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Understanding driver distractions in fatal crashes: An exploratory empirical analysis

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ABSTRACT

Introduction: Driver distraction has become a significant problem in transportation safety. As more portable wireless devices and driver assistance and entertainment systems become available to drivers, the sources of distraction are increasing. *Method:* Based on the results of different studies in the literature review, this paper categorizes different distraction enablers into six subcategories according to their fundamental characteristics and how they would affect a driver's likelihood of engaging in non-driving related activities. The review also discusses the characteristics and influence of external and internal distractions. The objective of this study is to examine the effect of different distraction sources in fatal crashes with the consideration of a driver's age and sex. Tukey test, chi-square test of independence, Nemenyi post-hoc test, and Marascuilo procedure have been used to investigate the top distraction sources, the trend of distraction-affected fatal crashes, the effect of different distractions on drives in different age groups, and their influence on female and male drivers. *Results:* It was found that inner cognitive interferences accounted for the greatest proportion of driver engagement in distractions. Young drivers show a larger probability of being distracted by in-vehicle technology-related devices/objects. Within the group of young drivers, female drivers showed a higher probability than their male counterparts of engaging in distracted driving caused by in-vehicle technology-related devices. Among six subcategories of distractions, drivers older than 80 years old were found to be most likely affected by inner cognitive interferences.

1. Introduction

Driver distraction has become an important issue of road safety around the world. Evidence from recent studies of vehicle crashes suggests that driver distraction has a more negative impact on driving safety than other factors often considered, such as alcohol intoxication and fatigue (Chen, Wu, Zhong, Lyu, & Huang, 2015; Craft & Preslopsky, 2013). A synthesis of research, including experimental studies, survey-based studies, naturalistic studies, and in-depth crash analyses has identified that driver distraction is one of the major factors leading to road crashes (Charlton, 2009; Fitch et al., 2013; Li, Gkritza, & Albrecht, 2014; Tison, Chaudhary, & Cosgrove, 2011). Technological advancement introduces new distractions to drivers at a great rate. Smart phones, wearable devices, portable devices, and in-vehicle information systems has put the issue of driver distraction to the fore of driving safety. For instance, cell phones were reported as the cause of distraction for 14% of drivers in fatal crashes (National Highway Traffic Safety Administration, 2015).

Reducing the losses caused by distraction-related crashes requires a clear understanding of driver distraction. There have been a number of discussions to define driver distraction (Horberry, Anderson, Regan, Triggs, & Brown, 2006; Laberge, Scialfa, White, & Caird, 2004; Lee, 2014; Manser, Ward, Kuge, & Boer, 2004). In general, four types of distraction sources were considered in these definitions, including people, objects, events, and activities (Bayly, Young, & Regan, 2008). A consistent definition of distraction helps interpret its role in fatal crashes, target the key distraction problems, and identify effective countermeasures. According to current research, distracted driving is defined as any physical distractors, events, or inner interferences that affect drivers' situational awareness and decision making necessary for safe driving.

There are two major types of activities that may cause driver distraction: internal and external interferences. Internal interferences include eating, drinking, smoking, inattentional blindness, mind wandering, zoning out, and lost in thought. It is worth mentioning that eating, drinking, and smoking are human automatic behaviors and are concurrent as secondary tasks in lots of human activities. Therefore, they are categorized as internal interferences. External interferences involve talking/listening on a cell phone, adjusting devices integral to vehicles,

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checking emails or texting on a cell phone, adjusting devices integral to vehicles, adjusting a navigation device, talking to passengers, and rubbernecking at on-road events. However, few databases contain comprehensive information about driver distractions in crashes; perhaps a reason why there is a lack of studies that investigate the impact of a variety of distraction sources in roadway safety. Current studies on driver distractions tend to focus on one kind of distraction sources in each individual study rather than concurrently investigate the different effects of multiple distraction sources (Charlton, 2009; Chisholm, Caird, & Lockhart, 2008; Crisler et al., 2008; Fitch et al., 2013; Jamson, Westerman, Hockey, & Carsten, 2004; Peng, Boyle, & Lee, 2014; Strayer & Drews, 2007; White, Fern, Kline, Chisholm, & Tech, 2006). Consequently, there is scant information about the leading sources of driver distractions in fatal crashes. Moreover, experimental data and data from surveys are difficult to represent the real driving situations and cannot capture drivers' cognitive status in real critical situations (Charlton, 2009; Chen, Wu, Zhang, et al., 2017Chisholm et al., 2008Crisler et al., 2008Fitch et al., 2013Jamson et al., 2004Li et al., 2014Peng et al., 2014Salvucci, Markley, Zuber, & Brumby, 2007Strayer & Drews, 2007Tison et al., 2011). The Fatal Accident Reporting System (FARS) database collected by the U.S. Department of Transportation includes device-related distractions, on-road distractions, and driver inner cognitive interferences, which satisfies the requirement of this study regarding the data content and quality.

This study is explicitly based on drivers' distraction involvement in fatal crashes. However, roadway characteristics, weather conditions, and other environmental conditions are known to affect crash occurrence. The authors are also aware that roadway characteristics and weather conditions influence driver distraction distractions and crash occurrence as well. To address the aforementioned issues, this study aims to further examine the effects of different distractions in fatal crashes. The primary questions that were tackled in this study include:

(1). What are the top distraction sources in fatal crashes?
(2). Are there any trends or patterns in the occurrence of distraction-affected fatal crashes?
(3). Are there any differences in distracted driving behaviors that are caused by external interferences such as devices, objects, events, people, and cognitive interferences such as daydreaming?
(4). How does a driver's age and sex affect the distribution of distractors in the distraction-affected fatal crashes?

First, however, issues related to driver distractions are reviewed.

2. Literature review

2.1. The nature of driver distraction

In the context of driver information processing, drivers usually divide their attention to more than one information source (Hancock, Mouloua, & Senders, 2008). However, human attention is limited and it is impossible to attend to everything simultaneously. Switching between multiple tasks involves a lot of cognitive efforts that compete with each other, lowering the reliability of performance and increasing susceptibility to interference from distractors. There is broad agreement that distracted driving could occur, either voluntarily or involuntarily (Feng, Marulanda, & Donmez, 2014; Ranney, Mazzae, Garrott, & Goodman, 2000; Young, Regan, & Lee, 2008). In other words, distracted driving can happen either because of salient stimuli that force drivers to distract from driving tasks or when drivers voluntarily divert their attention from driving tasks. On the one hand, driving tasks have become automatic with driving experience so that drivers allocate their attention to multiple tasks without awareness. On the other hand, drivers are also capable of consciously allocating their attention in responses to the dynamically changing environment. When drivers cannot afford sufficient attention to the distraction-filled driving environment, distracted driving will happen. Therefore, drivers' driving performance will be hindered and errors could occur that might lead to crashes (Young, Regan, & Hammer, 2007). Outlining the characteristics of attention allocation will allow the development of a clear picture of how distracted driving occurs and how the 19 distractors listed in FARS database can be categorized.

2.2. The distraction sources and their influence on driving performance

Physical objects, people, and activities that cause distractions inside a vehicle or on roadways all fit under external distraction, which can be subdivided as in-vehicle distractions and on-road distraction (Bayly et al., 2008). Different kinds of in-vehicle distractors have been studied experimentally. Many studies have demonstrated that the usage of a cell phone had negative effect on driving performance (Caird, Willness, Steel, & Scialfa, 2008; Haigney, Taylor, & Westerman, 2000; Lesch & Hancock, 2004; Rakauskas, Gugerty, & Ward, 2004; Strayer & Drews, 2007). Hosking, Young, and Regan (2009) found that texting while driving increased the occurrence of lane excursions. It was also identified that speech-based emailing could increase a driver's reaction time by 30% (Lee, Caven, Haake, & Brown, 2001). Interacting with the entertainment system in a vehicle was found to impede drivers' driving performance and preparedness to react to unexpected events (Horberry et al., 2006). The effect of interacting with an iPod on simulated driving performance has been investigated. For example, lane deviation was found to increase as drivers interacted with the iPod (Salvucci et al., 2007). Similarly, Chisholm et al. (2008) reported that when interacting with an iPod, a driver's perception-reaction time to braking events increased by 16%; they had greater steering angle variability; and they had more crashes compared with the baseline conditions (no secondary tasks). Radio, cassette players, and DVD players also present a significant distraction potential on driving performance (Horberry et al., 2006; Reeves & Stevens, 1996; White et al., 2006). In addition, operating navigation systems that have manual-based interface and speech-based interface could cause distractions and compromise drivers' lane-changing behavior (Harbluk, Burns, Lochner, & Trbovich, 2007).

Further, evidence has been accumulated on the impact of on-road distractors on driving performance. For example, roadside advertisements have a distracting effect on driving safety (Dukic, Ahlstrom, Patten, Kettwich, & Kircher, 2013) and will compromise drivers' attention and lateral control capability (Young et al., 2009). Billboards with negative words can decrease a driver's reaction time and driving speed compared to positive words. Analogous results have also been found that drivers paid less attention to the relevant road regions as they approached to a negative image advertisement compared to positive and neutral images (Megías et al., 2011). Internal distractors, such as lost in thought, mind-wandering, and absent-mindedness, have been stated to impair the driving performance as they shift drivers' attention away from the driving tasks. Over 4% of distraction-related crashes have been associated with not paying attention or daydreaming (Glaze & Ellis, 2003). In summary, few studies have been done to concurrently distinguish and compare the influence of different driver distractions in fatal crashes.

3. Data description

3.1. Background

In the United States, a comprehensive police crash report (PCR) is prepared routinely for every fatal vehicular crash that includes information about the driver, the occupants, and vehicle conditions, witness statements, diagrams of pre-crash and post-crash trajectories, and a narrative of how the crash occurred. Compared to driving simulator data, survey data, and naturalistic driving data, the FARS database is the most comprehensive one allowing one to study on the impact of distracted driving in fatal crashes. FARS recently started to record "driver distracted by" information individually, which was covered in "driver-related factor" before 2010. There were 18 distinct distractors recorded in 2010 and 2011, and some changes were made after 2011 to better account for the distraction categories of inattention and carelessness. Since there are possible negative implications associated with the distracted driving, the reported driver distractions during crashes might be lower than the actual occurrence. Although there is potential underreporting in FARS, the theoretical bases for the distraction categorizations and the large sample size allows researchers to make generalizable conclusions.

3.2. Data overview

All the data used in this study were fatal crashes that kill at least one person, who might be a passenger, pedestrian, biker, or a driver, but not necessarily the driver. Also, drivers under the influence of alcohol or drugs were excluded. This study is to examine the fatal crashes that took place from 2010 to 2013 in the 50 U.S. states and District of Columbia. The distractors included in the data are a series of discrete non-overlapping categorical data. The data file was first filtered by person type to associate drivers with distraction factors. During 2010 to 2013, a total of 13,707 out of 17,8677 (7.7%) drivers involved in fatal crashes were distraction-related. Once compiled, the contributing factors were analyzed for the frequencies and trends of their occurrence. The data were also stratified according to age, sex, and type of distractions to better understand the effects of different distractors on the driver population.

3.3. Data limitations

It is important to acknowledge that there are inherent limitations in the data collection of distraction-affected crashes. The data of whether a driver was distracted were collected based on PCRs. One limitation for collection of distracted driving data is PCR itself. The PCR in use varies across jurisdictions, which may create some potential inconsistencies in reporting. Some PCRs have a distinct field to identify distraction, while others do not have such a reporting field and distraction is extracted from the narrative section of the PCRs. Therefore, the distraction-affected crashes should be interpreted with the limitation in mind due to the variations of reporting. Secondly, there might be underreporting of distracted driving due to self-reporting and timing of data collection. Survey studies show that self-reporting of negative behavior is lower than actual occurrence of that negative behavior. It is reasonable to believe that self-reporting of distracted driving to a law enforcement officer is lower than the actual occurrence. Additionally, when a driver fatality occurs, law enforcement need to rely on crash investigation and witness account to report on whether driver distraction was involved. Despite the limitations of the FARS data, it still provides valuable insight into the distracted driving in the United States.

4. Distractor percentages and trends

This study first examines the percentages of all distraction sources in distraction-affected fatal crashes in each year. There are 19 different types of distractions recorded in FARS Database between 2010 and 2013, which are showed in the first column of Table 1. On the basis of the literature review and how they would affect a driver to perform driving tasks, the driver distractions recorded in FARS Database were categorized as following:

- In-vehicle technology-related distractions (IVTD);
- In-vehicle non-technology-related distractions (IVNTD);
- On-road distractions (ORD);
- Automatic behavioral distractions (ABD);
- Inner cognitive distractions (ICD); and
- Distractions that were not clear (DNC).

The trends of these six subcategories (IVTD, IVNTD, ORD, ABD, ICD, and DNC) are first examined. According to Fig. 1, the percentage of the fatal crashes affected by inner cognitive distractions increased between 2010 and 2013 while the percentages of the unknown distractions decreased. The percentages of drivers affected by in-vehicle technology-related distractions were the third highest group in each of the four years, ranging from 14% to 16% of total crashes. In 2010 and 2011, more than 45% of distraction-affected fatal crashes were for unknown distractions. In 2012 and 2013, drivers' inner cognitive distractions accounted for more than 50% of distraction-affected fatal crashes.

Then, the six subcategories of distractions were further classified as external and internal distractions (see Table 1). Essentially, the IVTD, IVNTD, ORD, ABD, ICD, and DNC distractions are either caused by internal interference or external interferences. In order to visually assess the relationships of external and internal distractions with respect to time, a scatterplot with a LOESS (locally weighted scatterplot smoothing) smoother was presented in Fig. 2. Because the nonparametric LOESS

Table 1
Percentage of specific and congregated driver distractions (2010–2013 FARS data).

Distractor	% (count)	Subcategory	% (count)	Category	% (count)
Other cellular phone related	5.8% (799)	IVTD	15.1% (2077)	External	25.7% (3518)
While talking or listening to cellular phone	3.5% (476)				
While manipulating cellular phone	2.0% (280)				
While using or reaching for device/object brought into vehicle	1.8% (251)				
Adjusting audio or climate controls	1.4% (185)				
While using other component/controls integral to vehicle	0.6% (86)				
By other occupant(s)	4.3% (586)	IVNTD	4.8% (646)		
By a moving object in vehicle	0.5% (60)				
By outside person, object or event	5.8% (795)	ORD	5.8%(795)		
Eating or drinking	1.1% (155)	ABD	1.5% (205)	Internal	42.1% (8223)
Smoking Related	0.4% (50)				
Inattention (inattentive), details unknown	17.5% (3523)	ICD	40.6% (8018)		
Looked but did not see	10.3% (1404)				
Lost in thought/day dreaming	7.8% (2403)				
Distraction/inattention	3.9% (539)				
Careless/inattentive	0.9% (125)				
Distraction/careless	0.2% (24)				
Distraction (distracted), details unknown	25.7% (1073)	DNC	32.2% (1966)	Unknown	32.2% (1966)
Other distraction	6.5% (893)				
Total	100% (13,707)	100%(13,707)		100%(13,707)	

Fig. 1. The percentages of distraction subcategories in distraction-affected fatal crashes.

technique does not require an a priori speciation of data distributions, it was selected to assist to foresee the trends in the occurrence of distraction-affected fatal crashes. In each local span defined in LOESS, the neighboring data are processed by a quadratic polynomial to determine the smoothed value. Seasonal patterns were discovered in the occurrences of the internal distractions, distractions with unknown sources, and all of the distraction-affected fatal crashes. The LOESS curve also yields a curvilinear nature of the relationships of internal and unknown distractions between 2010 and 2013. It was also discovered that fatal crashes affected by internal distractions gradually increased with seasonal patterns since 2010, while the ones affected by unknown distractions decreased.

5. Distractor rankings

The availability of the frequency of each distractor in the compiled dataset allowed researchers to identify the contributing factors that play significant roles in distraction-affected fatal crashes. For all clearly delineated distractors recorded in the FARS data (see Table 1), topping the list was “Inattention” (17.5%). Meanwhile, “Looked But Did Not See” (10.3%) was the second highest distraction source, followed by “Lost in Thought/Daydreaming” (7.8%). In addition, the crash data in each year was assigned to the six subcategories and the three corresponding source groups. It was found that internal interferences (42.1%) caused more driving distractions compared to external

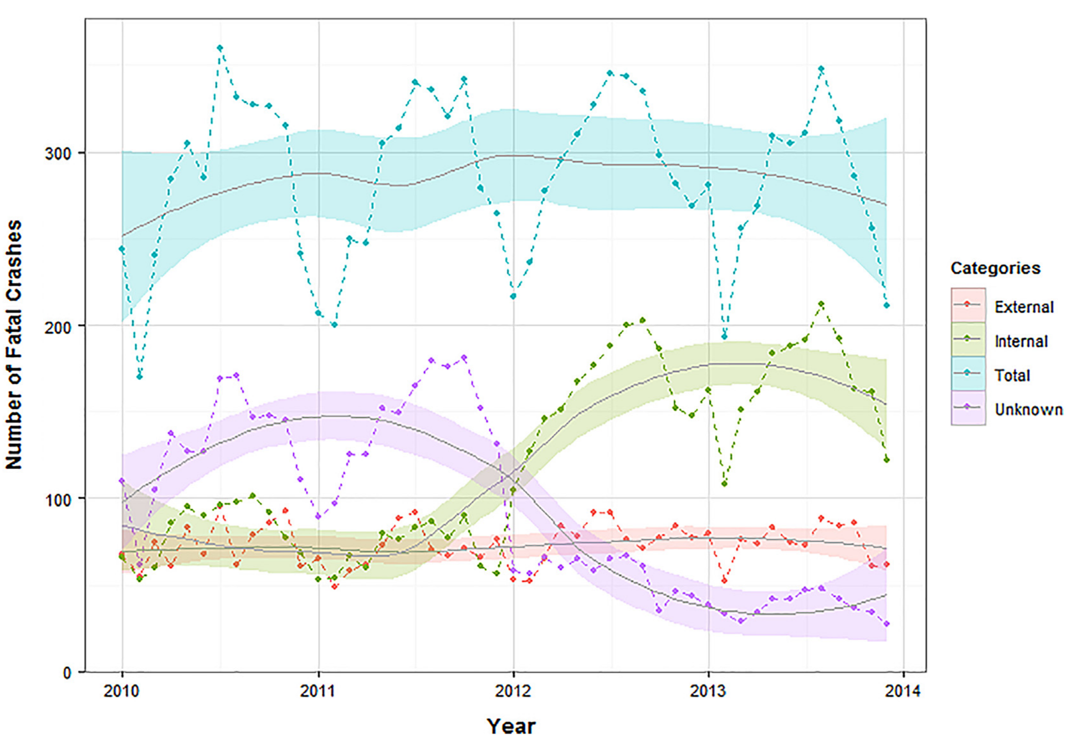

Fig. 2. The trends of the distraction categories with LOESS curves at 95% confidence interval.

distractions (25.7%). Moreover, the technology-related distractions (15.1%) contributed more compared to non-technology-related distractions (4.8%) in terms of in-vehicle external distractions. For all the objects, events, and people induced distractions, the occurrence of in-vehicle distractions (19.9%) was much higher than on-road distractions (5.8%). For all internal distractions, inner cognitive distractions (40.6%) contributed to a higher percentage than automatic behavioral distractions (1.5%) in distraction-affected fatal crashes.

The Tukey test (Tukey, 1949) was adopted to validate whether differences between the six distraction subcategories and between the three distraction source groups are significant. Based on the results of the Tukey tests, it can be concluded that at the significance level of 0.05:

- The mean number of fatal crashes affected by inner cognitive distractions was significantly higher ($p < .05$) than that of in-vehicle technology-related distractions.
- The mean number of fatal crashes affected by inner cognitive distractions was highly significant higher ($p < .01$) than that of in-vehicle non-technology-related distractions.
- The mean number of fatal crashes affected by unknown distractions was significantly higher than ($p < .05$) that of in-vehicle non-technology-related distractions.
- The mean number of fatal crashes affected by inner cognitive distractions was highly significant higher than ($p < .01$) that of on-road distractions.
- The mean number of fatal crashes affected by unknown distractions was significantly higher than ($p < .05$) that of on-road distractions;
- The mean number of fatal crashes affected by inner cognitive distractions was highly significant higher than ($p < .01$) that of automatic behavioral distractions;
- The mean number of fatal crashes affected by unknown distractions was highly significant higher than ($p < .01$) that of automatic behavioral distractions.
- Other contrasts were not significant ($p > .05$).

Therefore, it can be shown that inner cognitive distractions and distractions that were not clear were the top two factors in the distraction-affected fatal crashes. It is worth noting that the number of inner cognitive distractions were not significantly higher than that of the unknown distractions. In addition, the in-vehicle technology-related distractions were demonstrated to be the third highest contributing factors in distraction-affected fatal crashes. The differences between external, internal, and unknown distractions were not significant, indicating that the ranking of these three sources will not be statistically significant.

6. Distractions and ages of drivers

Drivers of different ages have different levels of functional abilities. The interrelations between different distraction subcategories and drivers of different age groups were presented in Fig. 3. Overall, unknown distractions and inner cognitive distractions display the highest occurrence rates among all age groups compared to the other distraction subcategories. The fatal crashes affected by inner cognitive distractions increased while the unknown distraction affected ones decreased within all age groups. For drivers in the first two age groups, the in-vehicle technology-related distractions have the third highest occurrence rates. There were more fatal crashes affected by automatic behavioral

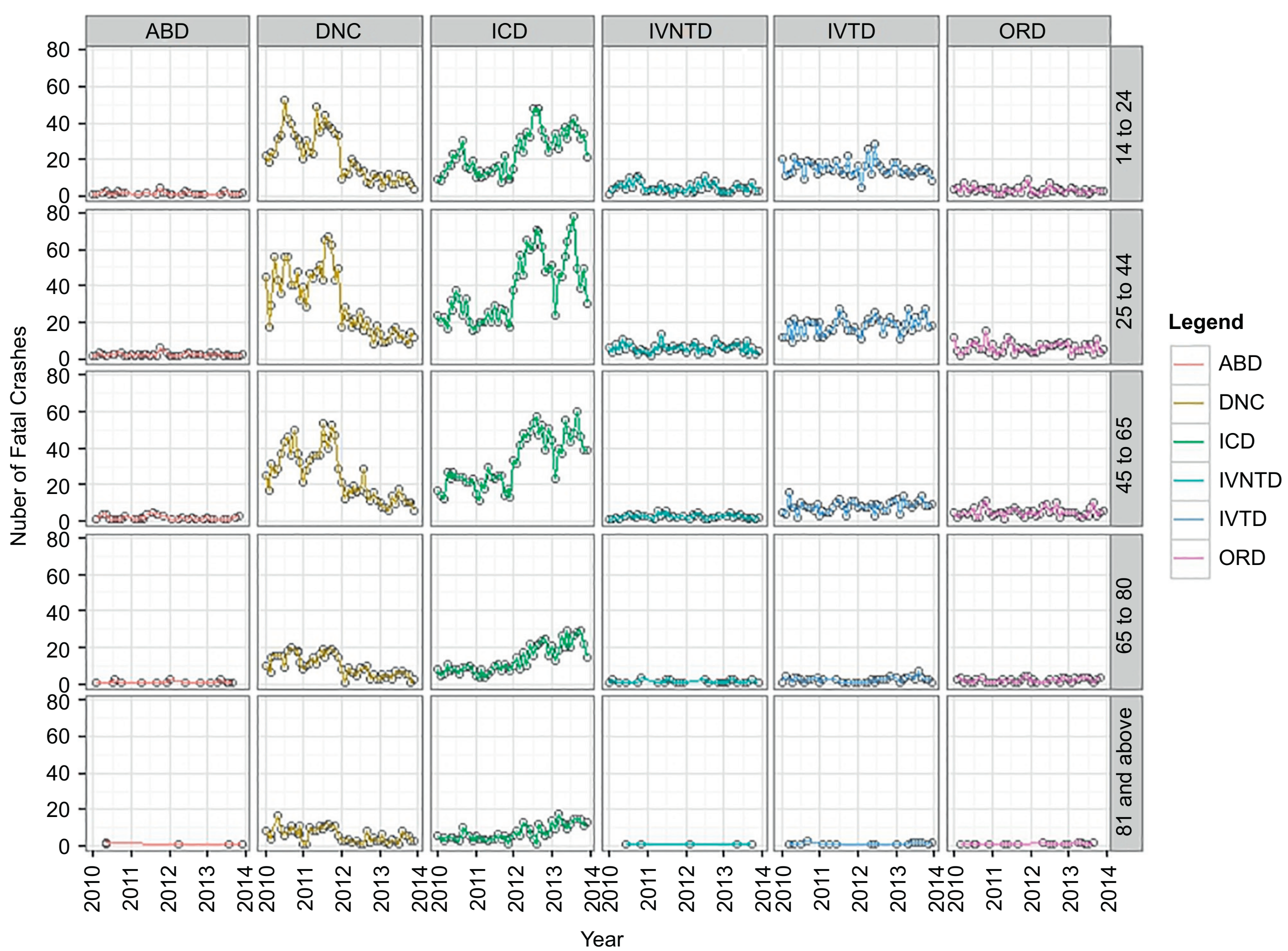

Fig. 3. The trends of distraction subcategories with respect to different age groups.

Table 2
Contingency table for the Chi-square test of independence (2010–2013 FARS data).

Age group (years)	IVTD	IVNTD	ORD	ABD	ICD	DNC	Total
14–24	730	222	159	49	1155	1032	*3347*
25–44	864	273	292	74	1835	1451	*4789*
45–64	381	111	242	57	1567	1187	*3545*
65–80	78	35	77	19	646	459	*1314*
81 and above	23	5	19	5	336	213	*601*
Total	*2076*	*646*	*789*	*204*	*5539*	*4342*	*13596**

Note*: 111 cases were dropped from the total sample because of missing driver ages.

distractions when drivers were in the late young and early middle-aged group (25–44 years old) compared to the teenaged and young drivers (14–24 years old). In the group of the older driver (which commonly accepted as whose ages were beyond the retirement age, 65), automatic behavioral distractions, in-vehicle technology-related distractions, in-vehicle non-technology-related distractions, and on-road distractions show relatively stable monthly frequencies.

To further investigate the relationship between the age of drivers and different subcategories of distractions, a contingency table was computed (see Table 2). The null hypothesis was that the observed frequency of each subcategory of distractions is independent of the drive age groups. Computing the chi-square statistics produces an overall measure of $\chi^2(\mathrm{df}=20, \mathrm{N}=13596)=519.88$, $p<0.001$. The null hypothesis of homogeneity of population proportions was rejected compared to the critical value of 31.4, suggesting a correlation between the different subcategories of distractions and driver age groups.

In light of this, the Nemenyi post-hoc test (Pohlert, 2015) was conducted in order to identify whether the differences between these samples are significant. The results of the multiple pairwise comparisons show that among drivers of different age groups:

- The effect of inner cognitive distractions differs highly significant ($p<.01$) to that of the automatic behavioral distractions, and differs significantly ($p<.05$) to that of the in-vehicle technology-related distractions and that of the on-road distractions.
- The effect of the unknown distractions differs significantly ($p<.05$) to that of the automatic behavioral distractions among drivers of different age groups.
- Other contrasts were not significant ($p>.05$).

7. Distractions and sex of drivers

The probability density functions of female and male drivers were presented in Fig. 4. Both young female and young male drivers had a larger probability engaging in external interferences than internal and other interferences. In more detail, young females have a higher probability than young males in engaging in external interferences. Fig. 4a further identified that high probabilities of in-vehicle technology-related distractions and non-technology-related distractions were the contributing factors of higher probabilities of external distractions among young drivers. Young female drivers had a high probability of engaging in in-vehicle technology-related distractions that affected fatal crashes compared to young male drivers (see Fig. 4a). Compared to other drivers, older drivers have the lowest probabilities of involving in any kinds of distractions included in this study. (See Fig. 5.)

The chi-square test of independence was applied to examine the relationship between different subcategories of distractors and sex of drivers (see Table 3). The null hypothesis was that drivers have equal proportions in different groups of distractors. After comparing the test statistics $\chi^2(\mathrm{df}=5, \mathrm{N}=13604)=131.41$, $p<0.001$ to the critical value of 11.1 at the significance level of 0.05, the null hypothesis was rejected. It was suggested that the likelihood of drivers' engagement in certain distractions was related to a driver's sex. Furthermore, the Marascuilo procedure (Berenson, Levine, Szabat, & Krehbiel, 2012) was used to compare all possible pairs of population proportions. The corresponding critical ranges (CR) of the Marascuilo procedure were computed by the following equation:

$$CR_{ij} = \sqrt{\chi^2_{1-\alpha,(c-1)*(r-1)}}\sqrt{\frac{p_i(1-p_i)}{n_i}+\frac{p_j(1-p_j)}{n_j}} \tag{1}$$

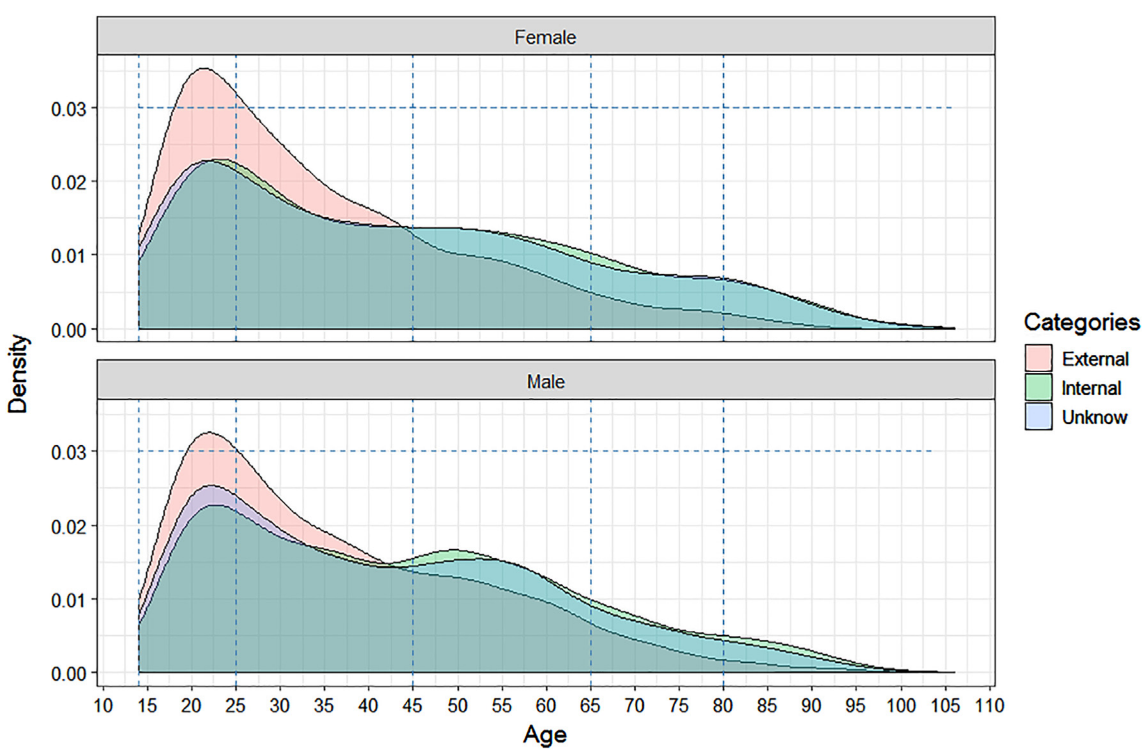

Fig. 4. Probability densities of internal, external, and unknown distractions.

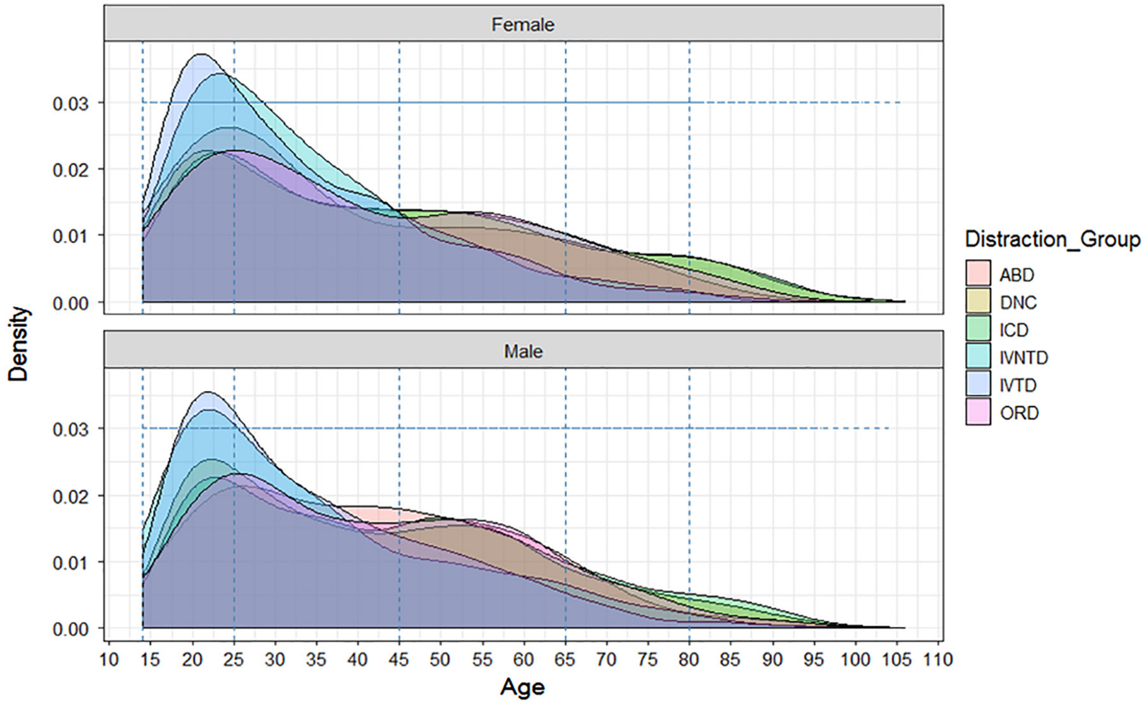

Fig. 5. Probability densities of distraction subcategories.

Table 3
Contingency table for the Chi-square test of independence (2010–2013 FARS data).

Sex	IVTD	IVNTD	ORD	ABD	ICD	DNC	Total
Male	1285(0.6196)	371(0.5743)	592(0.7484)	141(0.6946)	3948(0.7125)	3130(0.7197)	*9467*
Female	789(0.3804)	275(0.4257)	199(0.2516)	62(0.3054)	1593(0.2875)	1219(0.2803)	*4137*
Total	*2074*	*646*	*791*	*203*	*5541*	*4349*	*13604**

Note*: 103 cases were dropped from the total sample because of missing driver ages.

If the absolute difference of one pair is greater than its critical range, the proportions of this pair are significantly different (see Table 4). At the significance level of 0.05, driver engagement in in-vehicle technology-related distractions, on-road distractions, inner cognitive distractions, and unknown distractions were different for male and female drivers. In more detail, male drivers engagement in on-road distractions, inner cognitive distractions, and unknown distractions were significantly higher than in-vehicle technology-related distractions. Also, male drivers engagement in on-road distractions, inner cognitive distractions, and unknown distractions were significantly higher than in in-vehicle non-technology technology-related distractions.

8. Discussion of results

Systematically exploring the effect of different distractions in fatal crashes was achieved by Tukey test, chi-square test of independence, Nemenyi post-hoc test, and Marascuilo procedure. The results are discussed in more detail below.

In 2012 and 2013, the inner cognitive distractions accounted for more than 50% of distraction-affected fatal crashes. Although the percentage of in-vehicle technology affected fatal crashes in each year was low, it increased from 14% to 16% between 2010 and 2013. As drives are exposed to more and more wearable and portable technological devices, and driver entertainment and assistance systems, this momentum could continue. In addition, seasonal patterns were demonstrated by the occurrence of distraction-affected fatal crashes, which cycles over each of these four years with the peaks appearing in the summer months and the troughs resting in the winter months.

Internal interferences caused more distracted driving compared to external interferences. “Inattention,” “Looked But Did Not See,” and “Lost in Thought/ Daydreaming” were the top three factors in distraction-affected fatal crashes, which all belong to driver inner cognitive failures. For all internal distractions, inner cognitive interferences have a higher percentage than human automatic behaviors such as the consumption food or drink at the wheel in distraction-affected fatal crashes. In addition, the variable attributes changed since 2012 to account for inner cognitive distraction in PCRs (National Highway Traffic Safety Administration, 2015). Fig. 2 shows that as the number of fatal crashes

Table 4
The results of Marascuilo procedure.

Comparison	Absolute difference	Std. error of difference	CR	Results
IVTD vs. IVNTD	0.0453	0.0222	0.0739	Non-significant
IVTD vs ORD	0.1288	0.0188	0.0625	**Significant**
IVTD vs. ABD	0.0750	0.0340	0.1134	Non-significant
IVTD vs. ICD	0.0929	0.0123	0.0409	**Significant**
IVTD vs. DNC	0.1001	0.0127	0.0421	**Significant**
IVNTD vs. ORD	0.1741	0.0248	0.0827	**Significant**
IVNTD vs. ABD	0.1203	0.0377	0.1257	Non-significant
IVNTD vs. ICD	0.1382	0.0204	0.0679	**Significant**
IVNTD vs. DNC	0.1454	0.0206	0.0687	**Significant**
ORD vs. ABD	0.0538	0.0358	0.1193	Non-significant
ORD vs. ICD	0.0359	0.0166	0.0553	Non-significant
ORD vs. DNC	0.0287	0.0169	0.0562	Non-significant
ABD vs. ICD	0.0179	0.0329	0.1096	Non-significant
ABD vs. DNC	0.0251	0.0330	0.1101	Non-significant
ICD vs. DNC	0.0072	0.0091	0.0304	Non-significant

that related to internal distraction increases, the number of unknown distraction ones is decreasing. It indicates that the procedures and practices of reporting distraction-affected fatal crashes is improved after 2012. Furthermore, driving distraction that was classified as "details unknown" and "other distraction" are likely to be internal distractions since when the Unknown distraction decreases, the internal distraction increases (See Fig. 2).

In terms of external distractions that happen inside a vehicle, the technology-related distractions contributed three times as much as non-technology-related distractions in fatal crashes. Interacting with technological devices requires extra visual attention, cognitive resources, and motor movements that compete with driving tasks. It is more difficult for drivers to maintain safe driving between driving tasks and competing tasks. Overall, the roadway environment caused less distracted driving than the environment inside the vehicle.

9. Conlusions, recommondataions, and future work

This study has demonstrated major distraction sources for male drivers and female drivers, and for young, middle-aged, and older drivers. Based on the statistical analyses, the following findings were revealed:

(1). Inner cognitive distractions accounted for the greatest proportion of driver engagement in distractions.
(2). A sex difference of driver engagement in in-vehicle technology-related distractions, on-road distractions, automatic behavioral distractions, inner cognitive distractions, and unknown distractions has been revealed in fatal crashes.
(3). Among all six subcategories of distractions, drivers beyond 80 years old were most likely to engage in inner cognitive distractions.
(4). Both young male and young female had a larger likelihood involving in in-vehicle distractions compared to the other four types of distractions.
(5). Young female drivers had a larger likelihood engaging in in-vehicle technology-related distractions compared to young male drivers.

Young drivers have a larger proportion and higher probability of engaging in distracted driving, indicating more efforts are needed to promote safe driving among young drivers. As confirmed more broadly by previous sections, distractions have distinct impacts on drivers at different ages and of different sexes. This suggests that driving safety campaigns, programs, and policies should consider the effects of a driver's age and sex. Limited human cognitive capacities could explain both why the group of inner cognitive distractions tops the list of driver distractions and why internal interferences caused more distracted driving than external distractions. Proper designs of the vehicle interfaces and the road environments can help drivers keep sufficient attention on the driving tasks and reduces the likelihood of diverting their attention. In addition, the increase in in-vehicle technology-related distractions indicates that laws and regulations regarding the usage of the technological devices while driving still need to be stressed in order to reduce its negative impact on driving safety. Although on-road distractions contribute to a lower percentage compared to in-vehicle distractions in crashes, the highway designers and operation management sectors still need to find effective ways to assist drivers in keeping sufficient amount of vigilance while also reducing distraction, boredom, drowsiness, and fatigue.

On the basis of this study, further research is needed to identify proper, effective, and individualized countermeasures to reduce the negative effect of driver distractions that were caused by leading distraction factors identified in this paper.

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