Driver Distraction: A Review of the Literature and Recommendations for Countermeasure Development

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Biography
Michael Regan is a Senior Research Fellow with BSC(Hons) and PhD degrees in psychology and ergonomics/human factors from the Australian National University. His main research interests at present are in the areas of intelligent vehicle technologies and driver distraction. Michael is the Australian Representative on International Organization for Standardisation (ISO) Technical Committee 22, Sub-Committee 13, which develops international standards for the ergonomic design of vehicle cockpits.

Abstract
This paper reviews current research on in-vehicle driver distraction. The role of distraction in road crashes in Australia is discussed and, in the final section of the paper, recommendations for future research and for the management of driver distraction in Australia are provided.

1. INTRODUCTION

Anything that distracts a driver from the primary driving task has the potential to compromise safety. Distraction can derive from events occurring inside or outside the vehicle. Those occurring inside the vehicle, which are the focus of this paper, include the performance of everyday activities such as eating, and distractions arising from interaction with an ever-increasing range of communication (e.g. mobile phone, internet), entertainment (e.g. radio) and advanced driver assistance systems (e.g. in-vehicle navigation systems) which are entering the vehicle market. There is converging evidence that these in-vehicle sources of distraction are, to varying degrees, capable of degrading driving performance and compromising safety. The research, reviewed in this paper, has prompted some overseas authorities to develop countermeasures to manage the risk associated with distraction. Despite the evidence, however, driver distraction is not an issue currently on the Australian road safety agenda. Perhaps this is not surprising - there has been almost no research conducted here to quantify the increased risk associated with driver distraction and to measure the prevalence of driver involvement in distracting activities. There may also be a lack of awareness among the road safety community of the research literature linking driver distraction with degraded driving performance.

The purpose of this paper is to review what is known about the effects on driving performance and safety of distraction from within the vehicle. The role of distraction in road crashes in Australia is then discussed and, in the final section of the paper, recommendations are made for managing the risks associated with driver distraction in Australia.

2. WHAT IS DRIVER DISTRACTION?

The American Automobile Association defines driver distraction as occurring "when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object or person within or outside the vehicle compelled or tended to induce the driver's shifting attention away from the driving task." (Stutts et al., 2001).

According to the National Highway Traffic Safety Administration (NHTSA) there are four distinct, although not mutually exclusive, forms of driver distraction: visual, auditory, biomechanical (physical) and cognitive. Visual distraction occurs when the driver neglects to look at the road and instead focuses his/her attention on another visual target for a period of time. Auditory distraction occurs when the driver focuses their attention on auditory signals rather than on the road environment. Biomechanical distraction occurs when drivers remove one or both hands from the steering wheel to physically manipulate an object. Cognitive distraction includes any thoughts that absorb the driver's attention to the point where they are unable to navigate through the road network safely.

2.1 Technology-based distraction

Mobile Phones

There have been many studies of the impact of mobile phone usage on driving performance (Goodman et al. 1997). Findings from these suggest that using a hand-held phone degrades driving performance significantly. Many have found that the visual, physical and cognitive distraction caused by using a hand-held mobile phone while driving can impair a driver's ability to maintain speed, throttle control and lateral position on the road (Green et al., 1993; Reed et al., 1999). Distraction also impairs drivers' visual search patterns, reaction times, and decision-making processes and can increase the risk of being involved in a collision by up to four times (Harbluk & Noy, 2002; Redelmeier & Tibshirani, 1997). In response to these research findings, many countries, including Australia, have prohibited the use of hand-held mobile phones while driving (Goodman et al., 1997; Matthews et al., 2002).

Hands-free mobile phones were developed to reduce, or even eliminate, the physical distraction caused by handling the phone while driving (Wheatley et al., 2000). However, it is not just the physical distraction derived from handling the phone which may compromise safety. Many studies have found that using a hands-free phone while driving is no safer than using a hand-held phone (Haigney et al., 2000; Redelmeier & Tibshirani, 1997). Redelmeier and Tibshirani, for example, examined whether using a mobile phone while driving increases the risk of being involved in a vehicle crash and whether hands-free phones offer any safety advantages over hand-held phones. Their results revealed that the risk of being involved in a vehicle crash while using a mobile phone was four times greater than the risk among the same drivers when they were not conversing on a phone. Moreover, the authors observed no safety advantages of using a hands-free phone as opposed to a hand-held mobile phone while driving. The authors concluded that their results did not support the policy being adopted in many countries of prohibiting the use of hand-held, but not hands-free, mobile phones while driving. More recent studies by Haigney et al. and Matthews et al. reveal similar results.

Text Messaging

Very little research has been conducted on the distracting effects of sending or receiving text messages while driving. An Australian survey, commissioned by Telstra, found that one in six drivers regularly send text messages while driving (Telstra, 2003). Such a high prevalence of text messaging while driving is disturbing, given that the physical, visual and cognitive distraction associated with text messaging while driving is likely to be far greater than that associated with simply talking on a hand-held phone (Direct Line, 2002).

In-vehicle Navigation Systems

In-vehicle navigation systems are now available in Australia in some luxury vehicles and rental cars. Drivers program a destination into the system and it automatically plots the route to that destination and issues turn-by-turn instructions (voice instructions or instructions presented on a visual display screen) on how to reach it (Farber et al., 2000).

A major concern with using navigation systems while driving is the task of entering destination information. Various methods exist for doing so: selecting the required destination from a scrolling list of suburb and street names; manually typing in the number, street and suburb of the destination letter by letter; or using voice input to enter the destination details (Tijerina et al., 1998). The relative benefits of using voice rather than manual input for navigation systems has become a major focus of distraction research. Research by Tijerina and colleagues (1998) revealed that visual-manual destination entry is associated with longer completion times, longer eyes-off-road times, more frequent glances at the device, and a greater number of lane exceedences compared to voice activated systems. The authors conclude that navigation systems with voice recognition technology are a more viable and safer option than systems requiring visual-manual entry.

Once a driver has entered the destination information and is en route, the navigation system issues navigation instructions to the driver. This information can be presented using a visual display and/or computer-generated voice messages. In the case of visual displays, information can be presented either as an electronic map (similar to a conventional map), or as a turn-by-turn display. Studies have examined and compared the relative distracting effects of the various forms of presenting navigation information. One of these was conducted by the NHTSA (Dingus et al., 1995). Four different navigation conditions were examined: turn-by-turn navigation screens with and without voice guidance and electronic route map with and without voice guidance. Two control conditions, written directions and a conventional paper map, were also examined. Results revealed that the turn-by-turn navigation screen with voice guidance provided the best performance with regard to usability, safety and attentional demand. The voice-guided, turn-by-turn, system was also less distracting than using a conventional paper map, resulting in less abrupt braking manoeuvres and lower workload ratings. These results suggest that, if properly designed, in-vehicle navigation systems may be less distracting than conventional navigation using paper maps, although there are other issues which must be considered in determining the net safety outcomes associated with use of these systems (Regan et al., 2001).

In-vehicle Email and Internet Facilities

Email and Internet systems are not yet available in production vehicles in Australia. These will enable the driver to download traffic updates and weather reports to improve traffic flow, obtain information on parking availability and to access emails and web information (Burns & Lansdown, 2000). Lee et al. (2001) used a driving simulator to examine the effects of a speech-based email system (in which email messages were accessed, read and replied to using only voice commands) on drivers' attention and their reaction time to a braking lead vehicle. When interacting with the speech-based email system, regardless of the complexity of the system, drivers' reaction time to the braking vehicle was 30% longer than when not interacting with the system. Moreover, this 30% increase in reaction time translated into a 3.5 to 38.5% increase in collisions and 27.3 to 80.7% increase in collision velocity. Interaction with the speech-based email system also increased drivers' self-reported workload levels and this was highest for the complex email system.

Radios and Compact Disk (CD) Players

Despite being equipped to almost every Australian car, surprisingly little research has directly examined the distracting effects of interacting with, or listening to, car radios. Overseas research suggests that simply listening to radio broadcasts while driving can impair driving performance, resulting in more lane deviations, particularly under complex driving conditions (Jancke et al., 1994). Also, while several studies have found that tuning the radio is less distracting than dialling or talking on a mobile phone (McKnight & McKnight, 1993; Strayer et al., 2002) or operating a navigation system (Tijerina et al., 1998), numerous other studies have found that tuning a radio degrades driving performance more than holding a simple conversation on a mobile phone, particularly when driving in adverse conditions (Briem et al., 1995; Wikman et al., 1998). An on-road study conducted by Wikman et al. examined the allocation of visual attention of experienced and inexperienced drivers as they tuned a radio,

changed a cassette and dialled a mobile phone while driving. Results revealed that drivers spent greater lengths of time glancing away from the road when tuning the radio than when dialling the phone. Changing cassettes resulted in the shortest glance durations away from the road. Compared to the experienced drivers, novice drivers made more glances away from the road, which were associated with large deviations in lane position, suggesting that tuning a radio while driving appears to have a detrimental effect on driving performance, particularly for inexperienced drivers.

In-car CD players are also a common feature in many Australian cars, yet few studies have examined the distracting effects of using these systems while driving. In a study by Jenness et al. (2002), participants drove while eating a cheeseburger, reading directions, using a voice-activated or manual-dial system to place calls on a mobile phone, or continuously operating a CD player. The results indicated that participants made more lane deviations and glances away from the road and took the longest amount of time to complete the trials when operating the CD player, than when eating or dialling numbers on a mobile phone. However, recent evidence suggests that the use of voice-activation may minimise the distraction associated with using CD players while driving (Gartner et al. 2002).

Television, Video and DVD

Rear seat television/video/DVD systems are currently among one of the best selling in-car devices on the market in the United States (Technical Insights, 2001). These systems are now also available in some Australian cars. No research, to the knowledge of the authors, has examined the influence of these systems on driver performance. Although legislation already in place in Australia prohibits television and video/DVD systems from being mounted in the vehicle where the driver can view them while they are driving, it is likely that televisions and video/DVD systems could create an auditory and cognitive distraction as drivers try to 'listen in' to programs.

Portable Devices

There is an emerging trend towards the provision of services to the driver through portable devices such as the mobile phone or pocket PC. In Europe, for example, it is possible to access internet services, navigation assistance and entertainment information through a pocket PC or mobile telephone. These services can be expected to be available in Australia shortly. Currently, there are no guidelines, standards, or regulations in Australia governing the use of portable devices used for these purposes whilst driving.

2.2 Non-technology based distraction

Drivers often engage in a number of non technology-based activities, such as eating, drinking, smoking and interacting with passengers, that have potential to distract them. Eating and drinking are deemed legally in Australia as acceptable activities while driving, however they can create a physical and visual distraction. A recent study by Stutts et al. (2001) revealed that a greater proportion of drivers involved in traffic accidents are distracted by eating or drinking (1.7%) than by talking on a mobile phone (1.5%). Another study (Jenness et al. 2002) found that eating a cheeseburger was as distracting as using a voice-activated dialling system, but less distracting than continuously operating a CD player. Studies have also found that smoking while driving increases the risk of being involved in a crash (Brison, 1990; Christie, 1991). The association between smoking and increased crash risk could be the result of one or more of three factors: distraction caused by smoking, behavioural differences between smokers and non-smokers, and carbon-monoxide toxicity.

The potentially distracting effects of passengers are less well understood. Research on teenage passengers has revealed that their presence increases crash risk, particularly for young drivers, due to distraction and/or increased risk-taking (Williams, 2001). In a study by Regan and Mitsopoulos (2001), some participants reported that the presence of passengers

distracting them to the point where they were less likely to detect traffic light changes or road signs.

3. THE ROLE OF DRIVER DISTRACTION IN ROAD CRASHES IN AUSTRALIA

The extent to which distraction is a road safety problem in Australia is a function of both the increased risk associated with distraction and the prevalence of distraction while driving. There is some limited research currently being conducted in Australia by the University of Western Australia Department of Public health Injury Research Centre examining the increase in crash risk associated with distraction deriving from within and outside the vehicle (see www.irc.uwa.edu.au). The results of this study are not yet available. Research conducted in the U.S., however, has found that using a mobile phone while driving can increase the risk of having a crash by up to four times (Redelmeier & Tibshirani, 1997) and that interacting with an email system can lead to a 3.5% to 38.5% increase in crashes (Lee et al., 2002).

While there has been no systematic investigation of the prevalence of distraction while driving in Australia, limited survey evidence suggests that around one-third of mobile phone users regularly use hand-held phones while driving and one in six drivers send text messages while driving (Telstra, 2003). However, no information is available regarding the prevalence of other distracting tasks. Prevalence data from overseas studies suggests that, of the drivers involved in a distraction-related crash, 11.4% of drivers were distracted by the radio or CD, 1.7% were distracted by eating or drinking and 1.5% were distracted by using a mobile phone (Stutts et al., 2001).

The number of crashes in Australia for which distraction is a contributing factor is not known. Not all Police crash report forms have provision for recording the presence of distraction. Even where this provision exists, however, it can be unclear whether distraction played a role in the crash or was merely present. Where the presence of distraction can be noted but is not, this is not equivalent to recording the absence of distraction.

Given the increased crash risks and high prevalence of crashes associated with distraction demonstrated by overseas studies, and given that the effects of distraction on driving performance can be expected to be universal across jurisdictional boundaries, there is reason to believe that distraction is a significant contributing factor to crashes in Australia.

4. CONCLUSION AND RECOMMENDATIONS

In summary, there is converging evidence that driver distraction contributes to road trauma and that the prevalence of distraction as a risk factor will increase as new technologies proliferate the market. It is important, therefore, that policies and programs are developed and implemented in Australia to manage existing and emerging risks associated with driver distraction. The following countermeasures are recommended.

Research

- A carefully designed study of the prevalence of driver involvement in distracting activities within the vehicle should be undertaken. This information, combined with the epidemiological data from the previously mentioned Western Australian study, will enable an initial assessment of the magnitude of the problem in Australia to be made. If driver distraction is shown to be a significant problem, then better recording by Police of the role of distraction in crashes will be needed.
- An inventory of existing and emerging technologies and services which can be accessed on-board the vehicle or through portable devices within the vehicle should be compiled. The potentially distracting effects of these technologies and services should be established where these have not already been established.

- Research is required to better understand drivers' willingness to engage in potentially distracting tasks while driving, the factors that influence this willingness and under what conditions drivers engage in distracting tasks.
- There is currently little knowledge regarding how drivers use in-vehicle technologies: whether they use them in the manner intended by the designer; and at what point (or threshold) and under what conditions they become a distraction.
- Research needs to be conducted into whether and how individual difference factors such as age, gender, driving skill and experience influences the ease with which drivers are distracted.
- To complement the above activities, research is needed to identify and quantify the distracting effects of objects and events occurring outside the vehicle. Some research on this issue is being undertaken by the Monash University Accident Research Centre and this should be closely monitored.
- No research, to the knowledge of the authors, has examined the potentially distracting effects of portable devices used by pedestrians and other road users (e.g., mobile telephones, pedestrian navigators) to access information and services when negotiating their way through the road system.

Education and Training

- A good deal is already known about the risks associated with engaging whilst driving in various distracting activities. It is important that these are brought to the attention of drivers and passengers. As a matter of priority, it is important to make the motoring public aware that hands-free mobile phones can be just as distracting as hand-held phones.
- As with the use of mobile phones, drivers must be educated and trained in the optimal manner in which to interact with existing and emerging on-board technologies and services accessed through portable devices in order to minimise distraction.
- Where there is flexibility in the manner in which these devices can be operated (there are, for example, many ways to tune and select a radio station), user manuals and tutorials provided by vehicle manufacturers and service providers should point out the most ergonomic and least distracting methods for doing so.

Legislation and Enforcement

- Existing legislation should be reviewed and, where necessary, new legislation created to limit driver exposure to, and deter drivers from engaging in, activities which have the potential to distract them. There is sufficient evidence, for example, to justify a ban on the use of hands-free phones whilst driving if this can be practically enforced by the Police.

Vehicle Design

- The most effective way to minimise technology-based distraction is to design the Human Machine Interface (HMI) ergonomically. In Europe, North America and Japan, draft standards have already been developed which contain performance based goals which must be reached by the HMI so that the in-car technologies do not distract or visually entertain the driver while driving (e.g., the European Statement of Principles for Driver Interactions with Advanced In-vehicle Information and Communication systems). It is important that the development of these standards be closely monitored by relevant authorities in Australia and that local vehicle manufacturers and system developers are encouraged to refer to these standards in designing their systems.
- The operation of certain devices including mobile phones and route guidance systems often involves associated tasks such as accessing written information, which can further distract the driver. There is a need for research to develop the HMI so that it eliminates the need for these associated tasks.

Licensing

- Handbooks for learner and probationary drivers should draw attention to the potential risks associated with engaging in distracting activities within the vehicle.
- Knowledge tests should include items pertaining to the relative risks associated with engaging in these activities.
- Where appropriate, the graduated licensing system should be used to restrict driver exposure to distracting activities that are known to compromise safety. The findings presented here, for example, suggest that there is a case for restricting Probationary drivers from using (but not carrying) mobile phones while driving during some or all of the P-period.

The overall costs and benefits afforded by various technologies must be assessed before restricting or prohibiting drivers from engaging in distracting tasks while driving. Listening to a radio broadcast, for example, might be distracting: yet, for a truck driver, this activity might be beneficial in maintaining vigilance. The issues are complex, but fortunately we are at an early enough stage in the evolution of distraction to prevent it from becoming a major road safety problem.

References

Briem, V., & Hedman, L.R. (1995). Behavioral effects of mobile telephone use during simulated driving. *Ergonomics, 38*, 2536-2562.

Brison, R.J. (1990). Risk of automobile accidents in smokers. *Canadian Journal of Public Health, 81*, 102-106.

Burns, P.C., & Lansdown, T.C. (2000). *E-distraction: The challengers for safe and useable internet services in vehicles*. www.nrd.nhtsa.dot.gov.

Christie, R. (1991). *Smoking and traffic accident involvement: A review of the literature*. GR/91-3. VicRoads, Victoria.

Dingus, T., McGehee, D., Hulse, M., Jahns, S., & Manakkal, N. (1995). *Travtrek evaluation task C3 – Camera Car study*. Report FHWA-RD-94-076. Office of Safety and Traffic Operations, McLean, VA.

Direct Line (Motor Insurance). (2002). *The Mobile Phone Report*. Direct Line Insurance, UK.

European Commission. (2001). *Report of the expert group on the expansion of the principles on human machine interface for in-vehicle information and communication systems.*

Farber, E., Foley, J., & Scott, S. (2000). *Visual attention design limits for ITS in-vehicle systems: The Society of Automotive Engineers standard for limiting visual distraction while driving*. Transportation Research Board Annual General Meeting, Washington DC.

Gartner, U., & Konig, W., & Wittig, T. (2002). *Evaluation of manual vs. speech input when using a driver information system in real traffic*. http://ppc.uiowa.edu/

Goodman, M. J., Bents, F. D., Tijerina, L., Wierwille, W., Lerner, N., & Benel, D. (1997). *An investigation of the safety implications of wireless communication in vehicles*. Department of Transportation, NHTSA, Washington, DC.

Green, P., Hoekstra, E., & Williams, M. (1993). *Further on-the-road tests of driver interfaces: examination of a route guidance system and car phone.* Report UMTRI-93-35. University of Michigan Transportation Research Institute, Ann Arbor, MI.

Haigney, D.E., Taylor, R.G., & Westerman, S.J. (2000). Concurrent mobile phone use and driving performance: task demand characteristics and compensatory processes. *Transportation Research Part F, 3*, 113-121.

Harbluk, J.L., & Noy, Y.I. (2002). *The impact of cognitive distraction on driver visual behaviour and vehicle control.* Transport Canada.

Jancke, L., Musial, F., Vogt, J., & Kalveram, K.T. (1994). Monitoring radio programs and time of day affect simulated car-driving performance. *Perceptual Motor Skills, 79*, 484-486.

Jenness, J.W., Lattanzio, R.J., O'Toole, M., & Taylor, N. (2002). Voice-activated dialling or eating a cheeseburger: Which is more distracting during simulated driving? *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting.*

Lee, J.D., Caven, B., Haake, S., & Brown, T.L. (2001). Speech-based interaction with in-vehicle computers: The effects of speech-based E-mail on drivers' attention to the roadway. *Human Factors 45*, 631-639.

Matthews, R., Legg, S., & Charlton, S. (2002). The effect of cell phone type on drivers subjective workload during concurrent driving and conversing. *Accident Analysis and Prevention*. In Press.

McKnight, A.J., & McKnight, A.S. (1993). The effect of cellular phone use upon driver attention. *Accident Analysis and Prevention, 25,* 259-265.

Redelmeier. D. A., & Tibshirani. R. J. (1997) Association between Cellular Telephone Calls and Motor Vehicle Collisions. *The New England Journal of Medicine, 336(7*), 453-458.

Reed, M.P., & Green, P.A. (1999). Comparison of driving performance on-road and in low-cost simulator using a concurrent telephone dialling task. *Ergonomics, 42*, 1015-1037.

Regan, M.A., & Mitsopoulos, E. (2001). *Understanding passenger influences on driver behaviour: implications for road safety and recommendations for countermeasure development*. Report 180. MUARC.

Regan, M.A., Oxley., J.A., Godley, S.T., & Tingvall, C. (2001). *Intelligent Transport Systems: Safety and human factors issues*. Royal Automobile Club of Victoria Report 01/01. Melbourne, Australia: RACV.

Strayer, D.L., Drew, F.A., Albert, R.W., Johnston, W.A. (2002). *Cell phone induced perceptual impairments during simulated driving*. University of Utah. http://ppc.uiowa.edu/

Stutts, J.C., Reinfurt, D.W., Staplin, L., & Rodgman, E.A. (2001). *The role of driver distraction in traffic crashes*. Report prepared for AAA Foundation for Traffic Safety.

Technical Insights. (2001). *Human-vehicle interface*. Report No. 003. Technical Insights.

Telstra. (2003). *Telstra, Police and NRMA Insurance join forces to target mobile phone use on Australian Roads*. Telstra News Release. www.telstra.com.au/newsroom.

Tijerina, L., Johnston, S., Parmer, E., Winterbottom, M.D., & Goodman, M. (2000). *Driver distraction with wireless telecommunications and route guidance systems*. DOT HS 809-069. NHTSA, Washington, DC.

Tijerina, L., Parmer, E., & Goodman, M.J. (1998). Driver workload assessment of route guidance system destination entry while driving: A test track study. *Proceedings of the 5th ITS World Congress, Seoul, Korea.*

Wheatley, D.J. (2000). *The driving need for human factors in the car of the future*. Society of Automotive Engineers.

Wikman, A-S., Nieminen, T., & Summala, H. (1998). Driving experience and time sharing during in-car tasks on roads of different width. *Ergonomics, 41*, 358-372.

Williams, A.F. (2001). *Teenage passengers in motor vehicle crashes: A summary of current research.* Insurance Institute for Highway Safety, Arlington, VA.

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