.02*	1.89	9.57*	2.10
Throttle	**No Distraction**	**Hands-Free Call**	0.12*	0.02	0.04*	0.01	0.05	0.02	0.01	0.01
		Hand-Held Call	0.10*	0.02	0.04	0.01	0.04	0.02	0.00	0.01
		Voice Commands Text	0.11*	0.02	0.05*	0.01	0.04	0.02	0.02	0.01
		Text	0.04	0.02	0.04	0.01	0.01	0.02	0.01	0.01
		Taking off or on Clothing	-0.01	0.03	0.07*	0.02	0.04	0.02	0.00	0.01
		Eating or Drinking	-0.02	0.03	0.06*	0.01	0.02	0.02	-0.01	0.01
Brake	**No Distraction**	**Hands-Free Call**	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
		Hand-Held Call	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
		Voice Commands Text	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
		Text	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
		Taking off or on Clothing	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.02
		Eating or Drinking	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.02
Steering Velocity	**No Distraction**	**Hands-Free Call**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Hand-Held Call	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Voice Commands Text	0.00	0.00	-0.01	0.00	0.00	0.00	0.01	0.00
		Text	0.00	0.00	-0.01*	0.00	0.00	0.00	0.00	0.00
		Taking off or on Clothing	0.00	0.00	-0.02*	0.00	-0.01*	0.00	0.00	0.00
		Eating or Drinking	0.00	0.00	-0.02*	0.00	0.00	0.00	-0.01	0.00
Offset from Road Center	**No Distraction**	**Hands-Free Call**	0.01	0.09	0.36	0.33	0.01	0.35	0.00	0.06
		Hand-Held Call	0.05	0.09	0.20	0.34	0.19	0.35	0.00	0.06
		Voice Commands Text	0.00	0.10	0.14	0.34	0.09	0.35	0.04	0.06
		Text	0.03	0.10	0.08	0.34	0.14	0.35	-0.03	0.06
		Taking off or on Clothing	-0.52*	0.11	-2.55*	0.40	-1.41*	0.42	-0.29*	0.07
		Eating or Drinking	-0.55*	0.11	-2.58*	0.40	-1.31*	0.42	-0.26*	0.07
Brake Light	**No Distraction**	**Hands-Free Call**	0.03	0.09	-0.09	0.12	0.16	0.19	0.24	0.48
		Hand-Held Call	-0.14	0.09	-0.19	0.12	-0.04	0.19	0.15	0.47
		Voice Commands Text	-0.01	0.09	-0.05	0.12	0.25	0.19	0.27	0.47
		Text	-0.04	0.09	-0.01	0.12	0.28	0.19	0.09	0.47
		Taking off or on Clothing	0.09	0.10	0.26*	0.14	0.60	0.23	2.32*	0.55
		Eating or Drinking	0.09	0.10	0.26*	0.14	0.60	0.23	2.32*	0.55

relationship between eating/drinking and taking on/off clothing distractions and deviation from the road center, probably due to removing their hands off the wheel to do so.

Participants significantly reduced their speed and throttle on all four road classes in all six distractions compared to the no-distraction scenario. Table 4 presents lateral performance change percentages between each distraction and no distraction for all four road classes.

As presented in Table 4 and Figure 9, the greatest speed reduction happened on rural and local roads. Taking on/off clothing followed by eating/drinking had the highest speed reduction among all distractions. The results indicate that participants reduced their speeds by almost the same percentages while distracted by cell phones regardless of whether they were hand-held or hands-free, which is consistent with some previous studies [18]. Table 4 presents the lateral performance changes in all road types for every distraction.

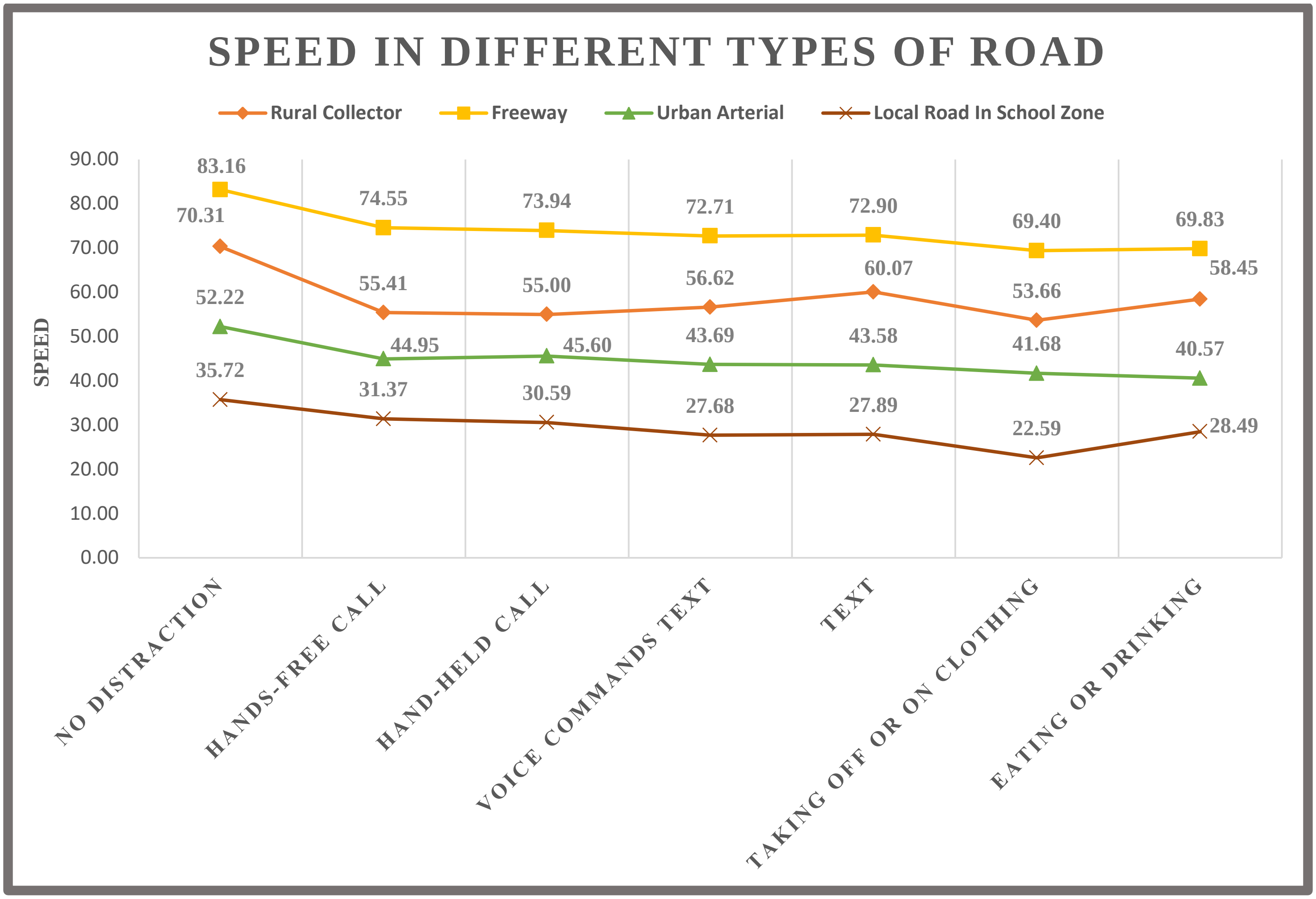


Figure 9: Mean speed among various distractions on different road classes

Table 4: Lateral performance changes in Comparison with No Distraction

DV	Type of Distraction	Road Type			
		Rural Collector	Freeway	Urban Arterial	Local road in a school zone
Speed	Hands-Free Call	-21%	-11%	-14%	-22%
	Hand-Held Call	-22%	-11%	-13%	-26%
	Voice Commands Text	-19%	-11%	-17%	-33%
	Text	-15%	-12%	-14%	-29%
	Taking off or on Clothing	-24%	-16%	-15%	-50%
	Eating or Drinking	-17%	-15%	-19%	-27%
Throttle	Hands-Free Call	-32%	-13%	-19%	-10%
	Hand-Held Call	-27%	-12%	-15%	-1%
	Voice Commands Text	-29%	-14%	-15%	-18%
	Text	-12%	-11%	-5%	-8%
	Taking off or on Clothing	3%	-21%	-14%	0%
	Eating or Drinking	5%	-17%	-8%	8%
Brake	Hands-Free Call	-28%	-3%	9%	-8%
	Hand-Held Call	9%	13%	29%	-9%
	Voice Commands Text	-37%	9%	15%	-14%
	Text	-23%	-10%	0%	-14%
	Taking off or on Clothing	70%	21%	32%	16%
	Eating or Drinking	-12%	-4%	33%	28%
Steering Velocity	Hands-Free Call	-23%	0%	-2%	7%
	Hand-Held Call	-17%	2%	-3%	-13%
	Voice Commands Text	-7%	16%	-7%	-19%
	Text	-11%	20%	-1%	-2%
	Taking off or on Clothing	-12%	64%	33%	-4%
	Eating or Drinking	6%	41%	20%	23%
Offset from the Road Center	Hands-Free Call	-1%	-10%	-1%	0%
	Hand-Held Call	-5%	-5%	-8%	0%
	Voice Commands Text	0%	-4%	-4%	-6%
	Text	-3%	-2%	-5%	5%
	Taking off or on Clothing	53%	68%	56%	47%
	Eating or Drinking	57%	69%	53%	43%
Brake Light	Hands-Free Call	-31%	34%	34%	-10%
	Hand-Held Call	161%	74%	74%	-6%
	Voice Commands Text	14%	19%	19%	-12%
	Text	45%	4%	4%	-4%
	Taking off or on Clothing	-100%	-100%	-100%	-100%
	Eating or Drinking	-100%	-100%	-100%	-100%

Description: calculated using the ANOVA analysis, Table 2.

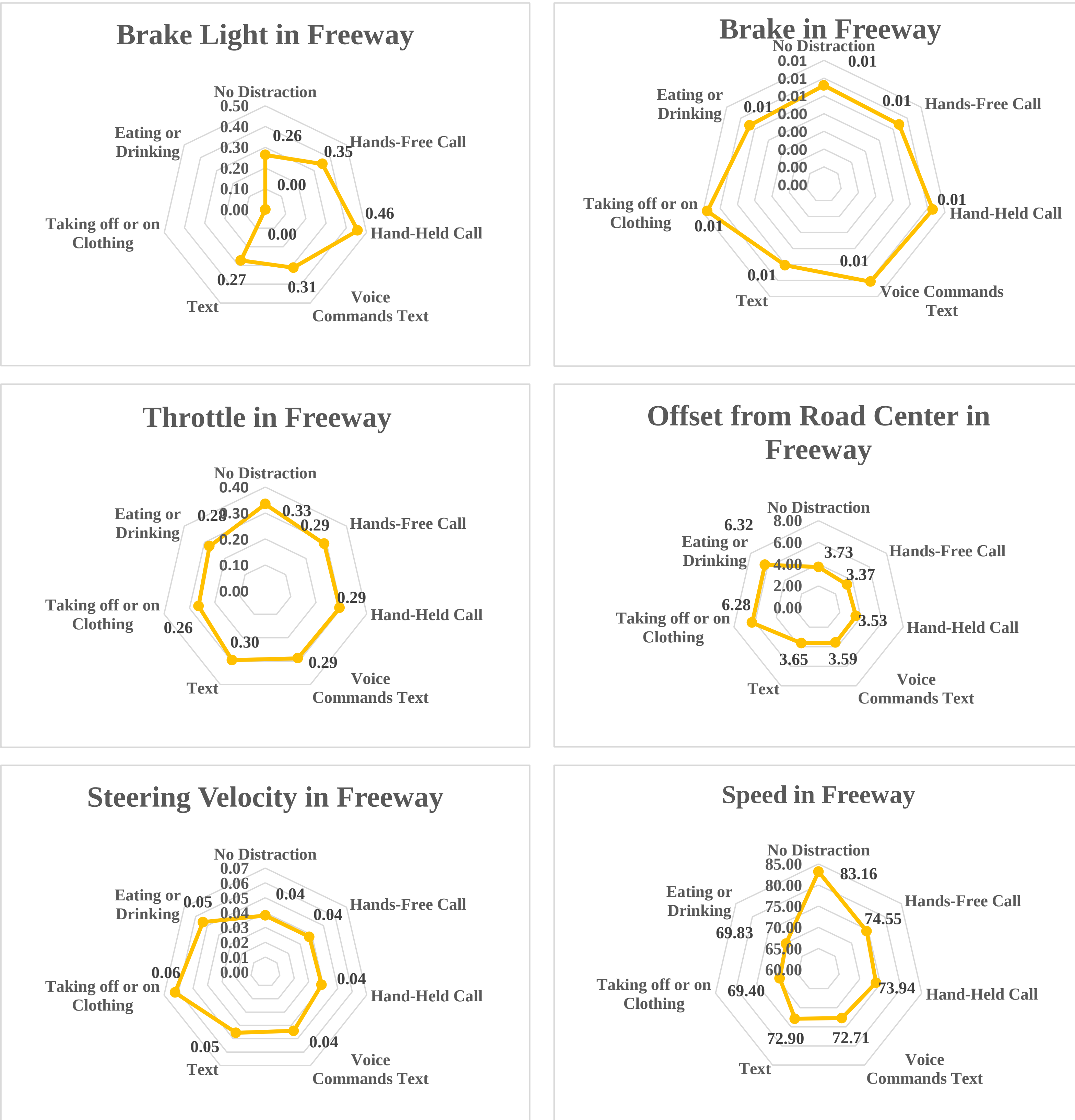


Figure 10: Lateral performance in Freeway concerning different types of distraction

Out-of-Vehicle Distractions (Billboards)

Three billboards were located on the freeway to find the effect of out-of-vehicle distractions on driving performance (speed, throttle, collision, lane changing, brake, and offset from the lane center), as presented in Figure 1 and Figure 11. By running a macro on Microsoft Excel, the average of those parameters was calculated for specific areas before and after each billboard, as shown in Figure 11. An ANOVA analysis was performed to find the variations in the above-mentioned parameters. The visible area is the area in which the billboard is visible but not readable. We tested a visible area for several participants and took an average, which was 820 ft. We selected the post area to be 820 ft to be easily compared with the pre- area. The average readable area for the first two signs was found to be 656 ft and for the third sign to be 525 ft.

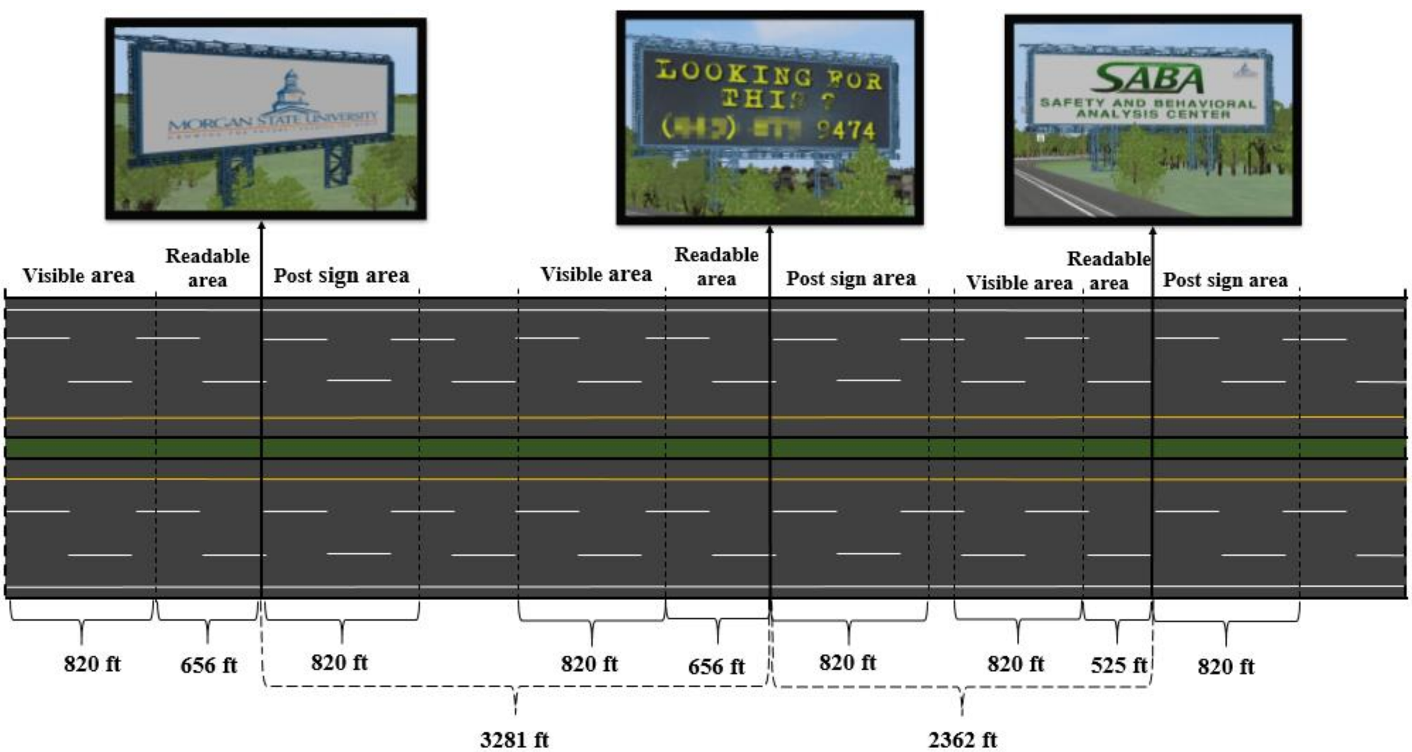


Figure 11: Visible, readable, and post sign (Billboard) areas

The results indicate that participants behave differently to a significant degree when approaching billboards, as shown in Table 5.

Table 5: Descriptive and ANOVA Analysis

Variables	Area	N	Mean	Std. Deviation	Std. Error		F	Sig.
Average Speed	Visible Area	600	51.078	10.883	0.444		8.646	.000
	Readable Area	600	49.898	10.987	0.449			
	Post Sign Area	600	49.516	10.684	0.436			
Average Throttle	Visible Area	600	0.287	0.159	0.006		11.341	.000
	Readable Area	600	0.246	0.137	0.006			
	Post Sign Area	600	0.265	0.147	0.006			
Average Brake	Visible Area	600	0.005	0.011	0.000		32.777	.000
	Readable Area	600	0.015	0.029	0.001			
	Post Sign Area	600	0.015	0.029	0.001			
Average Steering	Visible Area	600	0.024	0.023	0.001		56.979	.000
	Readable Area	600	0.038	0.045	0.002			
	Post Sign Area	600	0.051	0.056	0.002			
Average Offset from Road Center	Visible Area	600	7.319	3.001	0.123		3.269	.038
	Readable Area	600	7.473	2.976	0.121			
	Post Sign Area	600	7.756	3.016	0.123			
Sum Lane Changing	Visible Area	600	0.505	0.679	0.028		29.170	.000
	Readable Area	600	0.232	0.573	0.023			
	Post Sign Area	600	0.308	0.661	0.027			
Sum Collision	Visible Area	600	0.000	0.000	0.000			
	Readable Area	600	0.002	0.041	0.002			
	Post Sign Area	600	0.000	0.000	0.000			
Sum Brake Light	Visible Area	600	0.000	0.000	0.000			
	Readable Area	600	0.000	0.000	0.000			
	Post Sign Area	600	0.000	0.000	0.000			

We also performed a Tukey post hoc test to find the difference in driving behavior in different areas. As presented in Table 6, the mean speed in the visible area is significantly different from the mean speed in the readable area and post sign area. Participants drive on average 2.49 mph higher after they pass a billboard compared to when they were able to read the billboard. They also reduce their speed by 1.88 mph on average when they pass the visible area and reach the readable area. Similarly, they did more steering, more braking, and more offset from the lane center when they transitioned from the visible to the readable area, indicating they were distracted.

Table 6: Post hoc Analysis

Dependent Variables	Independent Variables		Mean Difference (I-J)	Std. Error	Sig.
Average Speed	Visible Area	Readable Area	1.887*	.627	.007
		Post Sign Area	2.499*	.627	.000
	Readable Area	Visible Area	-1.887*	.627	.007
		Post Sign Area	.611	.627	.592
	Post Sign Area	Visible Area	-2.499*	.627	.000
		Readable Area	-0.611	.627	.592
Average Throttle	Visible Area	Readable	.0406*	.009	.000
		Post Sign Area	.022*	.009	.026
	Readable Area	Visible Area	-.040*	.009	.000
		Post Sign Area	-0.018	.009	.077
	Post Sign Area	Visible Area	-.022*	.009	.026
		Readable Area	.0180	.009	.077
Average Brake	Visible Area	Readable	-.010*	.001	.000
		Post Sign Area	-.009*	.001	.000
	Readable Area	Visible Area	.010*	.001	.000
		Post Sign Area	.000	.001	.948
	Post Sign Area	Visible Area	.009*	.001	.000
		Readable Area	-0.000	.001	.948
Average Steering	Visible Area	Readable	-.013*	.003	.000
		Post Sign Area	-.027*	.003	.000
	Readable Area	Visible Area	.013*	.003	.000
		Post Sign Area	-.013*	.003	.000
	Post Sign Area	Visible Area	.027*	.003	.000
		Readable Area	.013*	.003	.000
Average Offset from Road Center	Visible Area	Readable	-0.153	.173	.648
		Post Sign Area	-.436*	.173	.032
	Readable Area	Visible Area	0.153	.173	.648
		Post Sign Area	-0.282	.173	.232
	Post Sign Area	Visible Area	.436*	.173	.032
		Readable Area	.2820	.173	.232
Sum lane Changing	Visible Area	Readable	.273*	.037	.000
		Post Sign Area	.196*	.037	.000
	Readable Area	Visible Area	-.273*	.037	.000
		Post Sign Area	-0.076	.037	.095
	Post Sign Area	Visible Area	-.196*	.037	.000
		Readable Area	.0767	.037	.095
Sum Collision	Visible Area	Readable	-.0017	.001	.439
		Post Sign Area	.0000	.001	1.000
	Readable Area	Visible Area	.0017	.001	.439
		Post Sign Area	.0017	.001	.439
	Post Sign Area	Visible Area	.0000	.001	1.000
		Readable Area	-.0017	.001	.439

Eye-Tracking Analysis

In-Vehicle Distractions

Two types of distractions were considered in the gaze analysis; in one scenario the participant had to type a text message while driving and the other scenario involved using voice commands to respond to a text message. Heat maps for both scenarios were developed, where red indicates the highest number of gaze fixations while green indicates the least number of fixations in the distraction area. The heat map for voice command usage while responding to a text message is shown in Figure 12.

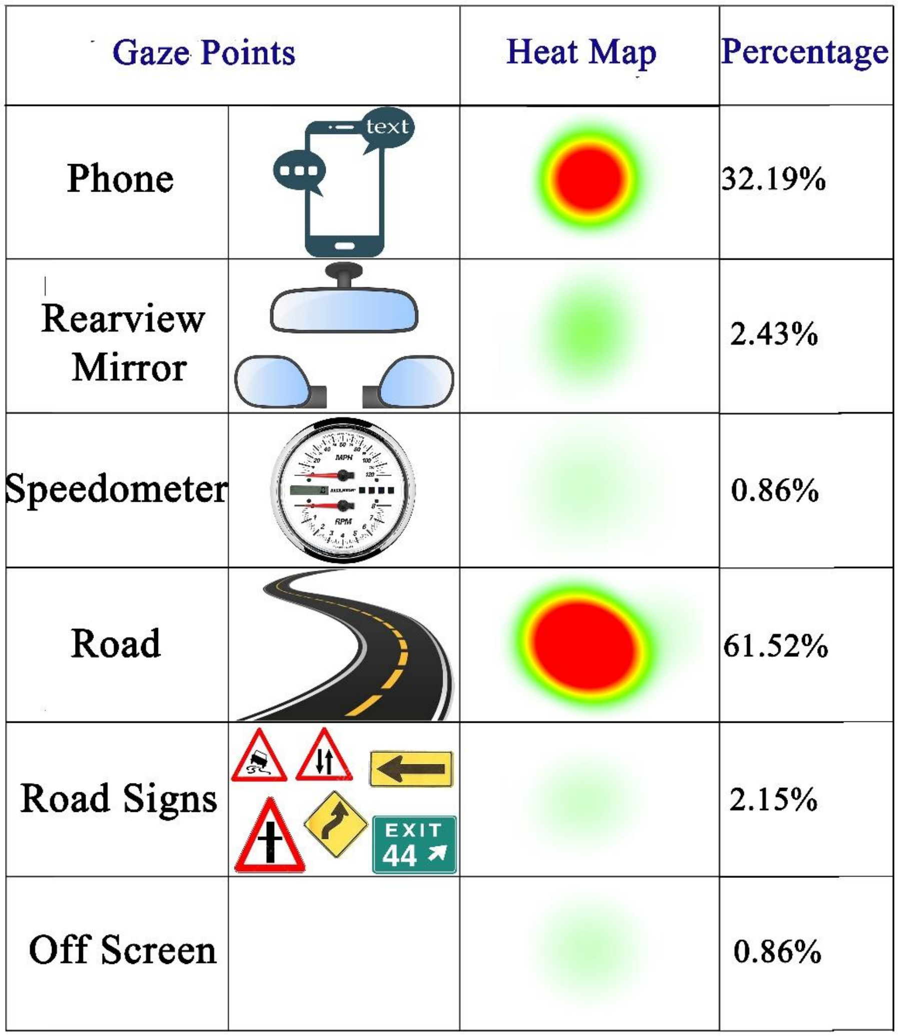


Figure 12: Voice Command response to a text message while driving – heat map

It can be seen that approximately 62% of all gaze fixations were on the road, i.e., the participants were not as distracted. Roughly 32% of all gaze fixations were on the phone while recording the message, which is a significant amount of distraction and could lead to a collision. A binary logit model was developed, in which the fixations were categorized into distraction and no-distraction. An assumption was made where if $\geq 2/3$ of the fixations were on the road, it was considered as a non-distraction and vice versa. The output from the binary logit model with distraction as the dependent variable is shown in Table 7.

Table 7: Binary Logit Model Output – Voice Command

Variables	B	S.E.	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
Age 18 - 25	-2.129	1.431	1	0.137	0.119	0.007	1.964
Age 26 - 35	-2.676	1.535	1	0.081**	0.069	0.003	1.395
Driving Experience: < 1 year	-20.894	22229.945	1	0.999	0.000	0.000	
Driving Experience: 1 - 2 years	1.474	1.376	1	0.284	4.367	0.294	64.761
Driving Experience: 2 - 3 years	-0.615	1.077	1	0.568	0.541	0.066	4.460
Miles per Week: < 100	0.976	0.957	1	0.308	2.654	0.407	17.314
Miles per Week: 101 - 200	0.627	1.195	1	0.600	1.872	0.180	19.492
Miles per Week: 201 - 300	0.524	1.175	1	0.655	1.690	0.169	16.902
Gender - Male	-1.906	0.816	1	0.020*	0.149	0.030	0.737
Constant	4.118	2.051	1	0.045*	61.410		

*Statistically significant at 95% C.I. **Statistically significant at 90% C.I.

Table 7 shows that male participants were less distracted than female drivers at 95% statistical significance, i.e., their gaze fixations were more on the road than the phone, compared to female participants. Participants were classified into two age groups, and the older participants were found to be less distracted, at 90% statistical significance. Figure 13 shows the heat map for typing a text message while driving.

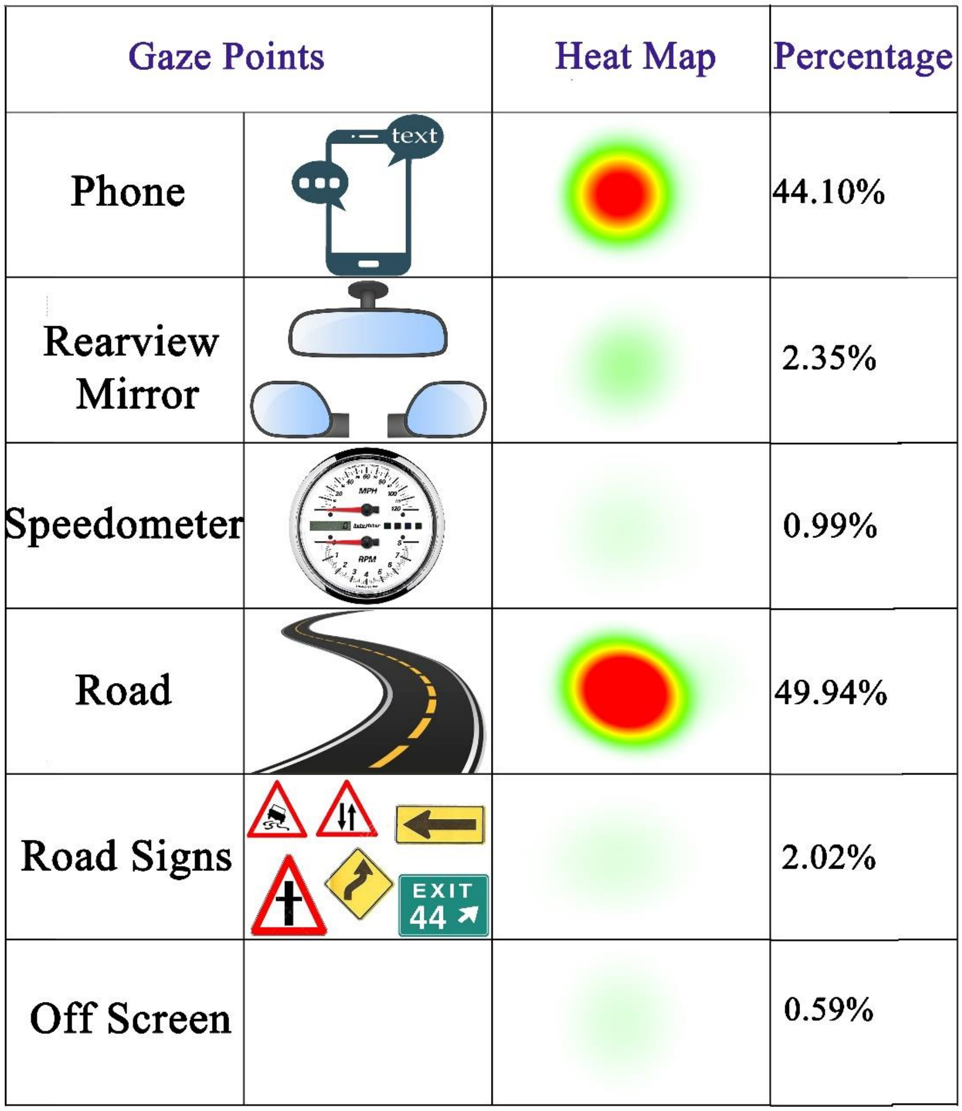


Figure 13: Typing a text message while driving – heat map

It can be seen that approximately 50% of all gaze fixations were on the road, i.e., the participants were not as distracted. Roughly 44% of all gaze fixations were on the phone while typing the message, which is a significant amount of distraction and 12% higher than the voice command scenario, which could lead to a collision. Another binary logit model was developed for this scenario, in which the fixations were categorized into distraction and no-distraction. The same assumption as the voice command scenario was made in this model, with regard to distraction and non-distraction. The output from the binary logit model with distraction as the dependent variable is shown in Table 8.

Table 8: Binary Logit Model Output – Text messaging

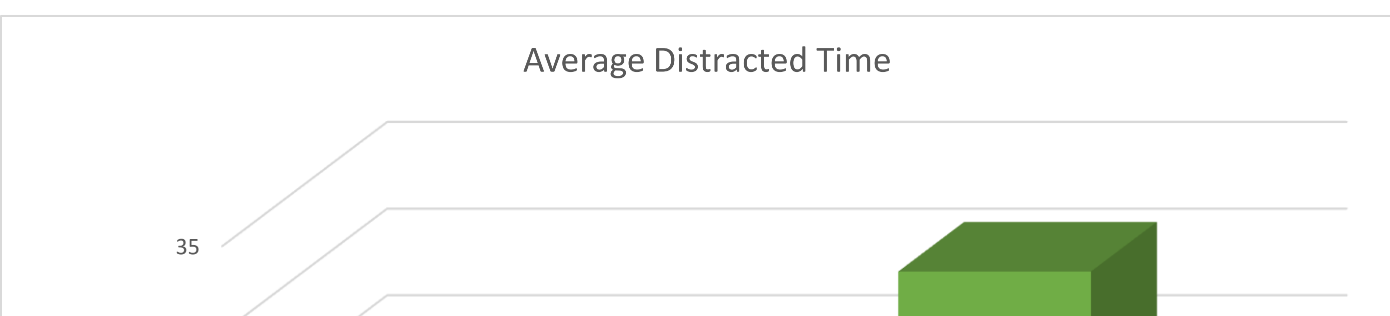
Variables	**B**	**S.E.**	**df**	**Sig.**	**Exp(B)**	**95% C.I.for**

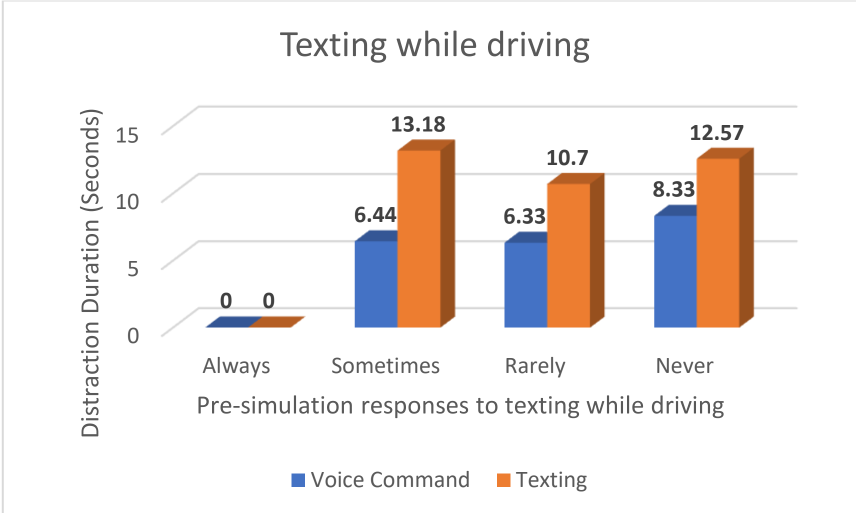
						EXP(B)	
						Lower	**Upper**
Driving Experience: < 1 year	2.414	1.627	1	0.138	11.176	0.461	271.071
Driving Experience: 1 - 2 years	1.108	1.366	1	0.417	3.029	0.208	44.083
Driving Experience: 2 - 3 years	2.877	1.658	1	0.083**	17.758	0.688	458.215
Miles per Week: < 100	-0.544	1.335	1	0.684	0.581	0.042	7.950
Miles per Week: 101 - 200	0.571	1.441	1	0.692	1.769	0.105	29.835
Miles per Week: 201 - 300	1.134	1.597	1	0.478	3.108	0.136	71.173
Gender - Male	-2.447	1.302	1	0.060**	0.087	0.007	1.111
Constant	0.985	1.777	1	0.579	2.678		

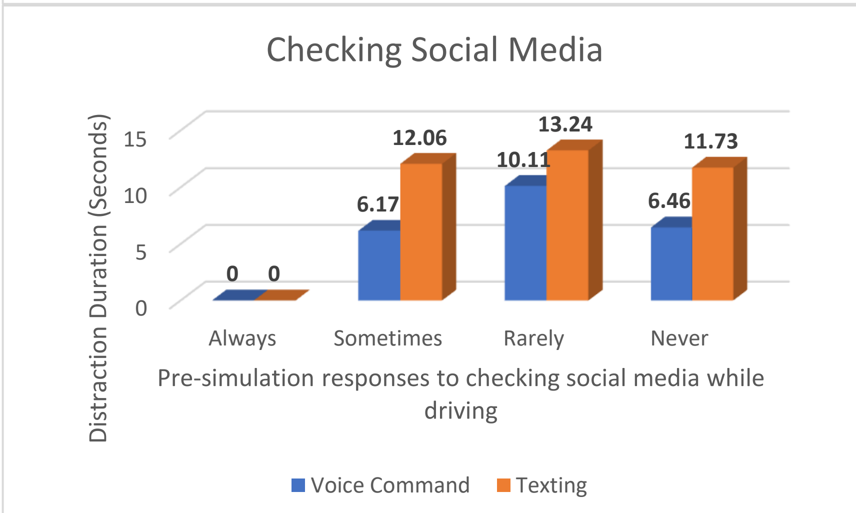
**Statistically significant at 90% C.I.

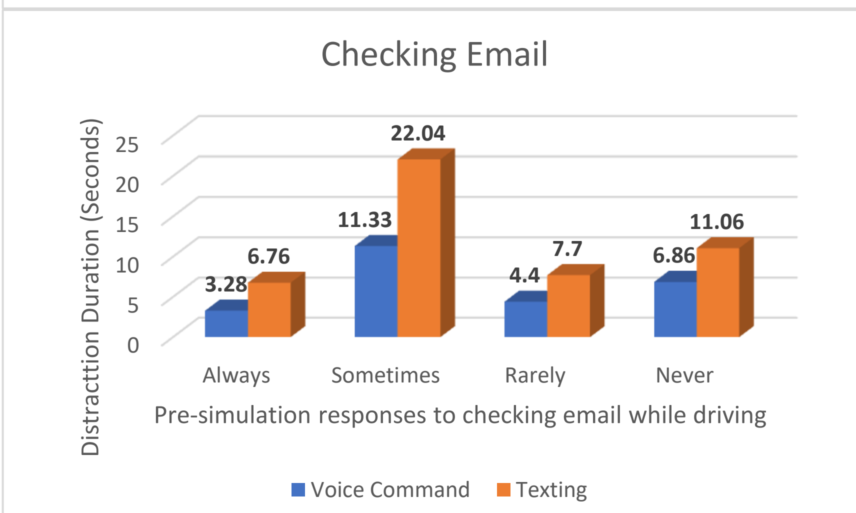
Table 8 shows that male participants were less distracted than female drivers, this time at 90% statistical significance, i.e., their gaze fixations were more on the road than on the phone, compared to female participants. Participants who mentioned that they have at least 2 – 3 years of driving experience had a positive impact on distraction, at 90% statistical significance. This infers that participants who have more driving experience, compared to participants with less driving experience, tend to be distracted or are overconfident while typing a message.

Researchers calculated the average time (seconds) that 22 participants were not looking at the road in the distraction duration intervals (Figure 14); as can be seen, fixation duration, fixation frequency and the average time eyes were off the road are higher for texting than voice command. Figure 15 presents participants responses to the pre-simulation questionnaire versus the time that their eyes were off the road, i.e. distraction duration. Distraction duration vary with participants' response to the pre-simulation questionnaire. Participants who sometimes check their emails while driving had the highest distraction duration in the text message distractions scenario (22.04 seconds) while those who rarely follow GPS when they drive had the highest distraction duration in the voice command distraction scenario (11.86 seconds).




Texting while driving
Distraction Duration (Seconds)
15
10
5
0
0
0
6.44
13.18
6.33
10.7
8.33
12.57
Always
Sometimes
Rarely
Never
Pre-simulation responses to texting while driving
Voice Command
Texting


Checking Social Media
Distraction Duration (Seconds)
15
10
5
0
0
0
6.17
12.06
10.11
13.24
6.46
11.73
Always
Sometimes
Rarely
Never
Pre-simulation responses to checking social media while driving
Voice Command
Texting


Checking Email
Distracttion Duration (Seconds)
25
20
15
10
5
0
3.28
6.76
11.33
22.04
4.4
7.7
6.86
11.06
Always
Sometimes
Rarely
Never
Pre-simulation responses to checking email while driving
Voice Command
Texting

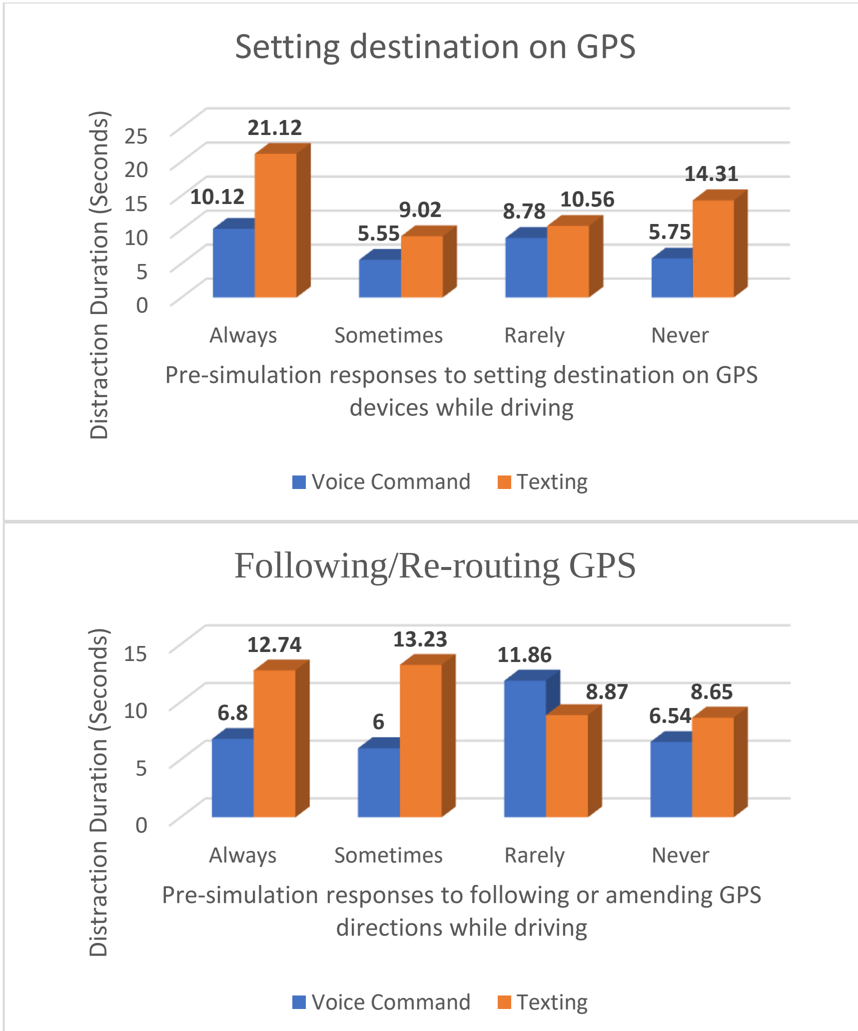


Figure 15: Selected participants' average distraction durations on a Freeway and their response to pre-simulation survey questions

Two text messages were sent to participants in the freeway section of the network during the data collection; one short message with a quick response from participants, and a longer message with more cogitation demanding message. The results show that the fixation frequency and fixation duration are higher by 24% in favor of the message with higher cognitive load. Furthermore, there is a 14% increase in the overall distraction duration when the message is longer.

Out-of-Vehicle Distractions (Billboards)

Based on the placing and content of the billboards, the expectation is to see more participants looking at the first billboard due to the long straight section of the highway, and fewer participants looking at the last one by virtue of its position behind trees right after a corner. However, the content of the second billboard makes it more visually demanding compared to the other two billboards.

Based on the eye-tracking analysis, 64.78% of participants looked at the first billboard for less than two seconds, and 32.21% looked for more than two seconds. Also, 61.97% and 38.02% looked at the second billboard less than two seconds and more than two seconds, respectively. For the last billboard, 91.54% looked for less than two seconds and 8.45% for more than two seconds without considering the number of times they looked at the billboards. Table 9 shows the fixation duration and frequency information for the three billboards.

Table 9: AOI (area of interest) fixation duration and fixation frequency data.

	Fixation analysis					
	AOI Fixation Duration			AOI Fixation Frequency		
	B1	B2	B3	B1	B2	B3
Average	2.87	3.33	1.09	5.71	4.96	2.88
Median	1.66	2.02	0.69	5	4	3

The average numbers of times looking at the three billboards were 5.71, 4.96, and 2.89, with an average of 0.5, 0.67, and 0.83 seconds per view, respectively. ANOVA results show that average durations are statistically different among the billboards (Table 10).

Table 10: ANOVA analysis result between three billboards.

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F critical
Between Groups	3.715	2	1.857	7.335	**0.0009**	3.055
Within Groups	38.749	153	0.253			
Total	42.464	155				

A generalized linear model (GLM) with log link function and Gamma probability distribution was conducted to find the relationship between sociodemographic characteristics and billboard characteristics with gaze fixation duration, as shown in Table 11. The results indicate that content, visibility, and gender significantly affected gaze fixation duration on billboards. Female participants had lower gaze fixation duration than their male counterparts. The billboard with long-distance visibility had a longer gaze fixation duration than the short distance one. The billboard with a lower cognitive load has less gaze fixation duration than the one with a higher cognitive load, which is intuitive.

Table 11: GLM Results

Parameter Estimates			
Parameter	B	Std. Error	Sig.
(Intercept)	-0.069	0.169	0.684
[Age: 18 to 26]	-0.203	0.153	0.187
[Age: 26 to 30]	-0.178	0.193	0.357
[Age: 31 to 45]	0[a].000	-	-
[Experience <1]	0.136	0.243	0.577
[1< Experience <2]	0.259	0.245	0.29
[2< Experience <3]	0.23	0.202	0.256
[Experience >3]	0[a].000	-	-
[Content: low cognitive load]	-0.681	0.147	0.000
[Content: high cognitive load]	0[a].000	-	-
[Visibility: visible from long distance]	0.25	0.144	0.083
[Visibility: visible from medium distance]	0[a].000	-	-
[Visibility: visible only from a short distance]	0[a].000	-	-
[Gender: Female]	-0.362	0.129	0.005
[Gender: Male]	0[a].000	-	-
(Scale)	.509[b]	0.053	-

Goodness of fit			
	Value	df	Value/df
Deviance	84.961	145	0.583
Pearson Chi-Square	98.015	145	0.676
Akaike's Information Criterion (AIC)	80.969		

*Description: *Dependent Variable: Billboard, Model: (Intercept), Age, Experience, Visibility, Content, Gender. a: set to zero because this parameter is redundant and b: maximum likelihood estimate.*

CONCLUSIONS

This study investigated the effect of six different in-vehicle distractions and an out-of-vehicle distraction on drivers' behavior using a driving simulator and an eye-tracking system. Some 92 participants drove a base scenario (without distraction) and six distractive scenarios on a realistic medium size road network north of Baltimore City; each scenario took about 15 minutes with different types of distractions, including no cell phone, hands-free call, hand-held call, voice commands text, text, clothing, eating and drinking. The results showed that participants decreased their speed in the presence of all in-vehicle distractions on all roads. Furthermore, speed reduction was the highest when distracted by taking on/off clothing and eating/drinking. The highest speed reduction happened on the local road when taking on/off clothing (50%), voice command texting (33%), and texting (29%). Speed reduction in hand-held and hands-free calling was almost the same. In general, speed reduction was the highest on the local road probably because of high cognitive load (stop signs and traffic lights, pedestrians, and cyclists). The high-speed reduction on the rural road was partly because of driving way over the speed limit due to low traffic and very few intersections. This could lead to crashes when high-speed vehicles approach the distracted low-speed vehicle, or an animal or a pedestrian crosses those roads. The results suggest a full ban on cell phone usage, not just hand-held devices. Also, transportation safety policymakers may need to make some regulations regarding clothing and eating/drinking.

Furthermore, participants decreased their throttle use and applied the brakes more often and more forcefully when distracted. Steering velocity increased on the freeway for all distractions and in eating/drinking distractions on all roads. Offset from the center increased dramatically in taking on/off clothing and eating/drinking distractions, especially on the freeway, about 70%.

Participants' eyes were on the phone 44% and 32% of the time during the distraction period in texting and voice command, respectively. As expected, the highest percentage of eyes off the road occurs in texting. Male participants were less distracted than female drivers, i.e., their gaze fixations were more on the road than off-road (e.g., phone), compared to female participants.

There was a difference in speed, throttle, brake, steering velocity, and lane changing, among the different areas (visible, readable, and post sign areas) of billboards. Participants reduced their speed when they were able to read billboards' contents (1.88 mph) and increased their speed (2.49 mph) after passing the billboard. Similarly, they reduced throttle, applied more brake force, and deviated from lane center during the billboard readable area.

Participants glanced at the billboards several times with different frequencies, the maximum of which occurred on the billboard with the highest cognitive load. About 74% of the participants didn't look at billboards for more than 2 seconds at each glance except for the billboard with a short visible area due to trees and a road curve. GLM (generalized linear model) analysis showed no connection between participants' age and driving experience with gaze duration. However, the visible distance of the billboard, gender, and billboard content had a significant effect on gaze duration.

Some 36.5% of the participants stated that the driving simulator experience encouraged them to reduce cell phone use while driving. After driving on the simulator, 51.8% expressed doubt about their ability to use cell phones freely and not make any driving mistakes; 26% had stated they were doubtful in the pre-survey. This confirms the effect of educating the public on the impact of distraction on their driving performance and the consequences of it.

This research can be extended to include more participants in other age groups and more analysis to develop models such as distracted prediction or recognition models.

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Pre-Survey

Dear Participant,

We greatly appreciate your participation in this brief survey. This study aims to investigate drivers' behavior in a distracted driving situation. Your participation is of a great importance to this study. Please note that there are no right or wrong answers and responses will remain confidential. Information provided will not be considered by individual and all responses will be recorded together and analyzed as a group. The survey should take no more than 10 minutes to complete.

Please fill in the appropriate choice for each question. Thank you.

1. **What is your gender?**
   - ☐ Female
   - ☐ Male

2. **What is your age?**
   - ☐ 16 to 17
   - ☐ 18 to 20
   - ☐ 21 to 25
   - ☐ More than 25 years old

3. **Please specify your ethnicity.**
   - ☐ White
   - ☐ Hispanic or Latino
   - ☐ Black or African American
   - ☐ Native American or American Indian
   - ☐ Asian / Pacific Islander
   - ☐ Other

4. **What is the highest level of education that you have achieved?**
   - ☐ High School or less
   - ☐ Associate degree
   - ☐ College student
   - ☐ College graduate
   - ☐ Post graduate

5. **Are you employed?**
   - ☐ No
   - ☐ Yes, part time
   - ☐ Yes, full time

6. **What type of driving permit do you have?**
   - ☐ Don't have
   - ☐ Learner's Permit

☐ Permanent license for regular vehicles (class C)
☐ Permanent license for all types of vehicles (class A)

7. What is your household annual income?

☐ Less than $20K
☐ $20K to $30K
☐ $30K to $50K
☐ $50K to $75K
☐ $75K to $100K
☐ More than $100K

8. What is your household size (the number of persons for whom you or your parents are financially responsible)?

☐ 1
☐ 2
☐ 3
☐ 4 or more

9. How many cars does your household own?

☐ No car
☐ 1 car
☐ 2 cars
☐ 3 cars or more

10. How long have you been driving?

☐ Less than a year
☐ 1 to 2 years
☐ 2 to 3 years
☐ more than 3 years

11. What is the average annual driving mileage on your own car (in miles)?

☐ I do not own a car
☐ Less than 8,000
☐ 8,001 to 15,000
☐ 15,001 to 30,000
☐ More than 30,000

12. How many miles do you drive per week averagely?

☐ Less than 100 miles
☐ 100 to 200 miles
☐ 201 to 300 miles
☐ 301 to 400 miles
☐ More than 400 miles

13. Do you have motion sickness?

☐ No
☐ Cars
☐ Boats/Ships
☐ Airplane

14. Do you wear glasses?
☐ No
☐ Yes

15. Which kind of driving distraction and how often do you usually do?

Talk on the phone (hands free)	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Talk on the phone (hand held)	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Text	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Read/update Social Media	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Play Games	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Read/respond to Emails	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Take pictures/record video	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Enter an address to GPS	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Follow GPS directions/reroute	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Eat/Drink	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Smoke	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Change Cloths	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Shave	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Make up	☐ Never	☐ Rarely	☐ Sometimes	☐ Always

16. Apart from in-vehicle distracted devices, which out-of-vehicle systems will distract you more?

	Not much distracting				**Very distracting**
Dynamic Message Signs	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Billboards	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other (Specify) ___________	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

17. What kind of social media and how often do you usually use while driving?

Facebook	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Snapchat	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Twitter	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Instagram	☐ Never	☐ Rarely	☐ Sometimes	☐ Always
Other __________				

18. What cell-phone-related technologies do you use while you drive?
☐ None
☐ Voice to text
☐ Text to voice
☐ Signal jammers (blocking the signal)

☐ Others (please specify ______________________________)

19. If you need to text or answer/make a call, while you are driving, how much is it likely that you pull over first and then use your cellphone?

☐ To a great extent
☐ Somewhat
☐ Very little
☐ Not at all

20. How confident are you that you would not experience any problem using your cell phone while you drive?

☐ Very confident
☐ Confident
☐ Neither
☐ Doubtful
☐ Very doubtful

21. How many times have you experienced a near-crash experience due to using cell phone while you were driving in the last three years.

☐ 0
☐ 1
☐ 2
☐ 3
☐ more than 3 times

22. How many times have you experienced a crash due to using cell phone while you were driving in the last three years.

☐ 0
☐ 1
☐ 2
☐ 3
☐ more than 3 times

23. How many times have your friends or family members experienced an accident due to using cell phone while they were driving in the last three years.

☐ 0
☐ 1
☐ 2
☐ 3
☐ more than 3 times

24. To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.?

No cellphone while driving ☐Very confident ☐Confident ☐Neither ☐Doubtful ☐Very Doubtful

Using accessories such as headsets ☐Very confident ☐Confident ☐Neither ☐Doubtful ☐Very Doubtful

Technologies such as voice to text ☐Very confident ☐Confident ☐Neither ☐Doubtful ☐Very Doubtful

Using cellphone freely ☐Very confident ☐Confident

Post-Survey

Dear Participant,

We greatly appreciate your participation in this brief survey. This study aims to investigate drivers' behavior in a distracted driving situation. Your participation is of a great importance to this study. Please note that there are no right or wrong answers and responses will remain confidential. Information provided will not be considered by individual and all responses will be recorded together and analyzed as a group. The survey should take no more than 5 minutes to complete.

Please share your experience with us. Thank you.

25. Please check the intensity of any symptom which applies to you now.

1-1-	General discomfort	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-2-	Fatigue	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-3-	Headache	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-4-	Eyestrain	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-5-	Blurred vision	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-6-	Salivation increase/decrease	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-7-	Sweating	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-8-	Dizziness	☐ No	Yes (☐ slight	☐ moderate	☐ severe)
1-9-	Nausea	☐ No	Yes (☐ slight	☐ moderate	☐ severe)

26. To what extent does this experience reduce the likelihood of you using a cellphone while driving?

☐ To a great extent
☐ Somewhat
☐ Very little
☐ Not at all
☐ Not applicable

27. How many times do you think you made a mistake (deviating from the destination, going through a red light, near-crash experience, crash, etc.) during the last simulation run?

☐ None
☐ 1
☐ 2
☐ 3 or more

28. Will you return for another simulation run using the driving simulator?

☐ Yes
☐ No

29. To what extent are you confident that YOU, driving in following situations, would NOT experience any driving mistakes such as deviating from the destination, going through a red light, near-crash experience, crash, etc.?

No cellphone while driving	☐Very confident	☐Confident	☐Neither	☐Doubtful	☐Very Doubtful
Using accessories such as headsets	☐Very confident	☐Confident	☐Neither	☐Doubtful	☐Very Doubtful
Technologies such as voice to text	☐Very confident	☐Confident	☐Neither	☐Doubtful	☐Very Doubtful
Using cellphone freely	☐Very confident	☐Confident	☐Neither	☐Doubtful	☐Very Doubtful