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Investigating the Effects of Alcohol Consumption on Manual and Automated Driving: A Systematic Review

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16. Abstract

There are direct correlations between drunk driving and car-related injuries, disabilities, and death. Autonomous vehicles (AVs) may provide useful driver support systems in order to prevent or reduce road accidents. However, AVs are not yet fully automated and require human drivers to take over the vehicle at times. Therefore, understanding how alcohol affects driving performance in both manual and automated driving is important because manual drives may offer insights into the takeover process in AVs. A systematic review of 53 articles from eight databases was conducted. Findings were categorized based on the human information processing model, which can be extended to the AV takeover model. The results demonstrated that different blood alcohol concentration (BAC) levels affect driving performance in various stages of the information processing model and the takeover model. However, existing studies tested limited levels of BAC, and there are few studies on AV takeover performance. Future work may focus on AVs and takeover performance. This review can also provide implications for future driving experiments and AV technology design.

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Executive Summary

There is a correlation between driving under the effect of alcohol and car-related injuries, disabilities, and fatalities. Autonomous vehicles (AVs), while not yet fully automated, offer potential driver support systems that could significantly reduce road accidents. However, since human intervention is required when necessary, it is crucial to understand how alcohol impairs driving performance in both manual and automated scenarios. Insights into manual driving could reveal valuable information about the takeover process in AVs. The purpose of this study is to comprehend the effects of alcohol on driving performance across manual and automated driving and understand how these insights might influence the takeover process in AVs. Additionally, we aim to classify our findings based on the human information processing model and its potential extension to the AV takeover model. To achieve these objectives, we conducted a comprehensive systematic review of the available literature. A total of 53 articles were scrutinized in full text, sourced from eight different databases. Our results reveal that varying blood alcohol concentration (BAC) levels influence driving performance at diverse stages of the information processing model and the takeover model. However, we found that existing studies only tested a limited range of BAC levels and that there is a significant research gap regarding AV takeover performance. Consequently, future work may focus on exploring AVs and takeover performance at varying BAC levels. The insights gained from our review could have crucial implications for future driving experiments and AV technology design.

1. Introduction

Driving under the influence of alcohol, such as drunk driving, constitutes a global public health crisis. In the United States alone, an average of 29 individuals lose their lives daily due to road traffic accidents involving intoxicated drivers (National Highway Traffic Safety Administration (NHTSA), 2022). Driving with a blood alcohol concentration (BAC) equal to or over 0.08 grams of alcohol per deciliter of blood (0.08 g/dL or 0.08%) is illegal in most states in the United States, except the state of Utah, where the limit is 0.05% (NHTSA, 2019). Despite the legal sanctions in place, people continue to drive after drinking alcohol; in fact, it was reported that drivers impaired by alcohol were responsible for 147 million instances of driving under the influence in 2018 (Centers for Disease Control and Prevention, 2020).

Alcohol may impair drivers' perceptual, cognitive, and motor functioning, which are essential elements to consider within the framework of the Human Information Processing Model (Proctor & Van Zandt, 2018; Wickens et al., 2021). This model shows how the human mind processes information and how memories are stored and retrieved when performing tasks. Throughout the process, stimuli are first perceived by an individual (perception), then the perceived stimuli undergo cognitive processing (cognition), and finally, actions are executed (action). The effects of alcohol on human information processing have been investigated. Overall, various alcohol levels affect people differently, resulting in impaired judgment, muscle control, or vision (NHTSA, 2022). Elements in human information processing, such as perceptual speed (Tzambazis & Stough, 2000) or higher-order cognitive functioning, are negatively affected by alcohol consumption (Koelega, 1995), and overall information processing is comprised of a chain reaction of impairments from early stages to later stages (Rohrbaugh et al., 1988). Specifically, for driving, it has been reported that alcohol could cause a delay in receiving perceptual information (perception), such as perceiving traffic signs or pedestrians, which then impairs cognition, such as speed estimation, and action, such as maintaining a consistent speed (Yadav & Velaga, 2020).

For example, Yadav and Velaga (2020) conducted an experiment in simulated rural and urban environments at four different alcohol levels (0%, 0.03%, 0.05%, and 0.08% BAC), and used pedestrian crossings and road crossings by parked cars (a car and a truck) in the perpendicular direction of traffic) in the simulator to test crash probability. They found that the crash probability increased proportionally to the BAC level in both environments because alcohol delayed drivers' perceptions of sudden events, which contributed to factors that may influence speeding behavior (e.g., by measuring the mean speed). Similarly, drivers under the effect of alcohol may also experience difficulty in judging (cognition) and maintaining the driving speed (action). For instance, Harrison and Fillmore (2011) conducted an experiment in which participants were randomly assigned to one of four groups: (1) alcohol, (2) alcohol plus divided attention, (3) placebo, or (4) placebo plus divided attention. The first and third groups drove without the secondary task, and the researchers recorded the average speed during each test. They discovered that drivers' average speeds were significantly higher than their baseline data, and drunk drivers did not slow down for the divided attention task, whereas sober drivers did. As a result of alcohol, drivers exhibit poorer perceptual, cognitive, and psychomotor abilities, which may worsen driving performance and unsafe driving conditions. According to NHTSA (2019), even BAC levels as low as 0.02% can impair alertness, inhibition, cognitive judgment, thinking speed, and coordination across all perception, cognition, and action phases of the information processing model.

With the advancement of technology and growing public interest in autonomous vehicles (AVs), it is imperative to observe how the current understanding of drivers under alcohol's influence may or may not transfer to AV use. AVs are categorized from Level 0—no automation—to Level 5—fully autonomous (SAE International, 2021). AVs have the potential to support accident prevention, particularly for drivers under the influence of alcohol, by reducing the reliance on potentially impaired perceptual and cognitive processing as well as motor functioning. However, AVs are expected to remain between Levels 2 and 3 for a few decades (Hedlund, 2016; Kyriakidis et al., 2019), which require drivers to stay in the loop for possible requests to resume manual vehicle control (i.e., takeover) when the system can no longer perform the driving task. The takeover process involves the perception of a takeover request (TOR), cognitive processing of TOR and information in the external driving environment, and action through actual takeover and resumed manual driving (Huang & Pitts, 2022; SAE International, 2021), mirroring the information processing model. Therefore, alcohol's effects can affect any takeover stage and may impact takeover performance, resulting in higher accident risk. In light of this, our study emphasizes the intersection of alcohol's impacts with the dynamics of AVs during the takeover process. By adopting the information processing model, we aim to research its potential effects on both manual and automated driving safety.

AVs can aid drivers and may promote road safety. However, the transition from manual to automated driving introduces unique challenges and opportunities. For instance, the takeover time in automated driving scenarios might differ from manual driving due drivers' potential complacency or reduced vigilance. Understanding the nuances of alcohol's impact in this context is vital. Therefore, before putting drivers under the influence of alcohol behind the wheel in AVs, it is crucial to understand alcohol's effects on drivers' manual driving and automated driving takeover performance (e.g., response time to TOR, speed, and lane position control after resuming manual control). To date, no systematic review synthesizes the literature on how alcohol may impact drivers' driving (takeover) abilities and performance. Therefore, this study performs a systematic review of alcohol's effects on both manual and automated (takeover) driving performance and provides recommendations for improving the design of future vehicles.

2. Methods

This review was conducted per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines (Moher et al., 2009). Eight databases were searched: SCOPUS, Web of Science, Engineering Village, ACM Digital Library, PsycINFO, Academic Search, PubMed, and TRID. All searches were completed in September 2021. The inclusion criteria include: publication years between 1980 and 2022; document type as either journal articles or conference proceedings; and written in English. The search syntax used was as follows: ("Intoxicat*" OR "Dr*nk*" OR "Under the influence" OR "Blood alcohol*" OR "Alcohol*" OR "Liquor" OR "Inebriate*") AND ("Self-driv*" OR "Semi-autonom*" OR "Intelligent" OR "Automated*" OR "Autonomous*" OR "Autonomous car*" OR "Driv*" OR "Operat*" OR "Vehicle*" OR "Truck*" OR "Automobile*" OR "Off-roading*" OR "Farm vehicle*").

Of the 24,776 identified articles, 3,612 duplicates were removed (Figure 1). Two reviewers conducted initial screening separately to avoid reviewer bias. Articles were excluded if they were (1) not both alcohol and driving-related, (2) about other drugs' effects, and/or (3) reviews (i.e., literature and scoping reviews or meta-analysis). Of 80 full-text articles, 31 were excluded, as they were non-experimental, testing driving-related skills (e.g., visual stimuli detection) but not actual driving performance. We found four additional articles from one of the 49 papers' reference lists that met our criteria but were not included during the initial search.

The final list comprises 53 full-text articles. Of these, all but one study conducted their driving performance tests in simulators, with the exception of Kearney and Guppy (1988) who carried out their experiment on a closed road section. We categorized the studies into five sections based on their primary focus and measures. Three of these sections were mapped according to the information processing model, encompassing perception, cognition, and action. The remaining two sections address predisposing factors and post-action effects. Naturally, there are descending effects of the earlier stage(s) in the models into the later stages, as each stage depends on the prior stage. The section addressing predisposing factors includes factors that influence how alcohol affects drivers, such as driving experience, drinking patterns, and road complexity. These are intrinsic (e.g., driving experience) and extrinsic (e.g., road complexity) factors that can create individual differences in drivers and/or the driving environment, exacerbating or mediating the effects of alcohol. Also, we grouped errors and accidents caused by driving under the influence of alcohol into a post-action section, as they are consequences of impaired driving following alcohol consumption.

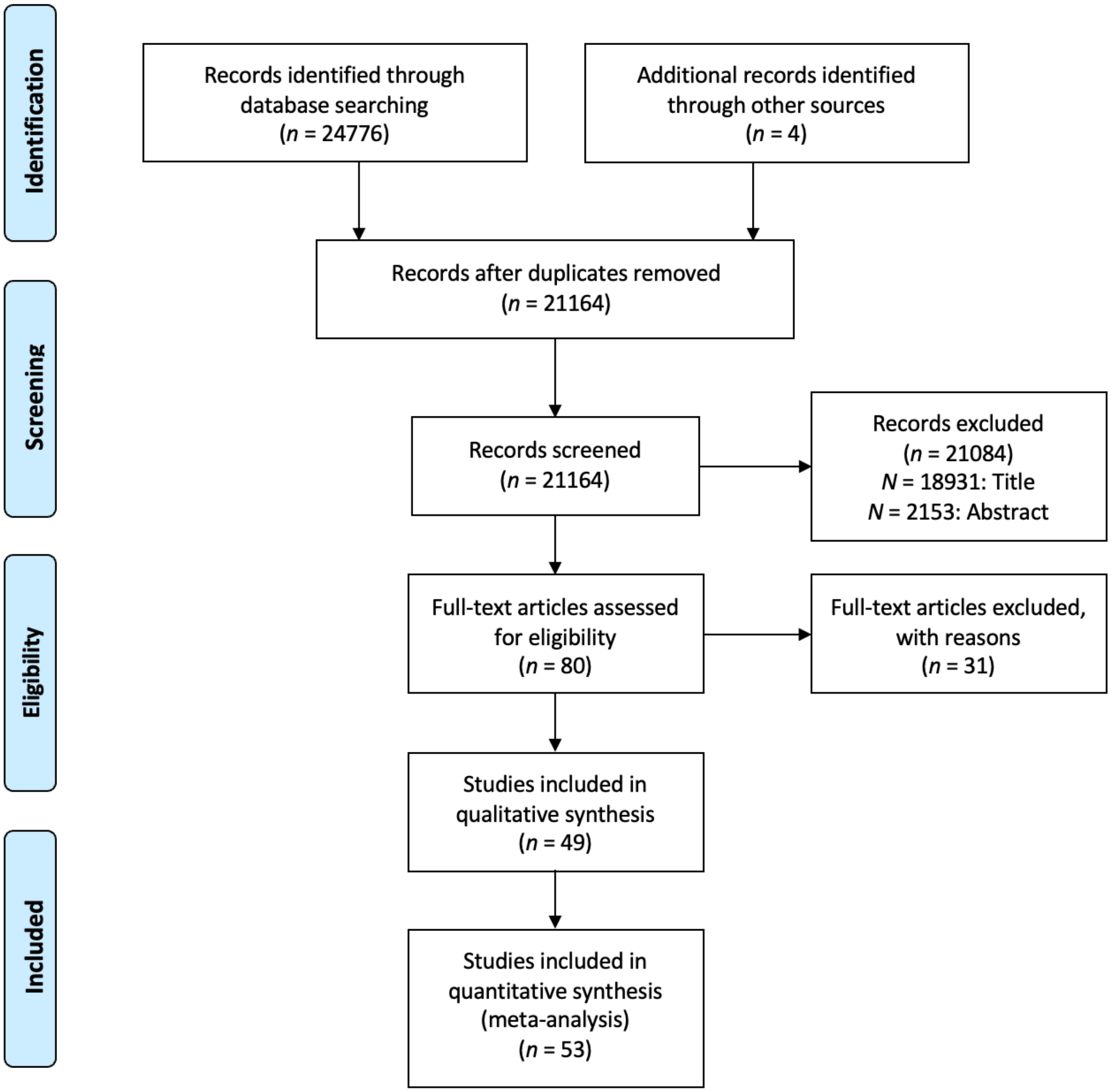

Figure 1. PRISMA Flow Diagram Summarizing Search Process

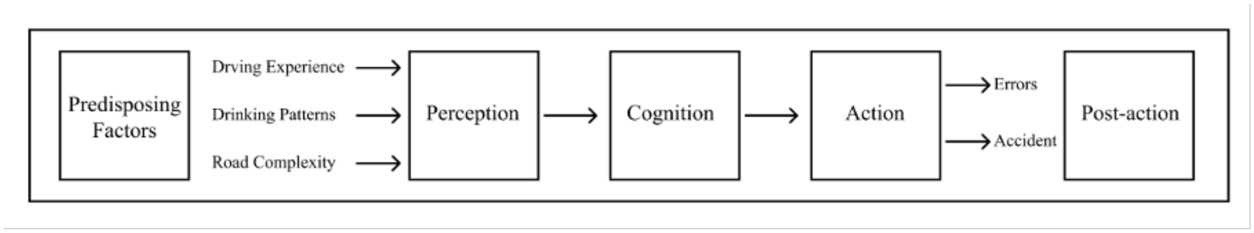

Figure 2. Information Processing Model with Added Factors from this Review

3. Results

3.1 Predisposing Factors

3.1.1 Driving experience

Six articles investigate how driving experience influences driving behavior after alcohol consumption. Age and experience were found to impact driving performance under the influence of alcohol (Freydier et al., 2014; Jongen et al., 2018; Lenne et al., 1999; Y. C. Li et al., 2016; Quillian et al., 1999; Yadav & Velaga, 2019b). Specifically, Li et al. (2016) conducted a manual driving study with four drives at a speed of 50 mph with emergency stop braking and car following braking events, discovering that the standard deviation (SD) of the speed was higher in younger (18–24 years of age) drivers compared to middle-aged (25–54 years of age) and older drivers (55 years of age or above). Additionally, Freydier et al. (2014) reported that novice drivers (i.e., less than two months and 5,000 km of driving experience) had higher vehicle position deviation under alcohol effects than experienced drivers (i.e., 3 years and more than 20,000 km of driving experience), which was supported by Lenne et al. (1999), who also found inexperienced drivers had a greater variation in lateral position than experienced drivers. In summary, older and more experienced drivers exhibited faster reaction time (RT), lower mean acceleration, and less mean brake pedal force after alcohol intake compared to younger or less experienced drivers.

3.1.2 Drinking patterns

Four articles compare manual driving performance among four types of drinkers: infrequent, frequent, binge, and non-binge drinkers (Bernosky-Smith et al., 2011; Y. C. Li et al., 2016; Marczinski et al., 2008; Yadav & Velaga, 2019b). Overall, frequent and binge drinkers had better driving performance. For example, Li et al. (2016) found in their study that frequent drinkers (twice or more per month) had faster breaking RTs than infrequent drinkers (less than twice per month) or non-drinkers (never). Yadav & Velaga (2019b) also observed that frequent drinkers (i.e., more than twice a week) had faster RT than infrequent drinkers (i.e., at most twice a week, varying between one to two times per week), which might be due to desensitization to alcohol effects. In studies examining binge and non-binge drinkers, participants were considered binge drinkers based on their scores (≥ 24) on the Alcohol Use Questionnaire (Mehrabian & Russell, 1978); binge drinkers, as per this criterion, reported less sedation, greater self-rated ability, and higher confidence to drive than non-binge drinkers at the same alcohol doses, measured by completing a visual analog scale and beverage rating scale (Bernosky-Smith et al., 2011; Marczinski et al., 2008).

3.1.3 Road complexity

Eight articles examined the effects of different road complexities on driving performance after alcohol consumption (e.g., varied traffic densities, straight or curved roads, and impoverished or normal environments) (e.g., Harrison et al., 2007; Ranney & Gawron, 1986; Vollrath & Fischer, 2017). Generally, complex roads (e.g., more traffic) resulted in increased speed variance and slower RTs for drivers under the influence of alcohol (Liu & Ho, 2007, 2010). Alcohol intake levels of 0.03%, 0.05%, and 0.08% were shown to increase drivers' mean speed in both urban and rural environments. However, crash frequency, measured by the probability of a crash occurring when the driver encounters hazardous events, such as pedestrian crossing or parked vehicles suddenly crossing the road (out of a sudden event), was higher in urban areas. Simpler rural environments evoked higher overall speeds than urban environments (Yadav & Velaga, 2020). In Ranney and Gawron's (1986) experiment, 12 participants drove under three BAC levels (0.00%, 0.07%, 0.12%) in a driving simulator with low-demanding (viz., driving on curved roads) and high-demanding tasks (viz., driving to avoid obstacles). They found that alcohol-dosed drivers drove at faster speeds with slower RTs in low-demanding task scenarios compared to sober drivers (Ranney & Gawron, 1986). Additionally, driving with higher BACs was associated with increased overall speed and standard deviation of speed compared to the placebo group on both straight and curved roads (Gawron & Ranney, 1988; Z. Li et al., 2019; Zhang et al., 2014). Interestingly, one study, which observed alcohol effects on driving in visually impoverished versus normal environments found that training drivers under the influence of alcohol (0.65 g/kg) on the driving task produced a driving performance that mirrored sober drivers', indicating that training or experience may mediate alcohol's effects at different levels of environment complexities, such as poor versus normal environments (Harrison et al., 2007).

3.2 Perception

3.2.1 Objective measures – Reaction time

Although reaction belongs in the action phase as discussed below, impairments in reaction time due to alcohol begin at the perception phase, i.e., stage one of the information processing model. Based on the literature, alcohol-dosed drivers had delayed RTs to traffic signs, hazards, pedestrian crossing events, and the behavior of other vehicles on the road (Y.-C. Liu & Fu, 2007; Yadav & Velaga, 2019b; Zhong et al., 2014). For example, Liu & Fu (2007) performed a visual task for participants in high and low driving load conditions by switching the indicator to match the sign provided on the screen of the driving simulator under BACs of 0 mg/l (BAC = 0.00%), 0.25 mg/l (BAC = 0.05%), 0.4 mg/l (BAC = 0.08%), and 0.5 mg/l (BAC = 0.10%). For each drive, two arrow signs were provided on the in-vehicle display four times. The participants' RTs to the signs were recorded. Longer RTs were found for the visual task under both high and low driving load conditions.

3.2.2 Subjective measures – Perception of driving-related abilities

Increased BAC levels resulted in lower perceived safety, higher intoxication, lower subjective driving ability, and higher drowsiness ratings (Brown et al., 2018; Landauer & Howat, 1983; Marczinski et al., 2008; Vollrath & Fischer, 2017; Weafer & Fillmore, 2012; Zhao et al., 2014). For example, Zhao et al. (2014) tested three levels (0.03%, 0.06%, 0.09%) of alcohol and one control group without alcohol in a manual driving environment. They collected participants' subjective ratings, including attitude, vigilance, attention, judgment, reaction, and ability to control the vehicle after each drive. The results showed that drivers' perceived driving speed was affected linearly by their alcohol levels, with higher BAC levels correlating with lower self-perceived driving ability. Drivers also tended to underestimate their intoxication compared to their actual BACClick or tap here to enter text.. For instance, Weafer and Fillmore (2012) found that participants' self-reported BAC levels, measured by the visual analog scale (i.e., willingness to drive and subjective intoxication), were lower than their actual BAC levels.

3.2.3 Physiological measures – Eye metrics

Two articles measuring a driver's eye movement found that alcohol-dosed drivers had longer eye fixation durations, lower total fixations, and higher blink rates compared to drivers in the placebo group (Chen et al., 2019; de Blasiis et al., 2020). Specifically, de Blasiis et al. (2020) used a virtual reality driving simulator to track participants' blink rates, finding that alcohol-dosed drivers had higher blink rates than sober drivers, indicating increased fatigue. Additionally, Chen et al. (2019) measured the physiological performance of 16 novice male drivers (with licenses held for less than a year) while under the influence of alcohol. Participants were divided into two groups: placebo and high alcohol dose (1g/kg). The simulated driving environment was divided into 12 areas to test the driver's eye movement in different areas of interest. They discovered that the total fixation duration of different areas in the alcohol group was shorter than the placebo group on straight, curved, and intersection roads. This suggests that alcohol affects the driver's attention on the road, which may cause safety issues. The findings that alcohol affects drivers' visual scanning behavior and increases fatigue indicate that alcohol limits the amount and quality of environmental stimuli drivers perceive from the driving environment.

3.3 Cognition

3.3.1 Objective measures – Divided attention task performance

BAC has a positive relationship with RT to off-road events that may divide drivers' attention (Liu & Ho, 2010; Rakauskas et al., 2008). Rakauskas et al. (2008) examined the effects of alcohol on drivers' divided attention abilities. In this study, participants performed secondary tasks (e.g., searching for specific information on the car dashboard or having hands-free cell phone conversations) while manually driving. The result indicated that under the influence of alcohol, the standard deviation of steering wheel position and lane position was more affected than it was for drivers who were dosed with the placebo.

3.3.2 Physiological measures – Decision-making, memory, and cognitive load

Four articles measure driver's physiological measures, such as brain activity and heart rate related to cognition, after alcohol intake and discovered that alcohol consumption negatively affects decision-making, memory, and cognitive load (A. J. Allen et al., 2009; Calhoun et al., 2004; Meda et al., 2009; Subramaniyam et al., 2018). Specifically, analysis of functional magnetic resonance imaging (fMRI) readings revealed changes in brain regions managing inhibition, decision-making, or memory, such as the frontal and prefrontal cortex, amygdala, hippocampus, and para-hippocampus in response to a BAC level of 0.10% (e.g., Meda et al., 2009). Similarly, Calhoun et al. (2004) found activation changes in the orbitofrontal and anterior cingulate cortices that manage decision-making and memory after drinking alcohol. Additionally, alcohol-dosed drivers showed decreased alpha and increased theta power frequency in the frontal and occipital lobes in electroencephalogram signals, indicating increased drowsiness after alcohol consumption (Subramaniyam et al., 2018), which may also impact cognitive performance, such as by decreasing thinking speed and decision-making ability (Kearney & Guppy, 1988). One article also measured drivers' heart rates during the experiment by using electrocardiogram analysis, finding that drivers experienced a significant increase in heart rate with an increase in BAC, which may imply heightened cognitive load or increased stress under the influence of alcohol (Subramaniyam et al., 2018).

3.4 Action

3.4.1 Objective measures – Driving performance

Eleven articles test the influence of alcohol on RT to different stimuli (i.e., actions such as the time from the stimuli to stepping on brake pedals) while driving (e.g., Flanagan et al., 1983; Harrison & Fillmore, 2011; Zhong et al., 2014). As described in Section 3.2, these studies found that RT increases linearly with higher BAC levels (Liu & Ho, 2007; Ou et al., 2010; Zhao et al., 2014). The impairments in the perception and cognition stages (i.e., the inability to detect and process information in the driving environment, such as traffic signs and hazards) manifested in the action stage, where alcohol-impaired drivers exhibited delayed RT. Findings in braking behavior indicated that alcohol-dosed drivers had a delayed time to brake (Harrison & Fillmore, 2011; Leung et al., 2012; Ou et al., 2010; Yadav & Velaga, 2019a; Zhong et al., 2014) and stepped on the pedal with greater force to compensate for the time lost (Ou et al., 2010; Vollrath & Fischer, 2017), which may be attributed to poorer motor control. Zhong et al. (2014) employed three levels of alcohol consumption for participants: light (20% of subjective max alcohol to drink (SMAD)), moderate (60% of SMAD), and heavy (100% of SMAD). They found that light and heavy alcohol consumption led drivers to decelerate less to avoid collisions, while moderate consumption led to more frequent deceleration compared to the placebo group (Zhong et al., 2014). Additionally, even at a peak BAC of 0.08%, alcohol affected speed deviation, which measures the amount of adjustment that the driver makes to maintain a desired speed (Marczinski et al., 2008), showing that drivers at legal limits are still unable to stably control vehicle speed. Alcohol-dosed drivers were also found to exceed speed limits more frequently than sober drivers (Flanagan et al., 1983; Mets et al., 2011; Subramaniyam et al., 2018; Zhong et al., 2014). As mentioned in the cognition section, this speeding impairment can be attributed to poorer judgment of speed after alcohol intake (Kearney & Guppy, 1988).

Fifteen articles mention how alcohol affects drivers' ability to control vehicle positioning; they indicate that alcohol increased lane deviation, lane positioning standard deviation, lateral position error, road departure distance, and steering errors (Bragg & Wilson, 1980; Charlton & Starkey, 2013; Jongen et al., 2018; Kenntner-Mabiala et al., 2015; West et al., 1993). For example, increased BAC levels were associated with higher lane deviation, a larger standard deviation of lane positioning, more lateral position errors, more lane line crossings, and higher road departure distance and time (e.g., Charlton & Starkey, 2013; Gawron & Ranney, 1988; Howland et al., 2011; Marczinski et al., 2008; Meda et al., 2009; Zhao et al., 2014). Additionally, drivers made more steering errors (i.e., vehicle positioning relative to the curve center or calculated ideal curve) after consuming alcohol compared to the placebo group, even at a BAC as low as 0.02% (Jongen et al., 2018; Rimm et al., 1982; Verster et al., 2009). Errors may arise from excessive steering intensity adjustments as a result of the increased speed with which alcohol-impaired drivers approach curves (Ou et al., 2010). Additionally, exaggerated steering responses to road hazards have been observed among intoxicated drivers in comparison to their sober counterparts (R. W. Allen et al., 1996; Starkey & Charlton, 2014; West et al., 1993).

3.4.2 Physiological signals - Brain activity

In addition to revealing that alcohol impairs decision-making and cognitive abilities, fMRI studies have demonstrated the effects of alcohol on brain regions associated with motor function. Three studies analyze fMRI readings during manual driving tasks and compare them to driving behaviors (e.g., reaction time) to identify trends in brain activation across different neural networks (Allen et al., 2009; Calhoun et al., 2004; Meda et al., 2009). They found that alcohol significantly impacts brain regions responsible for motor function. The participants' brain activity was scanned after they received an alcohol dosage by using an fMRI scanner. The results showed that fMRI signals in the primary motor cortex and supplementary motor area were impacted by different alcohol dosages (0.04% and 0.08% BAC) compared to the placebo group, suggesting impaired motor control and error correction abilities (Calhoun et al., 2004).

3.5 Post-Action Consequences

Nine experiments measured the frequency of driver errors and accidents after alcohol consumption. The findings indicate that drivers exhibit an alcohol dose-dependent increase in error frequency, such as steering error detected by software (Allen et al., 1996; Landauer & Howat, 1983; Rimm et al., 1982; Starkey & Charlton, 2014; Verster et al., 2009), and increased frequency of accidents or collisions with hazards and obstacles, including having to stop or reposition the vehicle (Berthelon & Gineyt, 2014; Flanagan et al., 1983; Gawron & Ranney, 1988). For example, Rimm et al. (1982) observed more braking and steering errors in a driving simulator after drivers drank alcohol. Furthermore, alcohol can lead to more aggressive driving behaviors, such as an increased number of cars passed (McMillen & Wells-Parker, 1987).

3.6 Alcohol Effects on AV Takeover Performance

Only two articles investigate alcohol effects in the context of automated driving, reporting that RT and driving performance metrics, such as SD of lane positioning (SDLP) and SD of speed, were all positively related to BAC levels. Specifically, Berthelon & Gineyt (2014) used four BAC levels (0%, 0.03%, 0.05%, 0.08%) to assess automated and controlled driving performance. The study measured automated driving parameters, such as lateral and longitudinal control (e.g., speed control and lane-keeping control), which are commonly used in Level 1–2 automated vehicles. The driving environment encompassed three scenarios varying in road complexity (viz., a highway without traffic, a car-following scenario, and an urban environment with other vehicles but no interaction). Their findings indicate that certain automated driving parameters, such as SDLP, varied in relation to alcohol levels, with the largest SDLP observed at a BAC of 0.08% (the highest BAC level in the study). Additionally, RT to braking and the number of crashes in response to specific events in the urban scenario were found to be less affected by the level of alcohol in the system. As a result, the study concluded that alcohol consumption influenced different aspects of automated driving performance, with some parameters being more sensitive than others. Wiedemann et al. (2018) tested three different BAC levels (0%, 0.05%, 0.08%) in a conditionally automated driving simulator, where the driving system provided longitudinal, lateral, and constant speed control (Level 3). The experiment features seven different takeover events based on real-life driving scenarios, such as pedestrian crossing. Takeover performance was measured using takeover time and responses to auditory (the sound of speech saying “take over”) and visual (a picture of hands grabbing the steering wheel and a message box with "take over") takeover requests. The results indicate that higher BAC levels correlated with longer takeover times, which is consistent with the findings from the manual driving studies included in this review.

Both studies present the effects of alcohol on various aspects of automated driving, from lane positioning to takeover times. In synthesizing these studies, it becomes evident that while the overarching effects of alcohol on driving are well-documented, its specific implications in automated driving remain unclear and require more exploration.

4. Summary & Conclusions

Fifty-three articles were reviewed for this study that discuss the effects of alcohol on manual driving and automated driving conditions. They were categorized based on the information processing model and two other factors that may also impact driving performance. In general, the articles demonstrate that alcohol affects various aspects of driving performance, which increases the risk to road safety.

Findings from the review showed that alcohol consumption could impact all three stages of the human information processing model, although experienced drivers and frequent drinkers may be less affected by alcohol. However, alcohol's effects on perception, cognition, and actions can all pose potential risks to driving, as evidenced by various physiological metrics such as eye movements, brain activity, and heart rate. Consequently, driving under the effect of alcohol presents numerous risks in manual driving, as it exhibits negative effects across all stages of the information processing model, increasing the likelihood of traffic accidents. Similarly, in the context of takeover models, alcohol can influence perception and cognition, leading to different takeover actions. While there are limited studies on the effects of alcohol on AV drives, the findings from manual driving studies align with those observed in AV drives. Since current AVs still rely on human drivers to take control when necessary, further studies are needed to examine the impact of different BAC levels on takeover performance in AVs.

In many studies, researchers examined different BAC levels, including light, moderate, and heavy, and found varying effects on driving performance. Although lower BAC levels (light) may have a minimal or low impact on driving performance, moderate and heavy alcohol consumption have been shown to affect the driver's ability to control the vehicle, such as driving speed or maintaining a consistent speed. It is important to note that the definitions of low, moderate, and heavy alcohol levels and the measurement units varied across the reviewed articles, including different alcohol percentages or grams per deciliter (g/kg). For future studies, establishing consistent measurement standards and units is critical.

With reference to the findings above, the following recommendations can be made: (1) There is a new car invention called an ignition interlock device, which requires drivers to blow into the device; the car will unlock if the BAC level is less than the set limit. This is recommended to be installed in vehicles to help detect alcohol consumption. (2) Since driving performance can be affected by all three stages in the information processing model, an in-car alert system will help alert drivers about the driving conditions at the starting stage (perception). (3) Following the cognition stage, a well-designed human-machine interface can assist drivers in better processing incoming information and quickly filtering out unusable information. (4) Finally, a reliable automated driving support system can give crucial real-time feedback to the driver, such as a tactile signal from the steering wheel or the driver's seat.

Bibliography

Allen, A. J., Meda, S. A., Skudlarski, P., Calhoun, V. D., Astur, R. S., Ruopp, K. C., & Pearlson, G. D. (2009). Effects of alcohol on performance on a distraction task during simulated Driving. Alcoholism: Clinical and Experimental Research, 33(4), 617–625. https://trid.trb.org/view/1093782

Allen, R. W., Stein, A. C., & Human Factors and Ergonomics Society. (1996). A driving simulator study of the performance effects of low blood alcohol concentration. Human Centered Technology, Key to The Future. https://trid.trb.org/view/632650

Bernosky-Smith, K. A., Shannon, E. E., Roth, A. J., & Liguori, A. (2011). Alcohol effects on simulated driving in frequent and infrequent binge drinkers. Human Psychopharmacology-Clinical and Experimental, 26(3), 216–223. https://doi.org/10.1002/hup.1195

Berthelon, C., & Gineyt, G. (2014). Effects of alcohol on automated and controlled driving performances. Psychopharmacology, 231(10), 2087–2095. https://trid.trb.org/view/1340142

Bragg, B. W. E., & Wilson, W. T. (1980). Evaluation of a performance test to detect impaired drivers. Accident Analysis & Prevention, 12(1), 55–65. https://doi.org/10.1016/0001-4575(80)90040-8

Brown, T. L., Lee, J. D., & Fiorentino, D. (2018). Effects of alcohol at 0.05% blood alcohol concentration (BAC) on low-speed urban driving. Traffic Injury Prevention, 19(sup2), S175–S177. https://doi.org/10.1080/15389588.2018.1532220

Calhoun, V. D., Pekar, J. J., & Pearlson, G. D. (2004). Alcohol intoxication effects on simulated driving: Exploring alcohol-dose effects on brain activation using functional MRI. Neuropsychopharmacology: Official Publication of the American College of Neuropsychopharmacology, 29(11), 2017–2097. https://doi.org/10.1038/sj.npp.1300543

Centers for Disease Control and Prevention. (2020). Sobering facts: Alcohol-impaired driving state fact sheets. https://www.cdc.gov/motorvehiclesafety/impaired_driving/states.html

Charlton, S. G., & Starkey, N. J. (2013). Drunker than you think: Delayed performance impairment from moderate amounts of alcohol (p. 11p). http://acrs.org.au/publications/conference-papers/database/

Chen, H., Yuan, X., Ye, H., Chen, L., & Zhang, G. (2019). The effect of alcohol on the physiological performance of the driver. International Journal of Crashworthiness, 24(6), 656–663. https://doi.org/10.1080/13588265.2018.1511226

De Blasiis, M. R., Ferrante, C., & Veraldi, V. (2020). Driving risk assessment under the effect of alcohol through an eye tracking system in virtual reality. Advances in Intelligent Systems and Computing, 969, 329–341. http://dx.doi.org/10.1007/978-3-030-20497-6_31

Drunk Driving | Statistics and Resources | NHTSA. (n.d.-b). Retrieved September 13, 2022, from https://www.nhtsa.gov/risky-driving/drunk-driving

Flanagan, N. G., Strike, P. W., Rigby, C. J., & Lochridge, G. K. (1983). The effects of low doses of alcohol on driving performance. Medicine, Science and the Law, 23(3), 203–208. https://doi.org/10.1177/002580248302300309

Freydier, C., Berthelon, C., Bastien-Toniazzo, M., & Gineyt, G. (2014). Divided attention in young drivers under the influence of alcohol. Journal of Safety Research, 49, 13–18. https://doi.org/10.1016/j.jsr.2014.02.003

Gawron, V. J., & Ranney, T. A. (1988). The effects of alcohol dosing on driving performance on a closed course and in a driving simulator. Ergonomics, 31(9), 1219–1244. https://doi.org/10.1080/00140138808966764

Harrison, E. L. R., & Fillmore, M. T. (2011). Alcohol and distraction interact to impair driving performance. Drug and Alcohol Dependence, 117(1), 31–37. http://www.sciencedirect.com/science/article/pii/S0376871611000500

Harrison, E. L. R., Marczinski, C. A., & Fillmore, M. T. (2007). Driver training conditions affect sensitivity to the impairing effects of alcohol on a simulated driving test. Experimental and Clinical Psychopharmacology, 15(6), 588–598. https://trid.trb.org/view/849795

Hedlund, J. (2016). Autonomous vehicles meet human drivers: Traffic safety issues for states.

Howland, J., Bliss, C. A., Hunt, S. K., Calise, T. V., Heeren, T., Winter, M. R., Littlefield, C., Gottlieb, D. J., Rohsenow, D. J., & Arnedt, J. T. (2011). The acute effects of caffeinated versus non-caffeinated alcoholic beverage on driving performance and attention/reaction time. Addiction, 106(2), 335–341. https://trid.trb.org/view/1093745

Huang, G., & Pitts, B. J. (2022). The effects of age and physical exercise on multimodal signal responses: Implications for semi-autonomous vehicle takeover requests. Applied Ergonomics, 98. https://doi.org/10.1016/j.apergo.2021.103595

Jongen, S., van der Sluiszen, N. N. J. J. M., Brown, D., & Vuurman, E. F. P. M. (2018). Single- and dual-task performance during on-the-road driving at a low and moderate dose of alcohol: A comparison between young novice and more experienced drivers. Human Psychopharmacology: Clinical and Experimental, 33(3). https://doi.org/10.1002/hup.2661

Kearney, S. A., & Guppy, A. (1988). The effects of alcohol on speed perception in a closed-course driving situation. Journal of Studies on Alcohol, 49(4), 340–345. https://doi.org/10.15288/jsa.1988.49.340

Kenntner-Mabiala, R., Kaussner, Y., Jagiellowicz-Kaufmann, M., Hoffmann, S., & Krüger, H. P. (2015). Driving performance under alcohol in simulated representative driving tasks: An alcohol calibration study for impairments related to medicinal drugs. Journal of Clinical Psychopharmacology, 35(2), 134–142. https://doi.org/10.1097/JCP.0000000000000285

Koelega, H. S. (1995). Alcohol and vigilance performance: A review. Psychopharmacology, 118(3), 233–249. https://doi.org/10.1007/BF02245951

Kyriakidis, M., de Winter, J. C. F., Stanton, N., Bellet, T., van Arem, B., Brookhuis, K., Martens, M. H., Bengler, K., Andersson, J., Merat, N., Reed, N., Flament, M., Hagenzieker, M., & Happee, R. (2019). A human factors perspective on automated driving. Theoretical Issues in Ergonomics Science, 20(3), 223–249. https://doi.org/10.1080/1463922X.2017.1293187

Landauer, A. A., & Howat, P. (1983). Low and moderate alcohol doses, psychomotor performance and perceived drowsiness. Ergonomics, 26(7), 647–657. https://doi.org/10.1080/00140138308963386

Lenne, M. G., Triggs, T. J., Redman, J. R. (1999). Alcohol, time of day, and driving experience: Effects on simulated driving performance and subjective mood. Transportation Human Factors, 1(4), 331–346. https://trid.trb.org/view/514700

Leung, S., Croft, R. J., Jackson, M. L., Howard, M. E., & Mckenzie, R. J. (2012). A comparison of the effect of mobile phone use and alcohol consumption on driving simulation performance. Traffic Injury Prevention, 13(6), 566–574. https://doi.org/10.1080/15389588.2012.683118

Li, Y. C., Sze, N. N., Wong, S. C., Yan, W., Tsui, K. L., & So, F. L. (2016). A simulation study of the effects of alcohol on driving performance in a Chinese population. Accident Analysis and Prevention, 95, 334–342. https://doi.org/10.1016/j.aap.2016.01.010

Li, Z., Li, X., Zhao, X., & Zhang, Q. (2019). Effects of different alcohol dosages on steering behavior in curve driving. Human Factors, 61(1), 139–151. https://doi.org/10.1177/0018720818791850

Liu, Y. C., & Ho, C. H. (2007). The effects of different breath alcohol concentration and post alcohol upon driver's driving performance. IEEM 2007: 2007 IEEE International Conference on Industrial Engineering and Engineering Management, 505–509. https://doi.org/10.1109/IEEM.2007.4419241

Liu, Y.-C., & Fu, S.-M. (2007). Changes in driving behavior and cognitive performance with different breath alcohol concentration levels. Traffic Injury Prevention, 8(2), 153–161. http://www.informaworld.com/10.1080/15389580601161623

Liu, Y.-C., & Ho, C. H. (2010). Effects of different blood alcohol concentrations and post-alcohol impairment on driving behavior and task performance. Traffic Injury Prevention, 11(4), 334–341. https://doi.org/10.1080/15389581003747522

Marczinski, C. A., Harrison, E. L. R., & Fillmore, M. T. (2008). Effects of alcohol on simulated driving and perceived driving impairment in binge drinkers. Alcoholism: Clinical and Experimental Research, 32(7), 1329–1337. https://trid.trb.org/view/875350

McMillen, D. L., & Wells-Parker, E. (1987). The effect of alcohol consumption on risk-taking while driving. Addictive Behaviors, 12(3), 241–247. https://doi.org/10.1016/0306-4603(87)90034-7

Meda, S. A., Calhoun, V. D., Astur, R. S., Turner, B. M., Ruopp, K., & Pearlson, G. D. (2009). Alcohol dose effects on brain circuits during simulated driving: an fMRI study. Human Brain Mapping, 30(4), 1257–1270. https://doi.org/10.1002/hbm.20591

Mehrabian, A., & Russell, J. A. (1978). A questionnaire measure of habitual alcohol use. Psychological Reports, 43(3 Pt 1), 803–806. https://doi.org/10.2466/pr0.1978.43.3.803

Mets, M. A. J., Kuipers, E., Domis, L. M. de S., Leenders, M., Olivier, B., & Verster, J. C. (2011). Effects of alcohol on highway driving in the STISIM driving simulator. Human Psychopharmacology: Clinical and Experimental, 26(6), 434–439. https://doi.org/10.1002/hup.1226

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., Atkins, D., Barbour, V., Barrowman, N., Berlin, J. A., Clark, J., Clarke, M., Cook, D., D'Amico, R., Deeks, J. J., Devereaux, P. J., Dickersin, K., Egger, M., Ernst, E., … Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Annals of Internal Medicine, 151(4), 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Ou, J., Zhao, X., Mao, K., Zhao, J., Rong, J. (2010). Effects of drinking on driving performance. ICCTP 2010: Integrated Transportation Systems, 253–261). https://trid.trb.org/view/1089746

Proctor, R. W., & Van Zandt, T. (2018). Human factors in simple and complex systems. CRC Press. Retrieved October 25, 2022, from https://www.oreilly.com/library/view/human-factors-in/9781482229592/

Quillian, W. C., Cox, D. J., Kovatchev, B. P., Phillips, C. (1999). The effects of age and alcohol intoxication on simulated driving performance, awareness and self-restraint. Age and Ageing, 28(1), 59–66. https://trid.trb.org/view/652916

Rakauskas, M. E., Ward, N. J., Boer, E. R., Bernat, E. M., Cadwallader, M., & Patrick, C. J. (2008). Combined effects of alcohol and distraction on driving performance. Accident Analysis and Prevention, 40(5), 1742–1749. https://doi.org/10.1016/j.aap.2008.06.009

Ranney, T. A., & Gawron, V. J. (1986). Task demand and alcohol effects on simulated driving performance. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 30(3), 265–269). https://trid.trb.org/view/238006

Rimm, D. C., Sininger, R. A., Faherty, J. D., Whitley, M. D., & Perl, M. B. (1982). A balanced placebo investigation of the effects of alcohol vs. alcohol expectancy on simulated driving behavior. Addictive Behaviors, 7(1), 27–32. https://doi.org/10.1016/0306-4603(82)90021-1

Rohrbaugh, J. W., Stapleton, J. M., Parasuraman, R., Frowein, H. W., Adinoff, B., Varner, J. L., Zubovic, E. A., Lane, E. A., Eckardt, M. J., & Linnoila, M. (1988). Alcohol intoxication reduces visual sustained attention. Psychopharmacology, 96(4), 442–446. https://doi.org/10.1007/BF02180021

SAE International. (2021, May 3). SAE levels of driving automationTM refined for clarity and international audience. https://www.sae.org/blog/sae-j3016-update

Starkey, N. J., & Charlton, S. G. (2014). The effects of moderate alcohol concentrations on driving and cognitive performance during ascending and descending blood alcohol concentrations. Human Psychopharmacology: Clinical and Experimental, 29(4), 370–383. https://doi.org/10.1002/hup.2415

Subramaniyam, M., Kim, S. E., Min, S. N., Lee, H., Hong, S. H., & Park, S. J. (2018). Study of effects of blood alcohol consumption (BAC) level on drivers' physiological behavior and driving performance under simulated environment. International Journal of Engineering and Technology, 7(2), 86–91. https://doi.org/10.14419/ijet.v7i2.8.10336

Tzambazis, K., & Stough, C. (2000). Alcohol impairs speed of information processing and simple and choice reaction time and differentially impairs higher-order cognitive abilities. Alcohol and Alcoholism, 35(2), 197–201. https://doi.org/10.1093/ALCALC/35.2.197

Verster, J. C., Wester, A. E., Goorden, M., van Wieringen, J.-P., Olivier, B., & Volkerts, E. R. (2009). Novice drivers' performance after different alcohol dosages and placebo in the divided-attention steering simulator (DASS). Psychopharmacology, 204(1), 127–133. https://doi.org/10.1007/s00213-008-1443-x

Vollrath, M., & Fischer, J. (2017). When does alcohol hurt? A driving simulator study. Accident Analysis and Prevention, 109, 89–98. https://doi.org/10.1016/j.aap.2017.09.021

Weafer, J., & Fillmore, M. T. (2012). Acute tolerance to alcohol impairment of behavioral and cognitive mechanisms related to driving: Drinking and driving on the descending limb. Psychopharmacology, 220(4), 697–706. https://doi.org/10.1007/s00213-011-2519-6

West, R., Wilding, J., French, D., Kemp, R., & Irving, A. (1993). Effect of low and moderate doses of alcohol on driving hazard perception latency and driving speed. Addiction, 88(4), 527–532. https://doi.org/10.1111/j.1360-0443.1993.tb02059.x

Wickens, C. D., Helton, W. S., Hollands, J. G., & Banbury, S. (2021). Engineering psychology and human performance. In Engineering Psychology and Human Performance. Taylor and Francis. https://doi.org/10.4324/9781003177616/Engineering-Psychology-Human-Performance-Christopher-Wickens-William-Helton-Justin-Hollands-Simon-Banbury

Wiedemann, K., Naujoks, F., Wörle, J., Kenntner-Mabiala, R., Kaussner, Y., Neukum, A., Woerle, J., Kenntner-Mabiala, R., Kaussner, Y., & Neukum, A. (2018). Effect of different alcohol levels on take-over performance in conditionally automated driving. Accident Analysis and Prevention, 115, 89–97. https://doi.org/10.1016/j.aap.2018.03.001

Yadav, A. K., & Velaga, N. R. (2019a). Effect of alcohol use on accelerating and braking behaviors of drivers. Traffic Injury Prevention, 20(4), 353–358. https://doi.org/10.1080/15389588.2019.1587167

Yadav, A. K., & Velaga, N. R. (2019b). Modelling the relationship between different Blood Alcohol Concentrations and reaction time of young and mature drivers. Transportation Research Part F-Traffic Psychology and Behaviour, 64, 227–245. https://doi.org/10.1016/j.trf.2019.05.011

Yadav, A. K., & Velaga, N. R. (2020). Alcohol-impaired driving in rural and urban road environments: Effect on speeding behaviour and crash probabilities. Accident Analysis and Prevention, 140. https://doi.org/10.1016/j.aap.2020.105512

Zhang, X., Zhao, X., Du, H., Ma, J., & Rong, J. (2014). Effect of different breath alcohol concentrations on driving performance in horizontal curves. Accident Analysis and Prevention, 72, 401–410. https://doi.org/10.1016/j.aap.2014.07.032

Zhao, X., Zhang, X., & Rong, J. (2014). Study of the effects of alcohol on drivers and driving performance on straight road. Mathematical Problems in Engineering. https://doi.org/10.1155/2014/607652

Zhong, M. E., Hong, H. C., & Cai, J. J. (2014). Study on changes of vehicle driving behavior characteristics for alcohol used drivers. Advanced Materials Research, 1030–1032, 2115–2120. http://dx.doi.org/10.4028/www.scientific.net/AMR.1030-1032.2115

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