Modeling safety risk perception due to mobile phone distraction among four wheeler drivers

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Abstract

Nowadays, there is an increasing trend in the use of information and communication technology devices in new vehicles. Due to these increasing service facilities, driver distraction has become a major concern for transportation safety. To reduce safety risks, it is crucial to understand how distracting activities affect driver behavior at different levels of vehicle control. The objective of this work is to understand how the vehicle and driver characteristics influence mobile phone usage while driving and associated risk perception of road safety incidents. Based on literature review, a man–machine framework for distracted driving and a mobile phone distraction model is presented. The study highlights the findings from a questionnaire survey conducted in Kerala, India. The questionnaire uses a 5-point Likert scale. Responses from 1203 four-wheeler drivers are collected using random sampling approach. The questionnaire items associated with three driver-drive characteristics are: (i) Human Factors (age, experience, emotional state, behavior of driver), (ii) Driver space (meter, controls, light, heat, steering, actuators of vehicle), (iii) Driving conditions (speed, distance, duration, traffic, signals). This mobile phone distraction model is tested using structural equation modeling procedure. The study indicates that among the three characteristics, ‘Human Factors’ has the highest influence on perceived distraction due to mobile phones. It is also observed that safety risk perception due to mobile phone usage while driving is moderate. The practical relevance of the study is to place emphasis on behavior-based controls and to focus on strategies leveraging perception of distraction due to mobile phones while driving.

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1. Introduction

The use of information and communication technology devices in four wheelers is on the rise. Such technological developments, while adding ease to life, increase the potential for drivers to engage in secondary tasks while driving [1,2]. Recent studies report phone use exposure estimates in the range 30–60% in a few developed countries [3]. The proportion of drivers using mobile phones has been increased over the past 5–10 years [4]. Driver distraction has become a major concern for transportation safety. Nature, severity, and frequency of distractions affect the safety of drivers, passengers, and vulnerable road users [5]. There is a growing body of evidence which shows that the distraction caused by mobile phones can impair performance in a number of ways, e.g., longer reaction time to external stimuli (notably braking time, response to traffic signals), impaired ability to maintain the correct lane, shorter following distances and an overall reduction in awareness of the driving situation [4,6]. Most secondary tasks lead to a decrease in driving speed, while visual–manual tasks additionally take driver’s eyes of the road, deteriorating the lateral performance [2]. The impact of using a mobile phone on crash risk is difficult to ascertain, but studies suggest that drivers using mobile phones are approximately four times more likely to be involved in crashes [4].

To reduce safety risks, it is crucial to understand how distracting activities affect driver behavior at different levels of vehicle control. There may be more than one reason or factor that motivates a person to involve in some secondary activity. The objective of the paper is to examine the role of vehicle and driver factors on risk perception of road safety incidents arising from the use of mobile phones while driving. First, a short literature review of a man–machine framework for distracted driving is presented (Section 2). Next section deals with distracted driving due to mobile phones by proposing a ‘mobile phone distraction model’. In Section 3, the study methodology highlighting ‘mobile phone distraction model’, questionnaire survey and the analysis procedure are presented.

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2. Literature review

Driving is a very critical task that requires undivided attention and complete commitment of associated skills of the driver. Driver distraction is defined as a diversion of attention from activities critical to safe-driving for performing any secondary competing activity [2]. Distraction to the driver occurs from any secondary physical or mental activity that shifts the attention of the driver from safe handling of the automobile [7]. Some distractions are initiated by the driver, and others are acute situations that demand a quick response from the driver [8]. Most in-vehicle distractions belong to the former, whereas most outside vehicle distractions are of the latter.

Man–machine interactions between the driver and device may involve inputs such as visual, audio, or tactile inputs from the device; and outputs like manual or voice responses. The secondary tasks which potentially distract the driver from the safe operation of the vehicle include interacting with a passenger, conversing on mobile phone, text messaging, use of smartphones and other office devices, navigation aids, background music, adjusting audio-video players, eating and drinking, manipulating in-vehicle environmental attributes, and seeking for objects. Fig. 1 presents the man–machine framework [9] for distracted driving. The major four-wheeler driver and driving characteristics that affect safety include ‘Human characteristics’, ‘Driving Conditions’, ‘Driver Space’ and ‘Interaction characteristics’ due to in-vehicle device and their use (Table 1).

The chain of events in the man–machine model are factors affecting the driving task (Human Factors, Driver space and Driving conditions), immediate-state and end-state (Fig. 1). ‘Driver Space’ is part of driver–vehicle interaction (inside vehicle) and ‘Driving Conditions’ is a part of vehicle-environment interaction (outside vehicle). Driver–vehicle interactions along with secondary tasks cause driving distraction and result in the immediate-state (loss of focus, steering control or pedal response). Driving distraction occurs in visual, manual, cognitive and audio forms [1], and can be studied through the multiple resource theory to examine the driver performance decrement [2]. According to the multiple resource theory, the resources allocated for visual attention and central processing while driving are forced to be divided by secondary tasks. Secondary tasks demanding these two types of resources (e.g., use of cell phone and navigation aid) pose visual and cognitive distractions while driving. Both visual and cognitive distractions increase driver workload and thereby influence the vehicle control and gaze behavior [2]. When distracted, drivers tend to place less emphasis on the visual scanning in favor of activities related to vehicle control [32]. Distraction enhances the chance of driving errors [33] and reduces situational awareness [34]. The man–machine interactions are indicated by the immediate states or driver performance indicators such as number of glances & glance time, speed, lateral position, posture, steering error, mental effort, NASA Task Load Index, time for detection of information, reaction time, lag distance, heart rate and committing errors. The end states are events or conditions that reflect a state of higher safety risk.

Intervention strategies to address distracted driving include legislation, enforcement, blocking technologies, using social media, education and transforming social norms [31,35–37]. Education related intervention strategy is based on risk perception of drivers who undertake distracted driving. Numerous literature indicate the difference in risk perception by different age groups, gender, in-vehicle devices or nature of secondary tasks [3,38,39]. Overall, the Man–machine model for distracted driving provides a useful framework for examining the role of major dimensions of driver-drive characteristics on distraction due to secondary tasks while driving.

3. Methodology

Considering the Man–machine model this paper specifically focuses on one of the secondary tasks, i.e., use of mobile phones. A mobile phone distraction model is proposed and validated.

3.1. Mobile phone distraction model

The mobile phone distraction model shown in Fig. 2 has three constructs, ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ that influence the driver's distraction due to a secondary task, i.e., ‘Distraction_Mobile’. The focus in ‘Distraction_Mobile’ is on the immediate effect due to its use, i.e., loss of focus or steering control. This is represented as the immediate-state in Fig. 1. The driver’s response while driving with secondary tasks results in end states such as ‘accidents’, ‘near miss’ and ‘erratic driving’. Overall the model represents the influence of ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ on the risk perception of the driver towards safety incidents arising from the use of mobile phones while driving (i.e., ‘Mobile Use’). Four hypotheses are tested in the mobile distraction model. First, the model

Results and discussion from the structural equation model (SEM) are shown in Sections 4 and 5 respectively. Finally, the conclusions of this study are presented in Section 6.

![Man–machine model for distracted driving.](Image)
hypothesizes that unfavorable ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ dimensions lead to stronger distraction perception (i.e., loss of control & focus) due to mobile phone use. Second, the model hypothesizes that stronger distraction perception from mobile use impairs a higher safety-risk perception. Third, the model hypothesizes that ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ dimensions are enablers to stronger safety-risk perception due to mobile phones. Fourth, the model hypothesizes that a stronger distraction and safety-risk perception due to mobile phones reduce the intention of the driver to use it. In this study ‘Risk Perception’ represent the end-state of the four wheelers drivers as shown in the man–machine model (Fig. 1). ‘Risk Perception–Mobile Use’ link is the test of hypothesis that ‘increased risk’ leads to reduced mobile use. This link is explored to leverage ‘education’ based intervention strategies (i.e., emphasizing on risk perception) to improve transport safety.

### 3.2. Instrument

From the literature review, critical factors leading to distracted driving were identified. An initial questionnaire was prepared and a pilot survey was conducted from a sample of drivers (n = 110) drawn from one district. Items with low Cronbach’s alpha (<0.6) were used to modify the questionnaire and the survey was conducted again. The final questionnaire was divided into three parts; Part A focused on extent of secondary tasks undertaken by drivers and included questions on the extent to which the respondents experience distractions inside the vehicle while driving. Part A used 5-point Likert scale with assigned values ranging from 1 being ‘Never’ to 5 being ‘Regularly’. Part B incorporated questions on perception towards immediate response state due to in-vehicle distractions and Part C contained questions on the risk perception associated with distractions mentioned in part B. Parts B and C also used 5-point Likert scale with assigned values ranging from 1 being ‘Strongly disagree’ to 5 being ‘Strongly Agree’. Considering the mobile phone distraction model (Fig. 2), Part B is used to model ‘Human Factors’, ‘Driver Space’, ‘Driving Conditions’ and ‘Distraction_Mobile’; Part C is used to model ‘Risk Perception’; and Part A is used to model ‘Mobile Use’. A set of sample questions are presented in Table 2. For data collection drivers were approached personally and in addition, an online survey was conducted. The final Cronbach’s alpha of the questionnaire was found to be 0.862.

#### 3.3. Data analysis

Missing values and outliers of all measured variables are examined to purify the data and reduce systematic errors, i.e., error due to instrument or mishandling of the same. Confirmatory factor analysis is undertaken to test and validate the proposed model. A structural equation model (SEM) is developed using SPSS AMOS software. Structural equation model is designed to evaluate how well a proposed conceptual model consisting of observed indicators and hypothetical constructs explains or fits the collected data. The estimation of parameters is based on the maximum likelihood method. The following indices have been chosen in this study: root mean residual (RMR), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). The default model

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**Table 1**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Authors</th>
<th>Key findings</th>
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<tr>
<td>Human characteristics (Age, Experience, Gender, Behaviour)</td>
<td>Young &amp; Lenne [3]; Lam [8]; Singh [10]; Simons-Morton et al. [11]; Knapper et al. [1]; Shinar et al. [12]; Singh [10]</td>
<td>Younger drivers are most distracted and are more prone to incidents, their risk perception and strategies differ from older drivers. Driving experience or experience in using in-vehicle devices has impact on distraction. Exposure to secondary tasks and safety risks are different among male and female drivers. Behaviour and states of driver influence exposure to secondary tasks. External condition such as traffic, duration etc., places higher vehicle handling demands and affect driver responses or compensating strategies adopted. In vehicle condition potentially affects the state of the driver. Position of displays and controls affect the driver responses.</td>
</tr>
<tr>
<td>Driving conditions (Speed, Traffic, Duration)</td>
<td>Johnson et al. [16]; Cooper et al. [17]; Stavrinos et al. [18]</td>
<td>Second, the model hypothesizes that unfavorable ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ dimensions lead to stronger distraction perception from mobile use impairs a higher safety-risk perception. Third, the model hypothesizes that ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ dimensions are enablers to stronger safety-risk perception due to mobile phones. Fourth, the model hypothesizes that a stronger distraction and safety-risk perception due to mobile phones reduce the intention of the driver to use it. In this study ‘Risk Perception’ represent the end-state of the four wheelers drivers as shown in the man–machine model (Fig. 1). ‘Risk Perception–Mobile Use’ link is the test of hypothesis that ‘increased risk’ leads to reduced mobile use. This link is explored to leverage ‘education’ based intervention strategies (i.e., emphasizing on risk perception) to improve transport safety.</td>
</tr>
<tr>
<td>Driver space (Seating, Driving controls &amp; Display, Heat)</td>
<td>Chen [13]; Regan et al. [14]; Vardaki et al. [15]; Johnson et al. [16]; Cooper et al. [17]; Stavrinos et al. [18]; Golias et al. [19]; Lenzuni et al. [20]; Lamble et al. [21]; Dukic et al. [22]; Ryu &amp; Lee [23]</td>
<td>Younger drivers are most distracted and are more prone to incidents, their risk perception and strategies differ from older drivers. Driving experience or experience in using in-vehicle devices has impact on distraction. Exposure to secondary tasks and safety risks are different among male and female drivers. Behaviour and states of driver influence exposure to secondary tasks. External condition such as traffic, duration etc., places higher vehicle handling demands and affect driver responses or compensating strategies adopted. In vehicle condition potentially affects the state of the driver. Position of displays and controls affect the driver responses.</td>
</tr>
<tr>
<td>Interaction characteristics (In vehicle devices, Human resources)</td>
<td>Knapper et al. [2]; Collet et al. [24]; Ural et al. [25]; Landsdown et al. [26]; Young et al. [27]; Cuenen et al. [28]; Knapper et al. [1]; Young &amp; Lenne [3]; Shinar et al. [6]; Collet et al. [24]; Brodsky et al. [29]; Knapper et al. [1]; Kaber et al. [2]; Shinar et al. [6]; Cooper et al. [17]; Pattan et al. [30]; Birrell et al. [37]; Briggs et al. [43]; Cairo et al. [47]</td>
<td>Nature of immediate states or driver performance indicators include number of glances &amp; glance time, speed, lateral position, posture, steering error, mental effort/ NASA Task Load Index, time for detection of information, reaction time, lag distance, heart rate, errors. Nature of end results or indicators include fatality, injuries, driver performance, negatively influenced traffic flow, increased congestion.</td>
</tr>
<tr>
<td>Safety impact</td>
<td>Bingham [7]; Lam [8]; Stavrinos et al. [18]; Overton et al. [31]</td>
<td>Secondary tasks compete for limited resource of driver, influence this resource allocation and consequently affect the driver response. Nature of in-vehicle devices &amp; tasks influence the physical or mental faculties employed and therefore the driver responses or safety incidents and risks. Nature of immediate states or driver performance indicators include number of glances &amp; glance time, speed, lateral position, posture, steering error, mental effort/ NASA Task Load Index, time for detection of information, reaction time, lag distance, heart rate, errors. Nature of end results or indicators include fatality, injuries, driver performance, negatively influenced traffic flow, increased congestion.</td>
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**Fig. 2.** Mobile phone distracted driving model.

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is checked for fitness and improved by carrying out modifications based on the ‘p’ (significance) value of the regression coefficients and the modification indices.

4. Structural equation modeling

4.1. Descriptive statistics

The survey is conducted over a period of 3 months and a total of 1203 responses are collected from 5 districts in Kerala, India. The mean age (standard deviation) of the respondents is 33.14 (SD = 10.66) years. The sample consisted of largely male drivers (84.8%) and most of them are private drivers (79.6%). Table 3 shows the summary of responses pertaining to age, driving experience and speed. Among the respondents, 15.6% have been penalized for driving faults and 16% have reported involvement in accidents. Further descriptive statistics from the survey can be found in Srinath et al. [40].

4.2. Modelling

Fig. 3 shows the mobile phone distracted driving model with four latent constructs ‘Human Factors’, ‘Driving Conditions’, ‘Driver Space’ and ‘Distraction Mobile’ and its items. The measurement model is developed and shown in Fig. 4. The measurement model fitness indices are, $\chi^2 = 234.034$ (df = 59, $p = 0.000$), RMR = 0.034, GFI = 0.955, AGFI = 0.931, CFI = 0.918 and RMSEA = 0.062. The value of RMR should be less than 0.1 and that of GFI, AGFI and CFI should be greater than 0.9 which indicate good fitness and acceptability of the model. The value of RMSEA indicates a reasonable fit since it is between 0.05 and 0.08.

The various goodness-of-fit statistics indicate that the measurement has a good fit with the obtained data. The measurement model has been transformed to a structural model to test the stated hypotheses (Section 3.1). The default SEM is shown in Fig. 5. Modification indices and critical ratios of path coefficients from AMOS have been examined to modify the default SEM. First, the insignificant links ‘Human Factors–Risk Perception’, ‘Driving condition–Distraction_Mobile’, ‘Driver Space–Risk Perception’ and ‘Risk Perception–Mobile Use’ are removed to improve model fitness. Next, the error terms of ‘emotion’ and ‘behavior’ are covaried, and that of ‘speed’ and ‘duration’ are covaried to improve the model fitness. The final SEM is shown in Fig. 6 and the model fit indices are given in Table 4. In the model, it is seen that there are direct effects of human factors and drive space on perception level of distraction due to mobile phones. The effect of ‘Human Factors’ on mobile distraction is 0.62 and that of ‘Driver Space’ on the latter is 0.2. ‘Driver Space’ has an inverse relationship with the risk of traffic incidents due to use of mobile phones. The loading of perceived distraction due to mobile phones on risk of incidents is 0.33. The influence of ‘Driving Conditions’ has no significant direct relation to mobile use being perceived as a distraction and is hence removed in the final model. The model fit indices are found to be acceptable (Table 4). The regression coefficients for the paths in the mobile phone distraction model (Fig. 6) obtained through the maximum likelihood method is shown in Table 5. The critical ratios for estimates of covariance between the constructs and variance of indicators were observed to be greater than 1.96 and $p < 0.05$.

5. Discussion

5.1. Effect of man–machine factors on mobile distraction

The loading weight of 0.62 (Fig. 6) between ‘Human Factors’ and ‘Distraction_mobile’ indicates that attributes like age, experience, emotion and behavior have significant contribution towards mobile phone distraction. The effect of ‘Human Factors’ is attributed to Age, Experience, Emotion and Behaviour with loading weights of 0.44, 0.66, 0.59 and 0.64 respectively (Table 5). Horberry et al. [41] and Simons-Morton et al. [11] highlighted significant differences in young and old drivers in undertaking distracting activities. Shinar et al. [12] pointed that as experience builds up, the drivers get more accustomed to the routine task of driving and additional activities. Romer et al. [42] explained the role of deficient situation awareness in novice drivers for attention failures. Briggs et al. [43] concluded that the more emotionally drivers are involved in a conversation, the greater potential for distraction exists. Simons-Morton et al. [11] and Westlake & Boyle [44] have attributed risk taking behaviour to driver distraction and accidents.

Drivers perceive facilities inside the vehicle such as lighting, meter console, equipment controls and music as enablers to mobile phone distraction with a regression weight of 0.2 (Table 5). The loading weights for lighting, meter console, equipment controls and music on ‘Driver Space’ are 0.62, 0.51, 0.65 and 0.45 respectively (Table 5). Golas et al. [19] pointed out that driver convenience is a key factor that affects performance and the interior space has a role in determining the same. Interestingly, ‘Driver Space–Risk Perception’ ($–0.09$) link does not turn up significant as hypothesized in our model (Fig. 5). Perhaps the need for mobile use outweighs the risk perception. Another hypothesis that has been rejected is the influence of ‘Driving Conditions’ on ‘Mobile_distraction’. This finding is rather unexpected and needs to be examined against the backdrop that ‘Driving Conditions’ influences ‘Risk Perception’ ($0.20$).  

5.2. Distracted driving and safety risk perception

The loading weight of 0.33 (Fig. 6) between ‘Mobile_distraction’ and ‘Risk Perception’ indicate that the perceived distraction due to use of mobile phones does increase the negative safety risk perception. The moderate level of impact of mobile distraction on risk perception can be attributed to the counter effect of purpose of using phone on the
driver’s perception of risk. Studies by Atchley et al. [38] and Nelson et al. [45] indicates that distracted driving behavior itself change attitudes towards risk. In addition, a number of existing research describes the compensatory strategies adopted by drivers in order to allocate the physiological elements required for carrying out secondary tasks [24,46].

5.3. Effect of man–machine factors on safety risk perception

The third hypothesis of the present study is that ‘Human Factors’, ‘Driver Space’ and ‘Driving Conditions’ dimensions are enablers to higher safety-risk perception due to mobile phones. These relationships have been examined in the default model. Two of the paths have turned out to be insignificant. First, the standardized estimates in the default structural model show that the relation between ‘Human Factors’ and ‘Risk Perception’ (0.05) is not significant. This could perhaps be due to the lack of awareness and ability of the respondents to assess the human limitations in driving. Another reason could be that of learning effect from repeated use of mobile phones reducing their risk perception. Second, the relationship between ‘Driver Space’ and ‘Risk Perception’ is found to have a regression weight of −0.09 which is also insignificant. But it is interesting to find that ‘Driver Space’ does have an impact on distraction due to mobile use. This means that even though the drivers identify

![Diagram](image-url)
distracting sources and activities inside the vehicle, they do not associate safety risk perception with it (i.e., direct effect). With these insignificant links removed, the only factor that has an influence on the safety risk perception is the ‘Driving Conditions’ (0.2). This relation shows that the probability of perceiving the safety risk associated with the use of mobile phones while driving is dependent on the traffic density, duration of travel and driving speed (Fig. 6). Meta analysis done by Caird et al. [47] highlight that cell phone conversation while driving increases reaction time to events and stimuli, and drivers compensate for potential reaction time decrements by speed reduction strategies.

5.4. Distracted driving and mobile use

A variable that measures the exposure to mobile phone use while driving has been included in the model. The hypothesis in the ‘Risk Perception–Mobile Use’ link is that a driver perceives using mobile phone reduces safety, it leads to reduced mobile use. In this study a loading of −0.27 (Table 5) has been obtained between perception of distraction due to mobile phones and the exposure variable of mobile use. But the link ‘Risk Perception–Mobile Use’ has turned out to be insignificant. This implies that the moderating effect on mobile use is rather due to distraction of mobile use than due to higher safety risk perception. Hence, the fourth hypothesis has been only partly confirmed. One possible explanation to the insignificance of the link ‘Risk Perception–Mobile Use’ is the emphasis on purpose and habit of using phones than on the risk perception towards its use while driving. Similar findings have been previously reported by Nelson et al. [45]. Choosing to engage in the behavior itself changes attitude towards risk [38]. Probably, the perception and confidence of drivers towards such strategies affect the overall risk perception, thereby preventing it from acting as deterrent to mobile use while driving.

Fig. 5. Default structural equation model of safety risk perception due to mobile phone distraction.

Fig. 6. Final structural equation model of safety risk perception due to mobile phone distraction.

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The practical relevance of the study is to place emphasis on behavior based controls to reduce mobile phone use. Strategies focusing on ‘Mobile distraction’ perception are likely to mitigate the problems aroused due to use of mobile phones while driving. There is a need to explore the ‘Risk Perception–Mobile Use’ link towards understanding why risk perception does not have a moderating effect on mobile use. In addition, the effect of other secondary tasks such as ‘Passenger conversation’, ‘Eating–Drinking’ and ‘Other in vehicle technologies’ such as personal assistants, laptops and tablet, computers, iPads, wireless and auxiliary input communication devices, navigation aids on distracted driving need to be examined. Further scope for research lies in classifying responses across different age groups, gender, profession, experience, etc., and modeling the effect of in-vehicle distraction under those control criteria.

6. Conclusion

Driver distraction due to evolution in vehicle information & communication technology devices has become a major concern for transportation safety. A Man–machine framework for distracted driving was presented and a mobile phone distraction model was proposed. The influence of ‘Human factors’, ‘Driver space’ and ‘Driving conditions’ on perception of mobile phone use while driving as a distraction were analyzed along with the associated risk of safety incidents. A questionnaire was prepared, pilot tested, modified and responses were collected from 1203 four wheeler drivers. Structural equation modeling was done to identify the effect of factors. The final SEM had model fitness parameters, $\chi^2 = 252.827$ (df = 80, p = 0.000), RMR = 0.032, GFI = 0.957, AGFI = 0.936, CFI = 0.927 and RMSEA = 0.053. The study reveals that among the three driver-characteristics ‘Human Factors’ influence the distraction perception due to mobile phone the most. It is also observed that the safety risk perception due to mobile phone use while driving is moderate. The inclusion of the exposure parameter affirms the theory that if using a mobile phone while driving is perceived as a distraction, the use of the same by the drivers will be low.

In conclusion, there is a need to emphasize behavior-based controls to reduce mobile phone use while driving. Strategies focusing on perceived distraction due to mobile phones are likely to mitigate this problem.

Conflict of interest

The questionnaire survey was undertaken in southern state of Kerala in India. The authors declare no conflict of interest in the study undertaken.

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