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The Naturalistic Driver Model: A Review of Distraction, Impairment and Emergency Factors

Authors
Caird, J.K.
Lees, M.
Edwards, C.

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CALIFORNIA PATH PROGRAM
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J.K. Caird
M. Lees
C. Edwards

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The Naturalistic Driver Model: A Review of Distraction, Impairment and Emergency Factors

by

J.K. Caird, M. Lees & C. Edwards

Cognitive Ergonomics Research Laboratory

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Project Title:	**The Naturalistic Driver Model: Development, Integration, and Verification of Driver Emergency and Impairment Modules**
Principal Investigator, **Mailing Address *(include institution)*** **Telephone** **Fax** **E-mail:**	**Delphine Cody** **California PATH program – UC Berkeley** **Richmond Field Station, Bldg. 452** **1357 S. 46th street** **Richmond, CA 94804** **510 231 9455** **510 231 9565** **cody@PATH.Berkeley.EDU**
Other Investigators, **Mailing Address *(include institution)*** **Telephone** **Fax** **E-mail**	**J.K. Caird** **University of Calgary** **2500 University Drive N.W.** **Calgary, Alberta T2N 1N4 Canada** **(403) 220-5571** **(403) 282-8249** **jkcaird@ucalgary.ca**
Submitting Unit; Institution/Address:	**California PATH program – UC Berkeley** **Richmond Field Station, Bldg. 452** **1357 S. 46th street** **Richmond, CA 94804**
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1. INTRODUCTION

1.1 Project Overview

The purpose of this project is to review the literature on driver distraction, impairment and emergency response that supports the development of the Naturalistic Driver Model. Driver models that are based on high-quality empirical research are more likely to serve as a useful and valid tool to professionals and researchers.

1.2 Project Objectives

The objectives of this review were to:

1. Generate an extensive literature review that identifies the extent that driver distraction and impairment affects reaction time, lateral and longitudinal vehicle control and other variables.

2. Review emergency responses in a variety of situations and determine their implications for lane change, car following and merging.

3. Synthesize the results on reaction time so that a range of values that can be incorporated into a driver model.

1.3 Project Scope

This technical report is structured into sections on driver distraction, driver impairment and emergency response. Within each section, prior literature reviews and recent empirical research is reviewed. Each of these areas has large bodies of literature. A certain proportion of it is methodologically and/or statistically flawed. Limitations of interpretation of the research are presented. Appendices A through C provide extensive details about each of the studies that were selected and reviewed in each area. Values for inclusion in a driver model and conclusions are set forth in the final section.

2. DRIVER DISTRACTION

2.1 Introduction

Concern about the contribution of driver distraction to crashes is not new. In one of the most comprehensive crash investigations ever conducted, Treat (1980) identified inattention and internal distraction as driver error causal factors. These factors are highlighted in Table 1 and represent errors associated with driver distraction. Inattention is defined as "a non-compelled diversion of attention from the driving task", whereas an internal distraction was defined as a "diversion of attention from the driving task that is compelled by an activity or event inside the vehicle" (Treat, 1980, p. 9). For example, Treat (1980) mentioned that during the data collection, from 1972 to 1975, there was an increase in accidents caused, in part, by 8-track and cassette players which represent a distraction within the vehicle. Historically, some activities such as adjusting the radio are well known to be distracting (cf., Goodman et al., 1997).

Table 1. Driver error causal factors in crashes (from Treat, 1980, Figure 4, p. 9).

Causal Factor	Definite	Probable
Improper Lookout	17.6	23.1
Excessive Speed	7.9	16.9
Inattention	**9.8**	**15.0**
Improper Evasive Action	4.8	13.3
Internal Distraction	**5.7**	**9.0**
Improper Driving Technique	6.0	9.0
Inadequate Defensive Driving Technique	2.4	8.8
False Assumption	4.5	8.3
Improper Manoeuvre	5.0	6.2
Overcompensation	3.3	6.0

The importance of the volumes of analysis produced by Treat et al. (1979) is that they established the relative contribution of the driver, vehicle and environment to crashes. Various factors were classified as "definite" (95% confidence) or "probable" (80% confidence) causes (see Table 1), where a causal factor indicates that the crash would not have occurred had the factor not been present. A primary conclusion was that human errors (70.7%) contributed significantly more to traffic accidents than did environmental (12.4%) and vehicle (4.5%) factors. (In 20% of cases, a definitive causal classification into driver, environment and vehicle could not be made.) The in-depth analyses revealed that human causal factors contributed from 70.7 to 92.6 percent (definite - probable) of crashes. Typically, 90 percent of crash causes are attributed to the driver as driver error without reference to the source.

In a study that emphasized visual distractions, Wierwille and Tijerena (1996) used a key word search of the North Carolina accident database for 1989 and one third of 1992 (also see Goodman et al., 1997). A set of object words was used to search accident narratives for instances where attention was drawn inside the vehicle, outside or in an unspecified manner. To be included in the classification scheme, two criteria were used. First, vision was directed in some way by the object from the forward view and second, visual allocation of attention was the primary cause of the accident. Overall, more cellular phone and fewer CB radio accidents occurred in 1992 than 1989, which is in accord with expected usage patterns. Radio, two-way radio (CB), HVAC, instrument, seat-belt, mirrors, reading in the vehicle, visual occlusion, and interaction with a person or animal formed the primary categories of attention errors. Those objects that required immediate attention, such as waving away a wasp or getting a guinea pig from underneath the accelerator, were particularly distracting.

Using a similar means to describe the degree to which driver distraction contributes to crashes, Stutts et al., (2001) used data from the National Accident Sampling Sytem (NASS) Crashworthiness Data System (CDS) for the years 1995 to 1999. Further, they defined driver distraction as "…when the 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 compels or induces the driver's shifting attention away from the driving task" (Stutts et al., 2003, pg. 3). They found that at the time of a crash 8.3% of drivers were distracted. The object(s) of distraction are shown in the category listings of Table 2. The re-direction of attention away from driving, to a large variety of objects within and outside of the vehicle, is evident.

Table 2. Driver distraction categories and overall percent (standard errors) for each category (based on Table 3, weighted CDS data, Stutts et al., 2001, pg. 11). To further illustrate the categories, narrative examples from Table 15 (pp. 26-27 of Stutts, et al.) are also included.

Driver Distraction	**Overall (N = 1,420K)**
Outside person, object, or event (e.g., vehicle, police, animal, novel events, people or objects in the road, etc.)	**29.4** (2.4)
Adjusting radio/cassette/CD	**11.4** (3.7)
Other occupant (e.g., talking, yelling, fighting, child, infant)	**10.9** (1.7)
Moving object in vehicle (e.g., insects, animals, objects)	**4.3** (1.6)
Other device/object (e.g., purse, water bottle, etc.)	**2.9** (0.8)
Adjusting vehicle/climate controls	**2.8** (0.6)
Eating/drinking (e.g., burger, tea, coffee, soda, alcohol, etc.)	**1.7** (0.3)
Talking/listening/dialing cell phone (e.g., answer, initiate call)	**1.5** (0.5)
Smoking related (e.g., reaching for, lighting, dropping, etc.)	**0.9** (0.2)
Other distraction (e.g., medical, other inside or outside events or objects, intoxicated, depressed, etc.)	**25.6** (3.1)
Unknown distraction	**8.6** (2.7)

2.2 Distraction from Cellular or Mobile Phones

Although cellular or mobile phones are not the largest contributor to distraction-related crashes (see Table 2, highlighted category), cell phone use by drivers has attracted considerable media attention. In addition, a modest body of research has emerged. Research that addresses the performance impact of cellular phone use while driving provides some insight into the biomechanical, visual and cognitive sources of distraction that other categories may share. A general introduction to this literature is given prior to an in-depth critique of driver performance research.

In general, the safety of using cellular, wireless or mobile telephones while driving has become a concern of individuals, governments, and corporations around the world. In North America, most of us have had to compensate for drivers engrossed in mobile phone conversations who appear to be oblivious to the movement of other vehicles around them. Hand-held mobile phones have been banned in a number of countries world-wide including U.K., Japan and Australia (Goodman et al., 1997), but they have not been in most Canadian provinces (except New Foundland) and U.S. states (except New York). Most state legislatures have debated the merits of legislation aimed at addressing cell phone use while driving (e.g., Sundeen, 2003).

The relative crash risk of a driver was found to increase if cell phones are used while driving (Redelmeier & Tibshirani, 1997), and more so as the frequency of phone use increases (Laberge-Nadeau et al., 2003). Additional epidemiological studies, that are immune to a number of methodological and statistical flaws, are needed to provide convergent evidence about crash risk (cf., Maclure & Mittleman, 1997; Redelmeier & Tibshirani, 2001).

At a driver performance level of analysis, a number of specific tasks; namely, answering a phone (e.g., retrieving it from a purse), dialing, talking and hanging up, have been implicated in crashes (Goodman et al., 1997; Redlmeier & Tibshirani, 1997). Banning hand-held phones while driving is based, in part, on epidemiological (Goodman et al., 1997) and performance (Stein et al., 1987; Zwalen et al., 1988) research that indicates dialing numbers while driving may take the eyes off the road. The crash potential of taking the eyes off the road to answer the phone or dial a number is somewhat self-evident. However, the effect that either hand-held or hands-free phone *conversation* has on driver performance is not as well understood and has been the focus of more recent human factors research activity (Ålm, & Nilsson, 1995; Cooper et al., 2003; Laberge et al., in press; Recarte & Nunes, 2003; Strayer et al., 2003). Cognitive distraction, or mind off the road, is more difficult to explain to legislators and also to adequately operationalize in an experimental context.

An important meta-analysis on conversation effects of cell phones was recently released by Horrey and Wickens (2004). To determine whether conversation affected reaction time (RT) and lane keeping (or tracking) performance, they did a meta-analysis of 16 studies. They examined whether using a cell phone, when compared to driving alone, degraded driving performance, and whether performance decrements were moderated by hands-free or hand-held phone use, conversation versus cognitive tasks (e.g., digit addition), conversation over hands-free versus with a passenger, or simulator versus on-road studies. Their conclusions were:

1. Reaction time tasks showed significant costs for both hands-free and hand-held phones.
2. Lane keeping and tracking measures had small or non-significant effect sizes.
3. Conversation tasks produced higher performance decrements than did experimental cognitive tasks.
4. Conversation task effects with either a passenger or over a cell phone were about the same.
5. Driving simulator and field study effects were roughly similar, with the latter being somewhat more variable.

A second meta-analysis of the studies used by Wickens and Horrey (2004) plus others reconfirmed their conclusions (Scialfa, Caird, Ho & Smiley, in preparation).

2.3 Literature Review Methods and Results

Up to 1997, Goodman et al. (1997) thoroughly reviews individual studies on driving and cell phones. Since 1997, several dozen studies or reasonable quality have been published. Here, studies of reasonable quality from both periods are examined in detail in Appendix A. The studies are presented chronologically. A number of studies are grouped together if they were published by the same authors in the same article, in different issues or different journals. The emphasis of each study, methods, participants, procedures, independent and dependent variables, results and notes are catalogued. The notes column lists study weaknesses, strengths and important considerations. Not all published studies were included in this review. Studies that lacked experimental or statistical detail, or did not include tasks related to cell phone use, or the constellation of tasks that compose driving, were excluded from consideration. A total of 40 separate experimental studies were examined in detail (see Appendix A). Three published studies had multiple experiments (Gugerty et al., 2003; Strayer, Drews & Johnson, 2003; Strayer & Johnson, 2001).

The scope of independent and dependent variables across studies is interesting. The independent variables manipulated or selected by researchers were:

- Study Type (i.e., Part Task, Driving Simulator, Test Track, On Road)
- Task Presence (i.e., With, Without Phone Task)
- Dialing
- Listening
- Conversation (e.g., PASAT, WMST, "Natural Conversation", Word Games, Spatial and Verbal Tasks, Digit Addition)
- Phone Type (e.g., Hand-Held, Hands-Free)
- Road Geometry/Condition (e.g., Straight, Curved, Intersection, Wet, Dry, Light, Dark, Divided, Undivided, Rural, Urban, Traffic Density, Freeway, Posted Speed Changes)
- Frequent Event (e.g., Lead Vehicle Braking, Red/Green Square Appearance, LED Detection, Signs)
- Surprise Event (e.g., Pedestrian, Intersection Incursion, Obstacle)
- Other Device (e.g., Tune Radio, Read CRT, HUD, Instrument Panel, Manipulate Cassette)
- Participant Characteristics (e.g., Male/Female, Age, Truckers, Experienced/Inexperienced)

The dependent measures taken by researchers were:

- Collisions
- RT (e.g., BRT, RT, CRT, PRT)
- Lateral Control (e.g., Lane position, SDLP, RMS Error, Heading Errror)

- Longitudinal Control (e.g., Mean Speed, Circuit Time, Headway, SD Speed, Stopping Time)
- Detection (e.g., Gap, Signs, p(Miss))
- Eye Movements (e.g., Fixation Duration, Fixation Frequency, Pupil Diameter, Time Off Road, Proportion of Gazes to Mirrors and Speedometer)
- Workload (e.g., HR Variability, NASA-TLX, SWAT)
- Secondary Task Performance (e.g., RT, Errors)

The success of the multitude of manipulations and sensitively of measures chosen is not described here, but the results of individual studies are summarized in Appendix A. Instead, the focus is on a quantitative analysis of reaction time that can be used in driver modeling.

Reaction Time. In an effort to synthesize the average distraction potential of cell phone-related tasks on driving performance, studies that measured reaction time, and variants of it, are graphed in Figure 1 (next page). The best-fit linear regression line was $RT_{DISTRACTED} = 1.1623\ RT_{NOT\ DISTRACTED} + 0.051$, which accounted for about 94 percent of variance. The grand mean for all studies was 0.25 seconds and the standard deviation of study means was 0.31 seconds. The quarter of a second represents a difference score between driving alone or with the listed tasks. The range of difference scores was from –0.11 to +1.46 seconds. Three of the 30 difference scores indicated a faster reaction time on the presence of a distractor task (Ålm & Nilsson, 1994, hard; Cooper et al., 2003, younger drivers; Strayer & Drews, 2003, with alcohol). These appear below the dotted line of Figure 1. Obviously, 27 difference scores indicated that in the presence of a distractor, drivers took longer to respond to a variety of stimuli and events, than without the distractor present.

An analysis of what response was required for different stimulus is indicative of the variability in methods and measures chosen by researchers. Thus, the context and constraints imposed on a response are important for understanding the range of response values graphed. The bulk of responses fell between 0.5 and 1.5 seconds, but the longer response times require some explanation. For the nearly 4 second value, Lamble et al.

(1999) had participants brake when the lead vehicle that was slowing, without their brake lights, while they dialed or added 2-single digit numbers. In the next 2 highest values, Ålm and Nilsson (1995) had younger and older drivers, who were engaged in memory task, brake to a lead vehicle, which was decelerating at 4 m/s^2. BRT in Hancock et al. (1999; 2003) was to the change of a traffic light from green to red while remembering a phone number and comparing the first digit of it to a displayed number, then entering whether it was the same or different. In the series of studies produced by Strayer et al., the primary scenario required participants to brake to a lead vehicle while in the right-hand turn lane of a 4-lane roadway. On the fastest end of the response continuum, Irwin et al. (2000) and Consilio et al. (2003) had participants respond to red brake light, in the absence of a steering task, while they performed a number of secondary tasks.

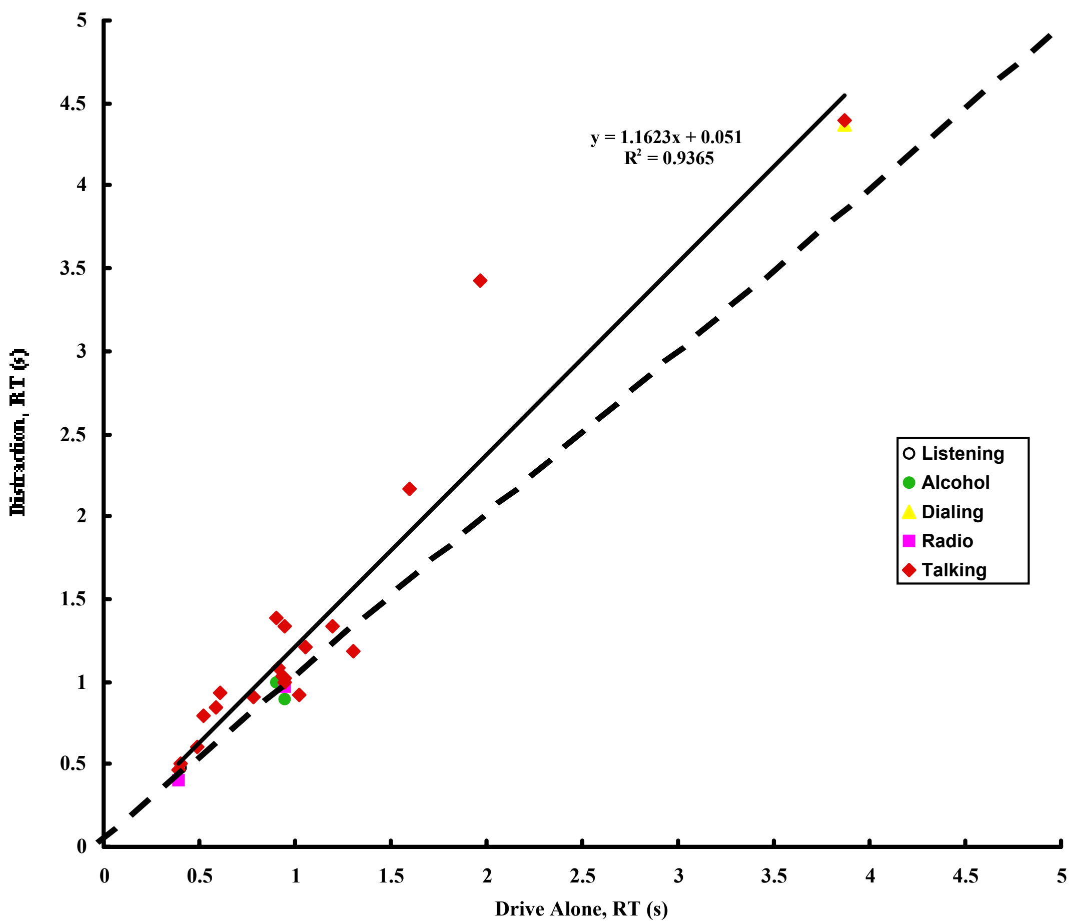

Figure 1. Reaction time to a variety of stimuli and events while driving alone, and while distracted by various tasks including talking, listening, radio tuning, dialing and impaired by alcohol. A total of 16 published studies and 30 mean differences are represented. See text for additional details.

Older Drivers. Older drivers had significantly higher performance decrements than younger participants in a number of studies (Ålm & Nilsson, 1995; Hancock et al., 2003; McKnight & McKnight, 1993; Strayer et al., 2003). The total mean latency for older drivers was 0.51 seconds (SD = 0.64) and 0.17 (SD = 0.29) for younger drivers. Studies that included older drivers as an age group did not include those over the age of 75 (Ålm & Nilsson, 1995, M = 67.6; Cooper et al., 2003, M = 60.0; Hancock et al., 2003, M = 60.2; Strayer et al. 2003b, M = 69.5).

2.4 Limitations and Future Research

1. Distraction from cell phones is likely to be heterogeously distributed over driving context. The measures of mostly brake reaction time (BRT) are reasonable estimates of cell phone task decrements. The selection of context in which to test drivers is over-represented by car following scenarios (Ålm & Nilsson, 1995; Lamble et al., 1999; Strayer et al., 2003a; 2003b) and under-represented by other crash-likely configurations such as intersections (e.g., Hancock et al., 1999; 2003).

2. Although grouped together, talking or conversation included a number of experimental tasks as well as more casual conversation. Naturalistic conversation was found to produce greater performance decrements than experimental tasks (Horrey & Wickens, 2004).

3. The impact of dialing and searching for a phone within the vehicle and holding cell phones to one side of the head with the hand or with the neck, on steering and execution of maneuvres has not been adequately researched. For example, does holding the cell phone with the head tilted restrict the drivers ability to detect threats on the same side?

4. How the intellectual or emotional content of a conversation varies over time and differentially affects driver performance has not been adequately measured or manipulated.

5. The face validity of some secondary tasks that are supposed to be representative of cell phone tasks stretches the human factors principle of task approximation (e.g., Strayer et al., 2001). Tasks that approximate those typically engaged in by drivers are more likely to estimate the true impact on driving performance. For example, Horrey and Wickens (2004) found that conversations tasks produced higher performance decrements than information processing tasks.

6. The amount of cell phone experience has varied over time by market penetration of sampled participants. For example, Stein et al. (1987) described the difficulty of finding one cell phone user per cell, whereas recent studies report rates of cell phone use as high as 80 percent and of these 75 percent reported driving with them too, which is likely to be susceptible to social desirability effects. Many studies fail to ask or report cell phone experience. None of the studies that were reviewed examined differential performance based on experience using cell phones while driving.

7. The precise coincidence of driving and distraction tasks is usually not adequately described. Despite clear variations in primary and secondary task demands, the assumption was that they were essentially concurrent.

8. Secondary task performance is frequently not collected or analyzed (e.g., Strayer et al., 2003). Analysis of linguistic variation, if the secondary task is conversation-like, requires effort and domain knowledge. LaBerge et al. (in press), for example, examines a number of linquistic variables that may vary as a function of a conversation task such as speech rate, linquistic frequency and word errors. Overall, 14 of the 40 studies reported secondary task performance. How drivers trade-off driving performance, if at all, for other task demands, is a fundamental question that

needs to be addressed by each study. The degree to which either drivers or protocol allocate effort to either task is rarely reported.

2.7 References

Ålm, H., & Nilsson, L. (1995). The effects of mobile telephone task on driver behaviour in a car following situation. *Accident Analysis and Prevention, 27*(5), 707-715.

Cooper, P.J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., & Siegmund, G. (2003). The impact of hands-free message reception/response on driving task performance. *Accident Analysis and Prevention, 35*, 23–35.

Evans, L. (2003). Transportation safety. In R.W. Hall (Ed.), *Handbook of Transportation Science*. Norwell, MA: Kluwer Academic Publishers. http://www.scienceservingsociety.com/p/133.pdf

Goodman, M.J., Bents, F.D., Tijerena, L., Wierwille, W., Lerner, N., & Benel, D. (1997). *An investigation of the safety implications of wireless communications in vehicles* (DOT HS 806-635). Washington, D.C.: National Highway Transportation Safety Administration. http://www.nhtsa.dot.gov/people/injury/research/wireless/

Hancock, P.A., Lesch, M., & Simmons, L. (2003). The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis and Prevention, 35*, 510–514.

Horrey, W., & Wickens, C. D. (2004). *The impact of cell phone conversations on driving: A meta-analytic approach* (Tech. Rep. No. AHFD-04-2/GM-04-1). Savoy, Illinios: Institute of Aviation. http://www.aviation.uiuc.edu/UnitsHFD/report_fulltext.html

Laberge-Nadeau, C., Maag, U., Bellavance, F., Lapierre, S.D., Desjardins, D., Messier, S., & Saïdi, A. (2003). Wireless telephones and the risk of road crashes. *Accident Analysis and Prevention, 35*, 649–660.

Laberge, J., Scialfa, C., White, C., & Caird, J.K. (in press). The effect of passenger and cellular phone conversations on driver distraction. *Transportation Research Record*.

Maclure, M., & Mittleman, M.A. (1997). Cellular telephones and traffic accidents (Letter). *New England Journal of Medicine, 337*, 129.

National Transportation Safety Board (2003). *Ford Explorer Sport collision with Ford Windstar Minivan and Jeep Grand Cherokee on Interstate 95/495 near Largo, Maryland February 1, 2002* (Rep. No. NTSB/HAR-03/02). Washington, D.C. NTSB. http://www.ntsb.gov/publictn/2003/HAR0302.pdf

Recarte, M.A. & Nunes, L.M. (2003). Mental workload while driving: Effects on visual search, discrimination, and decision making. *Journal of Experimental Psychology: Applied, 9*(2), 119-137.

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.

Redelmeier, D.A., & Tibshirani, R.J. (2001). Car phones and car crashes: Some popular misconceptions (Letter). *JAMC, 164*(11), 1581–1582.

Stein, A.C., Parseghian, Z., & Allen, R.W. (1987). *A simulator study of the safety implications of cellular mobile phone use* (Paper No. 405). Hawthore, CA: Systems Technology, Inc.

Stutts, J.C., Reinfurt, D.W., Staplin, L., & Rodgman, E.A. (2001). *The role of driver distraction in traffic crashes*. Washington, D.C.: AAA Foundation for Traffic Safety. http://www.aaafoundation.org/projects/index.cfm?button=distraction

Stutts, J.C., Faeganes, J., Rodgman, E., Hamlett, C., Meadows, T. & Reinfurt, D. (2003). *Distractions in everyday driving*. Washington, D.C.: AAA Foundation for Traffic Safety. http://www.aaafoundation.org/pdf/distractionsineverydaydriving.pdf

Sundeen, M. (2003, December). *Cell phones and highway safety: National Conference of State Legislatures: 2003 State Legislative Update*. Denver, CO: National Conference of State Legislature.

Treat, J.R. (1980). A study of the precrash factors involved in traffic accidents. *The HSRI Review, 10*(1), 1–35.

Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. D., Stansifer, R. L., and Castallen, N. J. (1979) *Tri-level study of the causes of traffic accidents: Final report-Executive summary* (Rep. No. DOT-HS-034-3-535-79-TAC(S). Washington, D.C.: National Highway Traffic Safety Administration.

Wierwille, W. W., & Tijerina, L. (1996). An analysis of driving accident narratives as a means of determining problems caused by in-vehicle visual allocation and visual workload. In A. G. Gale, I. D. Brown, C. M. Haslegrave, I. Moorhead & S. Taylor (Eds.), *Vision in Vehicles - III* (pp. 79-86). Amsterdam: Elsevier Science Publishers B. V.

Zwahlen, H, T., Adams, Jr. C. C., & Schwartz, P. J. (1988). Safety aspects of cellular telephones in automobiles (Paper No. 88058). *Proceedings of the ISATA Conference*, Florence, Italy.

3. IMPAIRMENT

3.1 Introduction

While drinking and driving has substantially declined in the last decade, it continues to be the leading cause of road accidents resulting in serious injury or death. In the year 2000, alcohol was involved in approximately 40% of all fatal crashes occurring in the United States (Fatality Analysis Reporting System, 2000). In an effort to reduce the impact, countries have identified certain blood alcohol concentration (BAC) levels when operating a motor vehicle is prohibited (c.f., Pedan et al., 2004). However, BAC limits vary between 0.05 and 0.10% depending on the country. In the Unites States, limits of 0.08 to 0.10 have been adopted, whereas in Canada limits of 0.05 to 0.08 have been implemented, depending on the state or province.

The effects of alcohol on driver performance have a vast corpus of literature on it. However, the quality of the research is highly variable and requires that filters or criteria are applied to separate the wheat from the chaff. The purpose of this review on alcohol impairment is to:

1. Summarize studies that examine the impact of alcohol on driving performance.
2. Contrast studies that have been carried out on road or in driving simulators with laboratory only based tasks.
3. Analyze the impact of BAC on reaction time in laboratory, driving simulation and on road studies.
4. Summarize the relevant reaction time results into a form that can be used for input into driver models.
5. Describe the limitations of existing research and identify gaps in the literature.

3.2 Driver Performance Reviews of Drinking and Driving

In 1968 Greenburg stated, "all of the scientific evidence indicates that above 0.05% alcohol in the blood many individual functions may suffer some impairment, that experimental driving performance depreciates, and that the probability of traffic accident causation increases with rising blood alcohol levels" (p. 262). In the years since, a number of researchers have reviewed research on alcohol and driving-related skills in an effort to quantify when deficits in performance first appear and in what context.

Moskowitz and Fiorentino (2000) reviewed 112 studies published during the years 1981 to 1998 that investigated how driving related skills were affected by low-doses of alcohol. Based on 109 studies, 27% of these studies found that blood alcohol concentrations as low as 0.039% caused decrements in performance. Incorporating all studies with blood alcohol concentrations of less than or equal to 0.079%, the number of studies reporting decrements in performance increased to 92%. The results were highly dependent on the sensitivity of the measures used, with some measures showing impairment at BACs as low as 0.009%. Sixty-one studies examined alcohol effects and either a divided attention, tracking, perception, information processing or reaction time task. The results of divided attention, tracking, perception and information processing and reaction time are highlighted because this is where the 61 of the studies focused.

1. *Divided attention.* Moskowitz and Fiorentino (2000) reviewed 18 studies investigating the effects of alcohol on divided attention using 52 behavioral tests. Thirteen out of 15 studies indicated a decrease in the ability to divide attention was first detected when blood alcohol concentrations of between 0.03-0.10% occurred. When asked to carry out two tasks simultaneously, which commonly involves performing a tracking task in conjunction with a peripheral search task; impairments could be detected at BACs as low as 0.05%. The research on divided attention also suggests that when asked to divide their attention between

two tasks, participants tend to focus on one task at the expense of the other (Kerr & Hindmarch, 1998; Moskowitz and Burns, 1990).

2. *Tracking performance.* Eleven of the studies reviewed by Moskowitz and Fiorentino (2000) examined how alcohol affected the ability to perform tracking tasks. When using adaptive tracking, which gets incrementally harder as participants perform better, performance deteriorated at levels as low as 0.018% BAC. Studies investigating the effect of alcohol on the ability to carry out pursuit tracking found decrements in performance starting at 0.054%. When compensatory tracking was tested decrements in performance varied depending on the study tasks. Four of the studies indicated an impairment in performance for BACs between 0.06 and 0.10%, whereas five of the studies found no impairment when investigating BACs ranging from 0.021 to 0.079%. Finally studies using a critical tracking task found performance deteriorated for BACs between 0.03% and 0.07%.

3. *Perception.* Twelve articles reviewed by Moskowitz and Fiorentino (2000) involved a perception related task, including but not limited to a signal detection task, visual search tasks and a traffic hazard perception task. The authors concluded that most of these tasks failed to show significant impairment below a blood alcohol concentration of 0.08%.

4. *Visual Function*. When they reviewed 19 articles pertaining to visual functions they found that visual acuity was quite resistant to the effects of alcohol, with significant impairment occurring only at a BAC of 0.07% or higher. However, contrast sensitivity and oculomoter control were affected at BACs as low as 0.03%.

5. *Eye Movements*. Moskowitz and Burns (1990) reported that as BAC increases there is the tendency for the eyes to fixate on the central visual field, while making fewer eye movements to the peripheral view. When presented with a

complex environment requiring the ability to rapidly process information being presented from a complex source, the interpretation of the information may be negatively affected by the presence of alcohol in the system. The authors remark that when under the influence of alcohol the driver uses fewer sources in the visual field to obtain information about the environment, they take longer to "recognize and respond" to aspects that present vital information about their environment (i.e. street signs) and they focus their attention on aspects occurring in their central field of vision often to the detriment of peripheral information (p.13).

6. *Reaction time.* Moskowitz and Fiorentino (2000) examined 15 studies and 37 behavioural indicators of choice reaction time and 5 studies and 20 behavioural test results of simple reaction time measures. In the choice reaction time tasks, impairment was first consistently observed at a BAC of 0.06%. The authors concluded that simple reaction time tasks are resilient to alcohol effects due to their simplistic and predictable nature.

7. *Information Processing.* Moskowitz and Burns (1990) indicated that the rate in which people can process information is hindered by the presence of alcohol in the system. As the number of stimuli present and the number of possible responses available to react to stimuli increases, so does the time it takes to make a response.

Kruger grouped tasks used in alcohol impairment studies into two categories (as cited by Holloway, 1995). First, automatic behaviors (i.e. easy tracking, simple reaction time, choice reaction time, etc.) which entail extensive practice and are often improved upon when attention is focused on performing the task in question. Second, controlled behaviors (i.e. difficult tracking, divided attention, information processing tasks etc.) that require performing multiple tasks concurrently. Holloway concluded, after reviewing 48 studies, that on average performance decrements of tasks requiring automatic behaviors were first impaired at BACs of 0.04 to 0.05%. Thirty-five studies investigating tasks classified as controlled behaviors were also reviewed, and these studies indicated that decrements in performance often first appear at a BAC of 0.03% or less. When looking at the research carried out using laboratory-based tasks it becomes apparent that as task complexity increases the probability that the task will be compromised at lower level of alcohol also increases (Kerr & Hindmarch, 1998).

3.3 Drugs and Driving

Illicit and licit drugs can have a detrimental effect on skills related to driving especially when used in conjunction with alcohol. A major impediment to understanding the relationship between drugs and driving behavior is that not all drugs have the same physiological or psychological properties or effects (Moskowitz 1999; 2002; Smiley & Brookhuis, 1987). Properties specific to the drug including the duration of effects, peak levels, when the drug is metabolized or excreted from the body and behavioral implications may differentially affect driving behavior. This is further complicated when several drugs are combined or used with alcohol, which may amplify the effects of the drug and/or the alcohol.

In contrast, alcohol is a distinctive drug that disperses equally throughout the body when water is present (Moskowitz 1999; 2002; Smiley & Brookhuis, 1987). Accurate measures of the blood alcohol concentration in the body at a given time can be obtained through blood, urine, or breath samples. Other drugs rarely share this feature and subsequently may target different parts of the brain, affecting different behaviors from person to person. Many drugs also remain detectable long after they exhibit any behavioral effects, making it difficult to obtain a clear understanding of a dose-response relationship and what specific concentration of the drug will affect driving performance.

While several epidemiological studies have attempted to establish the role drugs play in collisions, the following difficulties have limited widespread testing for drugs (Moskowitz 1999; 2002; Smiley & Brookhuis, 1987):

1. Few studies incorporated a control group making it difficult to compare drug presence in those that had a collision and those that did not based on the same roadway type at similar times of days in similar conditions.

2. Limitations in determining when drugs were taken causes drugs to be classified as either present or absent. When a drug was categorized as being present, it only indicated the driver had used drugs within a given period of time, but failed to determine whether the drug was a contributing factor to the accident.

3. In a large proportion of collisions drugs were combined with alcohol, making it hard to determine whether it was the drug, the alcohol, the combination of both or other factors (i.e. weather, other drivers, distraction, etc.) that contributed to the crash.

Due to these and other limitations, we have limited this review to studies concerning the relationship between alcohol and decrements to driving performance.

3.4 Literature Review Method and Results

Database searches were conducted using the keywords: drinking, driving and alcohol, BAC, intoxication, revealing 1674 article abstracts. Other articles were obtained through backwards referencing. In total 116 articles were retrieved; from this 27 were selected for review and these reviews appear in Appendix B.

The following criteria were used to limit the number of articles:

- The study was available for retrieval.
- The study was published in English.
- The study investigated driving related measures.
- The study was conducted on-road or used a simulator.

- Those that were not carried out using simulators or instrumented vehicles, used measures in which a direct relationship could be derived to indicate driver behavior or perception.
- If the study also investigated drugs, only those studies that had a clearly defined placebo group and an isolated alcohol group were reviewed.

Drivers must be able to successfully carry out a number of inter-related tasks based on information that is constantly changing. The driver is required to seek out, filter, and prioritize information presented to them from "multiple sources" (Moskowitz & Burns, 1990, pg. 14). Based on relevant information, drivers must be able to make accurate judgments concerning when or if a reaction is necessary. Perception, divided attention, tracking and lane position, information processing and reaction time are each fundamental processes involved in the task of driving. Rather than being isolated mechanisms, all of these factors come together when a person undertakes operating a motor vehicle. Accidents occur when the ability to carry out any of these components or to integrate information from multiple sources is broken down. The individual impact of each component will be briefly reviewed here.

1. *Divided attention.* While on route, the driver is continuously confronted with competing demands. A proficient driver is able to monitor their environment and their performance while carrying out multiple tasks at the same time. Based on constantly changing information they must determine what situation requires their immediate attention and anticipate future requirements.

   To understand the impact of alcohol on multi-tasking several researchers had participants track or maintain lane position while responding to intermittent stimuli presented in their peripheral or central view. At blood alcohol concentrations of 0.03 and above, reaction time increased, tracking was negatively affected and departure from the road becomes more frequent (Finnigan, Hammersley & Millar, 1985; Loomis & West, 1958; Roehrs et al., 1989). Finnigan et al. (1985) determined that the detrimental effects of alcohol on tracking can persist for up to 130 minutes, while the effect upon reaction time can last up to 70 minutes.

2. *Tracking and lane position.* The ability to avoid an accident is dependent on the drivers ability to monitor and adjust the position of their vehicle in their lane, to other vehicles, roadside markers and other hazards. When alcohol is consumed, participants had greater lane variability and tracking performance than without. They also adopted a position closer to the left edge of the road and made more steering errors. Dott & Mckelvey (1977) indicated high velocities and driver inexperience augment alcohols impact on steering errors. The above decrements in performance were reported at blood alcohol concentrations as low as 0.05% (Arnedt et al., 2001; Brookhuis & De Waard, 1993; Dawson & Reid, 1997; Lenne, Triggs, & Redman, 1999; Louwerens et al., 1987; Rimm et al., 1982, Roehrs et al., 1989; Roehrs et al., 1994).

3. *Eye Movements.* A competent driver continuously scans their surroundings, fixate on vital aspects, and from this derive necessary information that subserves action. At blood alcohol concentrations of 0.07% and higher, the total number of eye movements decreases, the duration in which the eye was closed increases, the frequency of long to short saccades begins to diminish and fewer fixations are made on objects lying in the peripheral view (Beideman & Stern, 1977; Schroeder, Ewing & Allen, 1974). Buikhuisen and Jongman (1972) determined that while under the influence drivers made fewer saccades and adopted a less flexible search strategy. This resulted in them observing fewer traffic aspects, and also taking a longer period of time to perceive an event. Due to the tendency to focus mainly on the roadway they subsequently ignored aspects occurring on the left and right of the road. Intoxicated drivers often overlooked stationary hazards while retaining their ability to identify moving hazards.

4. *Perception and Pattern Recognition.* Participants with a BAC of 0.025% to 0.05% took longer to indicate that a situation presented in a movie taken from

the driver's perspective was a hazard (West, et al., 1993). At blood alcohol concentrations as low as 0.04% the ability to exhibit detection accuracy and decision caution when performing signal detection task was impaired (Mongrain & Standing, 1989).

5. *Information processing and reaction time.* The driver must filter all of the information that is presented to them in a way that allows them to anticipate and react to future events. At blood alcohol concentrations as low as 0.03% participants took longer to react to red and amber lights or other hazards presented to them (Dennis, 1995; Horne, Gibbons, 1991; Loomis & West, 1958). Brookhuis and DeWaard (1993) indicated that although statistical significance was not reached, at blood alcohol concentration below or equal to 0.05% there was a trend towards a longer perception and response time to speed variation in a lead vehicle.

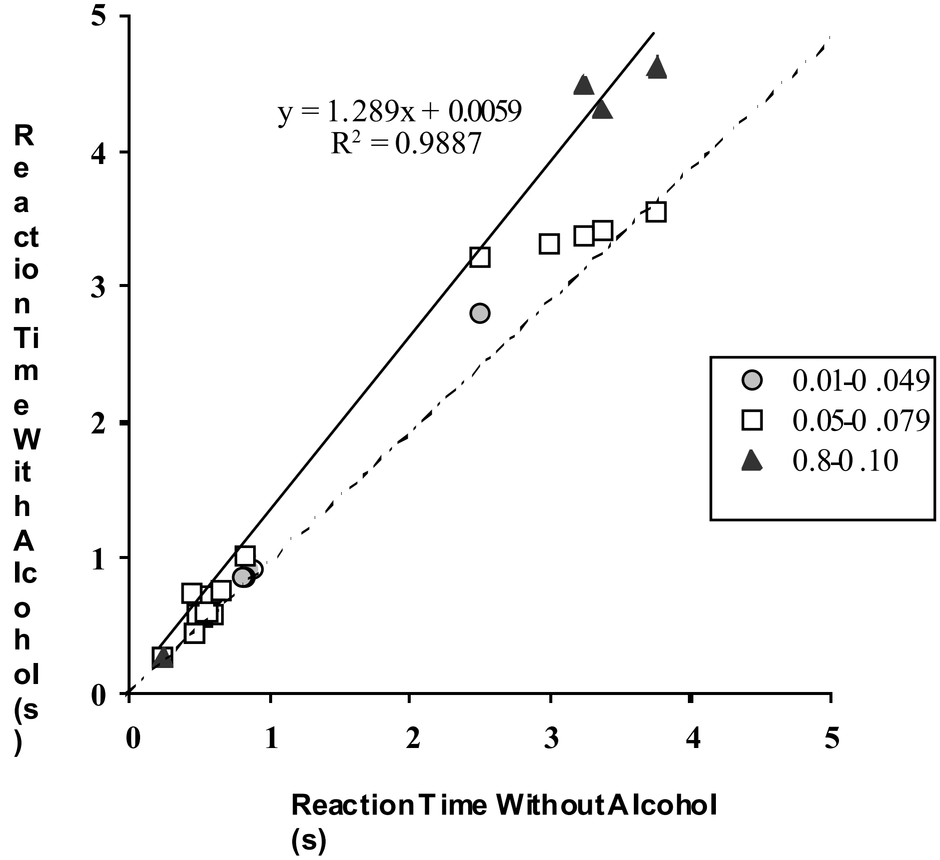

Figure 3. Reaction time with and without alcohol for 3 levels of BAC.

A clear linear relationship between alcohol and reaction time is shown. As BAC increases so does the time it takes for a person to react to a stimulus. The best fitting equation for this relationship was $RT_{ALCHOHOL} = 1.28\ RT_{NO\ ALCOHOL} + 0.0059$. The fit of the equation accounts for 98.87% of variance in the data included in Figure 2. Maylor and Rabbitt (1993) when reviewing the effect of alsohol on RT, carried out a meta-analysis based on 8 studies (that they had conducted). The best fitting equation for their data was $RT_{ALCHOHOL} = 1.12\ RT_{NO\ ALCOHOL} - 17.87$, which accounted for 99.8% of the variance. While the slopes of these equations are similar, the intercept is not. The range restriction imposed by a limited range of BAC used by Maylor and Rabbitt (1993) may account for this difference. A more thorough meta-analysis that encompasses RT data from laboratory-based, driving simulation and on-road studies should be conducted to test the significance of these collective effects.

The research on the ability to maintain and determine a safe velocity is equivocal. Some of the research suggests that participants who consume alcohol were able to maintain a constant speed (Dott, McKelvey, 1977; Kearney & Guppy, 1988; Louwerens et al., 1987; Mongrain & Standing, 1989; West et al., 1993). Others suggest that at blood alcohol concentrations of 0.05 to 0.08%, drivers increased their variance in speed through pressure applied to the gas pedal (Arnedt et al., 2001; Cox et al., 1995; Lenne, Triggs, & Redman, 1999). Sutton (1983) reported that participants who had a blood alcohol concentration of 0.06% drove slower in order to compensate for the effects of alcohol. Participants who consumed four units of alcohol also increased their following distance but experienced difficulty in maintaining a steady headway (Horne & Baubmer, 1991).

The ability to carry out maneuvers such as skid control and t-turns were impaired at BACs as low as 0.03% (Dennis, 1995; Sutton, 1983). Participants who consumed alcohol spent more time off the road and hit more hazards (Arnedt et al., 2001; Flanagan et al., 1983; Loomis & West, 1958). Rimm et al. (1982) found that at 0.064% participants made more breaking errors. Laurell (1977) indicated that at a BAC of 0.052 to 0.06% participants hit more pylons and took longer to stop, experienced difficulty when trying to align their car to a proper position and made more false actions. At higher BACs, drivers may not always be able to determine the correct course of action or to be able to effectively carry out the maneuvers required to avoid a potentially dangerous situation.

3.5 Limitations and Future Research

The interpretation and generalizability of the effects of alcohol on driver performance is limited by a number of experimental, paradigmatic, measurement precision and design limitations. The implications of these factors on future research is also introduced.

1. Many articles have investigated the impact of alcohol on experimental tasks related to driving, yet few have been done so using simulation or instrumented vehicles on-road. Studies performed with laboratory-based tasks indicate the impact alcohol has on individual task performance. Laboratory studies are assumed to generalize to actual driving. However, driving involves a constellation of overlapping tasks or activities that vary as the traffic context changes. A meta-analysis that contrasts the effect sizes of laboratory, simulation and on-road studies is required to determine if each of these methodological approaches yields similar or different results.

2. A number of studies reviewed did not explain how the task was indicative of driving. Brookhuis, De Waard and Fairclough (2003) list a number of measures that are more likely to indicate driver impairment. These measures included: vehicle control, headway distance, overtaking with oncoming traffic, overtaking at a junction, abrupt lane change, weaving between lanes and excessive speed. The authors suggest that time headway, time-to-collision, speed, lateral position, time-to-line crossing and steering position can be used to determine performance decrements related to alcohol use. The inclusion of these and other variables, using a multivariate approach, may uncover a number of interesting causal relationships among and between variables.

3. Laboratory studies indicate that at even low BAC levels, alcohol may negatively impact task performance related to driving. Many of the studies that investigated the relationship between alcohol and driving ability, failed to explore the effects of more than one level of BAC. Future research needs to define and implement low, moderate and high levels of BAC which would help to determine how performance is affected by different levels of alcohol, when decrements first appear, and how they fade as alcohol is metabolized.

4. A number of investigations did not control for participant consumption of caffeine, food, nicotine, or alcohol prior to entering the study. These foodstuffs can affect the rate at which alcohol is absorbed into the body. A common set of restrictions should be implemented to inform participants of what substances to abstain from and how long they should do so in the hours prior to an experimental session. Time-of-day effects must also be considered as performance differences have been found between afternoon and evening consumption (Maylor & Rabbitt, 1993).

5. The time allotted for participants to consume and absorb alcohol is highly inconsistent across studies. Greenburg (1968) stated that as the amount of alcohol consumed increased, so did the time the body required to absorb it into the blood stream. When alcohol is consumed over a short period of time the peak alcohol level will be higher and achieved faster than if alcohol consumption is spaced over a longer period of time. The timing of experimental trials relative to the peak and decline is at issue.

6. In a number of the studies reviewed, a large variation in the BAC levels was obtained between participants and over the time-course of the study. Subsequently a reliable calculation should be used to determine the amount of alcohol to administer, such as the weight approximation method. BAC levels should be continuously monitored.

7. A number of investigators failed to report important participant information such as driving history, drinking experience, age, and sex which may lead to performance variability. Large variations in these factors can limit the comparison of decrements across studies. When participant samples are considered, researchers should ask the following questions: What is the normal drinking pattern of those most affected? Is the sample indicative of those involved in accidents where alcohol was a contributing factor? Is the sample

representative of the population we are interested in examining (also see Maylor & Rabbitt, 1993)?

8. The vast majority of the studies used a repeated measures design. Using this design, participants take part in all the conditions thereby allowing the researcher to control for individual differences that might influence performance measures (Heiman, 1995). This design allows participant variables to be held constant, reduce error variance and increase "statistical power for detecting differences due to the influence" of the independent variables (pg. 217). At the same time, repeated exposure, expectancy effects, loss of subjects and order effects can affect performance and confound results. Studies that use repeated-measures designs need to be counterbalanced to minimize the influence of these factors. Many had small sample sizes, with only a few studies employing more than 20 participants. Future research needs to increase the number of participants in order to adequately measure between-subject effects (Maylor & Rabbitt, 1993).

9. Most studies used only men, while a few used only women, fewer still have a balance of men and women. When women and men both participate in a study, it is important that alcohol quantities are adjusted to obtain similar BAC levels. A common, but imperfect method to equalize intake levels between men and women, is to use a smaller dosage for females (e.g., 92% of male dosage).

10. Many of the studies failed to report all of their data, or insignificant results, making it difficult to combine statistical information into a meta-analysis. As a matter of review and publication, studies should make all data available and report both significant and insignificant effects (cf., Maylor & Rabbitt, 1993).

3.6 References

Brookhuis, K.A., De Waard, D. & Fairclough, S.H. (2003). Criteria for driver impairment. *Ergonomics, 46*(5), 433-445.

Greenberg, Leon A. (1968). The pharmacology of alcohol and its relationship to drinking and driving. *Quarterly Journal of Studies on Alcohol, Suppl. 4*, 252-256.

Heiman, G.A. (Eds.)(1995). *Research methods in psychology*. Boston: Houghton Mifflin Company.

Holloway, F.A. (1995). Low-dose alcohol effects on human behavior and performance. *Alcohol, Drugs and Driving, 2*(1), 39-56

Kerr, J.S., & Hindmarch, I. (1998). The effects of alcohol alone and in combination with other drugs on information processing, task performance and subjective responses. *Human Psychopharmacology*, 13, 1-9.

Maylor, E.A., & Rabbitt, P.M.A. (1993). Alcohol, reaction time and memory: A meta-analysis. *British Journal of Psychology, 84*, 301-317.

Moskowitz, H., & Burns, M. (1990). Effects of alcohol on driving performance. *Alcohol Health and Research World, 14*(1), 12-14.

Moskowitz, H., & Fiorentino, D. (2000). *A review of the literature on the effects of low doses of alcohol on driving-related skills.* Washington, D.C.: National Highway Traffic Safety Administration.

Moskowitz, H. (1999). Driving under the influence. In R.T. Ammerman, P.J. Ott & R.E. Tarter (Eds.), *Prevention and Societal Impact of Drug and Alcohol Abuse* (pp.109-123). Tucson, AZ: Lawyers and Judges Publishing.

Moskowitz, H. (2002). Alcohol and drugs. In R.E. Dewar & P.L. Olson (Eds.), *Human factors in traffic safety* (pp. 177-208). Tucson, AZ: Lawyers and Judges Publishing Company, Inc.

Peden, M., Scurfield, R., Sleet, D., Mhan, D., Hyder, A.A., Jarawan, E., & Methers, C. (2004). *World report on world traffic injury prevention.* Geneva: World Health Organization.
http://www.who.int/world-health-day/2004/infomaterials/world_report/en/

Smiley, A. & Brookhuis, K.A. (1987). Alcohol, drugs and traffic safety. In Rothengatter, J. A. (Ed); de Bruin, R. A. (Ed). (1987). *Road Users and Traffic Safety.* (pp. 83-104). Netherlands: Van Gorcum.

4. EMERGENCY RESPONSES

4.1 Introduction

Experimental psychology has lent to driving a methodological framework to investigate the speed that a driver can respond to various stimuli. However, like many paradigms, it is not immune to measurement and interpretive difficulties. It is generally accepted that a number of processes may contribute to the time it takes to respond to an event that requires braking or steering. In Figure 3, reaction time is fractionated into the psychological processes that contribute to a response. The various stages of information processing indicated are ranges of values for each stage. Perception-response time (PRT) corresponds to the time required by the following driver to detect, orient, recognize, decide, move, and engage the brake.

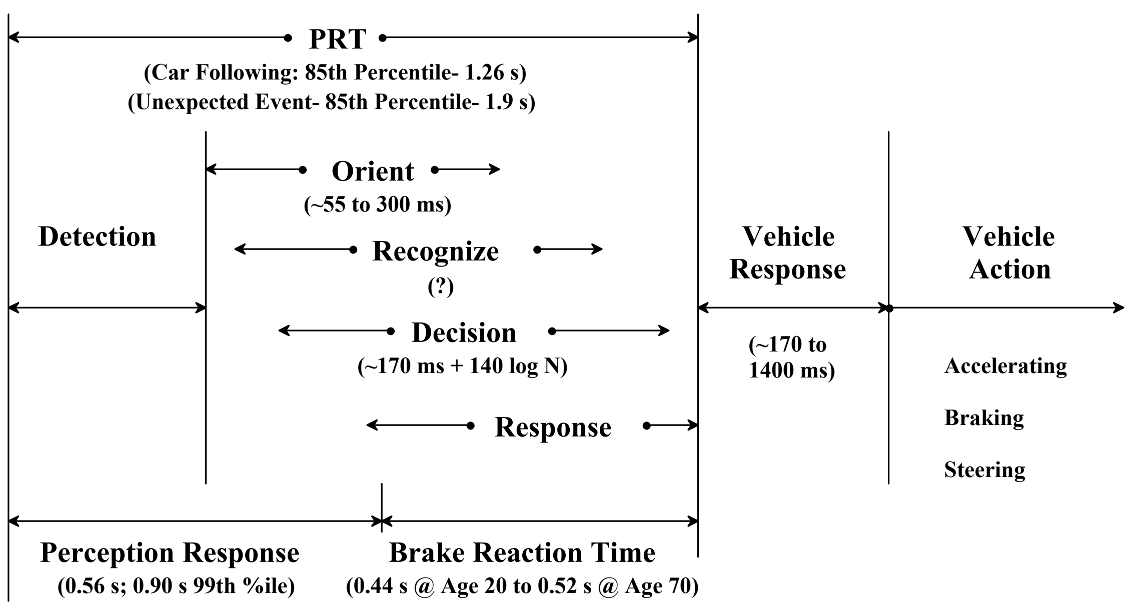

Figure 3. Perception reaction time (PRT), associated stages of processing and data from a number of sources. See text for additional details.

PRT is roughly equivalent to choice RT within experimental psychology. Practically, drivers lift their right foot from the accelerator and place it on the brake. The perception component is measured by the onset of a stimulus or event until the foot leaves the accelerator, whereas brake reaction time is measured from the point the foot leaves the accelerator until it contacts the brake. The capability of driving simulators and instrumented vehicles makes this definition somewhat confining, but it allows for comparison across studies.

Measurement of these two components does not necessarily indicate what information processing is achieved. For example, detection, decision and response elements may be contained in the perceptual component. In practical terms, unless circumstances demand a quick response, initiation of a response may be reflected in easing up on the accelerator. If the foot remains on the accelerator, in this situation, the true RT would not be necessarily be known. A differential application of pressure to the accelerator may reflect one headway regulation strategy that is not captured by the perception-reaction time paradigm. Thus, not all ongoing driver behavior is necessarily captured by PRT measures. Anticipation based on context, learned perceptual cues and other experience is the hallmark of defensive driving.

4.2 Processing Stages

The various processing stages from Figure 3 are further elucidated. The progression from one information processing stage to another implies a number of assumptions about processing, irrespective of driving context. What is not known is the degree of overlap, interaction, and separability of the processing stages specific to the task of driving (e.g., see Wickens & Hollands, 2000, pp. 361–373). For example, which stages are serial or parallel and where facilitation or interference effects exist, is not necessarily amenable to conclusive empirical investigation. For these reasons, attempts to sum individual processes may under- or over- estimate the true response time.

In addition, as the number of decision alternatives increases, overall response time increases linearly with the log of the number of choices. The continuum of choices available to the driver may include; to continue to move forward at the same velocity, to speed-up and pass, to reduce the action on the accelerator, to take the foot off the accelerator, to move it to the brake in preparation to brake, to differentially depress the brake, and perhaps down shift the car if it has a manual transmission. Each of these "decisions" may have differential degrees of automaticity associated with them, which in turn affects the time necessary to execute a response. This is supported by the finding that drivers with more driving experience reacted faster to changes in headway than less experienced drivers (Colbourn, Brown, & Copman, 1978). However, the processing stage that is automated, whether perceptual, decisional or motor, presents an empirical challenge.

Brake Reaction Time (BRT) is a measure of the time taken to move the foot from the accelerator to the brake. BRT is one component of PRT, however, in some papers is synonymous with it (e.g., Taoka, 1982). Care to precisely define measures and place results into a greater referential context is a common problem. The vertical and horizontal planes the foot moves in from the accelerator to the brake, the distance moved, and size of brake pedal affect BRT. A mean BRT value of 0.496 seconds was obtained for 1,461 subjects and varies upward with age as indicated in Figure 3. In simulators, test track, and on-road tests, BRT's and PRT's rise to between three-quarters to two full seconds (Triggs & Harris, 1982; Olson & Farber, 2003) depending on the complexity of the environment, and the disposition of the driver (fatigue, drugs, age). While stimulus complexity and number of decision choices tend to be minimized in laboratory-based studies, within real traffic environments, PR times can vary depending on the driving context (Triggs & Harris, 1982) and necessity for response (Caird & Hancock, 1994). The discrepancies between PRT values from real traffic environments and laboratory based experiments have troubled highway engineers and accident reconstructionists, because they must use these findings for design standards and determination of probable crash causes, respectively.

4.3 PRT Measures of Unexpected Traffic Events

A number of difficulties of real-world and laboratory measures have been noted. One of the primary difficulties that laboratory studies have is they indicate the fastest that a driver may respond. Participants are alerted and poised to respond as quickly as they can, they can do so in about a quarter of a second. Clearly, values of reaction time (RT) and choice reaction time (CRT) in the laboratory represent near optimal conditions, whereas, responses in a traffic environment are more complex. Traffic engineers, however, must base their design criteria on the slowest end of the RT distribution, that is, the slowest responses of the driving population. Differences between laboratory and on-the-road studies have produced discrepancies of 0.5 to a full second (Olson, 1989; Toaka, 1982; Triggs & Harris, 1982). As a result, a number of studies have sought to determine drivers' responses *in situ,* that is, on-the-road. Many of these studies are collated in Appendix C. Critical independent variables include the manipulation of the traffic environment (e.g. Summala, 1981a, 1981b; Triggs & Harris, 1982), sampling of older populations (Lerner, 1993, 1994), and introduction of unexpected events (e.g., Johansson & Rumar, 1971; Olson & Sivak, 1986). Studies included in Appendix C highlight the emphasis of transportation researchers to discover ecologically valid PRT measures.

Perhaps the most striking difference between experimental and real-world traffic events is the increase in PRT values of 0.2 to 0.5 s to being alerted or surprised (see Johansson & Rumar, 1971; Sivak & Olson, 1986). Clearly being ready to respond, contributes to the discrepancy between on-road and laboratory measurement. However, given this known and relatively consistent difference between the two settings, adjustments to data collected in the laboratory may suffice (see Johansson & Rumar, 1971), that is, it makes little sense to discard a corpus of research. On-road experiments or descriptive studies leave many variables uncontrolled and are expensive to conduct. A logical alternative is low-cost driving simulation.

On-road and laboratory reaction times are not normally distributed. Distributions are skewed to the left, that is, towards faster RT values (Olson, 1989; Olson & Farber, 2003; Taoka, 1982, 1989; Triggs & Harris, 1982). Thus, means and standard deviations do not necessarily reflect the upper regions of PRT distributions. In addition, researchers have failed to sample from populations that are functionally slower; namely older drivers.

Lerner (1993, 1994) examined stopping sight distance (SSD) and intersection sight distances for older and younger drivers (see Appendix C). His results for the 85th percentile do not exceed the design recommendation of 2.5 and 2.0 s for either traffic geometry respectively.

Another aspect of the design debate questions the generality of various design standards to all roadway scenarios. For example, Triggs and Harris (1982) cite numerous examples and add to the list from their own research scenarios that do not strictly adhere to design recommendations. Thus, design standards may not capture the interactions of traffic, weather, and individual differences such that all drivers are able to respond appropriately.

The fact that a percentile cutoff or criterion was used to describe acceptable regions of a distribution is somewhat troubling though. What should the percentile cutoff be? A portion of the distribution is accepted while a fraction, albeit small, is ignored. Any criterion implies that a small portion of drivers may exceed the criterion. A portion of the debate, surrounding SSD and other design values, centers on the degree that a standard captures the complete response distribution. If a study fails to sample drivers from the right tail of the distribution, the conclusions drawn from the results have little relevancy for scrutinizing a design standard. Only one study reviewed (Lerner, 1993), actively sought older drivers from a range of capabilities and backgrounds. If the proportion of the PRT values found in the right tip of the distribution is extrapolated to the greater driving population, how many people are represented that cannot function within the constraints of current highway design guidelines? It is precisely these questions that have been posed by researchers but remain unanswered.

4.4 An Example

Three experimental routes, each with a critical event, were developed for this study. Each route consisted of a series of intersections where a critical event occurred at one intersection in the series. The locations of the critical events changed in each series of intersections to prevent participants from anticipating an event. Critical events included the sudden appearance of a pedestrian during a right turn (Pedestrian), a last-second yellow light (Yellow Light), and a vehicle violating a red light while the participant had a green light (Vehicle Incursion). At each of the critical event intersections, other traffic, pedestrians and signs were present to increase the complexity of the visual field.

Table 3. PRT means and standard deviations (in seconds) for each event type and age group.

Event type	Age Group PRTs (s) (SD)	
	19 to 23	65 to 83
Pedestrian	0.97 (0.46)	1.44 (0.45)
Yellow Light	0.76 (0.18)	1.26 (0.29)
Vehicle Incursion	1.14 (0.31)	1.50 (0.28)

Table 4. Response types to critical events by age group.

Age group	Response type	Event Type (%)	
		Yellow Light	Vehicle Incursion
Young (19 to 22)	Braked	50	83.3
	Accelerated	50	-
	Braked but struck object	-	8.3
	Neither braked nor accelerated	-	8.3
Older (65 to 83)	Braked	25	41.7
	Accelerated	75	-
	Braked but struck object	-	25
	Neither braked nor accelerated	-	33.3

4.5 Summary

The processes that underlie the perception and response to traffic events were reviewed. Experiments that have used ecologically valid PRT measures are summarized in Appendix C. Primary differences between on-the-road and simulator or laboratory studies involve differences between prepared and unexpected responses to events. Issues that surround the use of PRT values for design standards were discussed. Finally, PRT values fail to capture other forms of adaptive responses to unexpected traffic scenarios. For example, drivers steer to avoid obstacles, brake to increase the time and distance between them and other vehicles, and when necessary brake and steer simultaneously.

5. DISCUSSION AND CONCLUSIONS

5.1 Summary

Driver distraction from technology in vehicles is not unique to mobile telephones (Stutts et al., 2003), although the largest collection research resides in this area. Talking, listening and dialing a cell phone is a relatively smaller category compared to even adjusting the radio/cassette/CD category which is nearly 10 times larger (i.e., if the the distances between numbers are, in fact, absolute) of the overall driver distraction problem (see Table 2).

To address the broad contribution of driver distraction to traffic crashes will require solutions from social policy, epidemiology, human factors, design, and engineering. Legislation and enforcement aimed at the broader problem of driver distraction, rather than just mobile phones, has the potential to reduce more overall crashes.

The distinction between inattention and distraction—especially when classifying a particular crash case with limited information—is not without semantic and operational difficulties. It is difficult to accurately infer that a driver is simply spaced out or intentionally absorbed by an object.

The effect of conversation on driver performance is to delay recognition and response to important traffic events. Hands-free phones produce similar performance decrements as hand-held phones. Legislation has not necessarily considered the impact that conversation has on driver performance.

The average performance of drivers in the presence of a distraction such as a cell phone probably underestimates the behaviour of drivers when not being observed and free to adopt typical habits of their own vehicles (cf., Evans, 2003).

Individual studies do not necessarily consider the overall pattern of research progress in an area and select measures and manipulations that satisfy more localized interest and potential knowledge generation goals.

Drivers who are alcohol impaired and distracted at the same time may additively or multiplicatively increase their crash risk. The reaction times associated with the interaction between these factors has not been investigated. Distraction by alcohol, alcohol by fatigue, and age by distraction are important interactions that require additional research.

5.2 Conclusions

Table 5. Summary of Mean Differences from a Driving Without Condition, Standard Deviation of Study Means, and Number of Studies Used to Calculate Means and SDs.

Condition	Mean Difference from Driving Without Condition (seconds)	Standard Deviation	Number of Studies
All Distraction Tasks	0.25	0.31	16
Talking Hands Free or Hand Held	0.25	0.31	12
Tuning Radio	0.41		2
Talking to Passenger	0.13		2
Younger Drivers	0.17	0.28	4
Older Drivers	0.51	0.64	4
BAC: 0.01 to 0.049	0.12		9
BAC: 0.05 to 0.079	0.13		20
BAC: 0.08 to 0.10	0.61		3

Table 6. Adapted from Peters, G.A., & Peters, B.J. (2002). *Automotive vehicle safety*. New York: Taylor and Francis. (pg. 95) Table 7.1, Human reaction times (highly variable)(seconds).

Activity	**Situation**	**Range**	**Commonly Utilized**	**Study**
Perception (detection and awareness)	Simple Complex	0.5 3.0 to 4.0	 1.5	AASHTO (1973)
Reaction (braking)	Simple Complex	0.5 1.0	1.0	AASHTO (1973)
Swerve (avoidance)		0.9 to 2.0	1.5	Johansson & Rumar (1971), Hulbert (1984)
Maneuver (passing)		3.5 to 4.5	4.5	AASHTO (1973)
Preview (scene)	Look ahead Look back	2.0 to 2.5 0.8 to 1.0	2.5	Hulbert (1984), Robinson et al. (1972), AASHTO (1973)
Headway (distance)	60 mph (96 km/h)	1.0	1.0	Robinson et al. (1972)
Search (visual)	Lane change Enter crossroad	0.8 to 1.6 1.1 to 2.6	0.8 2.5	Robinson et al. (1972) Hulbert (1984)
Sight distance (hazard detection up to braking)	Legal assumption 95th percentile	 1.6	0.75 2.5	Hulbert (1984) Olson & Sivak (1986)

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7.1 Distraction

Ålm, H., & Nilsson, L. (1994). Changes in driver behaviour as a function of handsfree mobile phones-A simulator study. *Accident Analysis and Prevention, 26*(4), 441-451.

Ålm, H., & Nilsson, L. (1995). The effects of mobile telephone task on driver behaviour in a car following situation. *Accident Analysis and Prevention, 27*(5), 707-715.

Briem, V., & Hedman, L. R. (1995). Behavioural effects of mobile telephone use during simulated driving. *Ergonomics, 38*(12), 2536-2562.

Brookhuis, K. A., de Vries, G., & de Waard, D. (1991). The effect of mobile telephoning on driving performance. *Accident Analysis and Prevention, 23*(4), 309-316.

Brown, I. D., Tickner, A. H., & Simmonds, D. C. V. (1969). Interference between concurrent tasks of driving and telephoning. *Journal of Applied Psychology, 53*(5), 419-424.

Consiglio, W., Driscoll, P., Witte, M., Berg, W.P. (2003). Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. *Accident Analysis and Prevention, 325*, 495–500.

Cooper, P.J., & Zheng, Y. (2002). Turning gap acceptance decision making: The impact of driver distraction. *Journal of Safety Research, 33*, 321-335.

Cooper, P.J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., & Siegmund, G. (2003). The impact of hands-free message reception/response on driving task performance. *Accident Analysis and Prevention, 35*, 23–35.

Fairclough, S. H., Ashby, M. C., Ross, T., & Parkes, A. M. (1991). Effects of handsfree telephone use on driving behaviour (ISBN 0 947719458). *Proceedings of the ISATA Conference*, Florence, Italy.

Green, P., Hoekstra, E., & Williams, M. (1993). *Further on-the-road tests of driver interfaces: Examination of a route guidance system and car phone* (Tech. Rep. UMTRI 93-35). Ann Arbour: MI: UMTRI.

Gugerty, L., Rando, C., & Rakauskas, Brooks, J., Olson, H. (2003). Differences in remote versus in-person communications while performing a driving task. *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting* (pp. 1855–1859). Santa Monica, CA: HFES.

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

Hancock, P.A., Hashemi, L., Howarth, H., & Ranney, T. (1999). The effects of in-vehicle distraction on driver response during a critical driving maneuver. *Transportation Human Factors, 1*(4) 295-309.

Hancock, P.A., Lesch, M., & Simmons, L. (2003). The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis and Prevention, 35*, 510–514.

Hanowski, R., Kantowitz, B. & Tijerina, L. (1995). *NHTSA Heavy vehicle driver workload assessment final report supplement—Workload assessment of in-cab text message system and cellular phone use by heavy vehicle drivers in a part-task simulator, Task 7B* (Rep. No. DOT HS 808 467 7B). Washington, D.C.: NHTSA.

Harbluck, J.L., Noy, Y.I., Eizenman, M. (2002) *The impact of cognitive distraction on driver visual behaviour and vehicle control* (TC Rep. No. TP 13889E). Ottawa: Transport Canada. Retrieved August 27, 2002 from the Transport Canada Web site: http://www.tc.gc.ca/roadsafety/tp/tp13889/en/menu.htm

Irwin, M., Fitzgerald, C., & Berg, W.P. (2000). Effect of the intensity of wireless telephone conversations on reaction time in a braking response. *Perceptual and Motor Skills, 90*, 1130-1134.

Ishida, T., & Matsuura, T. (2001). The effect of cellular phone use on driving performance. *IATSS Research, 25*(2), 6-14.

Kantowitz, B.H., Hanowski, R.H., & Tijerina, L. (1996). Simulator evaluation of heavy-vehicle driver workload II: Complex secondary tasks. *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting* (pp. 877–881). Santa Monica, CA: HFES.

Laberge, J., Scialfa, C., White, C., & Caird, J.K. (in press). The effect of passenger and cellular phone conversations on driver distraction. *Transportation Research Record*.

Lamble, D., Kauranen, T., Laakso, M., & Summala, H. (1999). Cognitive load and detection thresholds in car following situations: Safety implications for using mobile telephone (cellular) telephones while driving. *Accident Analysis and Prevention, 31*, 617-623.

McKnight, J.A., & McKnight, S.A. (1993). The effect of cellular phone use upon driver safety. *Accident Analysis and Prevention, 25*(3), 259-265.

Patten, C.J.D., Kircher, A., Ostlund, J., & Nilsson, L. (in press). Using mobile telephones: Cognitive workload and attention research allocation. *Accident Analysis and Prevention*.

Parkes, A.M., & Hooijmeijer, V. (2001). Driver situation awareness and carphone use. *Proceedings of the 1st Human-Centered Transportation Simulation Conference* (ISSN 1538-3288). Iowa City, IA: University of Iowa.

Rakauskas, M., Gugerty, L., & Ward, N.J. (in review). Effects of cell phone conversations with naturalistic conversations.

Recarte, M.A., & Nunes, L.M. (2000). Effects of verbal and spatial imagery tasks on eye fixations while driving. *Journal of Experimental Psychology: Applied*, *6*, 31–43.

Recarte, M.A. & Nunes, L.M. (2003). Mental workload while driving: Effects on visual search, discrimination, and decision making. *Journal of Experimental Psychology: Applied, 9*(2), 119-137.

Reed, M. P., & Green, P.A. (1999). Comparison of driving performance on-road and in a low-cost simulator using a telephone dialing task. *Ergonomics, 42*(8), 1015–1037.

Stein, A.C., Parseghian, Z., & Allen, R.W. (1987). *A simulator study of the safety implications of cellular mobile phone use* (Paper No. 405). Hawthore, CA: Systems Technology, Inc.

Strayer, D.L., Drews, F.A., & Crouch, D.J. (2003). Fatal attraction? A comparison of the cell-phone driver and the drunk driver. *Proceedings of the Second International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design* (pp. 25-30). Park City, Utah.

Strayer, D.L., Drews, F.A., & Johnson, W.A. (2003a). Effects of cell phone conversations on younger and older drivers. *Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting* (pp. 1860-1864). Santa Monica, CA: HFES.

Strayer, D.L., Drews, F.A., & Johnson, W.A. (2003b). Cell phone-induced failures of attention during simulated driving. *Journal of Experimental Psychology: Applied, 9*(1), 23-32.

Strayer, D. L., & W.A. Johnston. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science, 12*(6), 1-5.

Tijerina, L., Kiger, S., Rockwell, T., & Tornow, C. (1996). *Heavy vehicle driver workload assessment, Task 7A: In-car text message system and cellular phone* *use by heavy vehicle drivers on the road* (Rep. No. DOT HS 808 467 7A). Washington, D.C.: NHTSA.

Waugh, J.D., Glumm, M.M., Kilduff, P.W., Tauson, R.A., Symth, C.C., & Pillalamarri, R.S. (2000). Cognitive workload while driving and talking on a cellular phone or to a passenger. *Proceedings of the IEA/HFES 2000 Congress* (pp. 6-276–6-279). Santa Monica, CA: HFES.

Zwahlen, H, T., Adams, Jr. C. C., & Schwartz, P. J. (1988). Safety aspects of cellular telephones in automobiles (Paper No. 88058). *Proceedings of the ISATA Conference* , Florence, Italy.

7.2 Alcohol and Drugs References

Arnedt, J.T., Wilde, G.J.S., Munt, P.W., & MacLean, A.W. (2001). How do prolonged wakefulness and alcohol compare in the decrements they produce on a simulated driving task? *Accident Analysis and Prevention, 33*, 337-344.

Beideman, L.R., & Stern, J.A. (1977). Aspects of the eyeblink during simulated driving as a function of alcohol. *Human Factors, 19*(1), 73-77.

Brewer, N., & Sandow, B. (1980). Alcohol effects on driver performance under conditions of divided attention. *Ergonomics, 23*(3), 185-190.

Brick, J. (2000). Accident reconstruction analyses: An overview of biobehavioral effects on reaction time. *The Forensic Examiner, 9*(11-12), 19-23.

Brookhuis, K.A., & De Waard, D. (1993). The use of psychophysiology to assess driver status. *Ergonomics, 36*(9). 1099-1110.

Brookhuis, K.A., De Waard, D., & Fairclough, S.H. (2003). Criteria for driver impairment. *Ergonomics, 46*(5), 433-445.

Buikhuisen, W., & Jongman, R.W. (1972). Traffic perception under the influence of alcohol. *Quarterly Journal of Studies on Alcohol*, *33*, 800-806.

Burian, S.E., Liguori, A., & Robinson, J.H. (2002). Effects of alcohol on risk-taking during simulated driving. *Human Psychopharmacology*, *17*, 141-150.

Burns, M. (1985). Driving impairment: Blood levels of alcohol and other substances. *Alcohol, Drugs and Driving, 2*(1), 131-133.

Cox, D.J., Quillian, W.C., Gressard, C.F., Westerman, P.S., Gonder-Frederick, L.A., & Canterbury, R.J (1995). The effects of blood alcohol levels on driving variables in a high-risk population: Objective and subjective measures. *Journal of Alcohol & Drug Education, 40*(3), 84-98.

Dawson, D. & Reid, K. (1997, July 17). Fatigue, alcohol and performance impairment. *Nature*, *388*, 235.

Dennis, M.E. (1995). Effects of alcohol on driving task abilities. *ADTSEA, The Chronicle Summer Issue*, *43* (3), **pp.**.

Dott, A.B., & McKelvey, R.K. (1977). Influence of ethyl alcohol in moderate levels on the ability to steer a fixed-base shadowgraph driving simulator. *Human Factors*, *19*(3), 295-300.

Ferrara, S.D., Zancaner, S., & Giorgetti, R.(1994). Low blood alcohol concentrations and driving impairment: A review of experimental studies and international legislation. *International Journal of Legal Medicine, 106*, 169-177.

Finnigan, F., Hammersley, R., & Millar, K. (1995). The effects of expectancy and alcohol on cognitive-motor performance. *Addiction*, **x,** 661-672.

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(2), 203-208.

Green, P. (2002). Where do drivers look while driving (and for how long)? In R.E. Dewar & P.L. Olson (Eds.), *Human factors in traffic safety* (pp. 77-110). Tucson, AZ: Lawyers and Judges Publishing.

Greenberg, L.A. (1968). The pharmacology of alcohol and its relationship to drinking and driving. *Quarterly Journal of Studies on Alcohol, Suppl. 4*, 252-256.

Holloway, F.A. (1995). Low-dose alcohol effects on human behavior and performance. *Alcohol, Drugs and Driving, 2*(1), 39-56

Horne, J.A., & Baumber, C.J. (1991). Time-of-day effects of alcohol intake on simulated driving performance in women. *Ergonomics, 34*(11), 1377-1383.

Horne, J.A., & Gibbons, H. (1991). Effects of vigilance performance and sleepiness of alcohol given the early afternoon ('post lunch') vs. early evening. *Ergonomics, 34*(11), 67-77.

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), 340-344.

Kerr, J.S., & Hindmarch, I. (1998). The effects of alcohol alone and in combination with other drugs on information processing, task performance and subjective responses. *Human Psychopharacology*, *13*, 1-9.

Laurell, H. (1977). Effects of small-doses of alcohol on driver performance in emergency traffic situations. *Journal of Accident Analysis and Prevention*, *9*, 191-201.

Lenne, M.G., Triggs, T.J., & Redman, J.R. (2000). Alcohol, time of day, and driving experience: Effects on simulated driving performance and subjective mood. *Transportation Human Factors*, *1*(4), 331-346.

Loomis, T.A., & West, T.C. (1957). The influence of alcohol on automobile driving ability: An experimental study for the evaluation of certain medicological aspects. *Quarterly Journal of Alcohol Studies, 19*, 30-46.

Louwerens, J.W., Gloerich, A.B.M., Vries, D., Brookhuis, D. & O'Hanlon, K.A. (1987). The relationship between drivers' blood alcohol concentration (BAC) and actual driving performance during high speed travel. In P.C. Moordzij & R. Roszbach (Eds); *Alcohol Drugs and Traffic Safety – T86.* Amsterdam: Excerpta Medica, 183-187

Marczinski, C.A., & Fillmore, M.T. (2003). Preresponse cues reduce the impairing effects of alcohol on the execution and suppression of responses. *Experimental and Clinical Psychopharmacology, 1*, 110-117.

Martin, G.L. (1971). The effects of small doses of alcohol on a simulated driving task. *Journal of Safety Research, 3*(1), 21-27.

Maylor, E.A. & Rabbitt, P.M.A. (1993). Alcohol, reaction time and memory: A meta-analysis. *British Journal of Psychology, 84*, 301-317.

Mongrain, S., & Standing, L. (1989). Impairment of cognition, risk-taking, and self-perception by alcohol. *Perceptual and Motor Skills, 69*, 199-210.

Moskowitz, H. (1973). Laboratory studies of the effects of alcohol on some variables related to driving. *Journal of Safety Research, 5*(3), 185-199.

Moskowitz, H. (2002). Driving under the influence. In R.T. Ammerman, P.J. Ott & R.E. Tarter (Eds.), *Prevention and Societal Impact of Drug and Alcohol Abuse* (pp.109-123). Tucson, AZ: Lawyers and Judges.

Moskowitz, H. (2002). Alcohol and drugs. In R.E. Dewar & P.L. Olson (Eds.), *Human factors in traffic safety* (pp. 177-208). Tucson, AZ: Lawyers and Judges Publishing Company, Inc.

Moskowitz, H. & Burns, M. (1990). Effects of alcohol on driving performance. *Alcohol Health and Research World, 14*(1), 12-14.

Moskowitz, H., Burns, M.M., & Williams, A.F. (1985). Skills performance at low blood alcohol levels. *Journal of Studies on Alcohol, 46*(6), 482-485.

Moskowitz, H., & Fiorentino, D. (2000). A review of the literature on the effects of low doses of alcohol on driving-related skills. Washington, D.C.: National Highway Traffic Safety Administration.

Newman, H., Fletcher, E., & Abramson, A.B. (1942). Alcohol and driving. *Quarterly Journal of Studies on Alcohol, 3, 15-30.*

Peden, M., Scurfield, R., Sleet, D., Mhan, D., Hyder, A.A., Jarawan, E., & Methers, C. (2004). *World report on world traffic injury prevention.* Geneva: World Health Organization.
http://www.who.int/world-health-day/2004/infomaterials/world_report/en/

Ramaekers, J.G., Berghaus, G., van Laar, M. & Drummer, O.H. (2004). Dose related risk of motor vehicle crashes after cannabis use. *Drug and Alcohol Dependence,* 73, 109-119.

Rimm, D.C., Sininger, R.A., Faherty, J.D., Whitley, M.D., & Perl, M.B. (1982). *Addictive Behaviors, 7*, 27-32.

Roehrs, T., Beare, D., Zorick, F., & Roth, T. (1994). Sleepiness and ethanol effects on simulated driving. *Alcoholism: Clinical and Experimental Research, 18*(1), 154-158.

Roehrs, T., Zwyghuizen-Doorenbos, A., Timms, V., Zorick, F., & Roth, T. (1989). Sleep extension, enhanced alertness and the sedating effects of ethanol. *Pharmacology Biochemistry & Behavior, 34, 321-324*.

Schroeder, S.R., Ewing, J.A., & Allen, J.A. (1974). Combined effects of alcohol with methapyrilene and chlordiazepoxide on driver eye movements and errors. *Journal of Safety Research, 6*(2), 89-93.

Smiley, A. & Brookhuis, K.A. (1987). Alcohol, drugs and traffic safety. In Rothengatter, J. A. and de Bruin, R. A. (Eds.). (1987). *Road Users and Traffic Safety.* (pp. 83-104). Netherlands: Van Gorcum.

Sutton, L.H. (1983). The effects of alcohol, marihuana and their combination on driving ability. *Quarterly Journal of Studies on Alcohol*, 44(3), 438-445.

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*, 527-532.

7.3 Emergency Responses

Akari, K., & Matsuura, Y. (1990). Driver's response and behavior on being confronted with a pedestrian or a vehicle suddenly darting across the road. *SAE Technical Paper Series 900144*. Warrendale, PA: SAE.

Barrett, G. V., Kobayashi, M., & Fox, B. H. (1968). Feasability of studying driver reaction to sudden pedestrian emergencies in an automobile simulator. *Human Factors, 1*0(1), 19–26.

Crook, T.H., West, R.L., and Larrabee, G.J. (1993). The driving-reaction time test: Assessing age declines in dual-task performance. *Developmental Neuropsychology*, *9*, 31-39.

Edwards, M. L. (1985). *Precrash movements of traffic vehicles*. Unpublished manuscript. National Highway Traffic Safety Administration.

Evans, L. (1991). *Traffic safety and the driver*. New York: Van Nostrand Reinhold.

Hostetter, R., McGee, H., Crowley, K., Sequin, E., & Dauber, G. (1986). *Improving perception-reaction time information for intersection sight distance*. FHWA/RD-87/015.

Hooper, K. G., & McGee, H. W. (1983). Driver perception-reaction time: Are revisions to current values in order? *Transportation Research Record, 904*, 21–30.

Johansson, G., & Rumar, K. (1971). Driver's brake reaction times. *Human Factors, 13*(1), 23–27.

Kortelling, J. (1990). Perception-response speed and driving capabilities of brain damaged and older drivers. *Human Factors, 32*, 95–108.

Lerner, N. D. (1993). Brake perception-reaction times of older and younger drivers. *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting* (pp. 206–210). Santa Monica, CA: Human Factors and Ergonomics Society.

Lerner, N. D. (1994). Age and driver time requirements at intersections. *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting* (pp. 842–846). Santa Monica, CA: Human Factors and Ergonomics Society.

McKnight, A. J., & Shinar, D. (1992). Brake reaction time to center high-mounted stop lamps on vans and trucks. *Human Factors, 34*(2), 205–213.

Minnehan, D. J., & O'Day, J. (1979). Comparison of Michigan fatal and non-fatal car-into-truck accidents (Rep. UM-HSRI-79-49). Ann Arbor: University of Michigan, Highway Safety Research Institute.

Mortimer, R. G. (1988). Rear-end crashes. In G. Peters and B. Peters (Eds.), *Automotive Engineering and Litigation* (Vol. 2) (pp. 275–303). New York: Garland Law Publishing.

Mortimer, R. G. (1990). Perceptual factors in rear-end crashes. *Proceedings, Human Factors Society* (pp. 591–594).Santa Monica, CA: Human Factors Society.

Olson, P. L. (1989). Driver perception response time. *SAE Technical Paper 890731*. Warrendale, PA: SAE.

Olson, P. L., & Sivak, M. (1986). Perception-response time to unexpected roadway hazards. *Human Factors, 28*, 91–96.

Olson, P.L., & Farber, E. (2002). *Forensic aspects of driver perception and response* (2nd ed.). Lawyers and Judges Publishing.

Ranney, T. A., & Pulling, N. H. (1987). Stopping performance in familiar and unfamiliar vehicles. *Proceedings of the Human Factors Society 31st Annual Meeting* (pp. 762–765). Santa Monica, CA: Human Factors Society.

Sanders, A.F. (1970). Some aspects of the selective process in the functional field of view. *Ergonomics, 13*, 101–117.

Sens, M. J., Cheng, P. H., Wiechel, J. F., & Guenther, D. A. (1989). Perception/reaction time values for accident reconstruction. *SAE Technical Paper 890732*. Warrendale, PA: SAE.

Sivak, M., Flannigan, M. J., Sato, T., Traube, E. C., & Aoki, M. (1994). Reaction times to neon, LED, and fast incandescent brake lamps. *Ergonomics, 37*(6), 989–994.

Sivak, M, Olson, P. L., & Farmer, K. M. (1982). Radar-measured reaction times of unalerted drivers to brake signals. *Perceptual and Motor Skills, 55*, 594.

Sivak, M., Post, D., Olson, P. L., & Donohue, R. J. (1981b). Driver responses to high-mounted brake lights in actual traffic. *Human Factors, 23*, 231–235.

Spurr, (1969, February). Subjective aspects of braking. *Automobile Engineer*, pp. 58–61.

Summala, H. (1981a). Driver/vehicle steering response latencies. *Human Factors, 23*, 683–692.

Summala, H. (1981b). Drivers' steering reaction to a light stimulus on a dark road. *Ergonomics, 2*4(2), 125–131.

Summala, H. (2000). Brake reaction times and driver behavior analysis. *Transportation Human Factors, 2*(3), 217-226.

Toaka, G. T. (1982). Statistical evaluation of brake reaction time. *ITE Compendium of Technical Papers 52nd Annual Meeting*, Chicago, IL.

Toaka, G. T. (1989, March). Brake reaction times of unaltered drivers. *ITE Journal*, pp. 19–21.

Triggs, T., & Harris, W. (1982). *Reaction times of drivers to road stimuli*. Melborne Australia: Monash University, Department of Psychology. (ISBN 0 86746 147 0).

Wilson, F. R., Sinclair, J. A., & Bisson, B. G. (1989). *Evaluation of driver/vehicle accident reaction times*. Fredericton, N.B., Canada: The Transportation Group, University of New Brunswick.

Appendix A:
Research Summaries of Cognitive and Physical Interactions with Cellular Telephone Tasks

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Brown, Tickner & Simmonds (1969)	To determine if talking on a phone affected driver performance.	Drivers performed a grammatical reasoning task[a] on the phone as they drove though gaps of varying clearance on a test track (airfield). They had the option of taking a detour or going through a passage.	N = 24 males (21 to 57 years, median = 41). Driving experience (3 to 37 years, median = 15.5).	Gap clearance (–3, 0, +3, 6 and 9 inches). Judged whether the size of a gap was big enough for their car to pass through.	Judged and actual gaps cleared, speed of circuit completion, input frequency to brake and steering, and telephone task performance.	Judgment errors increased for all gaps and –3 and 0 gaps were significantly different than trials without the reasoning test. Steering was not affected by the telephone task. Circuit time increased by 6.6% when concurrent. RT and errors for the telephone task also increased during concurrency.	Younger drivers tended to focus on the telephone task at the expense of gap judgement and the converse tended to be true for older participants, however the statistical test was unreliable.

[a] Baddeley, A. (1968). A 3-minute reasoning test based on grammatical transformation. *Psychonomic Science, 10*, 341–342.

Authors	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Stein, Parseghian & Allen (1987)	Traffic safety implications of phone use while driving.	Participants drove a driving simulator (STI) over a 15-mile course while using a mobile phone. Phone was mounted on the dash or in a console.	N = 72, 12 men and women in each age group (<25, 25-55, 55 +). 3 cellular phone users were in each age category except older group. Phone task was to memorize flight information (airline #, origination, destination). Radio task was to find a frequency without a scan function. Reward/penalties for run completion and errors (accident, ticket, message or radio error).	Phone/radio task: baseline, cell phone task, radio tuning task. Driving condition: straight, straight with obstacle, curve. Call origination or receiving. Age group (<25, 25-55, 55+), Gender (M, F). Incomplete factorial design for combinations.	Accidents, speeding tickets, lane position (and variability), speed control, sign responses.	Collisions and speeding tickets were infrequent. SD of lane position indicated an interaction between age and task, where dialing 10 numbers produced greater weaving for older drivers than other age groups. Lane tracking was worse with age on the memory recall of flight information. Phone dialing when mounted in center console resulted in 5x increase in probability of a collision with obstacle for the 2 older age groups. Oldest age group had a 5 to 7 X increase in collision probability for radio dialing.	That users and non-user of cell phones may have differential performance effects is noted.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Zwahlen, Adams & Schwartz (1988)	To determine the degree to which lateral control of a vehicle changes while using a cell phone in several positions.	Participants drove on a test track (airfield) with an instrumented vehicle.	Participants were instructed to drive a straight path at 40 mph by aligning vehicle with runway centerline while dialing the cell phone.	Study 1: N = 10 men (M = 23.6). Study 2: N = 10 (5 men, 5 women) (M = 20.8). Dial 11 digit long distance number on phone, which was either dash-mounted or next to car seat, while either continuously looking at keypad or look back and forth to roadway.	Lateral path deviation (inches).	Lateral position when looking back and forth and keypad near dash least deviations. When dialing from phone near seat and not able to look at road, maximal deviation occurred in both studies (38.13 & 40.69 respectively). The Plymouth used in Study 2 may have skewed values to the right of centerline. Looks to the road when the keypad was in the seat position was 2.2 X per call and 2.9 X when next to dash.	Not being allowed to look at the road while dialing may not necessarily be realistic. Conversations were not examined.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Fairclough, Ashby, Ross & Parkes (1991)	To examine the effects of passenger and hands-free conversation on driver performance.	Participants drove on-road with an instrumented vehicle.	N = 24 (M = 45 years, M = 25 years driving experience). Drivers participated in normal driving (control), and in conversation on the phone or with a passenger (experimenter).	Conversation condition (control, conversing on hands-free phone, conversing with passenger).	Duration and frequency of eye-movements, NASA-TLX, heart rate (bpm), general questionnaire items.	Workload was rated higher in conversation conditions, specifically mental demand, mental effort and frustration. Driving speed decreased, as indicated by circuit completion time, with cell phone negotiation for both conversation conditions. No differences between conditions for eye-movements.	Participant characteristics were not elaborated.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Brookhuis, de Vries & de Waard (1991)	The effects of hands-free and hand-held telephoning while driving in a variety of traffic contexts.	On road with instrumented vehicle while performing a paced serial addition task (PASAT) on either a hand-held or a hands-free phone. [b]	Each participant was measured on weekdays over 3 consecutive weeks (i.e., 15 x). Driving performance assessed under phone and no phone conditions. Participants were to keep a constant distance to a lead vehicle while performing PASAT.	N = 12 (10 men, 2 women), none had previous cell phone experience. Traffic type (quiet road with light traffic, 4 lane motorway with heavy traffic, city traffic).	SD lateral position, reaction time, steering wheel movement, heart rate variability.	RT to the lead vehicle braking increased by 130 ms when talking in heavy traffic and adaptation to speed change 600 ms (in what condition). Steering wheel movements were elevated before hand-held phone call and afterwards for hands-free calls.	The study had a low total N and few women.

[b] Baddeley, A., Logie, R., Nimmo-Smith, I., & Brerefon, N. (1985). Components of fluent reading. *Journal of Memory and Language, 24*, 119-131.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
McKnight & McKnight (1993)	To determine the effects of a number of distraction tasks on the detection of traffic situations.	Participants watched a 25-minute video that contained 45 traffic events while they "manipulated" vehicle controls. Detection of traffic situations included: vehicles, roadway geometry changes, pedestrians and animals, sight limitations, roadside construction, traffic control signals, and road surface changes.	N = 150, 45 young (17-25), 56 middle-aged (26-49), and 49 older (50-80). M = 39 for whole sample and approx. balanced for gender. About 1/3 were cellular phone users.	Distraction type (place cellular phone call, converse casually, have intense dialogue, tune radio). Driver age (young, middle-aged, older).	Proportion responding to each traffic situation.	All 4 within-subjects, distraction tasks produced significantly higher proportions of missed traffic situations than without distraction.	Whether the manipulation of controls declined with the length of the video is not discussed. SD's were not reported.

Author(s)	**Primary Emphasis**	**Methods**	**Participants/ Procedures**	**Independent Variables**	**Dependent Variables**	**Results**	**Notes**
Green, Hoekstra & Williams (1993)	On-road examination of experimental navigation system while conversing on a hand-held phone.	An instrumented vehicle used to examine navigation and hand-held interaction on driver performance.	N = 8, 4 younger (<30), 4 older (60+), men and women were equal in both groups. Made 3 calls (3 conditions) while driving at 50 mph and 65 mph at the same locations in a 35-minute test route.	Hand-held, secondary tasks (each 30 s in length): listen to description and make decision, describe activity (e.g., what they did last weekend), list items in a category (e.g., fruits). Baseline driving. Age group (young, old).	Lateral lane position, throttle position, speed, steering wheel angle, eye fixation locations.	Older drivers had more variable (SD) steering wheel angles than did younger drivers and positioned the test vehicle closer to the center of the lane than younger drivers. SD of steering wheel angle indicated that all three conversing tasks were similarly difficult. Speed was more steady (SD of speed) and SD of lateral position was less variable when using cellular phone.	Eye fixation results are not discussed. Total number of participants was somewhat low.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Ålm & Nilsson (1994)	Driving in simulator with hands-free phone.	VTI driving simulator with varying road conditions while interacting with Working Memory Span Test[c] on a phone mounted to the right of steering wheel.	N = 40, 20 men and 20 women, aged 23 to 61 (M = 32.4, SD = 9.5). During 2 test routes each 80 km in length on 2 lane roadway 8 calls were received.	Telephone and Control Groups, Road type (straight, curvy).	Reaction time, lane position, speed and workload, Detect and brake to a red visual stimulus at left shoulder of road. Secondary task performance.	RT was slower for the straight drive with phone than without (0.385 s). No RT differences were found on the curvy route. Lateral position differed between phone and control for curvy drive at 500 meters prior and 2500 meters throughout call for curvy and straight drive. Workload was rated higher during task.	The precise coincidence of secondary tasks with the driving task is not described. What the red square meant to drivers is uncertain.
Ålm & Nilsson (1995)	Car following with hands-free phone in driving simulator.	VTI driving simulator with varying road conditions while interacting with Working Memory Span Test[c] on a phone mounted at right of steering wheel.	N = 40, 30 men and 10 women. Aged <60 (M = 29.3, SD = 8.1) and 60+ (M = 67.6, SD = 4.1). 80 km test route on straight 2-lane roadway with continuous on-coming traffic. 16 car following situations over route where 8 required a phone task.	Age (young, old), Group (telephone, control)	Choice reaction time (CRT), headway (m), lateral position, workload (NASA-TLX), secondary task performance.	CRT (brake response) to lead vehicle braking at 4 m/s^2 for 5 s was significantly higher for older drivers than younger and control (young talk, 2.19 s; alone, 1.63 s; older talk, 3.48 s; alone, 2.02 s). Minimum and average headway was closer in the phone than control condition. No lateral position differences were found. Mental demand, time pressure, effort and frustration, of NASA-TLX, was higher in the phone group than the control.	Two participants were lost to simulator sickness and replaced. Standard deviations not indicated.

[c] Baddeley, A., Logie, R., Nimmo-Smith, I., & Brerefon, N. (1985). Components of fluent reading. *Journal of Memory and Language, 24*, 119-131.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Briem & Hedman (1995)	The effect of hands-free phones on part-task, simulated driving.	Pursuit tracking task while interacting with secondary tasks.	N = 20, 2 groups 19 to 26 (Median = 21), 40 to 51 (Median = 45.5). Half were men and half were women. Telephone mounted just to the right of steering wheel.	Secondary task (simple conversation, intense conversation, car radio tuning & listening), road surface (slippery 50 km/h, firm 70 km/h), activity type (only driving, obstacles, conversation, manipulation of radio).	Road position (RMS), errors: % time on the shoulder, % time off the road, collisions, and speed.	RMS was greatest for radio manipulation (M = 21.2), followed by difficult conversation (20.7) and simple conversation (19.7).	Were blocks of trials randomized?

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Tijerina, Kiger, Rockwell & Tornow (1996)	To determine the workload effects that text messaging and cell phone systems have on heavy vehicle drivers.	Participants drove an instrumented truck on a 4-hour route around Columbus, Ohio. Drivers interacted with a number of in-vehicle tasks which were task-analyzed to approximate cell phone and other in-vehicle devices.	N = 16 (32 to 60, M = 47.2), 6 to 35 years of driving experience (M = 21.6), 7/16 had prior cellular experience. Drivers were prompted by a buzzer to read and perform the CRT displayed task (e.g., call a number, etc.). Manual task (auto dial, 7-digit, 10-digit phone dial, radio tuning), cognitive task (two question and answer dialogues + open road driving control).	Lighting (light N = 8, dark N = 8), road type (divided, undivided), traffic density (high, low), device (CRT, phone, radio).	Glance frequency, average road glance duration, total glance time to CRT, average glance duration to device, total task duration, steering position variance, # of steering wheel holds, # of steering wheel reversals, variance of accelerator position, # of accelerator holds, mean speed, speed variance, lane position variance, # of lane exceedances.	Reading (visual), dialing (visual-manual) and conversation (cognitive) tasks had differential impacts on driving performance. For the CRT reading tasks, steering wheel reversals were significantly greater for the 2 and 4 line messages than the 1 line message. Two and 4-line text reading took the eyes off the road for the longest total duration. Lane keeping performance was affected by the visual demand of reading 2 and 4 line CRT messages. 7 and 10 digit dialing required more glances to complete and thus, the eyes were off the road for longer periods. Lane exceedences occurred on 27% of manual task trials. Mirror sampling was curtailed during conversation tasks.	The scope of the results do not necessarily lend themselves to simple reduction. Gender is assumed to be male, but it is not listed.

Author(s)	**Primary Emphasis**	**Methods**	**Participants/ Procedures**	**Independent Variables**	**Dependent Variables**	**Results**	**Notes**
Hanowski, Kantowitz & Tijerina (1995) Also see Kantowitz, Hanowski & Tijerna (1996)	To determine the effects of cell phones and text messaging on heavy vehicle driver workload.	Truck mock-up with STISIM simulator was used to evaluate a range of in-vehicle tasks including dialing tasks, cognitive responses to cell phones, and CRT reading task.	N = 14 truck drivers with commercial licenses (26 to 68, M = 47.1), mean driving milage per year = 57,045 miles. Six routes (modules) were driven, each lasting about 30 minutes at 55 mph.	Road (right/left curve, no curve), Event (moving and stationary pedestrian, reading text message, tachometer reading, manual radio tuning, read time, dialing, cell phone dialogue)	Lane position (SD), mean speed (SD), mean steering wheel rate (SD), response latency to secondary task.	Radio tuning, text message reading, and dialing tasks produced greater SD of lane position than driving alone. Dialogue tasks produced higher normalized lane exceedances than driving alone.	The gender of drivers is assumed to be male, but it is not indicated. Potential carry-over effects from numerous treatment combinations.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Lamble, Kauranen, Laakso & Summala (1999)	Determine drivers' ability to use a mobile phone and detect lead vehicle deceleration.	Participants drove an instrumented vehicle on a 30 kilometer section of motorway in Helsinki. Participants did 10 trials of the control, 10 of dialing, and 10 of the cognitive task and this sequence of trials was repeated 3 times. To dial, participants interacted with a keypad-display located 35 degrees right of the line of sight.	N = 19 younger drivers (20-29, M = 22.7), 9 women, 10 men. Participants were instructed to follow the lead vehicle at 80 km/h with cruise control engaged. With foot over the brake, they were told to brake when the lead vehicle did so. Dialing: key in 3 numbers spoken by experimenter (self paced). The cognitive task was to???	Task type (control, dialing task, cognitive task).	Time to Collision (TTC) (s), BRT (s), glance duration.	TTC decreased for phone dialing (0.62 s) and cognitive task (0.95 s) over baseline. BRT increased when phone dialing (0.48 s) and cognitive task (0.50 s). Mean glance duration to roadway 1.25 s (0.65-2.03 s, SD = 0.36), keypad 0.79 s (0.52-1.23 s, SD = 0.22).	One control block was lost due to technical difficulties. Students and non-students may have had somewhat different cell phone use experience before entering in the study.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Reed & Green (1999)	To compare the driving performance decrements in a low-cost driving simulator and on the road while using a manual cell phone.	Driving performed in an instrumented vehicle was compared to that obtained in a low-simulator. Participants drove a freeway route in either experimental setting while dialing 11-digit phone numbers displayed on cards mounted above the center console.	N = 12, 6 were older than 60 (3 men, 3 women) and 6 were between 20 and 30 (3 men, 3 women). All participants had some cell phone experience while driving. Participants drove 60 mph (104 km/h) in the right-hand lane in off-peak drive times (i.e., 10-12 a.m. & 2-4 p.m. for on-road)	Scene fidelity (low, high), driving type (simulator, on-road), task (dialing, none), age (young, old) gender (M, F).	Lane position (SD), speed (SD), steering wheel angle (SD), throttle position (SD).	Without the dialing task on the road, driving performance over age and gender did not significantly differ. Older drivers had greater performance decrements when dialing than younger participants. On-road, mean lateral speed and SD of steering wheel angle while dialing, was greater then baseline for both young and old. The SD of speed and throttle position were both less in baseline driving than when dialing. Dialing, whether on-road or in the simulator, produced lane keeping and speed control decrements.	Order of performance was on-road and then simulator after 10 to 12 weeks. Mean age for each group was not reported. Dialing was performed with the right hand. The number of participants who were left-handed is not reported. Low cell sizes may impact effect sizes and statistical assumptions. Presumably the statistical reporting is found in their technical report.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Hancock, Hashemi, Howarth & Ranney (1999)	Effects of in-vehicle phone task on braking to a traffic light change.	Drove instrumented vehicle over 60 circuits of test track while performing a telephone matching task. Distraction task: when tone played, recall a previously memorized phone number, compare the first digit of it to displayed number. Enter whether it is the same or different.	N = 10, 5 male, 5 female (26-46, M = 36.0). Participants were instructed to stop as quickly as possible when a traffic light changed from green to red.	Speed (20 and 30 mph).	BRT (s), stopping time (s), stopping distance (ft.), digit matching task performance.	BRT without distractor (0.61 s) was significantly different than with (0.93 s). BRT at 20 mph was slower (0.78 s) than at 30 mph (0.68 s). Drivers stopped more quickly in the presence of a distractor (1.66 s, SD = 1.32) than without (2.55 s, SD = 2.55). Stopped faster at 30 mph (2.07 s) than at 20 mph (2.14 s).	Traffic light changed from green to red intead of green, yellow and red.
Hancock, Lesch & Simmons (2003)	Driver performance at an intersection with and without phone distraction task.	Test track with instrumented vehicle with same task as above. Participants practiced 12 trials (Trial was each circuit of test track, 0.5 mile.) Experiment session was 24 trials per block of trials X 2. Within a block, 12 control trials, 4 distraction task, 4 stopping, 4 stopping and distraction tirals were performed.	N = 42 (19 M, 17 F), 19 young (25-36, M = 30.1) 17 old (55-65, M = 60.2). Participants were instructed to stop as quickly as possible when a traffic light changed from green to red.	Age (young, old), Gender (M, F).	BRT (s), Stopping Time (s), Stopping Distance (SD), Stopping Accuracy, Secondary Task Performance, Stopping Compliance (%).	BRT was slower when distractor task present (0.71 s) than without (0.52 s). Distractor task affected older driver BRT more so than younger drivers. Stopping time was shorter in the presence of distractor task, which indicated harder braking. Compliance to the red light was 94.64%, but with distractor task , it decreased to 80.35%.	Data loss for 4 subjects, 2 subjects dropped because tasks were not performed correctly, thus N= 36. Responses on second block were faster than the first.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Haigney, Taylor & Westerman (2000)	The effect of mobile phone use on driving performance in a driving simulator.	Aston driving simulator (21" monitor) while performing a modified grammatical reasoning test[d] on a phone, mounted on the level of the dash, or on a hand-held phone.	N = 30 (13 male, 17 female) (M = 26.93, SD = 3.06.	Transmission (manual, automatic), phone type (hands-free, hand-held), pre-/post- call.	Speed, SD of accelerator travel, pedal travel, # of gear changes, number of overtakes, off-road excursions, # of collisions, heart rate.	No differences were found between hand-held and hands-free performance. Mean speed was lower during a call than before or after. While using the hand-held phone, the number of off-road excursions (0.32) was significantly greater than with hands-free (0.13). Heart rate was significantly higher during calls than before of after.	Experimental description and analysis elaboration was minimal. Off-road excursions not defined.

[d] Baddeley, A. (1968). A 3-minute reasoning test based on grammatical transformation. *Psychonomic Science, 10*, 341–342.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Waugh, Glumm, Kilduff, Tauson, Smyth & Pillaomarri (2000)	To determine the effects of passenger and cell phone conversation effects on driving performance in a closed course.	While driving their own vehicles, participants negotiated a traffic cone defined route, which was 80 feet long and 12 feet wide. Participants completed 6 training laps.	N = 12 (7 male, 5 female), 24 to 49 (M = 38.1). All participants were cell phone users. The Rosenbaum Verbal Cognitive Battery (RVCB)[e] was administered alone and while driving.	Baseline driving, baseline RSVB (no driving), passenger speaking RVCB to driver.	SWAT (every 20 s), mean lap times (s), # of cones hit, RT to RCVB sentences, RCVB verbal puzzles.	Mean lap time (s) for the phone condition was significantly longer than baseline and passenger conditions. RT (latency) to verbal puzzle questions, in both cell phone and passenger conditions differed from baseline, but not from one another. SWAT scores were significantly lower during baseline driving than all other conditions.	

[e]NOVA Online (1997). Alive on Everest; Base Camp; Test Yourself. http://www.pbs.org/wgbh/nova/everst/base/testmem1.html

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Irwin, Fitzgerald & Berg (2000)	To determine the reaction time to a brake light while engaged in various forms of conversation.	Laboratory mock-up of foot pedals, lamp and secondary tasks.	N = 16, 21 to 45 (M = 31.5, SD = 9), 8 men and 8 women.	Conversational task: control (A), listen to weather forcast (B), answer simple questions (C), respond to questions requiring deeper thought (e.g., route from home to school) (D), answer questions about beliefs (e.g., abortion) (E), gender (M, F).	Reaction time (ms).	Significantly longer RT (481-513 ms) for conditions B to E than control (401 ms). No significant differences between conditions B to E or between men and women.	Instructions for task prioritization were not clear. Results represent optimal performance in the absence of vehicle control.
Consilio, Driscoll, Witte & Berg (2003)	Reaction time to red brake lamp while interacting with secondary tasks.	Laboratory mock-up of pedals, lamp and secondary tasks.	N = 22, 10 to 27 (M = 21, SD = 2.1), 11 men and 11 women. 17/22 had cell phone experience.	Secondary task: control (no task), radio listening, converse with passenger, converse with hand-held, and hands-free (headset).	Reaction time (ms).	Control (M = 392 ms, SD= 33) and radio listening (M = 408 ms, SD = 31) were significantly faster to brake light than conversing with passenger (453 ms, 47), hand-held (464 ms, 41), and hands-free (465 ms, 51). No gender differences were found.	Same as above.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Ishida & Matsuura (2001)	Driver performance while using hands-free and hand-held phones.	Participants drove an instrumented vehicle over a test track while using a hands-free phone, a hand held phone or manipulating a cassette tape.	N = 50, age: 24 were less than 20; 10 were 21 to 22; and, 10 were 31+. One was female. Twenty-one had a license less than a year. Secondary task: radio, listen to news; hand-held, 1 or 2 figures on phone (button presses?), hands-free, same.	Driving condition (alone, hand-held, hands-free, cassette tape manipulation).	BRT (s), mean fixation duration, fixation frequency, total glance duration, following distance (m), lane keeping, and secondary task performance.	BRT was more variable and slightly longer for cassette, hands-free and hand-held phones than driving alone. Hand-held use produced a slightly longer following distance (14.2 m) compared to hands-free (13.5 m) and alone (13.7 m). Picking up phone from passenger seat required, on average, 1.9 s of eye movement time before re-engaging roadway.	Only one woman participated in the study. Ten training instructors participated in the study. What kind of instructor they were is not mentioned.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Parkes & Hooijmeijer (2001)	Driver performance while conversing on a hands-free cell phone.	Participants drove a driving simulator over a 15.5 mile rural route with a high level of oncoming traffic. Participants drove the route once while talking on the phone and once without. Participants were instructed to maintain speed as posted which changed twice (80 to 50 km/h at 4.5 miles, 50 to 80 at 7.0 miles).	N= 15 (22 to 31) (M = 24.0, SD = 2.3) had more than 3 years of driving experience and little or no experience using cellphones and driving. The conversation task was to reply to a series of questions that required "numerical and verbal memory, and arithmetic and verbal reasoning."	Task type (no conversation, conversation) event type (red, green square). Two unexpected events required immediate responses by participants: 1) a green square appeared (2 times) on the roadway for 2 s and required participants to flash their lights, and; 2) a red square appeared on the road (1 time) and participants were required to make an emergency stop.	CRT (s), lateral postion (SD), mean speed (SD).	RT to 1st green square was slower while engaged in conversation (1.13 s) compared to without conversing (1.01 s). However, RT did not differ to the second green square or red square. Conversation did not affect the variability of lateral postion. For those engaged in a conversation and passing a speed limit sign (50 km/h), while traveling at 80 km/h, a delay in speed reduction was observed. The number of correct answers about other traffic, rear-view mirror vehicles and rear-view mirror vehicle velocity was significantly less while conversing than not.	SD's and gender composition were not reported. A complete description of the conversation tasks was deferred to cited literature.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Strayer & Johnson (2001) Exp. 1	To determine the source of dual-task interference and it's effect on surrogate driving performance.	Participants performed a tracking task that combined 3 frequencies (0.07, 0.15 & 0.23 Hz). A target light flashed red or green every 10 to 20 s (M = 15 s). If the light flashed red, participants were to press the "brake button" while performing secondary task.	N= 48 (24 male, 24 female), 18 to 30 (M = 21.3). All had normal or corrected normal vision.	Task (listen to the radio, listen to a book on tape, hand-held conversation, hands-free conversation).	RT (ms), p(miss)	The p(miss) and RT for red lights, while tracking, was significantly higher while using the cell phone than baseline. (The hands-free and hand-held data was collapsed.) Conversations, whether on a hand-held or hands-free phone increased the probability of a miss from 0.28 to 0.70 and increased RT to the red light from 534 ms to 585 ms.	The generalizability of p(miss) is not addressed. RMS error and secondary task performance are not presented.
Strayer & Johnson (2001) Exp. 2	To determine the source of dual-task interference and it's effect on surrogate driving performance.	A word generation (shadowing and production of new words) was used as the conversation. [elaborate]	N= 24 (12 male, 12 female), 18 to 26 (M = 20.5). All had normal or corrected normal vision.	Tracking difficulty (easy, hard) conversation task (shadow, generation).	RMS error	Those in the easy tracking had less RMS error than in the hard tracking. The word generation task produced greater RMS error then the baseline and shadow task in the difficult condition.	Experiment 1 of Strayer, Drews, Albert & Johnson (2002) appears to be a combination of these two experiments so it is not reviewed.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Strayer, Drews & Johnson (2003) Exp. 1 (This study appears to be identical to Strayer, Drews, Albert & Johnson (2002) experiment 2.)	To replicate and extend Strayer & Johnson (2001) to a driving simulator (I-SIM).	Participants followed a pace car in the right-hand lane and appropriately braked when the lead vehicle did so on 32 occasions during a 10-mile (16 km) multilane course.	N = 40 (18 male, 22 female), 19 to 32 (M = 23.6). All had normal or corrected normal vision and 83% had used a cell phone while driving previously. The low density traffic condition involved only the participants and lead vehicle, whereas the high density condition involved 32 vehicles traveling in the left hand lane of a multi-lane highway at about 5 to 10% higher speed than the lead vehicle (which was traveling about 59 mph). Conversation was with a confederate.	Density (low, high), Task type (hands-free, baseline)	Brake onset time (BRT) (s), brake offset time (brake onset to release), collisions, following distance (distance from pace car to participants in meters), time to reach minimum speed (time from stop of deceleration to re-attaining "normal" highway speed).	Brake onset and offset were delayed in the conversation condition and more so when traffic density was higher. Three collisions with the lead vehicle occurred in the higher traffic density, conversation task and none in the other factorial combinations of task and density. Following distance at the time that the lead vehicle braked, in both the high- and low- density traffic, was significantly different between control and conversation conditions.	Was the reason a larger following distance was adopted because the lead vehicle braked so frequently? Smoothed and averaged braking, speed and following distance profiles may not indicate individual tactical compensation strategies.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Strayer, Drews & Johnson (2003) Exp. 2	To determine how cell phone conversations affect attention to billboards while driving.	Exp. 2: Same as Exp. 1 except route was a 1.2 miles (1.9 km) though a suburban roadway with right and left turns indicated by arrows	Exp. 2: N = 20 (11 men, 9 women) 18 to 24 (M = 20.1). 73% reported using cell phones while driving previously.	Exp. 2: Task condition (driving alone, conversing).	Exp. 2: Recognition memory performance (number of billboards correctly classified as old).	Exp. 2: Participants remembered more billboards when driving alone than while conversing on a phone.	Exp. 4 is not reviewed.
Exp. 3	To determine if cell phone conversations disrupt visual scanning of billboards while driving.	. Exp. 3: Same as Exp. 2, except with ASL 501 eye tracker.	Exp. 3: N = 20 (15 men, 5 women), 18 to 23 (M = 20.6). 15/20 participants owned a cell phone and 80% of these reported that they used it while driving.	Exp. 3: Task condition (driving alone, conversing).	Exp. 3: Recognition memory performance, fixation probability, fixation duration, conditional probability of recognition given billboard fixation.	Recognition memory performance was replicated. Fixation probability and duration did not differ between task conditions. However, conditional probabilities indicated recognition, given fixation, was twice as likely in the driving alone (0.47) condition than while conversing (0.22).	

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Strayer & Drews (2003)	To determine if age-related driving performance is affected by hands-free cell phone conversations.	Participants drove a multilane roadway where lead vehicle (pace car) in the right-hand lane braked 32 times in locations randomly selected. Participants drove 4, 10 minute sections.	N = 40, young, 18 to 25 (13 men, 7 women) (M = 20.2), 20 old (65 to 74, M = 69.5) (14 men, 6 women). Participants were told to respond to the lead vehicle in a timely and appropriate way.	Age (young, old), task (baseline, hands-free).	Mean speed, distance to other vehicles, following distance, braking onset time, BRT (ms) (lead vehicle lights onset to braking response), half-recovery time (time to recover 50% of speed lost to lead vehicle braking)	Interaction of age and task not significant although task and age produced significant main effects. Older drivers responded slower to lead vehicle braking than younger drivers, but not differentially when talking. Older drivers tended to drive slower and adopt greater following distances than younger drivers. Older drivers also took longer to recover their speed once they braked than their younger counterparts.	Braking in m/s^2 of lead vehicle not described. The prioritization of primary and secondary tasks is not indicated.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Strayer, Drews & Crouch (2003). (This study is also described in Strayer et al. (in press) as experment 4.)	To compare hands-free and hand-held driver performance with those who were legally drunk (i.e., BAC 0.08).	Participants drove in a driving simulator (I-SIM) over a 24 mile multi-lane highway while following a lead vehicle that braked a number of times (see Strayer et al., 2003, Exp. 1). BAC was measured by an Intoxilyzer 5000.	N = 41 (26 male, 15 female) 22 to 45 (M = 25.7). Normal and corrected normal vision. "Naturalistic" conversations with calls initiated before the start of a drive. Participants drank vodka and orange juice to achieve a BAC of 0.08 wt./vol.	Condition (alcohol, hands-free, hand-held).	Crashes, brake onset, % maximum braking, speed, following distance, half-recovery time (time to recover 50% of speed lost to braking of lead vehicle).	No significant differences between hands-free and hand-held were found so data was collapsed across conditions. Based on an inspection of means and SD's, brake onset was faster than baseline (943 ms) in the alcohol condition (888 ms) and slower in the cell phone condition (1022 ms). Percent maximum braking was much greater in the alcohol condition than baseline and cell phone conditions. Speed was slower in the alcohol and cell phone conditions than baseline. Following distance was closest in alcohol, followed by baseline and cell phone.	Essential statistical analyses to support statements were not included and are presumed to be part of a submitted manuscript. Drinking history, tolerance and achieved alcohol level are not discussed.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Cooper & Zheng (2002)	Closed course study to determine the effects of distraction on gap acceptance decision making in a left turn (i.e., crossing path).	While seated in a stationary instrumented vehicle, participants pressed on the accelerator if a gap was acceptable in a stream of 8 rotating vehicles at 55 km/h on a test track while listening and responding to a complex message on about half the trials.	N = 41, Wet conditions (11 male, 6 females), 4 were 19 to 24, 11 were 25 to 44, and 3 were 45 to 70. Dry conditions (17 males, 5 females), 3 were 19 to 24, 13 were 25 to 44, and 6 were 45 to 70.	Pavement condition (wet, dry), Age group (19-24, 25-44, 45-70), distraction (present, absent)	Minimum time-to-contact (MMTC), gap size (m), velocity of lead and following vehicles (km/h), gap acceptance or rejection (y, n), elapsed time between acceptances (s), presence or absence of message distraction.	When not distracted, gap size (larger), speed of trailing-through vehicle (slower), age (younger), pavement (dry) and time between decisions (less) made acceptance of a gap or decision to turn more likely. Those who were distracted by information messages were less likely to take into account pavement condition in their decisions.	Gap sequence affected 2 participants' data and their data was removed. Logistic regression models are not always easy to explain. Data collection for this study appears to part of Cooper et al. (2003).

Authors	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Cooper, Zheng, Richard, Vavrik, Heinrichs & Siegmund (2003)	To investigate the impact of cell phone use on situations where higher levels of information processing and decision making (e.g., left turns) are required.	Participants drove a closed course in an instrumented vehicle while performing 3 tasks; namely, responding to a traffic light, weaving through pop-up obstacles and making a left turn decision while stopped. After an alterting tone, taped instructions and passages were followed by target words separated by 1 (spatial) to 1.5 (verbal) s. (Task was pilot tested at UBC.)	N = 41 (30 male, 11 female), 7 were 19 to 24 (M = 21.6), 25 were 25 to 44 (M = 35.3), and 9 were 45 to 70, (M = 60.0). All had more than 3 years of driving experience. Additional incentives were given to perform the message and driving tasks as best they could. Participants drove at 50 km/h to perform the first 2 tasks while verbally responding to taped messages (hands-free) that coincided with driving task on 50% of the 24 laps.	Task (traffic signal, left turn, weaving), road surface (wet, dry), age (young, middle-aged, old), gender (male, female), message (none, hands-free), message type (spatial, verbal).	Velocity at light change (to amber), light change to foot on brake (BRT), average deceleration, TTC to stop line.	For the traffic signal scenario, analyses were separated into those who ran it and for those did not. For those who braked when a message was present in the short trigger condition, older drivers (45-70) braked later (1.21 s, SD = 0.21) when the message was present than not present (M = 1.05 s, SD = 0.27). For the longer trigger light, younger drivers initial speed was slower when the message was present than absent. Verbal semantic messages were more problematic when choosing to run a yellow light for those 19 to 24 and 45 to 70 than for imagery messages. When targets were closer (8 m), participants decelerated slower to the targets and proceeded through them at a higher average speed and changed their speed less intensely when the messages were present than not. For the left turn decision task, average gap size and average gap time accepted were least when message was present and most when road conditions were wet and message was absent.	The complexity of the experimental design and results are difficult to summarize. Given the low N in some cells, effect sizes would be useful to determine power.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Recarte & Nunes (2000)	To examine visual behaviour during on-road driving while performing spatial and verbal tasks.	On-road with an instrumented vehicle that collected video-based eye movement data. Participants drove 25 km to familiarize themselves with the test vehicle. Two highways and 2 roads were driven around Madrid by participants for a total of 83.7 km approx. half on each road type.	N = 12 (7 women, 5 men), 21 to 37 (M = 26.3, SD = 5). Each had a minimum of 2 years of driving experience, and total driving distance ranged from 15,000 to 300,000 km. Each task was performed for about 30 s. 16 task alternatives, 8 spatial and 8 verbal, were presented. Verbal tasks required participants to repeat words starting with a certain letter. For the spatial tasks, participants imaged letters A to Z and, 1) stated what letters remained the same if rotated on vertical axis; 2) which remained the same if rotated on horizontal axis; and, 3) stated which letters were closed (e.g., o); which were open (e.g., c). Task was repeated for upper and lower case.	Task type (verbal, spatial, no task), road type (highway, road).	Fixation (3 frames or 60 ms where gaze was in the same place), pupil diameter, fixation duration, fixation frequency.	Pupil size, as a proxy of mental workload, indicated that spatial and verbal tasks produced similar levels of workload above that experienced while driving with no task. Fixation durations were longest and most variable while performing imagery tasks, followed by no task and the verbal tasks. Horizontal and vertical gaze variability was reduced in the verbal condition and more so in the spatial tasks than while driving with no tasks at all. Saccade size (degrees) horizontally was significantly less than performing no task. Vertical saccadic size was less than no task for both spatial and verbal tasks. The proportion of fixations to the rear view and left mirrors and speedometer was significantly reduced while performing verbal and imagery tasks.	Intersections, roundabouts and highway entrances and exits were excluded from analyses. A recording system failure resulted in the loss of data for 2 participants in the road condition. Verbal task descriptions were inadequate.

Authors	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Recarte & Nunes (2003)	To examine the impact of cognitive tasks, including hands-free conversations, on visual behaviour while driving and interacting with a secondary detection task.	Participants drove an instrumented car with an unobtrusive eye movement system over a 300-kilometer section of highway north of Madrid. The detection and discrimination (secondary) task involved 6 LEDs, 4 reflection beams and 2 response buttons mounted on the steering wheel.	N = 12 (6 men, 6 women) (M = 23.4, SD = 2.5), traffic experience exceeded 3 years (M = 4.8, SD = 2.3). All participants did not require visual acuity correction. Acquisition tasks required listening to passages for 2 minutes, whereas production required generating responses based on their listening of the acquisition passages.	Detection (no detection, detection), mental tasks (none, acquisition (abstract, concrete), production (abstract, concrete), autobiography recall (passenger, hands-free), mental calculation of euro conversion (passenger, hands-free)).	Visual behaviour measures: pupil size, spatial gaze variability, proportion of gazes to rearview mirror and speed-ometer.	Pupil and workload ratings indicated higher workload for production tasks (generation of verbal responses) than acquisition (listening). Hands-free phone tasks were rated higher than passenger tasks. Spatial gaze variability was systematically increased when interacting with the secondary task and significantly decreased when performing all mental tasks. Production tasks produced greater spatial gaze variability reductions than listening tasks. Mental tasks produced fewer glances to the speedometer (M = 70%) and rearview mirror. With the exception of 3 conditions, all other tasks produced significant reductions in the number of targets detected.	Background contrast differences, lighting and reflections within the vehicle, probably affected LED and beam conspicuity. One 15-minute break was taken over 4 hours or 300 kilometers of driving.

Authors	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Harbluck, Noy, & Eizenman (2002)	To determine the distraction effect of hands-free conversation s on visual behaviour.	Participants drove an instrumented vehicle that included an eye tracker over a 4-lane route through Ottawa which was 8 km in length. Participants performed single-digit addition (e.g., 3+5) or double-digit addition (44 + 79) or no task at all. The conversation took place over a hands-free phone.	N = 21 (9 women, 12 men), 21 to 34 (M = 26.5, SD = 4.7). All had a minimum of 5 years driving experience and drove over 10,000 km per year. Vision was normal or corrected normal with contact lenses, but not glasses. Participants always drove in the left most lane.	Task type (none, single-digit or double-digit addition).	Mean # of saccades per 5 s, % time looking a left (50 degree +), central (15 degrees) and right regions (50+ degrees), % time looking to instruments, rear-view, left and right mirrors, % time looking in forward view (44 degrees) for no digit and double-digit addition tasks. Frequency of 0.25 g and 0.30 g braking events, NASA-TLX.	The mean number of saccades per 5 s decreased from 7.5 to 7.4, in the single-digit addition task and in the double-digit addition task. The % time looking to the central 15 degrees (and thus less to the right and left), increased with task difficulty (i.e., 78% no task to 82.7% for double-digit addition). The % time looking at rear-view and instruments significantly declined from no task to the double-digit addition task. others looked down. The number of 0.25g and 0.30g braking events significantly increased from no task to the double-digit addition. Drivers who looked up or down while performing the double-digit addition also were more likely to have more hard braking events (does not state whether 0.25 or 0.30g). Workload was rated higher for both addition tasks.	Dependent variables were largely constructed and are unique. Participants were not prescreened for individual differences on math ability or level of education. Loss of 3 participants braking data.

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Gugerty, Rando, Rakauskas, Brooks Olson (2003) Exp. 1 & 2	The effect of passenger and hands-free conversation of several types on driving awareness.	A low fidelity simulation was used to assess awareness or recall of cars after a scene presentation (18 to 35 s). Participants performed 18 trials of no verbal and 35 trials of verbal. Driver and passengers spoke words that began with the last letter of the word spoken by the previous speaker[f].	Exp. 1: N = 29 or 58 pairs (18 to 22). Participants were randomly assigned to pairs. One of each pair interacted with the driver as a passenger or as a caller on a cell phone. Exp. 2: N = 80 pairs (18 to 43). Only the driver did the last letter task. The word task was accelerated and a pay-off matrix was employed to enhance task perceived consequences.	Driving type (baseline and talking while on cell phone or with passenger).	Location recall, probes for avoidance, interpretation probes. Mean location-recall error (distance between recall and actual), % correct scene interpretations, % hazards detected, blocking car detection, RT to hazard detection.	Exp. 1: Longer word durations occurred in remote and driver conditions than in person. Location recall error, scene interpretation and hazard detection RT was worse while conversing over baseline. Remote and in-person conversation both degraded performance. Exp. 2: Location recall errors while driving and talking were slightly higher than in Exp. 1, as were RT's for detecting hazards. The results of Exp. 1 were essentially replicated.	Placement of partition between cell phone talker and driver may not have been sufficient to mask sound or produce the perception of a remote conversation.

[f] Last letter word generation task (see Strayer et al., 2001, Exp. 2)

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Patten, Kirscher, Ostlund & Nilsson (in press)	Driver distraction with manual automobile.	On-road driving over a low complexity motorway while performing a continuous visual secondary task. Drive length was 24 km with a maximum speed of 110 km/h.	N = 40 (21-60, M = 39.6), professional drivers (M = 43,100 km/yr) (taxi and courrier drivers). 8 female, 32 male. An array of 6 red LEDs positioned in a HUD (6.8 and 21.8 degrees left of steering centre). Each phone conversation lasted about 1.5 to 2 minutes.	Conversation type (hands-free, hand-held, baseline), conversation task (complex: single digit addition, simple: repeat single digits, no conversation).	LED RT (ms), LED hit rate.	Hands-free and hand-held device did not differentially affect detection of LED task, but were significantly higher than baseline. LED RT increased from 584 ms to 656 ms for simple conversation and to 845 ms for complex conversation. Those in the hands-free mode adopted a slightly higher speed than baseline and those using hand-held dropped their mean speed. Mean hit-rate declined 11% from baseline with telephone task.	Assumes RT to LED task is relevant. Secondary task performance for simple and complex conversations not presented.

Authors	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
LaBerge, Scialfa, White & Caird (in press)	To determine the differential effect of passenger and hands-free conversation on driving performance.	Study compared passenger and hands-free conversation in a driving simulator (UCDS) while playing a word game between speakers [g]. Rural (easy) and urban (difficult) driving routes (counterbalanced) were driven by participants.	N = 80 (46 men, 34 women), 10 to 27 (M = 20.6). Participants were randomly assigned to either baseline, hands-free, or passenger conditions and combined into pairs (1 talker, 1 driver) in the latter 2 conditions. 53 had prior cell phone experience.	Driving difficulty (rural, urban), task condition (baseline, passenger, hands-free). An intersection light change (green, yellow, red) occurred 3.5 s from intersection one time in the rural route and one time in the urban routes as did a pedestrian event (which walked into the roadway giving drivers 2.5 s to respond).	PRT, SD lane position, mean lane position, mean speed, SD speed, speech rate, word complexity, linguistic frequency, word errors, and NASA-TLX.	PRT (time from event occurrence to braking, 2% change or steering response, 5 degree change) were slightly faster responding to the pedestrian event in the urban route than the rural route. PRT's were slower to the pedestrian when talking with a passenger (M = 1.4, SD = 0.16) and in a hands-free conversation (M = 1.34, SD = 0.27) than alone (M = 1.20, SD = 0.25). Conversation did not affect lane position. Urban driving produced significantly less lane variability and less mean speed than the rural route. Conversation variables did not indicate differences between driving alone versus conversing with a passenger or over a hands-free phone. However, speech rates did indicate speech rates and repeating words indicated differences between rural and urban routes.	Intersections were excluded from analyses.

[g] see Strayer and Johnson (2001, Exp. 2)

Author(s)	Primary Emphasis	Methods	Participants/ Procedures	Independent Variables	Dependent Variables	Results	Notes
Rakauskas, Gugerty & Ward (in review)	To determine a number of naturalistic conversations on driving performance.	Participants drove a simulator (GlobalSim) over a 2-lane rural loop with a single light contolled intersection and four stop controlled intersections at 45 mph. Three hazards were presented; namely, a pull out vehicle, an oncoming vehicle that swerved into the path of the participant, and an ambulance that ran a red light.	N = 24 (12 men, 12 women) (M = 20.4), minimum of 2 years of driving experience. Participants drove 3, 10 min. driving trials. Measures were not taken in curves or intersections.	Conversation type (easy, hard, none), Easy and hard questions were established in pilot testing by rating the difficulty to respond to questions.	Accelerator position variability, SD speed, mean speed, steering offset, mean lateral speed, collisions, RT (trigger to accelerator = 0, brake > 0, steering > 3 SD from straight), workload (RSME).	Conversations increased acceleration variability, speed variability and slightly decreased speed relative to baseline. Workload was rated significantly higher for the conversation types over baseline, but easy and hard conversation types were rated about the same.	Timing of questions and events not considered. RT to hazards became faster with experience.

Appendix B:
Research Summaries of Alcohol and Driving Studies

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes:
Loomis & West (1958)	To examine the level of alcohol that brings about impairment in driving performance.	Simulation study.	N = 10 (22-39), all men. Two equal groups of 5.	BAC level: placebo, alcohol (0.03-0.18%).	Reaction time to amber and red lights (ms), time off road, lap time, time road belt in motion.	Participants were required to operate a miniature car along a belt using a steering wheel, brake and accelerator. Participants were required to stay within the confines of the belt. If participants ran off the road a light was presented. Participants were required to carry out a specific action when confronted with lights. A green light required participants to accelerate, an amber light required the release of the accelerator, and a red light required participants to brake. Red or amber lights were presented 8-10 times in the session and were presented for durations of 3 seconds. Participants practiced the task. Participants had 5 experimental sessions. Four of these were alcohol conditions, the 5th was placebo. They completed 240 tests, 119 of those were while BAC levels were between 0.03-0.18%	Participants who consumed alcohol took longer to react to the red and amber lights, and spent more time off the road compared to those in the placebo condition. These impairments were found for BACs as low as 0.03% For BACs of 0.10% performance decrements were approximately 85% of those that had been observed in the placebo condition. For BACs of 0.15% performance decrements were approximately 70% of those that had been observed in the placebo condition. The authors indicated that alcohol decreased participants ability to divide attention between staying on the road and reacting to information being presented.	One subject was dropped from the study due to sickness caused by alcohol and was not replaced. No women participated. Administration of alcohol was not controlled (i.e., based on weight). Participants made several different runs during the day which may have introduced time of day effects.

Note: Participants received an alcohol primer. To maintain BAC levels participants were given 11 ml of alcohol per hour for five hours. The primer dose was either a 275 ml martini mix, a 260 ml Manhattan or 230 ml 100 proof bourbon whisky. 8-10 oz were required to obtain a BAC of 0.13-0.18%. Prior to and during participation food intake was controlled by experimental protocol. Blood samples were taken, and processed using the macro-diffusion method and titration technique developed by Hemmingway, Bernat, and Maschmeyer (1948).

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Martin (1971)	To examine the effects of alcohol on psychomotor task performance.	Simulation study (Sim-L Car, Point-Light-Source Simulator).	N = 12, (22-28, Median =25), all men. Repeated Measures Design.	BAC level: placebo, alcohol (0.05, 0.10).	Steering reversal rate: (fine steering and gross steering), acceleration reversal, braking. Lateral position: (tracking errors), absolute error (deviation from center of lane), constant error (directional deviation from lane), time off road.	Participants were given a 15-minute practice two days prior to their first test session. Participants completed three testing sessions, each 48 hours apart. Participants drove 10 miles, going 60mph.	BAC produced significant variation in fine and gross steering deviation when compared to the placebo condition. When participants had a BAC of 0.051 they made fewer fine steering movements (20) compared to the placebo condition (23). However, gross steering movements of those with a BAC of 0.05 (11.5) were similar to the placebo condition (11.9). When participants had a BAC of 0.10 they made similar fine steering movements (22.7) compared to the placebo condition (23). Gross steering movements made in the BAC 0.09 condition (13.4) increased compared to the placebo group (11.9). When the two BAC levels were compared it was found that as those in the 0.09% BAC condition made more fine and gross steering movements compared to the 0.051% BAC condition. When compared to those in the placebo group, both BAC levels resulted in similar tracking performance, constant error, absolute error and time spent off the road. There was no significant relationship between BAC level and acceleration reversals.	Specific participant history is incomplete. Participants drank moderately, and possessed drivers license. No women participated. Braking was not analyzed. Testing began at 6 p.m. and participants were separated by 45 minute intervals.

Note: Administration of 0.42 grams of ethyl alcohol /kg of bodyweight was given to obtain a BAC of approximately 0.051%. To achieve a BAC of 0.094%, 1.30 grams of ethyl alcohol/kg of bodyweight was administered. Participants were allotted 15 minutes to consume their drinks. Another 25 minutes was specified to allow for the absorption of alcohol. Participants abstained from food for 6 hours prior to the study. The breathalyzer unit used was Model 600.

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes:
Buikhuisen & Jongman (1972)	To examine the effects of alcohol on traffic perception.	Viewed driving films.	N = 105, all men. Exp. Group: N = 50 Control: N = 55	BAC level: placebo, alcohol (0.08%).	Hazard perception and identification.	Participants viewed a five-minute film taken from the driver's perspective. The film contained approximately 25 situations in which a potential hazard was present. Participant's eye movements were monitored throughout the viewing of the film.	**Traffic Aspects**: (70 aspects) Those in the experimental group observed significantly less traffic aspects (15) than those in the control group (46). While there were no significant differences between groups in observation of on road scenario events or aspects which involved movement; those in the control group observed more traffic aspects that occurred on the left and right sides of the road and more stationary aspects than those in the experimental group. **Perception Time:** Based on 66 aspects, those in the placebo group perceived more traffic aspects (49) sooner than those in the alcohol condition (17). Of the aspects perceived sooner by the placebo condition, perception time was significantly different from the alcohol group in 10 instances. **Distribution of Attention:** In the 6 complex situations, participants in the control group made significantly more eye jumps than those in the alcohol condition. For the control group 9 made less than 1.76 eye jumps, 11 made between 1.76 and 2.25, 13 made between 2.26 and 2.75 and 22 made more than 2.75. For the alcohol group 13 made less than 1.76 eye jumps, 21 made between 1.76 and 2.25, 11 made between 2.26 and 2.75 and 7 made more than 2.75. **Perception Patterns (search strategy):** Those in the alcohol group used a less flexible search strategy and fewer eye movement deviations when compared to those in the control group. **Nystagmus:** A BAC of greater than or equal to 0.8 per mil led to nystagmus. Nystagmus was significantly related to a decrease in the observation of traffic aspects compared to the placebo group and to participants with a BAC of less than 0.8 per mil.	A wide range in BAC was obtained. Did not indicate which aspects were fixated on, and which aspects were ignored. Due to screening based on medical exam and other reasons not mentioned by the authors the original sample of 60 was reduced to 55 participants. Experiment started at 6 p.m.

Note: Participants were given 5 drinks containing 35-40% Brandy. They were allotted 45 minutes to consume the alcohol. Target BAC levels were approximately 0.08%. Participants abstained from food between lunch and 6pm. Blood samples were used to determine BAC levels. Thirteen participants had a BAC less than 0.7 per mil, 24 participants had a BAC from 0.7-0.9 per mil, and 13 participants had a BAC greater than 0.9 per mil.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Schroeder, Ewing & Allen (1974)	To examine the effects of alcohol on eye movements.	Viewed driving Film (Aetna training film, Aetna driver trainer simulator).	N = 30, all men.	BAC level: placebo, alcohol (0.07%). All participants had been licensed for a minimum of 5 years.	Steering, acceleration, deceleration and braking.	Participants viewed a six minute and ten second film. The film contained approximately 9 critical event situations. Participants responded to the events by steering, accelerating, decelerating or braking. If participants took longer than 20 seconds to respond the response was classified as an error.	There was no significant relationship between BAC and driving errors. Those in the alcohol + placebo drug condition had a mean error rate of 33%. Those in the placebo alcohol + placebo drug condition had a mean error rate of 29%. There were statistically significant differences in the type of maneuvers participants used to respond to the events. Alcohol decreased the total frequency of eye movements during the film compared to the placebo condition. Those in the alcohol condition had a lower frequency of long to short saccades per event compared to the placebo condition. This was the case even when alcohol was combined with drugs, compared to the effects of the drug alone. The authors concluded that when alcohol was consumed participants made fewer fixations in their peripheral view which resulted in an increase of driving errors.	Only undergraduate students participated. The range of BAC or type of breathalyzer used was not reported. Estimated BAC during the driving portion.

Note: Participants were given a capsule containing either a drug or placebo. Thirty minutes later they were given a drink containing either alcohol (0.4ml/kg which produced a BAC of approximately 0.07%) or a placebo which was consumed within 5 minutes. Twenty minutes later they were given a sandwich and soft drink. Ten minutes later, they went for their test session. Results presented here represent alcohol + placebo drug, and placebo alcohol + placebo drug. Participants abstained from food on the morning of the session. The eye movement system used was the Biometrics Model SCH/V-2 Infrared Eye Movement Monitor.

Chris Edwards
Comment: Did they define “critical” car/light/pedestrian/dog/etc?

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes:
Beideman & Stern (1977)	To examine the effects of alcohol on information processing as measured by eye blink frequency and eye closure duration.	Simulation study.	N = 20 (23-33, M = 27), all men. Repeated Measures Design.	BAC level: placebo, alcohol (0.073%).	Eye blink frequency and eye closure duration.	After eye calibration, the driving task required the participants to drive while watching "Intermediate Traffic" and "Drive in Review". They were expected to carry out the same maneuvers demonstrated in the film: brake, accelerate, steer or use turn signals.	Only eye closures that ranged between 10 and 150 ms were analyzed. Eye blink frequency increased in the placebo condition, with participants blinking more often in the second film than in the first. Eye blink frequency remained constant for those in the alcohol condition. The median eye closure duration was longer in the alcohol condition than in the placebo condition. Those that were in the placebo condition followed by the alcohol condition had a larger difference in their median eye closure duration. Median eye closure duration was longer in the second film than in the first film, this effect was more pronounced when alcohol was consumed. Those in the alcohol condition made significantly more long-duration blinks (longer than 50 ms) than those in the placebo condition. Significantly more long-duration blinks were made in the second film than in the first.	All participants were graduate students. All participants were experienced drivers. Driving history was not reported by the authors. Participants consumed 150-960cm^3 of alcohol on a weekly basis. No women participated. Testing was carried out during the afternoon.

Note: Alcohol was administered by means of bodyweight. The goal was to obtain "moderate" levels of intoxication. Participants were given 1 hour to consume alcohol. Participants were allotted 15 minutes to allow for the absorption of alcohol. The range in BAC was 0.05% to 0.10%. Participants abstained from food for 4 hours prior to the study.

Authors, year	Objectives	Features	Methods: Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes:
Dott, & McKelvey (1977)	To examine the effect of alcohol on perceptual motor skills (steering).	Simulation study.	N = 16, (M = 29, SD =8.9., 15 men, 1 women. Repeated Measures Design. The majority of participants had driven over 80,000 km since they were licensed. Experienced drivers were those 35 years or older (N = 12), Inexperienced drivers were younger than 35 years, (N = 4)	BAC level: placebo, alcohol (50 mg% and 75 mg %); speed limit (48, 64, 80 km/h).	Distance from center position, roadway position, velocity, and accumulated error.	Participants were given three hours of training over a 3 day period. They were required to accelerate to the speed limit and maintain their lane position.	Those in the 50mg% alcohol group made significantly more steering errors than those in the placebo condition. Those in the 75mg% alcohol group made significantly more steering errors than those in the placebo condition. There were no significant differences between the two levels of alcohol dosage for the amount of steering errors made. BAC did not significantly affect speed. Experienced drivers made more steering errors than inexperienced drivers. There were no significant effects of alcohol or speed on steering errors in the experienced group. Those in the inexperienced group made more steering errors when alcohol was involved and when they were traveling at higher velocities.	Sixteen of 24 original participants completed the study. 8 participants were lost because of procedural, equipment issues; sickness due to alcohol ingestion or unrelated illness. The drinking history of participants was not complete. Type of breathalyzer used was not mentioned. Too few women participated.

Note: On the basis of weight, 95% ethyl alcohol or 100 proof bourbon whisky mixed was administered. Participants were given 1 hour to consume the alcohol. Participants were allotted 1 hour to allow for the absorption of alcohol. The average BAL for 75 mg% was 74.5 mg% with a standard deviation of 5.98. The average BAL for 50 mg% was 47.8 mg% with a standard deviation of 4.90. Prior to and during participation food intake was controlled by experimental protocol.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Laurell (1977) **Pilot Study, Exp.1 and Exp. 2**	To examine the effects of alcohol on driving performance in emergency traffic situations.	Closed course study (1976 Volvo Station Wagon).	Pilot: N = 6 (19-31, M = 24.5, SD = 3.3) Exp. 1: N = 30 (19-31, M = 24.5, SD = 3.3) Exp 2: N = 10 (19-31, M = 24.5, SD = 3.3) Participants were all men. Repeated Measures Design. Participants drove an average of 12,000 km in the previous year. Seven of the participants did not own a vehicle.	BAC level: placebo, alcohol (0.06 or 0.052%).	Angle of car, stopping distance, pylons hit, false actions (did not maneuver or did so in the wrong direction) and distance of reaction.	For two hours participants practiced braking hard, then releasing the brake, swerving and realigning the car, then braking to a stop. Participants were given feedback on their performance. Participants participated in two experimental sessions, each lasting about 25 minutes. These sessions occurred on a 500 meter four lane motorway with no traffic. Participants drove in the middle lane at 50 km/hr. Emergency Situation: Participants practiced one trial run before the experimental session. Participants carried out emergency maneuvers at the first opening available after they were informed a response was necessary (2 brake lights 7 m from opening were lit up). There were 8 trials per condition. Surprise Situation: Participants were then presented with a blocking object and were required to brake or swerve in response. There was one trial at the end of the second night.	In the pilot, experiment 1 and experiment 2 the authors found that when consuming alcohol participants struck more pylons and took longer to stop when compared to the placebo condition. In both the pilot study and Experiment 1 there was no significant relationship between the BAC level and the angle of the car. In Experiment 2, when consuming alcohol participants experienced more difficulty when trying to align their car to the proper position when compared to the placebo condition. The limited number of trials for the surprise situation prevented false actions from being statistically analyzed. Combining the data the authors compared false actions between the alcohol conditions and the placebo condition. In the placebo condition 4 false actions were made, compared to 10 false actions being made in the alcohol condition. Due to problems encountered while carrying out the surprise event and data collection problems, the surprise situation could not be analyzed. When data was combined from all three experiments no significant differences were found between the groups.	Payment was dependent on performance No Statistics were reported to support the results. No women participated. Participants reported drinking a few times per month. Participants were trained in the daytime, but experimental sessions occurred at night.

Note: In the pilot session and experiment 1, participants were given 1.5 ml of whiskey per kg of bodyweight. In experiment 2, participants were given 1.3 ml of whisky per kg of bodyweight. They were allotted 15 minutes to consume the alcohol. Another 60 minutes was then allotted to allow for the absorption of alcohol before testing commenced. Participants ate 4 to5 hours prior to the experimental session. BAC was measured by taking blood samples.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Rimm, Siniger, Faherty, Whitley & Perl (1982)	To determine how alcohol and the expectancy of it affects driving performance.	Simulation study (All state good driver trainer, Link group-general precision, Inc.).	N = 44, (19-28), all were men. All held a valid drivers license for a minimum of 18 months. Eleven participants were assigned to each group. Balanced Placebo Design.	BAL: placebo, alcohol (0.064%); expectancy of alcohol.	Driver errors: braking, steering, signal light use and speed during drive.	Participants completed a baseline drive. Then they were put into their assigned groups (placebo, placebo who expected alcohol, alcohol, and alcohol who expected placebo). Participants were shown a BAL reading on a feedback display screen, which was in accordance with their expectancy for alcohol. Participants then completed a second driving session. The driving task required participants to drive while watching the video "Driving in Review".	Participants who consumed alcohol made more steering and braking errors compared to those in the placebo group. Expectancy of alcohol had no effect on driving performance in relation to errors made.	The authors failed to define what constituted an error which made the results difficult to interpret. There was a range in BAL levels obtained (0.053%-0.080%). All participants were undergraduate students. The video was not thoroughly explained. No women participated. Testing was carried out between 12:30 and 5:40 p.m.

Note: 0.74 grams of ethanol/kg of bodyweight was administered to obtain a BAL of approximately 0.07%. Participants were allotted 20 minutes to consume their drinks. Another 20 minutes was specified to allow for the absorption of alcohol. Participants abstained from food for 4 hours and tobacco for 1 hour prior to the study. The breathalyzer unit used was the ALERT Model J3AC.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Flanagan, Strike, Rigby & Lochridge (1983)	To examine the effects of alcohol on driving performance.	Closed course study.	N = 46, 11 women, 35 men. 82 pairs of driving tests. 69 involved alcohol, 13 involved placebo. All participants drove a baseline in addition to a second condition.	BAC level: placebo, alcohol (btw 30-60 mgms/100ml).	Accidents, hazard avoidance strategy, capability of avoiding a hazard and speed.	Participants used their own vehicles to drive through a 1.5 mile closed course. Participants were first familiarized with the course and the 29 hazards (plastic drums), and then given a test run. After the test run participants were administered either alcohol or a placebo with lunch. About 30 to 40 minutes later participants repeated the course. Participants were given penalties if they struck a hazard, avoided a hazard unnecessarily, if they had to stop and reposition themselves to avoid a hazard or if they exceeded the speed limit.	The analysis of pre and post lunch performance of participants that consumed alcohol indicated that the average penalty points significantly increased by 34.7 compared to their baseline drive. In comparison those in the placebo group significantly decreased their average penalty points by approximately 23.1 points compared to their baseline drive. Using a regression analysis no significant relationship was found between performance and BAC. **General Conclusions:** The majority of demerits were received for hitting a hazard. The majority of these occurred after alcohol was consumed. Specifically, accidents were mainly due to the drivers inability to correctly position the vehicle in relation to the hazard, or because the driver approached the hazards at excessive speeds. Performance decrements increased with alcohol consumption.	Information about participants, such as drinking experience and driving experience were not reported. Degrees of freedom for t-tests were not reported. There was a wide range of BACs obtained. Measures to accurately infer that drivers did not correctly position the vehicle in relation to hazards were not taken.

Note: Alcohol was consumed with food. Participants chose their own meal. Participants were allotted 1.25 to 1.5 hours to consume between 2 and 2.5 pints of beer or the equivalent. Another 30 to 40 minutes was specified to allow for the absorption of alcohol. BAC levels ranged from 30-60mgms/100ml. The breathalyzer unit used was the Alcolmeter M1, Lion Laboratories.

Authors, year	Objectives	Features	Methods: Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes:
Sutton (1983)	To examine the effects of alcohol and marihuana when used in isolation and when combined on driving performance.	Closed course study.	N = 9 (M =25.1), all men. Repeated Measures Design. Participants had been driving for an average of 7 years.	BAC level: placebo, alcohol (0.06%).	Traffic violations, speed, starting and stopping ability, weaving between lanes, "hugging" the center line, exiting the driving course.	Driving tests were carried out over a period of 4 days. Day 1: Participants practiced the course and interacted with the automobile to be used in following sessions. They were trained until they reached the ability to carry out the necessary maneuvers without committing errors. Days 2 through 4 Participants were given one lap of the course to practice the maneuvers. They were given alcohol (placebo vs. 0.06%) and marihuana. (Placebo or 2% D-9-THC) Participants were then required to drive through the obstacle course. Driving performance was evaluated by an officer, a safety manager with the AAA and a high school driving instructor.	There was no significant relationship between alcohol level and observed driving performance. The driving instructor and police officer only rated performance as impaired when alcohol was combined with marihuana. **Participant Remarks:** Qualitative differences between driver conditions were remarked on by the authors: some participants reported driving slower to compensate for alcohol consumption. Participants found certain maneuvers were more difficult to carry out, namely, U-shaped curve, tunnels and the "T"-exercise. Some stated that "they had to force themselves to keep their attention on the course".	All participants were graduate students All participants consumed alcohol and marijuana on a weekly basis outside of the study. Only overall driving performance is reported and not the performance for each maneuver.

Note: Forty-five minutes were allotted for the absorption of alcohol. When alcohol was combined with marihuana, participants waited 25 minutes after the alcohol had reached the desired BAC level before commencing the smoking of the marihuana cigarette. Blood samples were taken 45 minutes after drinking had ceased.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Brewer & Sandow (1988)	To examine the role of divided attention in accidents involving alcohol use. (Adelaide, South Australia from March 1976-77).	Accident analysis.	N = 403 (13 – 90, median 28) 306 men, 97 women.	BAC level: less than 0.05 g 100 cm^3 or equal to or greater than 0.05 g 100 cm^3.	Involvement in a secondary task prior to accident.	When informed of an accident, investigators went to the scene. A psychologist interviewed those involved in the accident and was responsible for identifying the maneuvers involved, and evaluated contributing factors to the accident. BAC was estimated by obtaining blood samples, breathalyzer tests requested by the officer at the scene, or by requesting a breath test. One to two weeks later a follow up interview was conducted to obtain driver history. Participants were questioned on whether they were involved in carrying out a secondary task prior to the accident. Participants also recollected what happened in the moments prior to the accident.	Those with a BAC equal to or greater than 0.05 were more likely to be carrying out a secondary task in the moments leading up to their accident. For those involved in single-vehicle crashes, those with a BAC equal to or greater than 0.05 were more likely to be carrying out a secondary task in the moments leading up to their accident. Degree of interaction between BAC and secondary task prior to accident involvement can only be inferred from the data available. The secondary activities were: finding or lighting a cigarette, getting something out of the pocket, eating, talking and looking at a passenger.	Within the article, Tables 1 and 2 seem inconsistent with the results section. In multiple vehicle collisions, more drivers reported not being engaged in a secondary task (152) compared to accidents where the driver was engaged in a secondary task (109). Similar results occur for single vehicle accidents. Eight drivers were involved in accidents while engaged in a secondary task, compared 12 whom where not involved in a secondary task at the time of the collision. Specific numbers of engagement in each secondary activity were not reported.

Note: The breathalyzer unit used was the Alcolmeter P.S.T.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Kearney & Guppy (1988)	To examine the effects of alcohol on speed perception.	Closed course study (Ford Cortina Estate).	N = 24 (22-48), all men. Repeated Measures Design. All participants were licensed for a minimum of 12 months.	BAC level: placebo vs. alcohol (100 mg/dl); drinking experience, high (drove after consuming 4 or more drinks on more than one occasion), low (never drove after drinking); presence/ absence of speedometer.	Speed.	Upon arrival the experimenter showed participants the course and requirements of the experiment. Participants engaged in a practice trial. Participants were then given either a alcohol or a placebo. Participants drove a 500-yard track. At 75 yards participants were required to have reached the speed limit of 30 mph. If they failed to reach the speed limit, the trial was repeated. Two hundred yards later, participants were required to decelerate to 20mph. Participants informed the experimenter when they felt their goal had been reached. Twenty yards prior to stop line, participants encountered a cone and were told to brake. Participants performed 4 trials (2 with the speedometer and 2 without).	There was no significant relationship between BAC levels and speed. Participants had a larger differential in speeds when the speedometer was absent. Participants in both conditions had difficulty accurately estimating their speeds when the speedometer was absent. When participants thought they were going 20 kph, they were actually going slower.	All participants attended an educational institution. All participants reported that they consumed alcohol on a weekly basis. No women participated.

Note: Participants consumed 0.8g/kg of alcohol within 10 minutes. Another 45 minutes was specified to allow for the absorption of alcohol, after the time expired participants began the experimental condition. Participants abstained from food and alcohol for 4 hours prior to the study. The breathalyzer unit used was the Alcolmeter (PST), Lion Laboratories.

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes:
Louwerens, Gloerich, Vries, Brookhuis & O'hanlon (1987)	To examine the relationship between alcohol and objective measures of driving performance.	Closed course study (Instrumented Vehicle).	N = 24, (22-45), equal proportions of men and women. Drivers had been licensed for a minimum of 3 years and drove at least 5000 km/year.	BAC level: Placebo, 0.5 g/kg, 1 g/kg, 1.5 g/kg and 2 g/kg.	Weaving (SD in lateral position) and speed variation.	Participants were required to drive a closed course while accompanied by two experimenters. Participants sustained 90km/h while maintaining their lane position.	BACs of 0.6 mg/ml and higher showed significant decrements in performance compared to the placebo condition. Specifically as BAC increased there was an increase in lateral position variability. BAC did not significantly affect speed variation. Women showed more behavioral effects than men when at similar BAC levels.	Subjects drank on average more than 4 drinks/ week, and no more than 4 glasses per day. There was variation in the BACs obtained between participants. Men achieved higher BACs than women. Breathalyzer unit used was not mentioned, nor was the time allotted to consume drinks.

Note: Participants were administered 0.5, 1.0, 1.5, and 2 grams of alcohol/kg of bodyweight to obtain BACs of approximately 0.024%, 0.06%, 0.085%, and 0.122%. Participants abstained from food for 5 hours prior to the study. Participants were given a meal consisting of soup and sandwiches when they arrived. Blood samples were also taken and analyzed.

			Methods					
Authors, year	Objectives	Features	Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes
Mongrain & Standing (1989) **Exp. 1**	To examine the effects of alcohol on risk taking behavior, visual signal detection and perceptual-motor tasks.	Simulation study (computer program – International Grand Prix, Riverside software) with a signal detection task.	N = 72 (*M* = 23.1, SD = 4.0), 12 men and 12 women were in each group.	BAC level: placebo and alcohol (0.04% and 0.12%).	Steering, speed (lap time), # of accidents, perceptual vigilance, and caution in perceptual decisions (β).	Participants drove 2, 5-lap trials. In each trial they were given 2 practice laps. Hand controllers were used for speed and steering. Signal detection task: Participants were required to detect the target X that was displayed among 50 distracters represented by the letter Z. The target was randomly placed. There were 100 trials, with each trial lasting 2 s. The target was presented in half of the trials[a].	There were no significant differences between the alcohol and placebo conditions for lap time, highest speed obtained and number of accidents. Performance on the signal detection task was impaired in the alcohol condition compared to the placebo. Both β and d′ decreased. That is, when consuming alcohol participants exhibited less caution and sensitivity to the signal detection task.	Risk taking was presumed to be reflected by the number of accidents a participant had during the study. Skill was equated with lap time. All participants were university summer students. Information about participants drinking histories was not indicated.

Note: Low alcohol: 0.34ml/kg bodyweight was administered to obtain a BAC of approximately 0.04%. Moderate alcohol: 1.04ml/kg bodyweight was administered to obtain a BAC of approximately 0.12%. Participants were allotted 30 minutes to consume their drinks. Participants abstained from food for 3 hours prior to the study. The breathalyzer unit used was the Hedonics PMT – 1 breathalyzer. Results are not reported for simulated racquetball task, the cognitive risk task, self-rated drunkenness scale or personality inventories.

[a] Program was developed by Perera & Houdin, 1983

Chris Edwards

Comment: How does that add up to 72? Is the total N = 24?
So this study was split into 2 experiments. This should be noted on the present page.

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes
Mongrain & Standing (1989) **Exp. 2**	To examine the effects of alcohol on risk taking behavior, visual signal detection and perceptual-motor tasks.	Signal detection task.	N = 72 (M = 20) 36 men and 36 women were in each group.	BAC level: placebo and alcohol (0.08% and 0.16%).	Detection of Targets (perceptual vigilance d′), caution in perceptual decisions (β).	Same as Exp. 1. but signal detection task was emphasized.	When the two blocks were combined for analysis, and when block one was analyzed separately there was a significant difference between the perceptual sensitivity of those who consumed alcohol (moderate BAC and high BAC) and the placebo condition. After consuming the alcohol participants exhibited less sensitivity to the signal detection task (0.08 and 0.16 BAC). No significant differences were found between the alcohol conditions. When block two was analyzed separately there were no significant differences between conditions, which was attributed to fatigue effects. When the first and second blocks of trials were combined, there were no significant difference between caution in perceptual decisions between the two BAC conditions and the placebo condition. Further analysis showed that there was a significant difference between caution in decision and level of BAC in the first trial of blocks. Participants who consumed alcohol exhibited less caution in the signal detection task than those in the placebo group. No significant differences were found in the 2nd block of trials. No explanation as to why the first block obtained significance while the second block did not, regarding the caution in perceptual decision.	Very little information was reported concerning participants drinking patterns. All participants were undergraduate students.

Note: Low alcohol: 0.68ml/kg bodyweight was administered to obtain a BAC of approximately 0.08%. Moderate alcohol: 1.35ml/kg bodyweight was administered to obtain a BAC of approximately 0.16%. Participants were allotted 30 minutes to consume their drinks. Participants abstained from food for 3 hours prior to the study. The breathalyzer unit used was the Hedonics PMT–1 breathalyzer.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Roehrs, Zwyghuizen-Doorenbos, Timms, Zorick & Roth (1989)	To examine the effects of whether high levels of alertness could counter the sedating effects of alcohol on divided attention.	Divided attention task.	N = 12 (21-34 years), all men.	Sleep extension: 8 hours sleep, 10 hours of sleep per night over a week.	Blood ethanol concentration (BEC) at each testing time, sleep latency and 4 measures of divided attention.	Divided attention task: Participants were given the task of using a joystick to track a moving target. They were also given the task of identifying when a stimulus was present in the peripheral or central area of the tracking field. Participants received training on the task before the experimental session began.	**Divided attention:** Ethanol was related to greater decrements in the ability to divide their attention, a longer time to identify when a stimulus was present in the central and peripheral area of the tracking field and an increase in deviations in tracking. Compared to 10 hours time in bed, participants who had 8 hours exhibited greater decrements in their ability to divide their attention and took longer to identify when a stimulus was presented in the central and peripheral area of the tracking field. They also exhibited increased deviations in tracking.	Participants consumed 1 to 12 drinks per week outside the study. Only participants identified as alert through the various tests were allowed to participate. Degrees of freedom were not reported. No women participated. Participants were tested at 10:00am, 12:00pm, 2:00pm and 4:00pm.

Note: Participants were given a bread roll with breakfast. Participants consumed 0.75g/kg of ethanol and were allotted 30 minutes to finish their drinks before testing was administered. The breathalyzer unit used was the Alcotest 7010, National Draeger.

Authors, year	Objectives	Features	Methods				Results	Notes
			Participants	Independent Variables	Dependent Variables	Procedure		
Horne & Baumber (1991)	To determine the effects of alcohol on driving during different periods of the day.	Simulation study (with full driving rig).	N = 24 (20-25 years), all were women. All held a valid drivers license for a minimum of 2 years and drove at least 2 hours per week. One group performed in the early afternoon and the other in the early evening condition. Repeated Measures Design.	BAC level: placebo, alcohol; time of day: early afternoon (alcohol intake ceased at 13:30), early evening (alcohol intake ceased at 18:30).	Following distance (feet) (mean and variability) and lateral position (feet) (mean and variability).	While driving a simulated two-lane motorway for 40 minutes. Participants selected and maintained a headway distance to a lorry (i.e., semi-truck). Participants maintained their lateral position, which was buffeted by wind gusts. Participants were given two, 20-minute practice sessions on the day prior to their test session.	There were significant differences between alcohol and placebo conditions for following distance and following distance variability. Those who had ingested alcohol adopted a larger following distance and had increased difficulty maintaining a stable headway than those in the placebo condition. There were no significant differences between the alcohol and placebo conditions for mean lateral position or lateral position variability. The non-significant results were attributed to the fact that steering corrections required more of a "reflex action" than maintaining headway distance. There was a significant interaction between alcohol and time of day. Specifically, participants tested in the early afternoon were affected to a greater degree than those tested in the early evening. Three participants in the early afternoon struck the projected lorry while under the influence of alcohol.	No men participated. Variability is undefined in terms of whether it represents SD or SE. Participants were recruited with a particular bodyweight in mind, because alcohol was administered as a fixed dose. Actual BAC varied. Those in the EA group obtained a higher BAC than those in the EE although similar trends between the two times of day were found.

Note: Four units of vodka (40% proof) diluted in tonic water were administered. Participants were allotted 20 minutes to consume their drinks. Another 10 minutes was specified to allow for the absorption of alcohol, after the time expired participants filled out questionnaires. There was a range in BAC between groups. BAC was just below the legal UK limit, but not specified. Participants abstained from alcohol and caffeine on the day of the study. Participants were given a cheese roll to accompany alcohol. The breathalyzer unit used was the Alcolmeter 2m^2 (Lion Laboratories).

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes
Horne & Gibbons (1991) **Main Study**	To examine the effects of alcohol and time of day on vigilance.	Wilkinson Auditory Vigilance Task.	N = 8 (18-23), all were women. Repeated Measures Design.	BAC level: placebo, alcohol (two units and four units); time of day: early afternoon (1300), early evening. (1830).	% targets identified correctly, % distracters identified as targets, % failed to respond, mean reaction time to both hits and false responses, hits and false alarms taken together (d′).	Participants listened to signals and identified which were the target sounds and which were the distracters by pressing one of two keys. Participants were given two, one-hour practice sessions one week prior to their testing session. In each subsequent session participants were given a 5-minute practice before the testing began.	There was a significant difference between alcohol and placebo for reaction time; those who had ingested alcohol exhibited decrements in their reaction time for both percentage of hits and d′. For percentage of hits, performance was worse in the afternoon, whereas for d′ performance was higher in the evening.	No men participated. Participants all had similar bodyweights. Alcohol was administered as a fixed dose which resulted in a variation in the actual BAC obtained. Participants had a history of consuming 0.5-2 units of alcohol per day.

Note: Participants were allotted 20 minutes to consume their drinks (0, 2 or 4 units of alcohol). Another 10 minutes was specified to allow for absorption of alcohol, after the time expired participants filled out questionnaires and completed a 5-minute practice session. Participants abstained from food for 2 hours prior to the study. Alcohol was taken with a buttered cheese roll. The breathalyzer unit used was the Alcolmeter $2m^2$ (Lion Laboratories). Participants were all non-smokers. Sleep-wake hours were regulated by experimental protocol.
Note: A pilot study was used to determine peaks in sleepiness and alertness, alcohol required to achieve desired BAC levels, what food should be administered, and to develop a time line of BAC over the two times of day. Pilot study results were not reported here.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Brookhuis & De Waard (1993)	To determine whether psycho-physiological measurements corresponded to decrements in driver performance in relation to driver status.	Closed course study (Volvo 245 GLD).	N = 20, all men. Repeated Measures Design. Participants had been licensed for five years, with a minimum mileage of 5000km per year.	Placebo, vigilance, BAC (less than or equal to BAC of 0.05%).	Lateral position and headway distance.	Alcohol: 1 hour driving test Vigilance: 3 hour driving test Four segments were completed as follows: Car Following Task: Participants were required to follow a lead car at a safe and constant distance. The lead car occasionally engaged in speed variation behavior. Time to complete the task was about 15 minutes for each of the two test segments. Standard Driving Task: Participants were required to drive a motorway track while maintaining their lane position and speed. Time to complete the task was approximately 50 minutes. Participants drove a second motorway track and were required to maintain their lane position and speed while low to medium levels of traffic were present. Time to complete the task was approximately 100 minutes.	Perception and response to speed variation in the lead vehicle increased in the alcohol condition; however, this did not reach statistical significance. Compared to the baseline condition there was a delay of 168 ms. In the vigilance condition there was shorter average time headway to the lead car. Compared to the baseline this time headway decreased from 959 ms to 853 ms. Alcohol failed to significantly affect headway time. In both the alcohol and vigilance conditions participants exhibited a statistically significant increase in variation of lane position compared to the placebo condition. There was no significant effect of alcohol on the standard deviation of steering wheel movements on straight road segments.	Did not report normal drinking habits of participants. No women participated. The specific breathalyzer unit used was not mentioned.

Note: BAC was calculated according to the participant's body weight. Thirty minutes after lunch alcohol was consumed. The mean BAC was 0.046% at the beginning of the study and was reduced to 0.035% after the test run had been completed.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
West, Wilding, French, Kemp & Irving (1993) **Exp. 1**	To examine the effects of alcohol on speed.	Closed course study (Ford Fiesta).	N = 15 (30-55 years old), 9 women, 6 men. Repeated Measures Design.	BAC level: placebo, low alcohol (0.025%), moderate alcohol (0.05%).	Time to complete the course.	Participants were given a practice session to familiarize themselves with the task prior to the experimental sessions. Participants drove a 12-minute course with no traffic. The experimenter recorded how long it took the participant to complete five separate road sections.	There was no significant correlation between alcohol level and speed. Speed remained stable over all five sections.	Participants consumed alcohol on a weekly basis, but less than 20 units per week.
West, Wilding, French, Kemp & Irving (1993) **Exp. 2**	To examine the effects of alcohol on hazard detection time.	Viewed film from a converted Austin Mini.	N = 20 (30-55 years old). 10 women, 10 men. Repeated Measures Design.	BAC level: placebo, low alcohol (0.025%), moderate alcohol (0.05%).	Reaction time (RT).	Participants viewed rural and urban road films and were asked to indicate the level of hazard (on a scale for 0-10) using a lever. Each participant had a 5-minute practice session. This was kept constant across sessions. This was followed by a 3-minute test in which three hazards were presented. (For each session participants viewed a different test film).	Hazard perception latency was significantly correlated with BAC. Participants who consumed alcohol took longer to perceive an event as a hazard compared to those in the placebo group.	Participants consumed alcohol on a weekly basis, but less than 20 units per week. Task was technically not a measure of reaction time.

Note: BAC was calculated according to the participant's body weight. Thirty minutes was allotted to allow for the absorption of alcohol before testing commenced. There were variations in BAC levels within both the low and moderate alcohol groups. In all cases, the low alcohol BAC obtained was below that achieved in the moderate alcohol BAC trial. The breathalyzer unit used was the Type SD2, Lion Laboratories.

Chris Edwards
Comment: It was a correlation wasn't it?

Chris Edwards
Comment: Correlation, df isn't

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Roehrs, Beare, Zorick & Roth (1994)	To examine the effects of ethanol and fatigue on driving performance.	Simulation study.	N = 12, (21-35), all men.	BEC level: placebo, ethanol (0.05%); sleep (4 hours, 8 hours).	Divided attention: reaction time and tracking deviations; driving performance: absolute lane deviation, lane deviation to the left and right, collisions, and "points out of range".	**Divided attention task:** Participants were required to track a moving target with a joystick controller. While carrying out this task a target appeared in their central or peripheral view. Participants were required to respond. Driving task: participants drove a 30 minute scenario.	*Divided Attention:* There was no significant relationship between condition and tracking performance. *Day 1 (HFH)* Participants receiving 8 hours of sleep who consumed ethanol took longer to respond to both central and peripheral stimuli, compared to those in the placebo condition. There was no significant relationship between peripheral or central reaction time in participants (placebo, alcohol) who received 4 hours of sleep. *Day 2 (UMTRI) Morning/Afternoon* In both testing phases, participants receiving 4 and 8 hours of sleep who consumed ethanol took longer to respond to both central and peripheral stimuli, compared to the placebo group who received 8 hours of sleep. *Lane deviations, morning/afternoon* In both testing sessions, when consuming alcohol participants made more left, right, and absolute deviations, and were more often out of range than those in the placebo condition. In the morning when participants had four hours of sleep there were decrements in all driving performance measures when ethanol was consumed compared to the placebo condition. Left and right deviations were significantly higher compared to when participants had 8 hours of sleep. In the afternoon participants with 4 hours of sleep scored lower on all measures compared to both placebo groups. Participants with 8 hours of sleep had lower scores on all of the dependent measures except "points out of range".	Participants had regular sleep patterns. No women participated. All participants were non-smokers. Participants consumed 1-14 drinks per week. What was required by the participant was not explained. Degrees of freedom were not indicated.

Chris Edwards
Comment: Required? The responses, how they presented themselves? Doesn't make sense.

Note: Participants were administered 0.06 grams of ethanol/kg of bodyweight to obtain a BEC of approximately 0.05%. BEC was maintained with supplemental drinks. Participants were allotted 20 minutes to allow for the absorption of ethanol. Sleep was monitored at the Henry Ford Sleep Disorder Center. Participants abstained from alcohol and caffeine after 4pm on the day prior to their session. Participants were given a light breakfast.

Authors, year	Objectives	Features	Methods: Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes:
Cox, Quillian, Gressard, Westerman, Gonder-Frederick, & Canterbury (1995)	To examine the effect of alcohol on driving (by heavy drinkers).	Simulation study (Atari games-developed driving simulator).	N = 23, (M = 21.9, SD = 1.16). Repeated Measures Design. Participants had been licensed for about 6 years on average.	BAC level: placebo, alcohol (greater than or equal to 0.08, greater than or equal to 0.10).	Steering: lane position, mean car yaw, crossing center line, and time off road; speed control: brake pressure, gas pressure and speed.	Participants were given 30 minutes to practice interacting with the simulator. The simulator was used to simulate highway driving. The scenario was 4 minutes long. Participants were required to interact with 2 stop lights, two 4-way stops, a bridge, and speed changes. There was traffic presented throughout the scenario.	Only BALs of greater than or equal 0.08% were analyzed. BAL did not have a significant effect on steering control. As BAL increased subjects drove at faster velocities, and there was more variation in the pressure applied to the gas pedal. When participants had a BAL greater than or equal to 0.08% their performance on all steering and speed control variables was poorer than when alcohol was absent.	All participants were members of a fraternity. Participants were heavy drinkers. Degrees of freedom were not given.

Note: Participants were administered 3.0 oz of grain alcohol to obtain a BAL of approximately 0.10%. Participants were given 10 minutes to consume the alcohol. Sleep and food intake was monitored at the General Clinical Research Center. The breathalyzer unit used was the alcosensor breathalyzer. Blood samples were taken at the peak of alcohol absorption.

Authors, year	Objectives	Features	Methods: Participants	Methods: Independent Variables	Methods: Dependent Variables	Methods: Procedure	Results	Notes:
Dennis (1995)	To examine the effects of alcohol on driving performance.	Closed course.	N = 20 Experimental group, N = 13, 7 women, 6 men (24-45). Control group N = 4, 2 men, 2 women (25-41).	BAC level: placebo, alcohol (0.03, 0.07, 0.11).	Brake control, vehicle control, reaction time, decision making, steering and vehicle skills.	**Skid control:** The objective was to maintain control of the vehicle while skidding. Participants accelerated to 35mph, braked at the entrance of skid pad, released brake and steered around the curve. The rear brakes were initiated and participants were required to regain control of the vehicle. **Accident simulator:** The objective was to move into the subsequent lane within 1 second of seeing a green light within one of the three lanes. They had 1 second to complete the task, while driving 30 mph. **Blocked lane:** The objective was to drive through an accident setting and stop. They entered the course going 45 mph, when they saw a red light, they braked, released the brake, then swerved into the left lane,, swerving to the right, and stopping the vehicle. **T-Turn** The objective was to enter the course at 40 mph, brake, steer around the corner, stop, backup and then pullout. **2-Point Turn:** The objective was use driveways to turn the car around. **Serpentine:** Participants made several turns, alternating the direction of the turns. One day was spent practicing these maneuvers.	Participants who consumed alcohol exhibited decrements in the ability to carry out the maneuvers compared to those in the placebo condition. The maneuvers most sensitive to BAC were the skid control task, the T-Turn, and the accident simulator. Reaction time increased until a BAC of 0.11% at which time reaction time leveled off.	Low N, originally exp. group had 14 participants and the control group had 6 participants. Participants were lost due to illness, other problems unassociated with the experiment and the inability to finish all the runs. Study does not mention participant driving or drinking history. No statistics were indicated. The maneuvers were taken from the Driver Skill Development Program at Texas A&M University.

Note: Alcohol was provided with the intent of obtaining BrAC of 0.00, 0.03, 0.07 and 0.11. Participants chose which type of alcohol they wanted to consume. The breathalyzer unit used was the Intoxilyzer 5000.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Finnigan, Hammersley & Millar (1995)	To examine the effects of alcohol and expectancy on performance.	Tracking task, with choice reaction time.	N = 90 (18-44, M = 24), all men. Repeated Measures Design.	BAC level: placebo, alcohol (40mg/100ml or 80mg/100ml); expectancy of alcohol.	Primary tracking, secondary reaction time; five choice reaction time task: decision time (from the time the stimulus was perceived to the time it took a subject to lift their finger from the spacebar), movement time (the time it took participants to move their finger from the spacebar to the corresponding key); BAL	Dual Task: Participants used a joystick to track a moving cursor which varied in speed and direction. Occasionally, a light would appear in the periphery during the tracking tasks. Participants were expected to respond by pressing the spacebar on the keyboard while maintaining tracking performance. Five one-minute trials were performed. Five Choice Reaction Time Task: Participants viewed 5 white circles displayed on a screen. When one of the circles switched to black participants were required to indicate which circle had changed by pressing the corresponding key (1-5). Each session lasted 30 minutes. Each session was composed of 30 trials. Participants practiced each task. Ten, one-minute dual task trials and 3 choice reaction time sessions were completed.	As BAC increased participants took longer to respond to the stimulus presented, made more tracking errors, and took longer to make a decision (CRT). Participants expecting alcohol performed better on the primary tracking task, compared to participants expecting placebo but receiving alcohol. Tracking was affected for up to 70 minutes and reaction time was affected for up to 115 minutes after participants ingested the alcohol. *Mean Tracking Performance (10 to 70 min).* Participants expecting water who received the high dose of alcohol had the largest decrements in tracking performance. Those in the high dose group, who expected alcohol, showed no significant difference in their tracking performance when compared to their baseline. In both the placebo condition and the 40mg/100ml condition performance on the tracking task improved compared to baseline performance. *Secondary reaction time (10 to 115 min)* There was a significant relationship between BAC and secondary reaction time. Participants who ingested the high dose of alcohol had a 25-30% slower reaction time compared to their baseline data. Participants who ingested the placebo or low dose of alcohol had a slower reaction time compared to their baseline data, but not to the same extent that the high dose condition did. *Tracking (100 and 130 min)* There was a significant relationship between BAC and reaction time. Those who expected alcohol performed better than those who were expecting the placebo but received alcohol. There was no significant relationship between BAC and tracking performance.	Participants drinking and driving histories were not reported. No women participated.

Note: Alcohol was administered based on the quantity required per litre of body water (Watson, Watson & Batt (1981)). Participants were given 10 minutes to consume the alcohol. Participants were allotted 10 minutes to allow for the absorption of alcohol and abstained from food prior to 11:30, when the session began, and alcohol 24 hours prior to the study. The breathalyzer unit used was the Lion AE-D3 Alco-meter.

Authors, year	Objectives	Features	Methods: Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes:
Dawson & Reid (1997)	To examine the effects of alcohol and fatigue on cognitive psychomotor performance (tracking).	Computer hand – eye coordination task.	N = 40	Fatigue and BAC.	Cognitive psychomotor performance (tracking).	All participants took part in the two experiments. To examine the effects of sleep, participants were required to stay awake for a total of 28 hours. To examine the effects of alcohol, participants were required to consume 10-15 grams of alcohol every 30 minutes until they achieved a BAC of 0.10% Every half hour participants hand eye coordination was tested using a computerized task.	There was a negative correlation between BAC and tracking performance, where higher levels of BAC produced poor tracking performance. BAC accounted for approximately 70% of the variance in tracking performance. As BAC increased by 0.01%, subsequent performance in tracking decreased by approximately 1.16%. The authors equated the decrements in performance that resulted from fatigue to those decrements in performance resulting from alcohol. Using this logic, they suggested that 17 hours of wakefulness brought about similar impairments in tracking as those with a BAC of 0.05%. Tracking decrements exhibited after 24 hours of wakefulness were similar to those with a BAC of 0.10%.	No placebo group. Actual BAC achieved varied up to 0.13 The details of the study are not reported. For example participant information was not provided. No statistics were reported in the article. Study procedures do not indicate how long the hand-eye coordination task lasted.

Note: Participants consumed 10-15 g/kg of alcohol every 30 minutes starting from 8:00 until a BAC of 0.10% was obtained. Participants in the fatigue condition were required to stay awake for 28 hours.

Chris Edwards
Comment: No correlation numbers either?

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Lenne, Triggs & Redman (1999)	To examine the effects of alcohol and time of day on driving performance.	Simulation study (Systems Tech Incorporated Driving Simulator, STI)	N = 28 Equal groups of men and women participated. Each group contains equal numbers based on gender and experience. Experienced (25-35, M = 27.4, SD = 1.8), inexperienced (18-20, M = 18.9, SD = 0.7). Repeated Measures Design Inexperienced: licensed for less than 1 year. Experienced: licensed for between 6 and 12 years.	BAC level: placebo, alcohol (0.05%); experience; time of day (12pm, 6pm, 11pm).	Mean lane position, standard deviation of lane position; mean speed, standard deviation of speed, reaction time to secondary task.	Participants were required to drive several rural 2 lane highway tracks. Each track contained 4 left curves, 4 right curves, 2 s-curves, and 2 oncoming vehicles. Curves were separated by straight sections. Participants were instructed to maintain their lane position and speed of 80kph. Occasionally, a red diamond presented on the screen changed to display a horn. Participants were to respond by pressing a foot pedal as fast as they could. This occurred 6 times during each trial. Participants received a 30 minute practice session. For the experimental session they drove four, 10 minute periods. They participated in six test sessions, two sessions, at each time of day, were conducted. Each time of day was included in the control and alcohol conditions.	Participants who consumed alcohol exhibited greater variance in their lane position, adopted a closer position to the left edge of the road, exhibited greater variance in their speed, and took longer to react to the secondary task when compared to the placebo condition Standard deviation in lane position varied with time of day, varied within the session when alcohol was administered, and was affected by driver experience. Mean lateral position varied within the session, and was not affected by experience or time of day. Standard deviation in speed increased in the alcohol condition but remained unaffected by session, time of day, or experience. Mean speed was not significantly affected by condition, session, time of day, or experience. Reaction time remained unaffected by session or experience, but was affected by time of day. When time of day effects were present, participants performed worse at 12:00p.m. and 6:00p.m. than at 11:00p.m, with performance at 12:00 p.m. being the worst.	Study does not indicate what BAC was obtained. BAC varied with session and time of day, which may have affected results. All participants consumed no more than 6 drinks per week. Kilometers driven per year are not reported. All participants were recruited through the campus.

Note: A concentration of 0.70 ml/kg of bodyweight of vodka was administered to obtain a BAC of approximately 0.05%. Participants were allotted 5 minutes to consume their drinks. Another 15 minutes was specified to allow for the absorption of alcohol. Mean BAC ranged from approximately 0.03 to 0.05%, BAC was highest at 12:00p.m., then 6:00p.m., then 11:00p.m. BAC also varied within the sessions. Participants abstained from food and caffeine for 4 hours and alcohol for 24 hours prior to the study.

Authors, year	Objectives	Features	Methods: Participants	Independent Variables	Dependent Variables	Procedure	Results	Notes:
Arnedt, Wilde, Munt & MacLean (2001)	To examine the effects of alcohol and fatigue on simulated driving.	Simulation study (York Driving Simulator).	N = 18, (19-35, M =19.9, SD = 2.3), all male. Repeated Measures Design.	BAC level: placebo, alcohol (0.05% and 0.08%); time of day tested (14:00, 17:00 and 20:00). Fatigue: Tested in a previous study by Arnedt, J.D. & MacLean, A.W. (1996): 24:00, 02:30, 05:00, and 07:30	Tracking (feet), tracking variation, speed deviation, speed variation, and time off road.	Two days prior to their first experimental session participants were given a 1-hour training session. On each test day there was a practice session. Participants were required to drive through a scenario while attending to road signs and traffic lights while maintaining their lane position. The scenario was made up of a four-lane road consisting of straight and curved sections. Speed varied between 70 and 100 km/h. There was no ambient traffic within the driving scenario.	When compared to the placebo, there was an increase in tracking variability and time spent off the road in the 0.05% BAC condition. When compared to the placebo, there was an increase in tracking variability, speed variability and time off road in the 0.08% BAC condition. When the two alcohol conditions were compared, there was an increase in tracking variability and time off road in the 0.08% BAC condition. The only variable affected by time of day was speed deviation which was the lowest at 17:00 hours. When the authors compared the effects of fatigue and alcohol, they found that participants who had been awake for 18.5 hours exhibited similar decrements as those participants who drove with a BAC of 0.05%. 21 hours of being awake was similar to decrements in driving performance exhibited by participants with a BAC of 0.08% The results indicate that BAC and prolonged wakefulness both resulted in participants spending more time off the road, higher variance in tracking and speed. However those with a BAC of 0.08% adopted a higher speed and spent more time off the road than those who had been awake for 21 hours.	All participants were non-smokers. Time licensed was not given. Food intake was not indicated. All participants were university students. No females participated.

Note: Alcohol content was administered per litre of body water. Participants consumed two drinks to obtain a BAC of approximately 0, 0.05% or 0.08%. Thirty minutes was allotted to consume the drinks and another 30 minutes was allotted to allow for the absorption of the alcohol. If BAC failed to reach the appropriate level, subjects were given an additional drink, which was consumed within 5 minutes. Participants were given a sleep regimen in which specific bedtime and rising time were outlined, and napping was prohibited. Participants abstained from alcohol for 48 hours and caffeine for 24 hours prior to the study. Two hours prior to the study participants consumed a light meal. The Breathalyzer unit used was the Borkenstein Breathalyzer.

Authors, year	Objectives	Features	Methods				Results	Notes:
			Participants	Independent Variables	Dependent Variables	Procedure		
Burian, Liguori & Robinson (2002)	To examine the effects of alcohol on risk taking in relation to driving.	Simulation study (ACG mobile operations simulator model SV5000LE).	N = 13 (M = 31, 23-43), all men. Repeated Measures Design.	Breath alcohol concentration (BrAC): placebo, alcohol (<0.03mg/l, 0.05mg/l, 0.08mg/l).	Cones hit, risky driving maneuvers (driving through a narrower lane with the risk of points being taken away for knocking over a cone being high); (lane width), speed	Participants took part in one practice session consisting of 80 trials and four experimental sessions of 30 trials each. **Trial 1-10 (30mph)** Participants entered the course. They were presented with three lanes of differing widths. In trials 1-5 they were given the choice of which lane they wanted to drive in. In trials 6-10 they were only allowed to drive in the left or right lanes. **Trials 11-20 (35mph)** Participants drove in the left lane 5 times and in the right lane 5 times. **Trials 21-50, 51-80 (35mph)** Participants started the course with 100 points. The goal was to see who could obtain the highest score. Points were received for lane width (+5 narrow, +3 wide). Points were taken away for knocking over a cone (-1, -3, or –5) depending on the trial.	Cone hitting, total points accrued, number of risk maneuvers carried out and speed were unaffected by BrAC level. As BrAC increased, the chances of hitting a cone also increased when the lane width was smaller. At the 0.3mg/l and 0.8 mg/l levels there was a decrease in risky maneuvers as penalties for hitting a cone increased. There was a significant interaction between BrAC and penalty on the number of risk maneuvers. Participants with 0.5mg/l of alcohol carried out the greatest number of risky maneuvers. Alcohol and penalty level failed to have a significant effect on speed.	Drinks were consumed using a straw which may have increased absorption rate. All participants were non-smokers. All participants consumed an average of 5 drinks (the range being 3-8 drinks) on a weekly basis. A bonus was offered to the participant who obtained the highest total points. No women participated. Statistics were not always reported. Compensation for participating in the study may have affected performance.

Note: Participants were administered 0.3, 0.5, 0.8 grams of alcohol /kg of bodyweight. Participants were allotted 15 minutes to consume their drinks. Another 10 minutes was specified to allow for the absorption of alcohol. Participants abstained from food for 4 hours and alcohol and caffeine for 36 hours prior to the study. Breath alcohol concentration was obtained using a handheld breathalyzer unit by Intoxilizers Inc. BrAC ranged from 0.0 to 0.10 mg/l.

Appendix C:
Research Summaries of Emergency Driver Response Studies

Study	Primary Emphasis	Paradigm	Procedures	Independent Variables	Dependent Variables	Results	Notes
Barret, Kobayashi, & Fox (1968)	Driver reaction to the sudden emergence of a pedestrian	Simulator (terrain model)	Participants were directed to stay in the right lane and to maintain a speed of 25 mph. A dummy was released at 82.5 ft from the subject and emerged from a shed. Subjects drove around the terrain model maintaining speed three times before the dummy popped out.	Eleven male subjects. From release to dummy middle of the road = 980 ms.	Steering deviation. Reaction time.	Mean speed at time the dummy was released was 24.3 mph. Two groups emerged; those that hit the dummy hard (n = 6) and those that hit soft (n = 5). Hard and soft groups differed in speed; 24.3 mph, 23.7 mph & RT; 1131 ms, 829 ms. Overall 10 braked and steered somewhat. One Steered exclusively (he was a pilot).	11/25 subjects became too ill to continue the study. Selected reporting of data. Limited field-of-view may have affected responses.
Johansson & Rumar (1971)	Differences between unexpected and expected brake reaction times.	On-the-Road	Exp1: Unexpected event: a klaxon horn sounded at random during a 10 km section of road. Exp2: buzzer presented and brake reaction time measured while driving.	Exp1: Unexpected event: a klaxon horn sounded at random during a 10 km section of road. Exp2: buzzer presented and brake reaction time measured while driving.	Exp1: Brake reaction times; measured from tone to onset of brake lights. Exp2: Brake reaction time (N = 5).	Exp1: 321 drivers. Median = 0.66 s, range = 0.3– 2.0 s, Adjusted = 0.9 s. 25% of the group had reaction times greater than 1.2 s. Exp2: differences between expected and unexpected signals ranged from 0.1 to 0.35 s. Median = 0.54 s, range = 0.4-0.8 s. Correction factor of 0.3 s is discussed.	Exp1: 0.001 s accuracy. Variability due to manual control of stopwatch RT. Exp2: accuracy to 0.1 s.
Summala (1981a)	Unalerted steering response latencies to a car door opening.	On-the-Road	Station-wagon car door opened that was parked 0.65 m from the right guide line. Door reached the guide line when open. Experiment completed in daylight.	Flow of the four lane roadway was 514 veh./hr in the same direction of measurement. 81.5% of traffic was in the right most lane and had an avg. speed of 60 kph.	Lateral displacement and speed measured using photocell arrangements.	N = 1326 observations. No effects were found for prior speed and lane position. Speeds differed little from approaching to passing positions (65.1 kph and 64.4 kph). Response latency approx. 1.5 s. Steering compensation @ 50% of lateral deviation occurred at 2.5 s, maximal lateral displacement was at 4 s.	Accuracy of timing was 0.1 ms.

Study	Primary Emphasis	Paradigm	Procedures	Independent Variables	Dependent Variables	Results	Notes
Summala (1981b)	Unalerted steering response latencies to a light along a road at night.	On-the-Road	Two lane trunk road 7.5 m wide with a 1 m paved shoulder. Stimulus was a small light that was lit as a car or truck approached it. Location was 1.2 m from the road and 0.5 m in height. Night time between 6 and 11 p.m.	The light was to mimic a point light from either a pedestrian or a reflector. Reference conditions: light on (8 s prior) or light off (baseline). Other conditions: light on 1, 2, 3, & 4 s prior to vehicle arrival.	Lateral displacement and speed measured using photocell arrangements.	N = 815 observations (69% cars and 31% lorries). Approx. 121–150 observations in each of the six conditions. Drivers did not brake to the light. Cars swerved more than lorries although not significantly. The amount of excursion was about 11-12 cm. The time course of the excursion begins to rise at 2 s and peaked at 3 s.	Accuracy of timing was 0.1 ms.
Triggs & Harris (1982)	Representa-tive, unobtrusive brake-RT measurement	On-the-Road	Videotaped brake responses subsequently analyzed in various situations. Clear visibility conditions. Measured scenarios were both at night and during the day.	Eliciting stimuli included: two triangles at night, various speed signs, rail crossing signals, speed zones, car following, pedestrian traffic signals, police presence, and so forth.	Response rates and response times.	Reduce speed sign; response time = 1.8 s. 44% braking to a driver changing a tire (0.97 s mean). 22% of vehicles braked for police presence; usually those that were traveling faster. Faster drivers had lower RT's. Railway response rates were greater at night than during the day (98 vs 70%) as were RT's (1.16 vs 1.77 s).	Accuracy of time clock = 0.01 s.
Akari & Matsurra (1990)	Pedestrian suddenly entering the roadway	Simulator	20 min practice. 2 events: Pedestrian enters 40 m away at a speed of 10 km/h. A car crossing the drivers path at 40 km/h. Precise procedures are difficult to ascertain.	Pedestrian N = 32 Car Crossing N = 6	Accelerator position, braking force, steering angle, eye movements, speed, strategies	Steering (18/32), braking (25/32), and steering and braking (14/32) were used to avoid the pedestrian 90% of the time (29/32). Experienced drivers performed sig. better than novice drivers.	Low N in second condition. Limited data reporting.

Study	Primary Emphasis	Paradigm	Procedures	Independent Variables	Dependent Variables	Results	Notes
Olson & Sivak (1986)	Stopping sight distance (SDD) to emergency events. 2.5 s design standard for an unexpected hazard.	On-the-Road	Test vehicle. Subjects drove for about 6 km before an un-alerted obstacle was encountered. For alerted trials the position of the obstacle changed forward and backward on the crest of the hill.	N = 64. 49 young (18-40; 32 M and 17 F) and 15 older (7 M & 8 F). 1 trial un-alerted. 5 trials alerted. 5 trials of braking. Obstacle: a piece of yellow foam 15 cm wide and 91 cm long in the left portion of the travel lane.	Perception time: object first visible to release of accelerator. Response time: release of the accelerator to contact with the brake.	Total time = brake + perception times. 95th %ile = 1.6 s. No differences between age groups on response perception or PR. Differences between alerted and surprised drivers were between 0.2 and 0.5 s. Mean young = . Mean old = . Grand mean = (SD = , range =	Limited older population. Measuring system accurate to 0.5 m.
Lerner, Huey, McGee, & Sullivan (1993)	Age differences in gap acceptance judgment.	On-the Road	Own vehicles. Seated subjects made judgments of whether it was safe to initiate a maneuver (left, right, or crossing) while stationed at an intersection. Pretext was to evaluate the road condition.	Cited in Lerner (1994)- older and younger ages-?. Report not issued by FHWA yet.	Headway difference in time between two vehicles.	50% gap acceptance for older drivers was 7.85 s and was 6.74 s for younger drivers. The lower bounds of gap acceptance for younger drivers was 5.32 s and 5.86 s. Only 56 subjects had measurable BRT's; i.e., 14, 18, 24 in each age group.	Only 116/200 trails were usable. Incomplete reporting.
Ranney & Pulling (1987)	Driving performance differences between familiar and unfamiliar vehicles. Implications for road and simulation experiments.	Closed-course track	One-half mile track. Own vehicle and unfamiliar vehicles (a passenger van).	14 licensed drivers (7 male and 7 female) aged 32-62. 50 trials broken into 8 sets of 13 completed over 2-3 days.	PRT, Q (smoothness of stops), stopping accuracy, and approach speed change.	Unfamiliar vehicles had a faster PRT than familiar vehicles (0.58 s vs 0.64 s). Drivers in unfamiliar vehicles slowed more than familiar vehicles (1.81 mph and 1.15 mph). Results are interpreted as reflecting heightened awareness and caution while operating the unfamiliar vehicle.	Design alternated unfamiliar and familiar vehicles.

Study	Primary Emphasis	Paradigm	Procedures	Independent Variables	Dependent Variables	Results	Notes
Lerner (1993)	Age differences in brake RT. SSD design assumption that brake PRT = 2.5 (AASHTO).	On-the Road	Own vehicles. Barrel entered @ 40 mph (200 ft or T_c = 3.4 s). Daytime. Clear weather.	Ages Group: 20-40 (n = 30), 65 - 69 (n = 43), 70+ (n = 43). Actively recruited elderly with a range of capabilities.	Brake PRT = Barrel emergence (when visible ?) to initiation of braking.	85% = 1.9 s PRT = 1.5 s (SD = 0.4). No age or gender differences. 87% maneuvered of these 43% steered and braked, 36% steered only, and 8% braked only.	Data from 1 hr route pooled with 3 mi route.
Lerner (1994)	Age differences in daytime intersection PRT and design model assumption that PRT = 2.0 (AASHTO).	On-the-Road	Own Vehicles. 56 mile route with 14 controlled intersections. Video taped. Pretext was for drivers' to judge road quality which controlled scanning behavior.	Ages Group: 20-40 (n = 25), 65 - 69 (n = 27), 70+ (n = 29).	Perception-reaction time. Initiation of intersection search to frame of response.	No age differences. 2.0 s = 85th %ile for all groups. Females in the eldest group were sig. slower than their male cohorts. Time to initiate movement may not be sensitive to age differences whereas gap acceptance may be (see Lerner, et al., 1993).	Only trials where there were no conflicting traffic at an intersection were used. Accuracy of 0.033 s.
Wilson, Sinclair, & Bisson (1989)	Collision avoidance PRT's and evasive maneuvers. RTAC (Canadian) 2.5 s design standard.	On-the-Road	2 km section of a secondary roadway. At night. Remote controlled plastic adult pedestrian entered the roadway from the right. Test vehicle traveled @ 60 kph.	Cross section of licensed drivers divided into M/F and 35< and 35>. N = 40. 10 each in each group by age cell.	Perception time = calibrated target activation to accelerator release. Brake Time = foot leaving accelerator to contacting brake.	Percep. Time = 0.56 s (SD = 0.16), 99th %ile = 0.90. Brake Response = 0.28 (SD = 0.10) 99th %ile = 0.58. Vehicle Response = 0.12 (SD = 0.03). Total = 0.96 (99th %ile = either 1.6 or 1.8?). If foot not on accelerator, PRT could not be assessed.	Practice effects and alert effects in data. Selective analysis of trials employed.

Study	Primary Emphasis	Paradigm	Procedures	Independent Variables	Dependent Variables	Results	Notes
Lieberman, Ben-David, Schwietzer, Apter & Parush (1995)	Replicate previous on-road studies that examined cues that modulate braking action.	On-the-Road	Two 1990 Seat Ibiza cars (1.6 m wide) were used. Drove 45-60 min between 9:00 and 15:00 in a intra-urban setting. Subjects performed 48 trials (semi-counterbalanced ?) with a 20 to 30s inter-trial interval.	N = 51 (9W & 36M, 21-30 yrs, athletes). Subjects had 2-12 yrs. manual exp. and they drove at least 5 hr/wk driving. Distance (6 & 12 m) x speed (60 & 80 kh/hr) x braking type (dummy & real).	TBT (total braking time) = BRT (lead veh. brakelight onset to release of accelerator) + MT (release of accelerator to brake pedal pressure).	Distributions reported as normal. Main effects of distance and brake type for TBT, BRT, & MT, i.e., drivers were faster for shorter distances and real trials. 83% of dummy trials resulted in braking (analyzed if MT & BRT complete) and 97% of real trials resulted in braking. Mean TBT = 0.561s	2 W did not finish 1/3 of the trials due to technical difficulties. The deceleration rate of the lead vehicle. was assumed to be maximal for 1s.
Schweitzer, Apter, Ben-David, Lieberman & Parush (1995)	Definition of minimum following gap (MFG) between vehicles (e.g., .75s specified in Israel).	On-the Road	Drivers preformed 16 trails per awareness condition (naive, partiallly aware, and fully aware) for a total of at least 48 trials. Condition was fixed in the order stated above, thus drivers became increasing aware that emergency braking events would occur.	Participants were the same as Lieberman, et al. (1995). Distance (6 & 12 m or approx. 1.5 & 3 car lengths) x speed (60 & 80 km/hr) x awareness condition. Dummy trials occured on 1/6 of the trials.	TBT (total braking time) = RT (onset of brakelights to accelerator release) + MT (accelerator release to brake contact).	M & F TBT's collapsed because no differences were found. Main effects for distance and awareness condition. Drivers were faster at closer distances and when alerted to potential emergency braking. Mean = 0.515s for 'fully aware' drivers (@ 80 km/hr & 6 m) whereas for 'unaware' drivers = 0.678s.	Trials < 0.2s and >1.7s eliminated. Low female N.