Impact of distracting activities and drivers' cognitive failures on driving performance

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Abstract

The rapid increase in the availability of smartphones and other infotainment devices, and their widespread use while driving, contributes significantly to car crash rates. Understanding of the impact of distracting activities on drivers' behavior is essential in order to support the development of effective technology and policy solutions to mitigate its potential risk.

The main objective of this study is to investigate the impact of several distracting activities on driving performance. A driving simulator experiment was developed to collect data on several driver performance measures while undertaking different distracting activities. 101 volunteer drivers participated in the study (68 males and 33 females) with age range between 18 to 57 years old. Each driver drove four scenarios on a two-lane rural highway, while undertaking various activities: (1) using a hand-held cell-phone; (2) texting; (3) eating; and (4) a control scenario (no distracting activity). In all of these scenarios the distracting activity took place during the entire scenario. Each scenario took on average 4 minutes to complete. The speeds and accelerations of the other vehicles within the scenarios were chosen randomly from pre-defined uniform distributions. Data on the longitudinal and lateral movements of the vehicles were recorded in the experiment and various measures were calculated from this raw data.

In addition, all participants completed a questionnaire on their personal characteristics, their frequency of involvement in distracting activities and level of distractibility, and the Cognitive Failures Questionnaire. Significant differences were found in the driving performance measures among drivers undertaking the various distracting activities. In particular, texting had the largest negative effect on driving performance. The results of this study show that distracting activities negatively impact driving performance for both genders and all age groups, regardless of their experience in performing a second task while driving.

Keywords – Distraction, driver behaviour, driving simulator, safety, cognitive failures

1. Introduction

Distracted driving is among the leading causes of fatal and serious injury crashes (NSC [27]; NHSTA [26]). Naturalistic driving studies (Klauer et al. [19]; Dozza [9]) have estimated that 80% of crashes and 65% of near-crashes involve some form of driver distraction. Distraction is a common cause for rear-end crashes which constitute about one-third of all reported crashes in the U.S. (NTSB [28]).

Driver distraction was defined by Lee et al. [21] as "The diversion of attention away from activities critical for safe driving toward a competing activity". Several types of distraction have been defined including visual (e.g. looking at an advertisement billboards while driving), manual (e.g. eating while keeping eyes on the road) or cognitive (e.g. making a hands-free cell phone call). Distracting activities may combine multiple types. For example, texting combines manual, visual and cognitive distractions. Driver distraction reduces drivers' awareness of the traffic situation, delays their responses to driving events, increases their perceived mental workload, and the intensity of disruptions in driving performance (Horberry et al. [15]; Laberge et al. [20]; Caird et al. [5]). It has also been shown that when drivers are distracted they travel at lower speeds and keep larger gaps from the vehicles in front (Horrey and Wickens [16]).

In recent years, there has been a rapid increase in the availability of smartphones and other connected and infotainment devices, even inside the vehicle, and thus an increase in their widespread use when driving. It is expected that this trend will continue in the future, and therefore exacerbate their potential negative effects on driving. An understanding of the impact of distraction on driver behaviour is essential in order to support development of effective technology and policy solutions to mitigate this potential risk.

Driver distraction, in all its forms, has been found to affect driver performance, especially at the operational and tactical levels (Wickens [40]; Regan et al. [31]). At these levels, drivers are required to make continuous and timely decisions, within fractions of seconds or seconds, in order to safely control their vehicles (Ma and Kaber [23]). Undertaking secondary tasks, even for short durations, and especially those that involve visual and cognitive distractions, might lead to failures in drivers' performance and consequently to crashes (Kaber et al. [17]). Visual distraction, which causes drivers to take their eyes off the road, was found to involve substantial increase in crash risk since the driving environment may change rapidly (Zhang et al. [42]). Cognitive distraction occurs when drivers' look at the road but fail to see, i.e., they do not perceive what they see (Staughton and Storie [34]; Strayer and Drews [37]). This happens because secondary tasks compete over the limited central processing resources in the brain. Carsten and Brookhuis [7] found that when drivers are cognitively distracted their car-following and reactions to leading cars are impaired, while their lane-keeping performance improved. The latter is a result of "tunnel vision" effect in which drivers focus their attention on the center of the road. In a driving simulator study, Muhrer and Vollrath [25] found that cognitive distraction negatively influences the anticipation of the future behaviour of other drivers, while visual distraction deteriorates the perception and reaction to unexpected events.

Several studies investigated the impact of specific distractions, especially the use of cell phones, on driver performance. Fitch et al. [13] summarized the results of previous studies that found significant impacts on driver performance of cell phone conversations in controlled experiments using driving simulators and test tracks. Drivers were found to reduce the area they scan (Atchley and Dressel [2]; Maples et al. [24]), have higher reaction times to unexpected events (Caird et al. [5]; Horrey and Wickens [16]), and have higher rates of "looked but failed to see" cases (Strayer et al. [36]) such as missing navigational signs (Drews et al. [10]) and signals

(Strayer and Johnston [38]). At the driving behaviour level, drivers decreased their travel speed, frequency of lane changing manoeuvres and increased their following distance while talking on a cell phone (Cooper et al. [8]; Young et al. [41]). Drews et al. [10] compared the operational and tactical performance of drivers while talking on a cell phone and while talking to a passenger. At the operational level, they found higher lateral movement of the vehicle when talking on a cell phone, compared to talking to a passenger. At the tactical level, following distances were higher when talking on a cell phone, but there were no statistically significant differences in the speed selection. Using naturalistic data, Fitch et al. [13] showed that all forms of cell phone use increase the rate of occurrence of safety critical events.

Texting is another distracting activity that has received attention in the literature. It is an increasingly common activity, with 18% of all drivers and 49% of those between 21 to 24 years old reported texting and driving in a nationwide US survey (Tison et al. [39]). Olson et al. [29] found that drivers take their eyes off the road for an average of 4.6 seconds over a 6-second interval when texting. Taking the eyes off the road for more than 1.5–2 seconds is considered risky (Hjort [14]). Several studies found that texting increases crash risks (Klauer et al. [19]), especially for young drivers who text extensively (Lenhart et al. [22]). A recent naturalistic study of novice drivers (Klauer et al. [19]) estimated that the odds ratio of texting among novice drivers is 3.87, which is the highest among the activities that were evaluated, including using a cell phone and eating.

Stavrinos et al. [35] studied the impact of cell phone use and of texting on the driving performance of 75 teens and young adults using a driving simulator. The experiment involved driving on a four-lane divided roadway under varying traffic conditions (Levels of service A, C and E). To evaluate the impact on safety they measured the numbers of crashes and lane departures that occurred in the experiment. Texting resulted in higher number of crashes, but not lane deviations, compared to driving without distraction. Cell phone conversations did not significantly affect the number of crashes and reduced the number of lane deviations compared to driving without distraction. To evaluate the impact on traffic flow, several measures related to speeds and its variability and passing manoeuvres were used. With both distractions, and in particular texting, drivers tended to drive slower, have more variability in their speed, and undertake less lane changes.

The current paper used a simple car-following scenario within a driving simulator to study drivers' performance at the operational and tactical levels while undertaking several distracting activities, namely using a cell phone, texting and eating. Thus, the research question for this work is about the impact of these activities on the driving performance.

The rest of this paper is organized as follows: the next section presents the study methodology and describes the driving simulator, the experimental design, and the participants. The subsequent section describes the data that were collected in the experiment and provides summary statistics. Then, the results of analysis of this data are presented, followed by a summary and conclusions.

2. Methodology

2.1. Driving simulator experiment

A laboratory experiment using a driving simulator was developed in order to collect data on driving behaviour while undertaking different distracting activities. The simulation scenarios included a two-lane rural highway section. Lane and shoulder widths were 3.75 meters and 1.5 meters, respectively. The sections were designed on a level terrain and with no intersections. The scenarios were designed with daytime and good weather conditions which allowed good visibility. Fig. 1 shows a snapshot of the driver's view in the driving simulator. Drivers were instructed to drive as they would normally do in the real world. They were not allowed to pass the vehicle in front. This was also indicted by the markings on the road. Following previous studies (Bar-Gera and Shinar [3]; Farah et al. [11]) drivers were given between 5 and 10 min to become familiar with the simulator.

Fig. 1 Snapshot of the driver's view in the driving simulator.

A scenario took about 4 minutes to complete. Each scenario was composed of six sections with different speeds for the vehicle in front of the subject. The leader speed in each section was constant, and different from that of the preceding and following sections. The speed transition from one section to the next was determined by a constant acceleration (or deceleration) rate, which was randomly selected in the range 0.4-2.5 m/sec^2. Four levels of speed ranges were used: 20-40, 40-60, 60-80, and 80-100 km/h. The realized lead speed was drawn from a uniform distribution over the speed range within the specific level. The duration of constant speed sections was 40 seconds when the speed was in the range of 20-80 km/h, and 30 seconds when the speed was over 80 km/h. Fig. 2 illustrates an example of the leader vehicle speed profile from one of the scenarios in the experiment.

Vehicles in the opposing direction travelled at a constant speed of 70 km/h. In case that the driver is involved in a crash, for example a rear-end crash with the lead vehicle, the driver hears a sound of crashing, the windshield breaks and the subject vehicle comes to a full stop. Then, the lead vehicle disappears and the scenario continues from the same point the crash occurs, with a new lead vehicle.

24 different scenarios were generated. Drivers drove four different scenarios each. In each one of the scenarios, the drivers were engaged in one of four distraction conditions. In all cases the activities took place throughout the driving scenario. The order of the activities within the experiment was randomly chosen. The distraction activities were:

1. Talking on a cell phone (hand-held): drivers received a phone call at the beginning of the scenario and were engaged in a conversation with the experimenter, in which they were asked several general questions.
2. Sending and receiving text messages: drivers received messages with general questions to their own cell phones and were requested to reply to those messages.
3. Eating a snack: the participating drivers were requested to eat a snack, such as potato chips, while driving.

4. No distracting activities (control case): the driver did not have any secondary tasks beside the primary task of driving.

The simulator used in this experiment, STISIM (Rosenthal [32]), is a fixed-base interactive driving simulator, which has a 60° horizontal and 40° vertical display. The changing alignment and driving scene were projected onto a screen in front of the driver. The simulator updates the images at a rate of 30 frames per second.

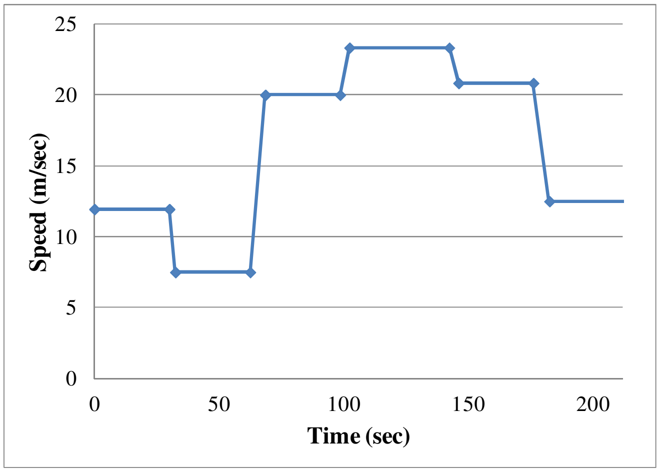


Fig. 2 An example of the speed profile of the lead vehicle.

2.2. Questionnaire

The questionnaire that was designed for this study consisted of three parts: a general part soliciting socio-demographic information, a second part concerning drivers' frequency of involvement in distracting activities and their level of distractibility, and the Cognitive Failure Questionnaire (Broadbent et al. [4]). The frequency of involvement in distracting activities while driving were examined using 12 cases, such as: talking using a hand-held and a hand-free mobile, reading and writing a text message, listening to music, changing in-car entertainment setting, etc. Drivers indicated their responses on a five point scale from never to very often. Drivers were also asked, on the same scale, to what level these activities distract them when driving (level of distractibility). The Cognitive Failure Questionnaire measures the general liability to failure using 25 items. Participants responded to the questionnaire on a similar scale ranging from never to very often. Examples, of items include “Do you read something and find you haven't been thinking about it and must read it again?”, “Do you fail to notice signposts on the road?”, and “Do you find you forget whether you've turned off a light or a fire or locked the door?”.

2.3. Participants

Participants were recruited using billboard advertisements at the Technion campus. Participation was voluntary, with screening criteria that the participant holds a driving license and drives on a regular basis. Participants were compensated with a voucher for a coffee shop at a value of about 6 USD. 139 potential participants, mostly students and employees at the university, expressed interest in participating in the study. They were sent a link to a web-based questionnaire administered using the Qualtrics software application (Qualtrics [30]). 101 participants completed the questionnaire and participated in the simulator experiment. 68 of the participants were males and 33 were females. Their age ranged from 18 to 57 years old (mean = 27.8; Std. = 8.3 years). On average the drivers had a driving license for 4 years.

2.4. Data collection

Data on the longitudinal and lateral position, speed and acceleration of the subject vehicle and other vehicles in the scenario was collected in the driving simulator at a resolution of 0.1 s. From this raw data, other variables of interest, such as distances between vehicles, relative speeds and headways were calculated. Average values were calculated for each variable in each section within a scenario. The final database used for analysis included 2424 observations (101 drivers x 4 scenarios x 6 sections).

3. Results and analysis

3.1. Self-reported questionnaire

Tab. 1 presents the results of correlation analysis between the Cognitive Failure Questionnaire responses and the reported frequency of involvement in distracting activities and level of distractibility. The results indicate significant and positive correlations among the three variables. Drivers with higher levels of cognitive failure also reported higher frequencies of involvement in distracting activities and higher level of distractibility. The results show that, counter to expectations, drivers that reported higher level of distractibility did not have lower frequencies of involvement in distracting activities. Thus, being suspect to distraction does not deter the participants from undertaking distracting activities.

Tab. 1 Pearson Correlations among frequency of involvement in distracting activities, level of distractability and cognitive failures

	Level of distractibility	**Cognitive failure**
Frequency of involvement in distracting activities	0.275***	0.386***
Cognitive failure	0.278***	

3.2. Road crashes

Involvement in road crashes under the various distracting activities is presented in Fig. 3. As expected, the number of road crashes when texting while driving was highest, followed by talking on the phone. Both of these activities involve cognitive distraction. However, opposite to expectations, drivers crashed less while eating, which involves manual distraction. Due to the low number of crashes that occurred in the experiment, the differences in the total number of road crashes were not statistically significant (p-value=0.508). Thus, involvement in road crashes as a result of distraction should be further examined in the future with larger data set in order to be able to reach solid conclusions.

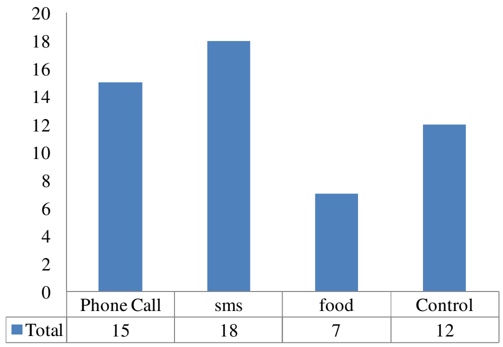


Fig. 3 Road crashes.

3.3. Speed correlations

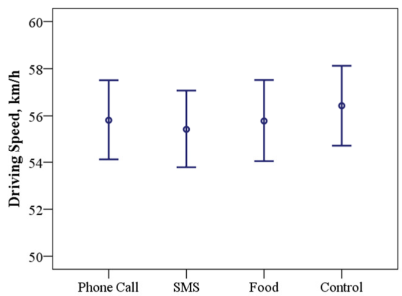
Ideally, the driver would follow the leader closely. Thus, the speeds of the two are expected to be highly correlated. Tab. 2 presents the correlations between the subject's and leader's speeds while engaged in the various activities. The correlation between the two speeds is lowest when the participant sends and receives text messages while driving.

Tab. 2 Pearson Correlation between subject's and leader's speeds

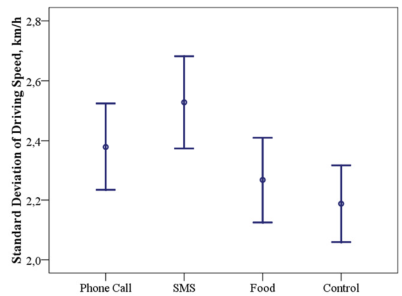
Activity	correlation
Call	0.937
SMS	0.793
Food	0.903
Nothing	0.936

3.4. Driving Performance

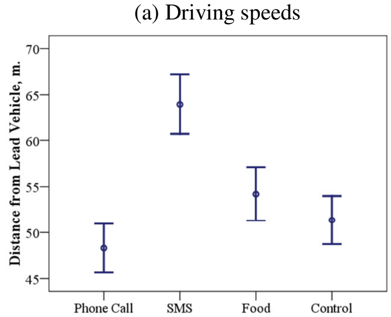
Several driving performance measures, which are known to be related to safety and traffic operations, were calculated for each driver in each one of the four scenarios. These include driving speeds and variability of speed, distance from lead vehicle and the variability of the steering wheel angle. Drivers' performances in these measures with the various distracting activities are compared. The results are presented in Fig. 4. The figures show the average value and ranges ±2 standard errors of the means. Many studies indicated the importance of speed and its variability to the increase in the likelihood of road crashes and their severity (e.g. Solomon [33], Aarts and Van Schagen [1]). Fig. 4(a) and Fig. 4(b) present the average speed and the standard deviation of the speed, respectively, while driving with the various distracting activities and in the control scenario. Average speeds are slightly lower when the driver is engaged in a distracting activity compared to the control. The decrease in the speed is largest while texting. The differences in speed variability are more pronounced. The variability is highest while texting and lowest in the control scenario. Fig. 4(c) presents the distance gap from the lead vehicle. This measure captures drivers' ability to maintain constant position and relation with the leader. The distance from the lead vehicle is largest while texting. This is consistent with the lower speeds in these scenarios. It may also reflect compensation behaviour. Finally, Fig. 4(d) presents the standard deviations of the steering wheel angle, which indicates on the extent of lateral movement within the lane and the ability of the drivers to maintain a constant position within the lane. Similar to the results of distance keeping, the variability in the steering wheel angle is considerably larger while texting compared to all other activities. The variability was lowest in the control scenarios, and substantially lower than when making phone calls and eating. The difference between the control scenario and the phone call scenario is opposite to previous findings by Carsten and Brookhuis [7] in which drivers moved less laterally while talking on the phone. This might be explained by the use of a hand-held phone in the current study.



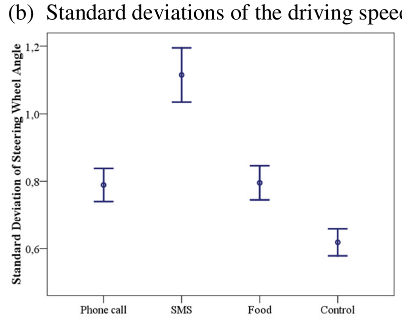
(a) Driving speeds



(b) Standard deviations of the driving speeds



(c) Distance from lead vehicle



(d) Standard deviations of the steering wheel angle

Fig. 4 Average and Standard Error of Driving Performance Measures.

The results presented above are aggregated, averaging the differences between individuals and in the speeds of the lead vehicles in the various scenarios and in sections within a scenario. To further investigate whether these differences are statistically significant linear mixed models were developed. These models take into account characteristics' of the driver (i.e. age, gender, distractibility, and reported cognitive failure), and the differences among the scenarios and sections within the experiment. The models were developed for each of the driving performance measures described above. The specification of the final linear mixed models is given by:

$$
\begin{aligned}
Y_{nij} = {} & \beta_o + \beta_{call}\delta_{ni}^{call} + \beta_{SMS}\delta_{ni}^{SMS} + \beta_{eat}\delta_{ni}^{eat} + \beta_{lead\ speed}\delta_{nij}^{leader} + \beta_{male}\delta_{n}^{male} + \beta_{age1}\delta_{n}^{age1} \\
& + \beta_{age2}\delta_{n}^{age2} + \beta_{FreqDist}\delta_{n}^{FreqDist} + \beta_{LevDist}\delta_{n}^{LevDist} + \beta_{CognFail}\delta_{n}^{CognFail} \\
& + \sum_{i=1}^{4}\beta_{scenario\_i}\delta_{n}^{scenario=i} + \sum_{i=1}^{6}\beta_{section\_j}\delta_{n}^{section=j} + \mu_{on} + \varepsilon_{nij}
\end{aligned} \tag{1}
$$

Y_{nij} is the value of the performance measure for individual n in scenario i and section j of the experiment. β_X is the coefficient of explanatory variable X. δ_{ni}^{call}, δ_{ni}^{SMS} and δ_{ni}^{eat} are indicator variables with a value of 1 if in scenario i participant n was engaged in the making phone calls, texting or eating, respectively, and 0 otherwise. V_{nij}^{leader} is the speed of the vehicle in front of the subject. δ_{n}^{male} is an indicator variable with a value of 1 if participant n is a male, and 0 otherwise. δ_{n}^{age1} and δ_{n}^{age2} are indicator variables with a value of 1 if participant n is in age group 1 (22 years old or younger) or 2 (23-35 years old), respectively, and 0 otherwise. $\delta_{n}^{FreqDist}$, $\delta_{n}^{LevDist}$, $\delta_{n}^{CognFail}$ are the reported scores of the driver's frequency of involvement in distracting activities, level of distractibility, and cognitive failure, respectively. $\delta_{n}^{scenario=i}$ and $\delta_{n}^{section=j}$ are indicator variables capturing the order of the scenarios and the sections, respectively. They are intended to capture biases stemming from the ordering, for example through boredom, fatigue or learning of the experiment task. μ_{on} is an individual specific random constant that captures differences in the performance measures among drivers. It is assumed to follow a normal distribution in the population: $\mu_{on} \sim N(0, \sigma_o)$.

Tab. 3 presents the estimation results for models for the four performance measures discussed above. The coefficients of the scenario and section variables, which are meant to correct biases in the experiment, are not presented. The order of the scenarios was not significant at the 95% confidence level in any of the four driving performance measures. In other words, we did not find an effect on the results for the order in which the distracting activities were presented to the drivers. The order of the sections within a scenario was found to have a statistically significant impact on the results except for the model of the lateral deviations. It is unlikely that this captures a boredom or fatigue effect within the scenario, as the effect does not carry over between scenarios. Both sets of variables were retained in the model so that their effects are corrected for. The results in Tab. 3 show that engagement in the various activities affects some of the driving behaviours. All activities reduce the average travel speed compared to the control and cause an increase in the standard deviation of speed. Both these effects are largest for texting, followed by making phone calls, and smaller for the eating activity. However, for the speed, none of these effects is statistically significant. Also, post-hoc Bonferroni analysis for pairwise comparisons of activities, did not show any significant differences in the speeds with the various activities. For the standard deviation of speed, the two larger effects of texting and making phone calls are statistically significant (compared to the control), while the effect of eating is negligible and insignificant. The pairwise comparisons show that also the difference in variability of speed between driving while texting and while eating are also statistically significant (p-value=0.02).

Drivers engaged in texting and in eating tend to have longer distance headways from the lead vehicle. This effect is especially large with texting, and is consistent with the reduction in speed that is associated with the secondary task. In contrast, making phone calls reduces the distance from the leader. This effect is marginally significant. The distances kept from the leader while texting and eating are significantly larger compared not only to the control, but also to driving while making phone call (p-value<0.001 in both cases). The difference between driving while texting and while eating is also significant (p-value<0.001).

The most pronounced effect of the distracting activities is on the standard deviation of the steering wheel angle, which captures the lateral control of the vehicle. All three activities increased the variability compared to the control. These effects are significant in all cases. The effect of texting is substantially and significantly larger than these of the two other activities. The pairwise comparisons find p-value<0.001 in both cases.

Tab. 3 Mixed models results for the various driving performance measures

Term	**Speed (km/h)**		**Std. of driving speeds (km/h)**		**Distance from lead vehicle (m.)**		**Std. of the steering wheel angle (degrees)**	
	Est.$^{sig.}$	**S.E.**	**Est.$^{Sig.}$**	**S.E.**	**Est.$^{Sig.}$**	**S.E.**	**Est.$^{Sig.}$**	**S.E.**
Intercept	1.55	1.26	0.36	0.27	9.83	9.25	0.87***	0.23
Phone Call	-0.34	0.51	0.20**	0.09	-2.38*	1.28	0.17***	0.03
SMS	-0.58	0.51	0.35***	0.09	13.12***	1.27	0.50***	0.03
Food	-0.001	0.51	0.08	0.09	3.61***	1.27	0.18***	0.03
Leader speed	0.79***	0.008	0.03***	0.001	0.96***	0.02	-0.0001	0.0004
Male	-0.005	0.42	-0.02	0.09	0.71	3.84	-0.37***	0.09
Age ≤22	0.67	0.71	-0.09	0.17	-12.54**	6.45	-0.22	0.17
23≤Age≤35	0.34	0.64	-0.22	0.15	-11.29**	5.79	-0.33**	0.15
Distractibility	0.61**	0.28	0.19***	0.07	-2.66	2.59	0.08	0.06
Intercept $\left(\sigma_0^2\right)$	0.48	0.55	0.09***	0.03	288.14***	44.92	0.19***	0.03
Akaike's Information Criterion (AIC)	17074.07		8995.57		21612.02		3845.70	
Schwarz's Bayesian Criterion (BIC)	17085.61		9007.10		21623.55		3857.24	

*** Sig.≤0.01; ** 0.01<Sig.≤0.05; * 0.05<Sig.≤0.1

As expected, the speed of the lead vehicle was found to significantly affect the longitudinal driving performance measures: As the speed of the leader increases, drivers drive faster, have larger speed variations and keep larger distance gaps from the leader. The speed of the leader does not affect the lateral control of the vehicle through the steering wheel angle variability.

The effects of gender and age were not large in most cases. The effect of gender was small and insignificant, expect in the standard deviation of the steering wheel, in which males had lower values. Compared to the older groups (drivers 36 years or older), younger drivers kept significantly shorter distances from their leader and had better lateral control (lower variability in the steering wheel angle) of their vehicle. They also travelled slightly faster and with less variability in speed, but these effects are not statistically significant.

Drivers' reported level of distractibility while driving was found to significantly affect the driving speed and speed variability: drivers with higher level of self-reported distractibility tend to drive faster and have higher variability in their driving speeds. Both substantially affect safety. The reported frequency of involvement in distracting activities and the score on the cognitive failure questionnaire were not found to significantly affect the driving performance.

4. Discussion

This paper used a simple car-following scenario within a driving simulator to study drivers' performance while engaging in distracting activities: cell phone use, texting, eating and a control scenario with no distracting activity. Data on the longitudinal and lateral movements of the vehicles were recorded in the experiment.

Analysis of this data showed significant differences in the driving performance measures among the different distracting activities. In particular texting which involves visual, cognitive and manual distraction had by far the largest negative effect on driving performance. It was found that it increases the variability in driving speeds and steering wheel angle. This indicates on a lower ability of the driver to control the vehicle. Drivers were also found to be involved in more road crashes compared to while engaged in other activities. These results are in accordance with the results by previous studies (Kaber et al. [17], Zhang et al. [42], Klauer et al. [19]) that secondary tasks, even for short durations, and especially those that involve visual and cognitive distractions, might lead to failures in drivers' performance and consequently to crashes (Kaber et al. [17]).

Similar but milder effects were also found for the two other distracting activities: talking on the phone and eating while driving. When using a hand-held cell phone while driving, drivers have more difficulty to control their vehicle which is expressed by significantly higher variation in the driving speeds and increased variability in the steering wheel angle. No significant impact was found on the driving speeds. These results are in accordance with the results by Drews et al. [10] but opposite to the findings by Stavrinos et al. [35] and Carsten and Brookhuis [7] with respect to the lateral control. However, these differences might stem from the fact that in this study hand-held phone was used, so drivers also experienced manual distraction. Drivers in this study also tended to keep shorter distances from the lead vehicle when talking on the phone while driving, which is opposite to the finding by Drews et al. [10]. Finally, eating had the least distracting effects on driver behavior compared to talking on the phone and texting.

Drivers' reported frequencies of involvement in distracting activities while driving were not found to significantly affect drivers' performance. This is in contrast to drivers' levels of distractibility. Drivers with higher levels of distractibility are more vulnerable to distracting activities. It can be argued here that higher involvement in distracting activities does not improve drivers' abilities in handling these extra activities while driving. The significant positive correlation between the reported frequency of involvement in distracting activities and the reported level of distractibility, also support this result.

The current study has several limitations. First, the study was conducted in a virtual simulator environment, in which previous studies have shown that drivers may behave differently compared to real-life driving, and especially take more risks (Farah et al. [12]). Analysis of naturalistic data would be needed in order to further confirm the results of this study.

Second, this study analyzed the distractions with specific setups. However, the setup may affect the results. For example, in this study drivers used hand-held cell phone while talking and texting. The use of hand-held devices is illegal in Israel, and many other jurisdictions, for both phone calls and texting. However, other ways of engaging in these activities (e.g. hand-free talking, speech-to-text technologies) are becoming increasingly available. For the specific case of hands-free devices, a recent study by Fitch et al. [13] found that drivers that use these devices are still involved in visual and manual distraction.

Third, despite the fact that each distracting activity lasted for the whole scenario in the driving simulator, detailed information regarding when in practice the driver was really engaged in the distracting activity was not recorded. For example, in the distracting activity of texting, we did not record the time when the driver was writing a message, reading a message, or waiting to receive a message. The intensity of the impact of the distracting activity in these different phases might be different, and thus recording detailed information in future studies would be useful.

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