

Can We Design Cars That Prevent Alcohol-Related Collisions?

Reginald G. Smart

Centre for Addiction and Mental Health

Denis Gingras

Université de Sherbrooke

Anne W. Snowdon

University of Windsor

Robert E. Mann and Gina Stoduto

Centre for Addiction and Mental Health

Peter Frise

University of Windsor

Copyright © 2009 SAE International

ABSTRACT

Alcohol-related collisions cause numerous deaths and injuries. The purpose of this paper is to review the technological changes that could be made and are being made that could reduce rates of impaired driving collisions. These can be classified into four categories: 1) interlock systems based on testing drivers' blood alcohol concentration, 2) systems for monitoring driver behaviors such as head and eye or pupil movements, 3) systems that monitor vehicle dynamics and behavior, and 4) remote detection and stopping vehicles technologies. Each of these technologies has some efficiency and uses and varying levels of social and individual acceptance. Innovation may come from looking at novel ways of combining these technological designs to achieve targets to reduce the devastating effects of impaired driving for many communities.

INTRODUCTION

Alcohol involved collisions cause numerous deaths and injuries in all countries where alcohol consumption is common. The Traffic Injury Research Foundation (TIRF,

2005) reports in Canada over 1,000 fatalities each year are the result of alcohol-related collisions. In the United States, about 8,515 drivers are fatally injured and about 17,000 in total occur because of alcohol (Insurance Institute for Highway Safety (IIHS), 2006). Although rates of alcohol-related deaths were declining since 1982, that decline stopped in the late 1990s when a slight increase was seen in the rate of drivers and pedestrians killed in alcohol-related crashes (IIHS, 2006). The continuing trend of alcohol-related collision warrants exploration of innovative design technologies that may reduce the prevalence of drinking and driving and reduce the fatalities associated with impaired driving.

Motor vehicles have not been designed to prevent drinking and driving. However, numerous laws have been introduced to prevent driving after drinking, e.g., breath-testing drivers, license suspensions for drinking driving, impounding a vehicle for driving under suspension. Also, remedial programs for convicted drinking drivers have been instituted in many jurisdictions. In recent years new technologies for cars (e.g., the alcohol ignition interlock) have been considered for use in prevention of impaired driving.

However, these devices were not designed as original equipment for cars. Technologies that prevent all types of collisions have become more common in the past few years. Some motor vehicles have been equipped with electronic stability controls and collision warning systems. Although not designed for this purpose, some of these technologies could prevent alcohol-related collisions.

In-depth studies over many years (Storie, 1975; TIRF, 1975) have established alcohol as a factor in many crashes, especially the more serious crashes. Storie (1975) found that alcohol was involved in 9% of all collisions, 14% of single vehicle crashes and 30% of nighttime crashes. In Canada, 38% of driver fatalities had blood alcohol concentrations (BACs) over 80 mg% (the legal limit), with 27% in multiple vehicle collisions and 53% in single vehicle crashes (TIRF, 1975). More recent statistics (IIHS, 2006) show that 31% of fatally injured drivers had a BAC over 80 mg%. Among those killed in single vehicle nighttime crashes in the U.S., 72% had a high BAC (IIHS, 2006). Studies in other countries have confirmed these findings (Nordzij, 1983; TIRF, 1975; Gjerde et al., 1993) and now single vehicle nighttime fatalities or crashes are viewed as an important indicator of the effect of laws to decrease drinking and driving (e.g., Preusser et al., 1988; Ross, 1982).

Single vehicle roadway departure crashes involve one vehicle running off the road, usually to the right and rolling over, hitting a tree, building or other object. Almost all (95%) of these types of crashes involve excessive speed, poor lane tracking, driver intoxication, excessive evasive measures or some type of driver error or impaired driver condition (Mironer and Hendricks, 1994). Single vehicle crashes are more likely to occur at night. Alcohol involved injured drivers are less likely to be wearing seat belts and are more likely to be traveling at high speeds (Stoduto et al., 1993). The majority of alcohol-related fatalities occur on rural or secondary roads, not well-traveled routes or divided highways (Blatt and Furman, 1998).

Many studies have examined the characteristics of drinking drivers in the general population, drinking drivers involved in collisions, and drivers caught and convicted of a drinking driving offence. While the overlap between these groups is not complete (e.g., Mann et al., 1983), the commonalities are sufficient so that shared characteristics can be described. Drinking drivers are typically male and young to middle-aged. Most are married and employed, and the largest proportion have a high school education (Macdonald and Mann, 1996; Sharpley et al., 2007). As a group, they consume more alcohol than the general population on average; most would be characterized as episodic heavy drinkers, but the prevalence of alcohol dependence appears low (Macdonald and Mann, 1996; Sharpley et al., 2007; Vingilis, 1983).

A typical alcohol-related collision involves a driver and a passenger drinking in a local pub in a small city or town (Blatt and Furman, 1998) who each consume 5 or 6 drinks and leave at midnight to drive home. They travel over unpaved roads because that is convenient or to avoid police. The driver is intoxicated and may be drowsy; he loses control of the car, often on a hill or bend, and runs off the road hitting a tree or building and perhaps rolling over. Neither driver nor passenger are wearing seat belts and are typically taken to hospital with severe or fatal injuries (Stoduto et al., 1993). In order to reduce alcohol-related collisions substantially, methods will have to be found to reduce the number of single vehicle rural crashes. The challenge for public health and for the auto industry is to devise ways of preventing this scenario or at least reducing the resulting injuries. The purpose of this paper is to consider design innovations in motor vehicles with the potential to prevent or reduce drinking-driving collisions. We should note that while vehicle design innovation is an inherently attractive method to reduce deaths and injuries from impaired driving, it is important to recognize that no technological innovation will solve the drunk driving problem by itself. However, with innovation in vehicle design in combination with education, public awareness, legislation and enforcement it is possible that drunk driving injuries and fatalities may be greatly reduced from present levels.

SYSTEMS AND TECHNOLOGIES USED TO PREVENT DRINKING DRIVING COLLISIONS

Many existing automotive technologies may help reduce impaired driving and others could be developed easily with what is already known. Apart from some road infrastructure improvements such as implementing rumble strips everywhere or better road markers, current and future technologies to reduce injuries and fatalities due to alcohol impaired driving can be classified roughly into four categories: 1) interlock systems based on testing drivers' blood alcohol concentration, 2) systems for monitoring driver behaviors such as head and eye or pupil movements, 3) technologies to monitor vehicle dynamics and behavior, and 4) remote detection and stopping vehicles technologies. Each of these technologies has some efficiency and uses and varying levels of social and individual acceptance.

IGNITION INTERLOCK SYSTEMS – The current technologies available are based on the measurement of alcohol from the exhaled breath of the driver, and those based on optical measurement from the skin.

Alcohol ignition interlocks based on breath analysis have been available for about 20 years and are used in many countries in North America and Europe (Bierness and Marques, 2004; Voas and DeYoung, 2002). An alcohol ignition interlock or alcolock is an integrated system for vehicles aimed at preventing drunk or alcohol impaired drivers from starting their engine by measuring the alcohol concentration in the breath of the individual and

by locking the starter, if the alcohol concentration level is over a predefined limited value. They are often mandated for convicted impaired drivers before they can get their licenses back. They resemble a large car phone on a tube and they fit under the dashboard. The driver must blow into the device and the car will not start if the BAC is over 10 mg%, which is equivalent to about 1 or 2 drinks for most people. At random intervals, the device also requires the driver to provide a breath sample while they are driving. The device can only be operated by someone sitting in the driver's seat and not by passengers.

One automotive manufacturer, Volvo, introduced in 2005 an alcolock system built into the seat belt (Alcolock News, 2005). When one enters a car with an integrated alcohol interlock system the driver is prompted to execute the process of alcohol measurement by using the integrated handheld device immediately before turning the key. If the alcohol concentration is below the predefined limiting value the control unit will unlock the starter. If the alcohol concentration exceeds the limit, the starter will stay locked and the car cannot be started.

Blood ethanol (i.e., alcohol) concentration can be determined from its concentration in breath (Mizohata, 1983); a blood-breath alcohol partition ratio of 2000 is widely adopted (Sato and Kitagawa, 1993). The permissible legal limit of blood ethanol for driving in most countries is 50-80 mg%, which corresponds to 130-208 ppm in human breath (Park et al., 1999). Generally, reliable sensors that can detect breath ethanol concentration ranging from 20-800 ppm are required for the rapid assessment of drunken driving. Many types of gas sensors have been investigated and developed (Garzella et al., 2002; Brousse and Schnleich, 1996). The detection of breath ethanol has generally been performed by gas sensors based on a chemically sensitive semiconductor. To evaluate breath analysis sensors, we need to consider metrics such as sensitivity, calibration behavior and selectivity. Considerable effort has gone into improving the ethanol selectivity and sensitivity of semi-conductor type gas sensors (Maekawa et al., 1992; Liewhiran et al., 2007). Semiconductor sensors are, however, still at present inadequate for sensing multi-analyte samples such as human expiratory gas, because the sensor response is based on only changes in electrical conductivity of the device following adsorption of gaseous substances (Mitsubayashi et al., 2004; Maekawa et al., 1992). This has translated thus far into extremely poor selectivity of such devices. However, improvement in semiconductor based-sensors for gaseous ethanol has been reported recently (Liewhiran et al., 2007) using flame made ZnO nanoparticles as sensing mechanism of semiconducting material printed on Al₂O₃ substrate interdigitated with Au electrodes. It has been reported that a thick (5 nm) ZnO film-based sensor showed high sensitivity and fast response times. The sensitivity increased and the response time decreased with increasing ethanol concentration. However, the current sensors provide a selectivity still far lower than the selectivity achievable using biological recognition systems, such as enzymes.

Among the proposed breath analysis sensors based on enzymes, a stick-type bio-electronic sniffer using the enzyme catalytic reaction for measurement of gaseous ethanol has been proposed (Mitsubayashi, 2004). The sensor has dimensions of 70 mm x 2.0 mm and was constructed in a sandwich configuration with a filter paper placed between carbon- and Ag/AgCl electrodes by immobilizing an alcohol oxydase. The calibration range for ethanol vapor covered the concentration range encountered in breath after alcohol consumption including the permissible legal limit of 130 ppm for driving, and the sensing range of smell in humans. This type of sensors has been reported to be much more selective and accurate than semiconductor based sensors.

The i-Key™ is a commercial product proposed by Champion Technology (2004) that is based on breath analysis, where the sensing module is integrated into the car key. Implementing the alcohol test into the key avoids the need for modification of the vehicle and therefore makes the technology independent of the body of the vehicle. According to the company, the device integrates a breath analyzer to any car key and can function regardless of the type of vehicle. The key has a protruding interlock that blocks entry to the ignition and retracts once a breath sample under the legal limit has been analyzed. The driver needs to blow into a small mouthpiece on the side of the key to get the "green light" to start the car engine. If the alcohol level exceeds the legal limit, a red light will show and the interlock will disable the car key. Despite its simplicity, no information is available about the sensitivity of the device and the problem of driver identification remains unresolved. Indeed it is rather easy to let someone else blow into the key to cheat the interlock system.

First time offenders in Canadian provinces must use interlocks for one year, and longer if they are repeat offenders, in order to get their driver's license back. Reconviction rates are very low for drivers using interlock devices because they do prevent drinking and driving while they are being used (Voas and De Young, 2002). However, they have no long-term beneficial effect. After they are disconnected, rates of drinking driving reconviction return to normal. Interlocks are an engineering success but are a very clear example of the failure of any technology that attempts to control human behavior. Studies indicate that very few drivers who should use them actually do (e.g., Voas et al., 1999). In Alberta, only 8.9% of convicted impaired drivers actually had them installed (Voas et al., 1999). They are expensive for drivers, currently about \$1500 for one year. They require maintenance and calibration, plus the breath test results must be gathered at regular intervals. Interlocks are also problematic due to social desirability. Since the majority of these drivers do not want others to know about prior convictions for impaired driving, a