Comparison of driving performance during the blood alcohol concentration ascending period and descending period under alcohol influence in a driving simulator

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Abstract: The objective of this research was to study the performance of young novice male drivers in a driving simulator after they were administered different doses of alcohol (placebo: 0 g/kg; medium dose: 0.75 g/kg; high dose: 1 g/kg) during the blood alcohol concentration (BAC) ascending and descending periods. The high dose of alcohol produced an average peak BAC of 74±5.477 mg/100 ml at 30 min after administration, and the medium dose produced an average peak BAC of 47.714±17.68 mg/100 ml at 10 min after administration. Compared with the placebo, the drivers’ performance under the high dose of alcohol was characterised by more abrupt steering manoeuvres, a greater average speed, and a greater offset from the lane centre. The drivers were more timid under the medium dose administration. The study on driver behaviour plays an important role on constructing the early warning model, so as to put forward the corresponding intervention measures of unsafe driving behaviour and improve vehicle safety in reducing accidents due to drinking and/or drunk driving on public roads.

Keywords: driving performance; blood alcohol concentration; ascending period; descending period; driving simulator; early warning model.

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Guanjun Zhang has been engaged in vehicle engineering and study of vehicle collision safety for many years. As the core of personnel he has been responsible for conducting the collision tests on State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body. He has presided over and participated in many projects supported by National Natural Science Foundation of China, as well as published a number of papers in the international authoritative journals and international conferences.

Renjie Chen has been engaged in the research in Communication Engineering.

Lei Chen, Associate Professor, has been engaged in vehicle engineering research work and participated in a number of national, provincial and ministerial level projects, published more than 30 articles, of which EI, SCI search more than 20 articles.

Xiexing Feng is a graduate student, and engaged in vehicle safety research, and can independently carry out the driving simulator test.
1 Introduction

Alcohol’s effect on cognitive and neurological functions is well-known and may create a high probability of traffic accidents. In Australia, a blood alcohol concentration (BAC) of 0.05% has been found in approximately 30% of all the drivers who were fatally injured in crashes (Drummer et al., 2003; Zhang et al., 2014). In Canada, 38.3% of the fatal driver injuries in 2003 were alcohol-related (Traffic Injury Research Foundation of Canada, 2005; Zhang et al., 2014). Drinking and driving is thought to be responsible for approximately 20% of all road fatalities in Europe every year (Sørensen and Assum, 2008; Zhang et al., 2014). Alcohol-impaired driving was the cause of nearly 11,000 deaths in 2009, which accounted for nearly one-third of all US traffic-related fatalities (Lee et al., 2010; MacLeod et al., 2015). Approximately 34% of the road crashes in China were related to alcohol consumption (Li et al., 2012). Statistics show that 1973 fatal traffic accidents occurred in Taiwan in 2010. Of these accidents, 373 were caused by drunk driving, which resulted in 395 deaths (Chang et al., 2013).

Many countries around the world have enacted laws that prohibit driving after alcohol consumption and have imposed severe penalties on violators. The legal limits of BAC vary among countries and are between 0.01% and 0.08%. For example, the limit is 0.02% in Sweden, 0.05% in Israel, Korea and Australia, and 0.08% in Canada, England and Mexico. In China, driving with a BAC level of between 0.02% and 0.08% is defined as drink-driving, and the driver is penalised. Moreover, driving in China with a BAC higher than 0.08% is considered drunk driving, and the penalty is even more severe. Although alcohol consumption is legal for US citizens who are 21 years of age or older, it is illegal in all states to drive with a BAC level of 0.08% or greater (NHTSA 2004). In Italy, a driver is considered liable for driving under the influence of alcohol if his/her BAC level is higher than 0.05%. In the BAC interval from 0.05% to 0.08%, drivers in Italy are only subject to an administrative fine. With a BAC level above 0.08%, offenders can potentially be convicted of a criminal offence in Italy, with more severe sanctions if their BAC is above 0.15% (Leporati et al., 2015).

Research into driver’s behaviour has advanced with improvements in vehicle active safety technologies that help compensate for the cognition, judgement, and actions of drivers. The study on driver behaviour after drinking would provide theoretical support for the development of alcohol-related active safety system. Many scholars have conducted studies in driving simulators because this type of study addresses driving performance during critical decision times; these studies are not feasible on a real road and therefore are best conducted in a simulator. Leung and Starmer (2005) investigated the effects of a moderate dose of alcohol on a driver’s perception of speed, hazards and risk acceptance; they concluded that young and mature drivers demonstrated pivotal differences in behaviour. Liu and Fu (2007) found that increasing the alcohol dose may not pose an immediate impact on external vehicle driving behaviour but may negatively affect a driver’s motor behaviour, even at low breath alcohol concentration level. Weafer and Fillmore (2012) suggested that an acute tolerance to the impairment of motor coordination is insufficient to promote the recovery of driving performance and that the persistence of alcohol-induced disinhibition may contribute to the risky decisions to drive on the descending limb. Helland et al. (2013) used ethanol as a positive control and
examined whether ethanol affects driving performance in the simulator and whether these effects are consistent with performance during real driving on a test track when also under the influence of ethanol. There was a positive dose-response relationship between higher ethanol concentrations and increases in the standard deviations of lateral position (SDLP) in both the simulator and on the test track. Van Dyke and Fillmore (2014) found that although offenders driving under the influence of alcohol (DUI) self-reported greater levels of impulsivity than the control group (without a DUI history), no group differences were observed in the degree to which alcohol impaired inhibitory control and driving performance. Zhang et al.’s (2014) results showed that the speed throughout curves was higher when drinking and driving than during sober driving. The significant interaction between alcohol and radius exists in the middle and tangent segments after a curve exit. Alcohol and radius have interactive effects on the standard deviation of speed in the entry segment of curves and drivers tend to travel on the right side of the lane when drinking and driving, mainly in the approach and middle segments of curves. Charlton and Starkey (2015) explored alcohol-induced performance impairment in the context of a somewhat more naturalistic drinking environment where the participants consumed alcohol in social groups and maintained a BAC plateau over a longer period of time. These researchers found strong placebo effects on the ratings of subjective intoxication. Driving and cognitive performance both showed dose-dependent alcohol impairment, and some measures displayed an acute protracted error. Cannabis legalisation is a crucial road safety issue. Cannabis and alcohol, which are frequently detected together, produced greater impairment effects together than either substance separately. Downey et al. (2013) found that driving simulator performance was more impaired in the driver’s blood with combined Δ⁹-tetrahydrocannabinol (THC) and alcohol conditions, and regular cannabis users have higher levels of THC in their plasma than non-regular users. Generally, regular cannabis users displayed more driving errors than non-regular cannabis users. Hatman et al. (2015) evaluated cannabis’ effects, with and without concurrent alcohol, on driving. These scholars found that standard deviation of lateral position was a sensitive cannabis-related lateral control impairment measure.

Young novice drivers are over-represented in crash and fatality statistics worldwide. In 2005, 30% of the drivers who died because of a motor vehicle crash were aged 18 to 25 years in the Australian State of Victoria, but this age group constituted only 14% of all Victorian licence holders (Mitsopoulos et al., 2005). The police-reported fatal and injury crash data in Taiwan indicated that the number of road crashes for drivers who were aged 18–24 years comprised 22% of all traffic crashes (Chang et al., 2009). A lack of experience is believed to be the major factor that contributes to the high crash rate among young drivers (Mitsopoulos et al., 2005; Chang et al., 2009), and male drivers are more prone to be involved in DUI crashes compared with their female counterparts (Zhang et al., 2014).

This paper’s contribution is to test three alcohol doses (0 g/kg, 0.75 g/kg, 1 g/kg) under three conditions, namely, non-BAC and the BAC ascending and BAC descending periods, in a driving simulator. The results can then be used for traffic safety enforcement and providing a better comprehension of driving performance after drinking, as well as benefit in constructing an early warning model.
2 Method

2.1 Participants

A total of 18 novice drivers who were aged between 18 and 24 years and had held a licence for not more than 12 months were selected. Most of the participants were recruited through paper flyers and recommendations.

2.2 Apparatus

Driving Simulator. The experiment was conducted in a portable driving simulator at the State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body of Hunan University in Changsha, China. The simulator runs on a PC platform using the Microsoft Windows system. Standard 3D graphic boards generate images, and driver interaction is achieved by interfacing with real Hyundai car equipment. The steering wheel is linked to an active force feedback system, which is controlled by the software according to the speed of the car, the road surface, and the type of power steering. The passive force feedback mechanism that is incorporated into the pedal reproduces the feel of a real car clutch and brake.

The simulator is built around a dedicated PC that integrates the visual system, the sound system, and a custom I/O board. The image of the driving simulation is displayed on 3 LED screens. The driver is positioned approximately 0.8 m from the centre screen. The visual angle to the screens is 90 degrees, but the simulator software adjusts the image to provide a 120 degree field of view. The simulator sampling rate was 30 Hz.

Breath Alcohol Analyser. A breath alcohol analyser (Alcostop A) that is used by the police authority in China for routine roadside breath alcohol screening was employed in this study to measure the subjects’ breath alcohol levels and was converted to BAC levels.

2.3 Data analysis

Analysis of variance (ANOVA) was employed to study the statistical differences in driving performance compared across three statuses, namely, non-BAC, BAC ascending and BAC descending periods, as well as to explore any differences in driving performance among placebo, high dose (1 g/kg) and medium dose (0.75 g/kg) of young novice male drivers. \( \alpha = 0.05 \) was chosen as the significance level in this study. The driving performance data that were collected in this study were speed, steering rate, and offset from lane centre.

2.4 Procedures

The participants were asked to have sufficient sleep the night before the experiment and refrain from consuming any food or drink that contained alcohol the day before the experiment. Two hours before the experiment, the participants were prohibited from consuming high-fat, high-sugar, or caffeinated substances that may affect alcohol absorption. The participants’ breath was analysed in the laboratory to ensure that their pre-test status was zero-alcohol.
Comparison of driving performance during the blood alcohol

When the participants arrived in the simulation room, the laboratory staff introduced the basic process, driving task, basic operation and safety knowledge of the simulator. Consent forms were signed, which meant that the participants officially consented to this experiment. The participants were then asked to provide personal information, such as gender, age and driving experience. The participants completed a current well-being questionnaire and were weighed. Then, the researcher explained the simulator study. To familiarise the participants with the simulator controls and dynamics, each participant conducted practiced a simulator drive for 5 min.

The participants were then required to receive one of the following three doses of alcohol: 0.0 g/kg (placebo); 0.75 g/kg; and 1 g/kg. The dose of 1 g/kg was intended to produce a target BAC of 80 mg/100 ml, and the dose of 0.75 g/kg was intended to produce a target BAC of 50 mg/100 ml (Charlton and Starkey, 2014).

The alcohol dose was calculated based on body weight and administered as absolute alcohol mixed with orange juice. According to the participants’ weight, the staff calculated the amount of alcohol and mixed it with two times the amount of orange juice. The participants drank the beverage in 15 min, and the first BAC measurement occurred after 10 min. The staff recorded the BAC value. The participants in the placebo group received a 200 ml beverage that consisted of orange juice with 3 ml of white wine that was added to the top of each drink. The BAC value was recorded. Of the 18 participants who completed the full experimental sessions, six were assigned to the placebo group, six were assigned to the medium dose group, and six were assigned to the high dose group.

The BAC ascending test was conducted 30 min after beverage consumption. Subjective intoxication was assessed by using a visual analogue scale in which the participants were asked to respond to the question “How intoxicated do you feel right now?” by giving a score of 0–10 (Cromer et al., 2010), with 0 being sober, and 10 being totally intoxicated. The participants’ self-assessment of driving control was evaluated by giving a score of 0–10; 0 represents an inability to control the car, and 10 represents total control of the car. The road had two lanes in each direction, and the posted speed limit was 60 km/h. The participants finished the ascension test in 15 min. The BAC descending test was conducted 90 min after beverage consumption. Subjective intoxication and the self-assessment of driving control were also scored. The simulator scene was counterbalanced to minimise the practice effects. The subjects’ BACs were measured at 10 min, 30 min (before and after the test), 60 min, 90 min (before and after the test) and 120 min post-administration. Breath samples were also taken at these times during the placebo session, ostensibly to measure the BACs. Once the testing was finished, the subjects remained at leisure in the lounge until their BACs fell to 20 mg/100 ml or below. Transportation home was provided after the sessions. Each participant was paid RMB 80 yuan for their involvement.

3 Results

All data that were collected from the driving simulator experiment were cleaned to meet the assumptions of statistical techniques and were analysed by using SPSS 16.0 (Pallant, 2007). Analysis of variance (ANOVA) was employed to study the statistical differences in driving performance compared across three statuses, namely, non-BAC,
BAC ascending and BAC descending period, as well as to explore any differences in driving performance among placebo, high dose (1 g/kg) and medium dose (0.75 g/kg) of young novice male drivers.

BAC was measured in mg per 100 ml (mg/100 ml). The comparison results for different doses are statistically significant ($P_{\text{dose}} < 0.001$), as shown in Table 1. The BAC of the high dose group was larger than the BAC of the medium dose group, and the differences between recording times were also statistically significant ($P_{\text{time}} < 0.001$). The post-hoc tests showed that the comparison for every two times was significant ($P < 0.05$), except for the BAC difference between 10 and 30 min.

**Table 1** Comparison of BAC (mg/100 ml) at different times of different doses when breath samples were obtained

<table>
<thead>
<tr>
<th>Dose</th>
<th>Time</th>
<th>$F_{\text{dose}}$</th>
<th>$F_{\text{time}}$</th>
<th>$P_{\text{dose}}$</th>
<th>$P_{\text{time}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 g/kg</td>
<td>10 min</td>
<td>71±5.83</td>
<td>5.831</td>
<td>8.28</td>
<td>10.167</td>
</tr>
<tr>
<td></td>
<td>30 min</td>
<td>74±5.477</td>
<td>5.477</td>
<td>8.28</td>
<td>10.167</td>
</tr>
<tr>
<td></td>
<td>60 min</td>
<td>65.83±8.28</td>
<td>8.28</td>
<td>10.167</td>
<td>7.333</td>
</tr>
<tr>
<td></td>
<td>120 min</td>
<td>49.167±7.333</td>
<td>10.167</td>
<td>7.333</td>
<td>58.858</td>
</tr>
<tr>
<td>0.75 g/kg</td>
<td>10 min</td>
<td>47.714±17.68</td>
<td>43.286±9.464</td>
<td>37.429±9.624</td>
<td>33.286±8.674</td>
</tr>
<tr>
<td></td>
<td>60 min</td>
<td>37.429±9.624</td>
<td>33.286±8.674</td>
<td>25.857±8.454</td>
<td>18.857±8.454</td>
</tr>
</tbody>
</table>

Notes: *denotes the ‘10 min’ group ($P<0.05$); △ denotes the ‘30 min’ group ($P<0.05$); ▲ denotes the ‘60 min’ group ($P<0.05$); ◇ denotes the ‘90 min’ group ($P<0.05$).

The participants’ subjective intoxication was assessed by using a visual analogue scale where the participants were asked to respond to the question “How intoxicated do you feel right now?” by giving a score of 0–10, with 0 representing sober and 10 representing totally intoxicated. The comparison results were not statistically significant ($P > 0.05$) (see Table 2).

**Table 2** Comparison of the subjective intoxication levels at different BAC statuses of different doses

<table>
<thead>
<tr>
<th>Subjective intoxication</th>
<th>BAC status</th>
<th>$F_{\text{dose}}$</th>
<th>$F_{\text{status}}$</th>
<th>$F_{\text{interaction}}$</th>
<th>$P_{\text{dose}}$</th>
<th>$P_{\text{status}}$</th>
<th>$P_{\text{interaction}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High dose (1 g/kg)</td>
<td>BAC ascending period</td>
<td>5±1.26</td>
<td>4±1.41</td>
<td>2.045</td>
<td>3.636</td>
<td>0</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>BAC descending period</td>
<td>3.67±2.16</td>
<td>2.67±1.86</td>
<td>1</td>
<td>0.071</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Note: *$P<0.05$.

The participants’ self-assessment of driving control was evaluated by scoring 0–10, with 0 representing an inability to control the car and 10 representing total control of the car. The comparison results at different statuses of different doses are shown in Table 3. Both dose and status were statistically significant. The self-assessment of driving control under the medium dose was greater than the self-assessment of driving control under the high dose. In addition, the self-assessment of driving control during the descending period was greater than the self-assessment of driving control during the ascending period. There were no interaction effects between dose and status.
Comparison of driving performance during the blood alcohol

Table 3  Comparison of the self-assessment of driving control at different BAC statuses of different doses

<table>
<thead>
<tr>
<th>Self-assessment of driving control</th>
<th>BAC status</th>
<th>F&lt;sub&gt;dose&lt;/sub&gt;</th>
<th>F&lt;sub&gt;status&lt;/sub&gt;</th>
<th>F&lt;sub&gt;interaction&lt;/sub&gt;</th>
<th>P&lt;sub&gt;dose&lt;/sub&gt;</th>
<th>P&lt;sub&gt;status&lt;/sub&gt;</th>
<th>P&lt;sub&gt;interaction&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAC ascending period</td>
<td>BAC descending period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High dose (1 g/kg)</td>
<td>4.5±1.97</td>
<td>7.67±0.82</td>
<td>12.526</td>
<td>4.966</td>
<td>2.079</td>
<td>0.002*</td>
<td>0.037*</td>
</tr>
<tr>
<td>Medium dose (0.75 g/kg)</td>
<td>6.83±1.94</td>
<td>8.17±1.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:  *P<0.05.

The driving speed was measured in kilometres per hour (km/h) during the test. The interaction effects between different doses and BAC statuses were analysed and found to be statistically significant (P<0.001). The speed during the BAC ascending period under the high dose was the highest (see Table 4).

Table 4  Comparison of speed (km/h) at different BAC statuses of different doses

<table>
<thead>
<tr>
<th>Dose</th>
<th>BAC status</th>
<th>F&lt;sub&gt;interaction&lt;/sub&gt;</th>
<th>P&lt;sub&gt;interaction&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAC ascending period</td>
<td>BAC descending period</td>
<td>Non BAC</td>
</tr>
<tr>
<td>High dose (1 g/kg)</td>
<td>69.017±0.187</td>
<td>64.164±0.178</td>
<td>–</td>
</tr>
<tr>
<td>Medium dose (0.75 g/kg)</td>
<td>58.572±0.133</td>
<td>60.401±0.124</td>
<td>–</td>
</tr>
<tr>
<td>Placebo (0 g/kg)</td>
<td>–</td>
<td>–</td>
<td>63.837±0.179</td>
</tr>
</tbody>
</table>

Note:  *P<0.05.

Table 5  Comparison of the steering rate (degrees/s) at different BAC statuses of different doses

<table>
<thead>
<tr>
<th>Dose</th>
<th>BAC status</th>
<th>F&lt;sub&gt;interaction&lt;/sub&gt;</th>
<th>P&lt;sub&gt;interaction&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAC ascending period</td>
<td>BAC descending period</td>
<td>Non BAC</td>
</tr>
<tr>
<td>High dose (1 g/kg)</td>
<td>5.130±0.270</td>
<td>4.590±0.270</td>
<td>–</td>
</tr>
<tr>
<td>Medium dose (0.75 g/kg)</td>
<td>5.400±0.108</td>
<td>3.510±0.108</td>
<td>–</td>
</tr>
<tr>
<td>Placebo (0 g/kg)</td>
<td>–</td>
<td>–</td>
<td>3.780±0.270</td>
</tr>
</tbody>
</table>

Note:  *P<0.05.

The steering rate is a measure of the rate at which the driver turns the steering wheel to maintain the vehicle’s position on the road. The steering rate was measured by the degree change in the steering wheel per second. The interaction between different doses and
BAC statuses was analysed and found to be statistically significant (\(P<0.001\)). The steering rate during the BAC ascending period under the medium dose was the highest as shown in Table 5.

The offset value from the lane centre was used as an indicator of the degree of adjustment by the driver to maintain the desired position in the lane. The drivers were asked to stay in the centre of the lane. A greater offset indicates poorer driving performance. The interaction between different doses and BAC statuses was analysed and found to be statistically significant (\(P<0.001\)) as shown in Table 6. The offset value from the lane centre during the BAC ascending period under the high dose was the highest.

**Table 6** Comparison of the offset value from the lane centre (m) at different BAC statuses of different doses

<table>
<thead>
<tr>
<th>Dose</th>
<th>BAC status</th>
<th>(F_{\text{interaction}})</th>
<th>(P_{\text{interaction}})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAC ascending period</td>
<td>BAC descending period</td>
<td>Non BAC</td>
</tr>
<tr>
<td>High dose (1 g/kg)</td>
<td>0.99±0.495</td>
<td>0.757±0.514</td>
<td>–</td>
</tr>
<tr>
<td>Medium dose (0.75 g/kg)</td>
<td>0.269±0.512</td>
<td>0.147±0.434</td>
<td>27.36</td>
</tr>
<tr>
<td>Placebo (0 g/kg)</td>
<td>–</td>
<td>–</td>
<td>0.703±0.517</td>
</tr>
</tbody>
</table>

Note: \(*P<0.05\).

### 4 Discussion

The present study examined the impairment effects of alcohol on simulated driving performance. The high dose (1 g/kg) of alcohol produced an average peak BAC of 74±5.477 mg/100 ml, and the medium dose (0.75 g/kg) of alcohol produced an average peak BAC of 47.714±17.68 mg/100 ml. The drivers’ subjective intoxication was not significant. However, the drivers’ self-assessment of driving control under the medium dose was greater than the drivers’ self-assessment of driving control under the high dose. In addition, the drivers’ self-assessment of driving control during the descending period was greater than the drivers’ self-assessment of driving control during the ascending period. Compared with the placebo, the drivers’ performance under alcohol was characterised by faster and more abrupt steering manoeuvres, a greater average speed, and a greater offset from lane centre. As predicted, the BAC value ascends at approximately 30 min after administration and descends at 90 min after administration.

There were significant differences in the BAC values for different doses. The high dose (1 g/kg) of alcohol produced an average peak BAC of 74±5.477 mg/100 ml, and the medium dose (0.75 g/kg) produced an average peak BAC of 47.714±17.68 mg/100 ml. The peak BAC was generated at 30 min after the administration of the high dose, and the peak BAC was generated 10 min after the administration of the medium dose. Although previous studies have suggested that the BAC peak will occur at approximately 60 min after alcohol administration (Weafer and Fillmore, 2012; Van Dyke and Fillmore, 2014), the results in this study showed that 30 min was the peak BAC time when the drivers...
consumed a high dose of alcohol, and the peak BAC time was even shorter when the drivers consumed a medium dose of alcohol. The peak timing was variable according to the dose. During the 10 and 30 min periods, the BAC value did not show a significant effect, and the 30 min period was chosen as the BAC ascending period. The BAC values showed a downward trend at 60 min in this study, and the BAC at 90 min was significantly different from the BAC at 60 min. The 90 min period was chosen as the BAC descending period. The BAC at 120 min began to decline, and the decline was rapid.

The drivers’ subjective intoxication did not show any significant effects. Although the mean value of subjective intoxication under the high dose was larger than that under the medium dose and the value of the ascending period was larger than the descending period, the differences were not significant. These results imply that drivers are unable to judge their intoxication level regardless of how many doses they are administered, although the BACs were significantly different.

However, the drivers’ self-assessment of driving control under the medium dose was greater than the drivers’ self-assessment under the high dose. Moreover, the drivers’ self-assessment of driving control during the BAC descending period was greater than that during the BAC ascending period. There were no interaction effects between dose and status. We can see from the results that the self-assessment score during the ascending period under the high dose was 4.5±1.97 and that the self-assessment score during the descending period under the high dose was 7.67±0.82 (the full score is 10), although the BACs were 74±5.477 mg/100 ml and 56.167±10.167 mg/100 ml, respectively. People are over-confident in their driving control ability after alcohol administration, which may induce them to drive, especially during the BAC descending period, when people had a 76% degree of control in this study.

Speed is always chosen as an index to evaluate driver performance. The given speed limit was 60 km/h in this study. The placebo drivers had the mean speed of 63.837±0.179 km/h. The high dose of alcohol increased the speed to 69.017±0.187 km/h. This finding is similar to many studies (Van Dyke and Fillmore, 2014; Zhang et al., 2014); drivers are likely to speed when they are administered large amounts of alcohol. However, the speed during the BAC ascending period was 58.572±0.133 km/h when drivers were administered a medium dose of alcohol. This result is because drivers are more timid and overcautious when given a medium dose of alcohol.

Alcohol-impaired drivers can be slow to make adjustments to their road position, which requires them to execute quick, abrupt manipulations to the steering wheel. These late corrections are reflected by an increased steering rate value (Van Dyke and Fillmore, 2014). Steering rate can represent a driver’s ability to control a vehicle. The simulator test scene was a straight road, and a larger change of steering rate induced a greater chance of danger. The BAC ascending period under the medium dose had the highest steering rate (5.400±0.108 degrees/s). Drivers are more timid when they consume alcohol, which is consistent with the lowest speed that is indicated above. Interestingly, the BAC descending period of the medium dose had the lowest steering rate of 3.510±0.108 degrees/s.

The offset value from the lane centre was used as an indicator of the degree of adjustment by the driver to maintain the desired position in the lane. The drivers were asked to stay in the centre of the lane. A greater offset indicates poorer driving performance. The BAC ascending period under the high dose had the largest value of offset of 0.99±0.495 m, which implies that a high dose of alcohol will worsen a driver’s
ability to control the vehicle. The smallest value of 0.147±0.434 m occurs during the descending period under the medium dose, which is similar to the speed and steering rate in this study. The mechanism and reason for this result should be investigated in future studies.

As seen from the data, approximately 34% of the road crashes in China were related to alcohol consumption. However, the temporary examination by traffic police is the primary means to find the drinking driving in China. The breath alcohol content detector is the main testing equipment to determine whether the driver is drinking driving or not. The active detection and intervene system is considered to be the best way to effectively reduce the alcohol-related traffic accident rate. The study on driver behaviour plays an important role on constructing the early warning model, which would find driving behaviour differences and rules in the specific conditions, so as to put forward the corresponding intervention measures of unsafe driving behaviour. The driving behaviour characteristics of various traffic patterns studied in this paper can provide theoretical support for the development of automotive active safety system.

The results generated from experiments conducted in this study are useful for alcohol-related active safety system. As is well known, there are some drinking driving warning devices on the market, which normally measure the air alcohol concentration in the car or test driver’s physiological response characteristics. The associated algorithms that used in these existing devices are based on a single Eigenvalue only to make the judgment of drinking driving, which are prone to error. The data of vehicle dynamic characteristics and driver behaviour characteristics obtained from studies in this paper. These valuable information when combined with air alcohol concentration value can then be integrated into an applied support vector regression method to establish an early warning model. Such model when implemented into production can enhance capability of breath alcohol detectors, thus improving vehicle safety in reducing accidents due to drinking and/or drunk driving on public roads.

Finally, it must be pointed out that the limitations of this study include the relatively small sample size, which undermines its statistical power and results in insensitivity in generating external validity with other driver populations and some indices, such as the standard deviation of the lane position. The participants in this study were young novice drivers, and the sample can be extended to include mature experienced drivers, which may lead to different results. The metabolic rate of alcohol consumption varies among individuals; thus, when and how alcohol levels change inside a body is unknown. In addition, the BAC ascending and descending periods may vary between doses. Thus, the preparation for the BAC test should be developed in detail, and more tests be carried out in the future.

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References


