Identifying risky drivers with simulated driving

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**ABSTRACT**

Objective: The present study aimed to examine whether high-risk drivers differ from low-risk drivers in driving behavior in a simulated environment.

Method: The 2 risk groups including 36 drivers (18 males and 18 females) performed driving tasks in a simulated environment. The simulated driving behaviors are compared between the 2 risk groups.

Results: The high-risk drivers drove much faster and exhibited larger offsets of the steering wheel than did the low-risk drivers in events without incidents. Additionally, the high-risk drivers used turn signals and horns less frequently than the low-risk drivers.

Conclusions: The present study revealed that the high-risk group differed from the low-risk group in driving behavior in a simulated environment. These results also suggest that simulated driving tasks might be useful tools for the evaluation of drivers’ potential risks.

**Introduction**

Driving safety is a major concern of the Chinese public because motor accidents are one of the leading causes of fatalities in China (X. Zhang et al. 2011). According to the China Road Traffic Accident Statistics Bureau (2011), approximately 211,000 motor vehicle accidents resulted in loss of life and personal injury in 2011, and these accidents resulted in approximately 62,000 deaths and 237,000 injuries. Risky driving behaviors are considered to be the primary causes of motor vehicle crashes (Blows et al. 2005). The China Road Traffic Accident Statistics Bureau (2011) identified drivers’ risky driving behaviors (e.g., speeding, drunk driving, and making turns without using turn signals) as major causes of accidents.

To prevent risky driving, the Chinese Traffic Administration identifies high-risk drivers by recording their traffic violations. According to traffic regulations, drivers are penalized based on the severity of their traffic violations and receive penalty points accordingly. For example, driving at speeds that exceed 1.5 times the speed limit is penalized with 3 points. Whenever a driver reaches 12 points or above, his or her driving license is detained by the Traffic Management Bureau. Identifying high-risk drivers by referring to their penalty points and records of traffic violations has been shown to be an effective practice (Chen et al. 1995; Gebers and Peck 2003; Jun et al. 2011; Mesken et al. 2002).

However, it is unknown whether we can identify high-risk drivers with a short driving test in a simulated environment. Studies on risky driving behaviors on the road might provide some guidance on this issue. For example, speeding is the number 1 cause of traffic fatalities and injuries (Elvik 2012). Studies have shown that speeding not only increases crash risks (Dhungana and Qu 2005) but also affects the severity of crashes (Aarts and Van Schagen 2006). A case–control study in Adelaide found that severe crashes were 7.8 times more likely to occur at speeds of 75–84 km/h than at speeds of approximately 60 km/h (Moore et al. 1995). Therefore, the enforcement of speed limits might be critical for traffic safety. It is likely that speed is also critical for identifying high-risk drivers in simulated driving tasks.

Drivers’ steering performance can also predict driving safety. Excessive steering activity and high steering variability have been linked to increased at-fault safety errors (Donmez et al. 2007; Engström et al. 2005; Mueller and Trick 2012; Thompson et al. 2012). Additionally, the use of turn signals has been associated with driving safety. Studies have reported that a high proportion of drivers (approximately 20–59%) do not use their turn signals before lane changes, which might cause lane change crashes (Kiefer and Hankey 2008; W. Zhang et al. 2006). Although turn signals are important for safety during lane changes, drivers tend to neglect to use turn signals, particularly when they are distracted by secondary tasks.

Excessive horn honking might also be associated with dangerous driving behavior. Turner et al. (1975) suggested that aggressive driving behaviors might be linked to excessive use of the horn. Another study showed that male drivers tend to exhibit their frustration through excessive horn honking, which elicits anger in other drivers and contributes to hazardous driving conditions (McGarva et al. 2006). Thus, Dula and Geller (2003) labeled excessive horn honking as a signature of dangerous driving. However, horn honking might be
modulated by cultural norms, actual and perceived delays in travel, congestion, and individual characteristics (Shinar 1998; Shinar and Compton 2004).

Because driving simulators have been of great use in driving behavior research by offering a controllable, cost-effective, and safe testing environment (Richer and Bergeron 2012; Risto and Martens 2014), the present study aims to explore which types of driving behaviors can be used to separate high-risk drivers from low-risk drivers in a simulated environment. Driving simulators have been successful in discriminating the driving behaviors of novice and experienced drivers (Chan et al. 2010; De Winter et al. 2009). Driving simulators have also been used to measure aggressive driving behavior (Abou-Zeid et al. 2011) and driver frustration (McGarva et al. 2006). However, to the best of our knowledge, no study has examined whether simulated driving performance can be used to measure risky driving behavior. Thus, the present study aimed to examine which types of simulated driving behaviors are related with high-risk drivers. To accomplish this goal, we separated participants into low- and high-risk risk groups based on their actual records of traffic violations and penalty points. We expected to observe differences in the simulated driving behaviors of the 2 groups.

Material and methods

Participants

Thirty-six people (18 males and 18 females) participated in the present study, which was recruited through advertisement. Participants were selected based on the following criteria: they (1) had had valid driver’s licenses for more than 3 years and had driven more than 20,000 miles; (2) drove at least twice a week; (3) knew how to drive a car with a manual transmission; (4) had normal or corrected-to-normal vision; (5) experienced no nausea when watching 3D movies or playing 3D games; and (6) provided their accident and traffic violation records.

Three participants did not complete the experiment because they experienced nausea in the driving simulator. The remaining 33 participants were divided into 2 groups according to traffic violation records over the previous year. The low-risk group was composed of 16 participants (8 males and 8 females) who reported having fewer than 6 traffic penalty points in their traffic violation records. The high-risk group included 17 participants (9 males and 8 females) with more than 6 penalty points in their traffic violation records.

All participants provided written informed consent and were paid for their participation. This experiment was approved by the internal review board of the Institute of Psychology, Chinese Academy of Sciences.

Driving simulator and driving environment

As shown in Figure A1 (see online supplement), the driving simulator (Sim-Trainer, Beijing Sunheart Inc.) used was the same as in our previous study (Qu et al. 2014). The simulator had an interactive cockpit, a 120° field of view, side-view mirror, dashboards, and a manual transmission. The driving simulator software package is SCANeR®DT developed by OKTAL (France), which is used for vehicle ergonomics and advanced engineering studies as well as for road traffic research and driver training.

The simulated driving environment was a 3.6-km-long city street. The route is illustrated by the red lines in Figure 1. To test driving behavior, we designed 31 events that occurred during the driving simulations. These 31 events were divided into 2 categories. The first category was composed of 25 events in which unexpected incidents occurred. For example, in event 2, a pedestrian stood on the sidewalk and abruptly ran across the street when the participant’s car approached the pedestrian (see Figure 1A). The participant should stop the car rapidly to prevent a collision with the pedestrian. Event 14 involved overtaking another car. Specifically, a truck drove slowly in front of the participant’s car. The participants received an auditory instruction to overtake the truck from the left side (see Figure 1C). The other category included 6 events in which no incidents occurred. For example, the drivers were required to cross an intersection with no traffic lights in event 9 (see Figure 1D).

Procedure

First, participants drove in a practice session to acclimatize to the driving simulator. In this practice session, the participants also drove a city route, which was not the same route in the experimental session. The practice session lasted approximately 5 min. Before the experimental session, participants were instructed to drive as they do in real life and handle the incidents as if they were on real road. The experiment session lasted 12–15 min. Finally, participants were required to answer the questionnaire and provide demographic information including age, length of time they had had a driver’s license, weekly driving mileage, etc.
Measures

Personality and risky driving behavior
First, we used a questionnaire to measure participants’ personalities and risky driving behaviors. The questionnaire was taken from a previous study that reported the high reliability and validity of the questionnaire (Yang et al. 2013). The personality scale measures personality traits of anger, altruism, and normlessness. The first 2 dimensions were adopted from the International Personality Item Pool (Goldberg 1999), and each dimension consisted of 10 items. A measure of normlessness was adopted from Kohn and Schooler (1983), which included 4 items. All items were answered on a 5-point Likert scale ranging from fully disagree to fully agree. Two subscales of the Driving Behavior Questionnaire were used to measure participants’ risky driving behaviors, including drivers’ aggressive violations (3 items) and ordinary violations (9 items; Lawton et al. 1997; Parker et al. 1998). Participants were required to answer on a 5-point Likert scale ranging from never to all the time, which indicated how often they were involved in aggressive and ordinary violations when driving.

Speed maintenance
Speed was recorded 4 times per second by the simulator. The speed of each event was taken as the mean speed (km/h) across the entire event. The speed variability of each event was calculated as the standard deviation of the driving speed during each event (km/h).

Steering wheel offset
The offset of steering wheel was measured 4 times each second. The mean offset of the steering wheel during each event was calculated as the mean of the unsigned extent to which the steering deviated from its center position (0° = center, 540° = the rightmost or leftmost position) during each event.

Turn signal, horns, and collisions
Participants should have turned on the turn signal in 8 events prior to changing lanes or making turns. Additionally, the participants should not have honked their horns in 8 events. For example, according to Chinese traffic regulations, drivers should not honk their horns when pedestrians or bicyclists suddenly rush out in front of the driver’s car. Thus, the number of times each participant honked their horn in these 8 events was recorded to determine whether they respected traffic laws. Finally, the total number of collisions by each participant was also recorded as an index of their driving performance.

Brakes
Participants should have braked to stop the car in 14 events, including 10 events with incidents and 4 events without incidents.

Results

Demographic information
As described in Table 1, there were no significant differences between the 2 risk groups in age, time of possession of a driver’s license, cumulative mileage, or weekly mileage (all \( P > .1 \)). Table 1 also lists the self-reported accidents and at-fault accidents in the past 3 years for both risk groups. When the total accident rates were collapsed into 2 categories (2 accidents or less vs. more than 2 accidents), the 2 risk groups differed significantly in their accident rates in the past 3 years (Pearson’s chi-square = 5.546, \( P = .019 \); Fisher’s exact test, \( P = .044 \)), indicating that a larger proportion of the high-risk group reported having more than 2 accidents. The at-fault accident rate over the past 3 years exhibited the same pattern. These results served as a manipulation check of the 2 risk groups that were formed based on penalty points. The high-risk group was risky drivers with more accident rates compared to the low-risk group.

The high-risk group scored significantly higher in the personality traits of normlessness than the low-risk group, \( \eta^2 = −2.595, P = .014 \). Although the high-risk group scored higher in the personality traits of anger and altruism, aggressive violations, and ordinary violations than the low-risk group, none of those differences between the 2 groups reach significant levels (all \( P > .1 \)).

Speed maintenance
Figure 2A illustrates mean speed as a function of the type of event (with incident vs. without incident) for the 2 risk groups. There was a significant main effect of event type, \( F_{(1,31)} = 136.936, P < .001, \eta^2 = 0.815 \), that was driven by greater speeds in the events without incidents than in the events with incidents. More important, the interaction between event type and risk group was significant, \( F_{(1,31)} = 6.655, P = .015, \eta^2 = 0.177 \). Further pairwise comparisons with Bonferroni corrections showed that the average speed of the high-risk group was greater than that of the low-risk group in the events without incidents (\( P = .022 \)).

We also compared the mean speeds of the 2 risk groups in each event. The high-risk group drove significantly faster than the low-risk group in 2 events without incidents (both \( P < .05 \); see Figure 2B for the results of events 9 and 26).

Figure 2C illustrates the average speed variability (i.e., the mean of the standard deviation of the speed in each event) as a function of the type of event (with incident vs. without incident) for the 2 risk groups. There was a main effect of event type, \( F_{(1,31)} = 22.393, P < .001, \eta^2 = 0.419 \), and the speed variability was greater in the events with incidents than in the events without incidents.

Table 2 lists the cumulative durations of speeding, maximum speeds, and average number of events in which speeding occurred for each group. Surprisingly, the high-risk group only exhibited numerically longer durations of speeding, higher maximum speeds, and greater frequencies of speeding compared to the low-risk group. These differences between groups were not significant (all \( P > .3 \)).

Offset of steering wheel
Figure 3 illustrates the average offset of the steering wheel in the different event types (events with incidents vs. events without incidents) for the 2 risk groups. There was a significant main effect of risk group, \( F_{(1,31)} = 8.538, P = .006, \eta^2 = 0.216 \), and the average offset of the steering wheel in the high-risk group
Table 1. The average ages, times of possession of driver’s licenses, average penalty points, cumulative mileages, weekly mileages, personality traits and risky driving behavior for the two risk groups. Weekly mileage data for one participant in the high-risk group were missing.

|                | High-risk group (N = 17) | Low-risk group (N = 16) | Statistical test | P-value |
|----------------|--------------------------|-------------------------|------------------|---------|
| Age (years)    | 33.2 ± 7.42              | 31.7 ± 7.08             | –                | p > 0.1 |
| Average penalty points in last year | 6.71                     | 0.25                    | –                | –       |
| Cumulative penalty points over 3 years | 16.18                   | 0.25                    | –                | –       |
| Total accidents in past 3 years |                          |                         |                   |         |
| 0              | 6                        | 7                       | Pearson chi-square $X^2 = 5.546$; Fisher’s exact test, $p = 0.044$ |
| 1              | 4                        | 5                       | –                | –       |
| 2              | 2                        | 4                       | –                | –       |
| >2             | 5                        | 0                       | –                | –       |
| At-fault accidents in past 3 years |                          |                         |                   |         |
| 0              | 9                        | 11                      | –                | –       |
| 1              | 3                        | 4                       | –                | –       |
| 2              | 0                        | 1                       | –                | –       |
| >2             | 5                        | 0                       | –                | –       |
| Period of having a driver’s license (N) |                          |                         |                   |         |
| 1–3 years      | 0                        | 1                       | –                | p > 0.1 |
| 3–5 years      | 4                        | 7                       | –                | –       |
| 5–15 years     | 9                        | 5                       | –                | –       |
| 15–20 years    | 4                        | 3                       | –                | –       |
| Cumulative mileage (N) |                          |                         |                   |         |
| 10,000–50,000 km | 3                      | 9                       | –                | p > 0.1 |
| 50,000–100,000 km | 7                      | 4                       | –                | –       |
| 100,000–300,000 km | 5                      | 3                       | –                | –       |
| Above 300,000 km | 2                      | 0                       | –                | –       |
| Weekly mileage (N) |                          |                         |                   |         |
| Below 50 km    | 1                        | 4                       | –                | p > 0.1 |
| 50–150 km      | 3                        | 7                       | –                | –       |
| 150–400 km     | 10                       | 4                       | –                | –       |
| Above 400 km   | 2                        | 1                       | –                | –       |
| Personality Scales |                          |                         |                   |         |
| Anger          | 2.49 ± 0.77               | 2.47 ± 0.72             | –                | p > 0.1 |
| Altruism       | 3.82 ± 0.30               | 3.79 ± 0.36             | –                | p > 0.1 |
| Normlessness   | 2.62 ± 0.54               | 2.14 ± 0.52             | t(31) = −2.959   | p = 0.014 |
| Risky driving behavior questionnaire |              |                         |                   |         |
| Aggressive Violations | 2.53 ± 0.74             | 2.19 ± 0.74             | –                | p > 0.1 |
| Ordinary Violations | 2.25 ± 0.56             | 2.04 ± 0.54             | –                | p > 0.1 |

Table 2. Cumulative durations of speeding, maximum speeds and average numbers of events in which speeding occurred for the two groups.

|                          | High-risk group (N = 17) | Low-risk group (N = 16) | P-value |
|--------------------------|--------------------------|-------------------------|---------|
| Cumulative duration of speeding |                          |                         | p > 0.3 |
| Maximum speed |                          |                         | p > 0.3 |
| Events in which speeding occurred |                          |                         | p > 0.3 |

was greater than that in the low-risk group. The interaction between these factors was significant, $F_{(1,31)} = 6.084$, $P = .019$, $\eta^2_p = 0.164$). Further pairwise comparisons with Bonferroni corrections revealed that the steering wheel offset in the high-risk group was greater than in the low-risk group in the events without incidents ($P = .004$).

**Turn signals, horns, and collisions**

Table 3 shows the turn signal use frequencies in the 8 events and horn honking frequencies of the 2 risk groups in the simulated driving task. The low-risk group used the turn signal more frequently than the high-risk group ($Z = −2.317, P = .021$). The low-risk group honked the horn more frequently than did the high-risk group ($Z = −2.453, P = .014$).

Table 3 also shows the number of drivers in each of the 2 risk groups as a function of collision rates in the simulated driving task. The average collision rate of the high-risk group (1.12) was only numerically higher than that of the low-risk group (0.75); the difference between the 2 groups was not significant ($Z = −1.491, P = .136$). However, when the collision rates were collapsed into 2 categories (no collisions vs. collisions), the 2 risk groups differed marginally in their collision rates in the simulated driving task (Pearson’s chi-square $= 3.696$, $P = .055$; Fisher’s exact test, $P = .080$), which indicates that a slightly larger proportion of the high-risk group had collisions in the simulated driving task compared to the low-risk group.

**Braking**

Table 3 illustrates brake usage as a function of event type (with incident vs. without incident) for the 2 risk groups. There was no significant difference between the 2 groups for both scenarios with incidents and scenarios without incidents (scenarios with incidents: $Z = −0.261, P = .794$; scenarios without incidents: $Z = −0.953, P = .341$).

**Discussion**

The present study aimed to examine whether the high-risk group differed from the low-risk group in driving behaviors in a simulated environment. The results showed that the high-risk drivers differed significantly from the low-risk drivers in average speeds and steering wheel offsets while driving in events without incidents. Additionally, the high-risk group exhibited less frequent turn signal and horn usage than the low-risk group. These
Table 3. Numbers of turn signal, horn honking, collisions and braking in the high- and low-risk groups.

|                           | High-risk group (N = 17) | Low-risk group (N = 16) | Statistical test | P-value  |
|---------------------------|--------------------------|-------------------------|------------------|----------|
| **Turn signal use frequencies** |                          |                         |                  |          |
| 0                         | 1                        | 0                       |                  |          |
| 1                         | 0                        | 0                       |                  |          |
| 2                         | 2                        | 0                       |                  |          |
| 3                         | 1                        | 1                       | Z = -2.317       | p = 0.021|
| 4                         | 5                        | 1                       |                  |          |
| 5                         | 4                        | 6                       |                  |          |
| 6                         | 4                        | 7                       |                  |          |
| 7                         | 0                        | 1                       |                  |          |
| **Horn honking frequencies** |                          |                         |                  |          |
| 0                         | 15                       | 8                       |                  |          |
| 1                         | 2                        | 5                       | Z = -2.453       | p = 0.014|
| 2                         | 0                        | 1                       |                  |          |
| 3                         | 0                        | 2                       |                  |          |
| **Rates of collision in simulated driving task** |                  |                         |                  |          |
| 0                         | 4                        | 9                       | Pearson chi-square | p = 0.055; Fisher’s exact test, p = 0.080 |
| 1                         | 8                        | 4                       |                  |          |
| 2                         | 4                        | 1                       |                  |          |
| 3                         | 1                        | 2                       |                  |          |
| **Braking**                |                          |                         |                  |          |
| **Events with incidents**  |                          |                         |                  |          |
| 3                         | 1                        | 0                       |                  |          |
| 4                         | 1                        | 0                       |                  |          |
| 5                         | 0                        | 0                       | Z = -0.261       | p > 0.1  |
| 6                         | 4                        | 6                       |                  |          |
| 7                         | 5                        | 5                       |                  |          |
| 8                         | 5                        | 2                       |                  |          |
| 9                         | 1                        | 3                       |                  |          |
| **Events without incidents** |                          |                         |                  |          |
| 0                         | 10                       | 8                       |                  |          |
| 1                         | 4                        | 2                       | Z = -0.953       | p > 0.1  |
| 2                         | 3                        | 4                       |                  |          |
| 3                         | 0                        | 2                       |                  |          |

Results suggest that simulated driving tasks might be useful tools for identifying high-risk drivers.

**Speed maintenance**

The present study showed that the high-risk drivers tended to drive faster than the low-risk drivers in the simulated events without incidents (6 events in total). This is most evident in 2 events. Specifically, the drivers were supposed to stop at an intersection without a traffic light (event 9) and slow down on a downhill road (event 26) to ensure safety. However, the high-risk group maintained significantly greater average speeds than did the low-risk group when driving in events 9 and 26. Thus, the present study confirmed that average speed is a sensitive index of risky driving behavior when no abrupt incidents occur in a simulated driving task.

These findings also suggest that, whenever possible, the high-risk group had a stronger tendency to speed up than did the low-risk group. This frequent occurrence of incidents simulates the complex traffic environments of large Chinese cities and makes it difficult for drivers to exceed the speed limit. Nonetheless, the high-risk drivers drove at higher average speeds than did the low-risk drivers if no incidents occurred. Additionally, speeding was more likely to occur and occurred for longer durations in the high-risk group than in the low-risk group; however, these differences were not significant. These findings are consistent with the findings of previous studies that identified speeding as a major cause of traffic fatalities and injuries (Dhungana et al. 2005). The lack of difference in the events with incidents might be due to the intense arrangement of 25 incidents in a single 3.6-km-long driving route. Such an intense arrangement of incidents may have induced the drivers to forgo speeding up in the events with incidents. Moreover, these incidents might have served as warning signals and induced the drivers to take precaution.

**Steering activities**

On average, the high-risk group exhibited larger steering wheel offsets than did the low-risk group in the events without incidents. These results indicate that the low-risk drivers drove more steadily and smoothly than did the high-risk drivers in the events without incidents. This finding is consistent with the well-established association between excessive steering activity and low perceived safety (Donmez et al. 2007; Engström et al. 2005; Mueller and Trick 2012; Thompson et al. 2012). The present study confirmed that excessive steering activity in the events without incidents was associated with the high-risk group. These findings have 2 implications. First, steering activity can be used to identify high-risk drivers in simulated events without incidents. Second, simulated events without incidents provide more sensitive testing environments than events with incidents. Thus, the events without incidents deserve more attention regarding the future development of simulated driving tests.

**Use of turn signals, horns, and brakes**

The use of turn signals has also been associated with driving safety. The present study found that the low-risk group used turn
Figure 2. (A) Mean speeds as a function of event type with and without incidents for the 2 risk groups. (B) Mean speeds in events 9 and 26 for the 2 risk groups. (C) Mean speed variabilities (i.e., the standard deviations of the speeds) in the events with and without incidents for the 2 risk groups. The error bars represent one standard error.

signals more frequently than the high-risk group when the use of turn signals was required. This finding shows that the failure to use turn signals while changing lanes or making a turn is a robust index of risky driving behavior in simulated driving environments.

Additionally, the low-risk group honked the horn more often than did the high-risk group in the present experiment. Initially, this finding seems to be in sharp contrast to previous findings that have suggested that excessive horn honking might be related to aggressive driving behaviors (Dula and Geller 2003; Turner et al. 1975). For example, drivers, particularly male drivers, exhibit their frustration and anger via excessive horn honking (McGarva et al. 2006). However, there are crowds of pedestrians and bicyclists in the city streets of China. Chinese drivers tend to use horns to give pedestrians warning signals because pedestrians’ behaviors are difficult to predict. Therefore, rather than expressing anger or aggressive attitudes toward other drivers, horn honking is actually a responsible practice that may reduce collisions with pedestrians and bicyclists. These results suggest that the reluctance to use the horn might be a signature of risky driving behavior in China and can be used to identify high-risk Chinese drivers within a simulated driving task.

**Risk of crashes**

Insurance companies usually rely on accident rates to identify high-risk drivers. The present study confirmed that high-risk drivers had higher accident rates within the last 3 years than low-risk drivers. This golden rule is also consistent, with a marginally significant trend toward greater crash risks of the high-risk group compared to the low-risk group in the simulated driving task. There are 2 possible explanations for why this difference in crash risk between the 2 groups was only marginally significant. First, the driving route was only 3.6 km; this route was likely too short to illuminate differences in crash rates. Second, the high-risk group may have been more cautious in these monitored experimental conditions than they would have been in naturalistic circumstances, which may have reduced their probabilities of having accidents. Thus, crash rates might be a good yet not sufficiently sensitive index for identifying high-risk drivers via a short simulated driving task.

**Testing in a simulated environment**

Driving simulators have been widely used to study driving behaviors in situations with potential risks for traffic accidents. For example, a recent study showed that aggressive drivers had higher maximum velocity and maximum acceleration than timid drivers in simulated driving tasks (Abou-Zeid et al. 2011). However, researchers are concerned about these experiments regarding risky conditions using simulators. Drivers may become cautious about potentially risky situations once they experience a risky situation (Sato et al. 2013). The present experiments showed that events with risky incidents were not sensitive enough to separate the high-risk drivers from the low-risk drivers. However, the high-risk drivers could be discriminated from the low-risk drivers through measures of risky driving behavior in a relatively short simulated driving task. Thus, the disadvantage of the driving simulator could be remedied...
through the use of more events without incidents. Thus, we suggest that a simple task of driving through a route that is potentially dangerous but has few eminent threats would most likely be a more sensitive task for identifying high-risk drivers. This supposition deserves further study.

The present study revealed that the high-risk group differed from the low-risk group in driving behavior in a simulated environment. The high-risk group drove much faster and exhibited larger steering wheel offsets than did the low-risk group in events without incidents. Additionally, the high-risk group utilized turn signals and the horn less frequently than did the low-risk group. Thus, all of these indices generated in a simulated driving task are useful for identifying high-risk drivers. The crash rate might be a useful index for identifying high-risk drivers when drivers are given a sufficiently long driving task. These findings not only provide strong evidence that risky driving behavior can be identified in a short simulated driving task but also pinpoint several important behavioral indices that may sensitively identify high-risk drivers. It is worth noting that further studies with larger samples might be helpful for examining the marginal significant correlations found in present study.

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