EFFECTS OF CELLULAR TELEPHONES ON DRIVING BEHAVIOUR AND CRASH RISK: RESULTS OF META-ANALYSIS

Prepared for:

CAA Foundation for Traffic Safety

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October 25, 2004

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ABSTRACT

This report addresses the effects of cell phones on driving by means of meta-analysis and review of 84 epidemiological and driver performance studies.

Epidemiological findings consistently showed an increase in crashes associated with use of cell phones. However, these studies did not control for exposure to cell-phone use or to driving. A meta-analysis of performance studies showed that conversation on cell phones, either hand-held or hands-free, was associated with deterioration in driving performance. Differences in findings were evident among computer-based studies, driving simulator studies and on-road studies, with the strongest effects found for the first of these.

Based on the available data, performance did not differ between hand-held and hands-free cell phones. More study is needed of the former, which are more widely used. With respect to age effects, older drivers are more likely to be at risk of a crash because of further decrements in already slowed reaction time. However, they are also less likely than younger drivers to be regular users of cell phones while driving.

Crash studies are hampered by inadequate reporting on cell phone use on the accident report form. Once reporting improves, it seems likely that the number of cell phone-related crashes will grow. Use is high – one study showed that about 60% of drivers had a cell phone and 30% used it regularly while driving.

Policy makers must weigh the benefits of using cell phones while driving against the growing literature suggesting negative impacts. Currently, 45 countries have implemented bans on using cell phones while driving.

EXECUTIVE SUMMARY

1 INTRODUCTION

This report addresses the effects of cell phones on driving by means of a review of the literature and an analysis of scientifically credible epidemiological and driver performance studies. A total of 84 articles were obtained covering the period 1969 – 2004. Sixty-eight articles were research papers measuring driving performance while using a cell phone and 16 articles were epidemiological studies that examined cell phone usage and their relationship to vehicular crashes.

Based on an initial review of this literature, and with the agreement of the Alberta Motor Association (AMA), the analysis and report were focused on 15 epidemiological studies and 22 performance studies which were used to answer four questions:

1. Does conversation on cell phones, whether hand-held or hands-free, influence driving performance?
2. Are there differences in findings among computer-based studies, driving simulator studies and on-road studies?
3. Does performance differ between hand-held and hands-free cell phones?
4. Are some age groups more susceptible to negative influences of cell phone use on driving?

2 METHODOLOGY

The methodological approach was as follows. Where there were sufficient studies, meta-analyses were carried out to combine study results to answer the above questions. Where there were not sufficient studies, the results of individual epidemiological (i.e., crash risk) and performance (i.e., reaction time and driving variables) studies were reviewed. In addition, because of the availability of a large number of studies, a quantitative analysis of reaction time, as affected by cell phone characteristics, cell phone tasks, driving tasks and driver age was carried out. Finally other study findings of interest are reported.

3 RESULTS

In answer to the first question, **conversation on cell phones, both hand-held and hands-free, was found to influence driving performance.** Epidemiological findings consistently showed an increase in crashes associated with use of cell phones. However, these studies did not control for exposure. Those who use cell phones more while driving may also drive more. It is well known that more driving leads to higher likelihood of having a crash. The contribution of driving exposure is a particular concern because, in most studies, phone use was not controlled at the time of the crash, and a connection is assumed. A meta-analysis of the performance studies showed moderate-to-large negative effects of the use of cell phones on driving performance. The largest negative effects were found for reaction time (an increase of 0.23 of a second on average and for older drivers, in particular, about 1/2 second). There were lesser size effects for lateral and longitudinal (headway) control, and speed control.

In answer to the second question, **differences in findings were evident among computer-based studies, driving simulator studies and on-road studies. A meta-analysis of the performance studies showed the strongest effects for laboratory studies, in comparison**

to on-road or driving simulator studies. Nonetheless, even using the most conservative analysis, on-road studies showed moderate impacts of cell phone use on performance.

In answer to the third question, **based on the available data, performance did not differ between hand-held and hands-free cell phones.** There were insufficient studies to carry out a meta-analysis. A single epidemiological study found an unexpected effect of a slightly higher risk for hands-free use. This may be confounded by exposure to driving as well as exposure to phone use while driving which may differ between drivers using hand-held versus hands-free phones. Most driving performance studies found no difference between hands-free and hand-held phones. However, the comparisons made have not focused on those situations in which hand-held phones are likely to be more of a liability with respect to physical demands of driving – for example, while merging into traffic, or while dialling or answering a call.

In answer to the fourth question, **the evidence is that, should cell phone risk be measured on a per kilometre driven basis, then older drivers are more likely to be at risk of a crash.** This is based on an analysis combining studies of reaction time, which found older drivers showing almost a half-second delay in response, when cell phones were in use, compared to one-fifth of a second for younger drivers. However, it is likely that younger drivers use cell phones more while driving. Even though they may not have as poor a reaction time as older drivers, they are more likely to be using the phone while driving and therefore more likely to have a crash while on the phone. This provides an explanation for the results of the three epidemiological studies: two found that it was younger to middle-aged rather than older groups who were most at risk; one found no difference related to age.

4 CONCLUSIONS

Our conclusions were similar to those of other reviews of the cell phone and driving literature. Additional findings of interest, not included in the meta-analyses, were that the reaction time increase was greater for lead vehicle braking as compared to other reaction time situations, and that use of a cell-phone while driving reduced the eyes-on-road time while driving, and narrowed the areas to which drivers attended.

5 RESEARCH GAPS

A number of gaps in research were identified. These include:

- Insufficient control for exposure to driving in crash studies
- Insufficient control for exposure to cell phone use, confounding age effects
- Insufficient study of hand-held as compared to hands-free cell phones
- Lack of clarity concerning the timing of the cell phone task and a critical driving event and the performance of the cell phone task
- Lack of clarity regarding the meaning of reported driving performance variables with respect to changes in risk

5.1 Exposure, Cell Phone Use and Crash Risk

In studies of crash risk associated with cell phone use there are issues of both cell phone exposure (frequency of use while driving) and driving exposure (kilometres driven per year), which can confound results. Frequent users of cell phones may be more able to carry out the division of attention required. On the other hand, they are more likely to be exposed to attention-dividing circumstances, and whether or not they can handle themselves better than less frequent cell phone users, they may be more likely to have a crash involving the use of a cell phone. Epidemiological studies are required that consider both cell phone and driving exposure. Performance studies are required to examine the impact on driving of cell phone use, for both experienced and inexperienced users of cell phones.

5.2 Cell Phone Use, Age and Driving Experience

While this is expected to change somewhat over the next decade, currently young drivers are more likely than older drivers to be frequent users of cell phones while driving. Young drivers are also at higher risk of a crash. Higher frequency of cell phone use while driving, and greater experience as a driver may both reduce the impact of cell phone use on driving performance. The naïve assumption that either negates the impact of cell phone use on driving needs further investigation.

5.3 Hand-Held vs. Hands-Free Cell Phone Use

Studies examining cell phone use while driving have predominantly focused on hands-free versions of cell phones even though the majority of drivers are using a hand-held phone. More studies are needed comparing the differences between these two types of units, particularly looking at newer phone interactions, such as text-messaging, that require more visual processing time. Various interfaces should also be researched in more depth to determine those that may mitigate or exacerbate existing problems with hand-held phones.

5.4 Secondary Task Performance

Studies of driver response to a critical event while performing a secondary distraction task, such as using a cell phone, frequently do not report the timing of the critical event relative to the distraction task. Furthermore studies do not generally report whether the drivers ignore the distraction task in order to maintain performance on driving tasks. This information would be helpful in determining safety impacts.

5.5 Meaning of Driver Performance Variables

Interpretation of the meta-analysis of cell phone effects on driver performance measures (e.g., lane position) is problematic because of ambiguity in the interpretation of these measures vis-à-vis driver risk. For example, a change in mean lateral lane position may indicate either increased or decreased risk depending on roadway and traffic characteristics. Future research should indicate *a priori* the pattern in these measures that is associated with greater risk.

6 POLICY IMPLICATIONS

With respect to policy implications, four issues arise:

- Legislation concerning cell phone use while driving and the tradeoff of costs and benefits
- The need to consider restrictions on cell phone use for inexperienced drivers
- Private sector response to cell phone crash risk
- Crash reporting and database improvement

Each of these is discussed below.

6.1 Legislation

In the debate to prohibit the use of cell phones while driving, policy makers must weigh the social and economic benefits of using cell phones while driving against the growing literature that suggests that using cell phones while driving has negative impacts. Currently, 45 countries have implemented bans on using cell phones while driving. In Canada, only Newfoundland and Labrador has introduced a ban on cell phone use while driving. In the U.S., although the majority of states have looked at the issue only three states now have full cell phone bans. No legislation has dealt specifically with novice drivers and cell phone use. Since younger drivers are heavier cell phone users, and since the least experienced drivers have high crash rates, a specific ban for these drivers may be warranted.

6.2 Inexperienced Drivers and Cell Phone Use

Graduated licensing programs are becoming the norm to licensing new drivers in North America, and represent an opportunity to address the issue of inexperienced drivers interacting with cell phones. During the probationary period, drivers are only allowed to operate vehicles under restricted conditions. In many jurisdictions, for example, new drivers cannot have any alcohol in their blood while operating an automobile. No restrictions are made for cell phone use. This despite the fact that young people are among the largest users of cell phones, and according to one study, most likely to be involved in distraction related crashes.

6.3 Private Sector Response

A number of companies have instituted bans on cell phone use while driving by their employees. Phone companies and insurance companies have begun to warn users of the increased crash risk associated with cell phone use.

6.4 Better Crash Reporting

Currently, our knowledge of cell phone impacts is limited because Canadian accident report forms do not require use of a cell phone at the time of the crash to be reported. This requirement has been added to the forms recommended for use in the U.S. Once reporting improves, it seems likely that the number of crashes identified as being associated with cell phones will grow. Use is high – one study showed that about 60% of drivers had a cell phone and 30% made or received calls on a regular basis while driving.

EFFECTS OF CELLULAR TELEPHONES ON DRIVING BEHAVIOUR AND CRASH RISK: RESULTS OF META-ANALYSIS

1 INTRODUCTION

This report addresses the effects of cell phones on driving by means of a review of the literature and an analysis of scientifically credible epidemiological and driver performance studies. The epidemiological studies provide evidence of changes in crash risk **associated with** cell phone use, but are limited in their ability to determine whether the use of a cell phone was the **cause** of a crash. Performance studies provide a direct link between use and changes in driving behaviour, but are limited in their ability to predict the degree to which such changes result in increased crash risk. Thus it is important to consider both types of study.

Literature on the effects of cell phones on driving was collected by searching online and through psychology, ergonomics, engineering, and medicine databases. Additional data came from articles cited in these sources and contact with a number of authors. The literature comprised: peer-reviewed journal articles, book chapters, government funded reports, review articles and privately funded reports. In addition, the literature included policy papers and opinion papers that were not reviewed and will not be discussed in this document.

A total of 84 articles were obtained covering the period 1969 – 2004. Sixty-eight articles were research papers measuring driving performance while using a cell phone and 16 articles were epidemiological studies that examined cell phone usage and their relationship to vehicular crashes. Some studies were published in both proceedings and peer-reviewed journals. Duplicate studies were eliminated. A number of studies were of good quality, whereas others had insufficient statistical information (e.g., t-values or F-values for critical comparisons) to allow their use in a meta-analysis. Studies that did not measure reaction time (RT), lateral, longitudinal control or speed were dropped from further consideration. Studies included in the meta-analysis are indicated by an asterisk (*) in the references. Appendix A shows summary tables, which briefly describe each of the studies reviewed.

Based on an initial review of this literature, and with the agreement of the Alberta Motor Association (AMA), we focused the analysis and report on four questions:

1. Does conversation on cell phones, whether hand-held or hands-free, influence driving performance? (see Section 3)
2. Are there differences in findings among computer-based studies, driving simulator studies and on-road studies? (see Section 3)
3. Does performance differ between hand-held and hands-free cell phones? (see Section 4)
4. Are some age groups more susceptible to negative influences of cell phone use on driving? (see Section 5)

2 METHODOLOGY

2.1 Sample Size for Meta-Analysis

There were insufficient epidemiological studies, and their methods were too diverse, to carry out a meta-analysis to answer any of the four questions outlined above. Instead, results of individual studies relevant to the question at hand are reported.

There were sufficient performance studies to perform a meta-analysis to address two of the four questions of interest. The other two questions were addressed by summarizing findings from the relevant performance studies.

Based on a review of 22 performance studies, the subset of dependent variables used frequently enough to allow for analysis were as follows:

1. Responses to critical events, by which is meant reaction time (RT) and the probability of missing the event (e.g., a stop sign or pedestrian entering the roadway)
2. Lateral vehicular control (e.g., average lane position, variability of lane position)
3. Longitudinal control (e.g., headway distance)
4. Speed

Table 1 shows a breakdown of the number of studies by experimental conditions addressed, and by dependent variables. Reaction time (RT) is the most common variable used to evaluate driving performance. RT is loosely used here to include brake reaction time (BRT), as well as choice reaction time and simple reaction time in response to various types of signals. For example, Cooper et al. measured BRT, which refers to the time from the onset of a stimulus (e.g., the sudden onset of a traffic light) to the initiation of a brake depression (Cooper, Zheng, Richard, Vavrik, Heinrichs, & Siegmund, 2003). RT in other studies reflects the RT of a key press in response to the detection and identification of a target (McPhee, Ho, Dennis, Scialfa, & Caird, 2004).

Lateral control includes all variables that examine the ability to control an object (usually a vehicle) within predefined boundaries. This includes lane position, standard deviation of lane position, and steering angle. Longitudinal control is generally measured as following distance of a lead vehicle, although other variables can be used such as time to collision and speed. Instead, we decided to include speed in a separate analysis. These analyses should be considered with caution because the interpretation of vehicular control variables vis-à-vis driver risk is not clear. Thus, for example, a change in mean lateral lane position may indicate greater risk if nearer the median on a two-lane roadway with wide shoulders, but may indicate greater risk if further from the median on an isolated, rural roadway where no shoulders exist.

TABLE 1. The number of studies reviewed by experimental conditions addressed and by dependent variables

		Reaction Time	Lateral Control	Longitudinal Control	Speed
Phone type	Hands-free	12	5	3	6
	Hand-held	1	2	1	0
	Both	7	2	2	3
Driving	Lab	6	1	0	0
	Simulator	13	6	2	8
	On-road	4	3	2	1
Age		4	3	2	0

2.2 Measure of Effect Size

A meta-analysis is a statistical method of combining results from studies that examine similar measures. For those questions and performance measures where there existed sufficient numbers of studies to perform a meta-analysis, the approach taken was as follows. The effect of cell phone use (irrespective of phone type) was calculated as:

$$r_{ES} = \sqrt{\frac{t^2}{t^2 + df}} = \sqrt{\frac{F}{F + df_{error}}}$$

where r_{ES} represents effect size, that is the size of the difference between conditions (e.g., between reaction time while talking on a cell phone vs. reaction time while not using a cell phone); t and F represents the value on a t or F distribution based on the respective test of statistical significance and df represents the degrees of freedom in the error term based on the statistical test performed.

This measure of effect size (Rosenthal & DiMatteo, 2001) was then converted to a z-score, using Fisher's r-to-z transformation. The transformation expresses an effect in standard deviation units. Thus, an effect of .5 means that the condition of interest (e.g., hand-held) differed from the control condition (e.g., hands-free) by about one-half of a standard deviation. In the behavioural sciences, an effect of 0.5 is often considered of moderate magnitude while an effect of 1 or greater is quite large. While there is no fixed minimum number of studies required for meta-analysis, if the number of studies is too small, the resulting effect size can be unstable, and vary depending on which studies are included (Rosenthal, 1995).

Each of these analyses was conducted twice. In the first instance, when an effect was reported as non-significant or was not reported, it was simply eliminated from the analysis. If one assumes that these are true null effects, then their exclusion biases the results by suggesting a larger effect of cell phone use than might exist in reality. In the second case, where it was clear from the published report that an effect was non-significant but it was not reported, the effect size was set to zero, the most conservative estimate possible. As well, in this second analysis, when there was more than one dependent measure from a study, the effects were averaged to produce a single relevant value for each study. The use of zero for the effect when it might have been larger, and averaging effects, leads to the opposite outcome, namely a greater likelihood of the meta-analysis finding no difference. As would be expected, the first approach produces higher estimates of effect sizes than the latter.

3 THE IMPACT OF CELL PHONE USE

This section addresses the first two questions:

1. Does conversation on cell phones, whether hand-held or hands-free, influence driving performance?
2. Are there differences in findings among computer-based studies, driving simulator studies and on-road studies?

3.1 Epidemiological Studies

Lam analyzed accident reports in the state of New South Wales in Australia from 1996 – 2000 and compared death and injurious crashes associated with cell phones to crashes not associated with distraction (Lam, 2002). The odds ratio (OR) for cell phone use exceeded 1.0 in only 1 of the 6 age groups tested, those aged 25 – 29 years. This suggests that there is an increased risk of a death or injurious crash while using a hand-held cell phone for this age group. This may be misleading since the author did not control for the high rate of phone use among this age group. Also, only 134 crashes out of over 400,000 crashes were reported to be directly related to hand-held cell phone use.

Laberge-Nadeau et al. sent questionnaires to drivers registered with the Société de l'assurance automobile du Québec (SAAQ) and obtained cell phone records from those who consented to provide such information (Laberge-Nadeau, Maag, Bellavance, Lapierre, Desjardins, Messier, & Saïdi, 2003). They examined 36,078 accident records from SAAQ, and compared the annual crash rates from 1996 – 1999 for cell phone users and non-users. They found an average OR of 1.11 for male cell phone users and 1.21 for female cell phone users. They also reported that certain demographic groups are more likely to use cell phones. Cell phone users are predominantly male, have incomes above $30,000, and are between the ages of 25 and 54 years. These differing exposure rates to cell phones were not controlled for in this study or in Lam (2002).

In two studies that did control for various confounding variables, including cell phone exposure, the data still suggest that using cell phones while driving is dangerous. Violanti and Marshall obtained data from a group of 100 drivers involved in crashes in a 2-year period and 100 who were not involved in crashes over a 10-year period (Violanti & Marshall, 1996). Using a multivariate logistic regression, they found that those phone users who used the cell phone for 50 minutes or more per month had an elevated risk of having a crash by a factor of 5.59 (i.e., an odds ratio [OR] of 5.59) compared to those who did not use cell phones while driving.

Redelmeier and Tibshirani surveyed drivers who were reporting crashes at a traffic collision centre (Redelmeier & Tibshirani, 1997). They found that almost a quarter of those drivers who owned cell phones were using their phone prior to the crash, which produced an elevated risk of a crash for both hand-held (OR = 3.9) and hands-free units (OR = 5.9).

The data summarized above shows that cell phone usage is associated with increased risk of crashes in a number of studies. The one study that examined hands-free and hand-held units separately did not find any difference in associated crash risk. However, several factors preclude any firm conclusions about the effect of cell phones of any type. The low frequency of crashes reported renders statistical tests insensitive and/or unreliable. Differences in methodology can make across-study comparisons difficult. Most studies do not control for driving exposure. The more one drives, the higher the risk of a crash. Cell phone use and amount of driving may be confounded, in that those who drive a lot are more likely to use cell phones while driving. Studies that control for exposure are badly needed.

Finally, a critical problem in most of these studies is that there is no means by which cell phone usage can be identified at the individual level as a causal factor in the crashes reported. For example, retrospective studies (e.g., Laberge-Nadeau et al., 2003) examine past accident records in relation to current cell phone use. Clearly, in these circumstances, it is not possible to discern if the phone was in use at the time of the crash, much less its effect on the crash's occurrence or characteristics. An implication for future research is that epidemiological studies may have to be co-ordinated across several jurisdictions to allow a large enough database and that the methods should be such as to estimate risk associated with cell phone usage at the time of the crash. This could be accomplished via access to usage records.

3.2 Driving Performance Studies

Two meta-analyses were carried out to address the influence of cell phones on driving performance. The first analysis was done to determine the effects of cell phone use on performance. Three categories of performance were considered: RT to critical events (e.g., a vehicular incursion), driving control variability variables (i.e., lane position, headway and speed variability) and speed (i.e., mean speed).

The second analysis compared cell phone effects as a function of whether the experiment was carried out on a desktop computer (e.g., a search task executed while engaged in conversation), a simulator, or on the road. As discussed in the section on methodology, each meta-analysis dealt with unknown effects. Two approaches were used, one more conservative and the other less conservative, to determine the maximum and minimum likely effects.

3.2.1 Effects of Cell Phone Use on Performance

Table 2 addresses the first question: *Does conversation on cell phones, whether hand-held or hands-free, influence driving performance*? Table 2 provides summary statistics for measures of effect for RT, driving control variability measures and speed.

It is clear that the cell phone conversation and information processing tasks used to simulate the distraction of conversation interfere with performance. The largest effect is seen on RT to a variety of stimuli. The discrepancies between averages and medians are small, indicating that there are no outliers influencing the means unduly. The conservative analysis that sets to zero all non-significant effects produces a reduction in estimated effect size, which remains moderate in magnitude for the RT measures but is reduced to a small and likely non-significant value for the driving variables. Horrey & Wickens also found greater effect sizes for RT and smaller or non-significant effect sizes for lane-keeping and tracking measures (Horrey & Wickens, 2004).

TABLE 2. Summary statistics for effects of cell phone use on reaction time and driving variable studies

Statistic	Reaction Time	Driving Variables
Ignoring Data Reported as Non-Significant		
Average	0.64	0.31
Standard Deviation	0.41	0.18
Median	0.59	0.30
N of Data Points	28	16
Setting to Zero Non-Significant Effects and Averaging Across Measures		
Average	0.44	0.23
Standard Deviation	0.40	0.23
Median	0.42	0.20
N of Data Points	21	12

One can also ask if cell phone usage has an impact on measures of driving speed or variability in driving speed. Such an effect could be important if, for example, people increase their speed while using a cell phone or if they became more erratic in maintaining speed. In order to address this question, the literature was examined for studies that included speed as a dependent measure. There were 18 studies found, but due to failure to report accurate test statistics, only 9 of them could be used in the analysis (see the Reference Section for a list of these citations). All but one of these studies was conducted in a simulator, so it was not possible to examine the effect of study type, as has been reported for other performance analyses.

The analysis revealed that there was a small effect of cell phone usage on driving speed. Specifically, drivers tended to drive more slowly while using a cell phone. However, the average effect size was .26 and had a median of .2. Thus, relative to other measures like RT or vehicular control, the use of a cell phone does not have as large an impact on the speed at which people drive.

3.2.2 Effects of Cell Phones by Study Type

Table 3 addresses both the first and second questions:

1. Does conversation on cell phones, whether hand-held or hands-free, influence driving performance?
2. Are there differences in findings among computer-based studies, driving simulator studies and on-road studies?

Table 3 provides summary statistics for the comparison of effects by study type. The average effect size indicates the degree to which performance differed when a cell phone was in use in comparison to when it was not. As noted earlier, an effect of 0.5 standard deviations is considered of moderate magnitude, while an effect of 1 or greater is considered quite large. The number of data points indicates the number of individual values used in the meta-analysis.

From Table 3, several trends are apparent. Consider the analysis that ignores null effects. First, regardless of the context in which the study took place, a cell phone conversation interfered with performance. Second, the medians are consistently lower than the means, suggesting that one or a small number of studies with large effect sizes are influencing the averages and that, in consequence, confidence intervals about the mean might be biased in a liberal direction. That is, studies are more likely to report an impact of cell phone use, even if it is not reliable. Third, the laboratory studies show the largest effects, the average effect size being considerable in magnitude. Effects found in both on-road investigations and simulator-based studies were smaller, but still in the moderate-to-large range.

Now consider the results from the analysis that set to zero all reported null effects and aggregated effects within studies. It can be seen that the effect of a phone conversation is diminished in all categories, while the relative ranking stays the same, in that the effect size is largest in the laboratory studies, followed by on-road studies and then driving simulator studies. The discrepancy seen between means and medians still argues against the use of confidence intervals about the mean and that the reduced number of data points leads to less confidence in the estimates of effect. Still, it is clear that both lab and on-road studies collectively show moderate-to-large effects of the use of cell phones on driving performance.

TABLE 3. Effects of cell phone vs. no cell phone on driving

Statistic	Lab Studies	Simulator Studies	On-Road Studies
Ignoring Data Reported as Non-Significant			
Average Effect	0.89	0.36	0.64
Standard Deviation	0.40	0.20	0.42
Median	0.87	0.35	0.59
N of Data Points	9	21	11
Setting to Zero Non-Significant Effects and Averaging across Measures			
Average Effect	0.57	0.26	0.38
Standard Deviation	0.54	0.18	0.36
Median	0.59	0.26	0.28
N of Data Points	5	12	6

The larger effects found in laboratory studies may result from the fact that these studies generally focus on a few task interactions, measured intensively. Task requirements are very precise, for example, a tracking task will require exact positioning of a cursor on a screen. Laboratory tasks often bear little resemblance to driving or talking on a phone. For example, Consiglio et al., McCarley et al. and McPhee et al. do not have participants engage in steering at all, which is essential to the task of driving (Consiglio, Driscoll, Witte, & Berg, 2003; McCarley, Vais, Pringle, Kramers, Irwin & Strayer, 2001; McPhee et al., 2004).

On-road studies and simulator studies, on the other hand, generally sample a larger variety of driving skills, with less of a sample of each type of task, and less precise task requirements in some cases. For example, drivers control lane position to stay within the lane but do not attempt to position their vehicles exactly in the centre. An approximate correspondence of driving simulation to on-road effect sizes was also found by Horrey & Wickens (2004).

Some of the simulated distraction and driving tasks used in cell phone studies do a poor job of approximating the actual demands on drivers. Tasks that approximate those typically engaged in by drivers—for distraction, lane-keeping and hazard detection—are more likely to estimate the true impact of distraction on driving performance (Caird, Lees & Edwards, 2004).

4 THE IMPACT OF HAND-HELD VS. HANDS-FREE CELL PHONES

This section addresses the third question: *Does performance differ between hand-held and hands-free cell phones?*

One epidemiological and seven performance-based studies were found that compared the impact of hand-held and hands-free units. While a preliminary and qualitative summary of the data may be feasible, there were insufficient behavioural or epidemiological studies to warrant a quantitative analysis.

4.1 Epidemiological Studies

The only epidemiological study to explicitly compare hand-held and hands-free risk is Redelmeier and Tibshirani (see also Section 3.1) (Redelmeier and Tibshirani, 1997). This study reports a somewhat higher risk for hands-free use, although the confidence intervals overlap.

4.2 Driving Performance Studies

Among the driving performance studies reviewed, the results are mixed. Consiglio et al. (2003) had participants seated in a low-fidelity mock vehicle and either listen to the radio, converse with a passenger, converse over a hands-free phone, or converse using a hand-held phone. Occasionally, a red light was flashed and participants were required to brake as quickly as possible. Brake responses were significantly slower when participants were conversing. However, there was no difference between phone types. Similar results were reported by Patten et al., who also used an on-road driving task (Patten, Kircher, Ostlund, & Nilsson, 2004), that is, conversing on a phone increased RT to a light signal equally, regardless of phone type. These findings are further supported by a series of studies by Strayer and his colleagues (Strayer, Drews, Albert, & Johnston, 2002; Strayer, Drews, & Crouch, 2003; Strayer & Johnston, 2001). Using both computer-simulated tracking tasks and moderate-fidelity simulator driving tasks, Strayer and his colleagues have reported that conversing on a cell phone increased RT to a lead vehicle braking. All three studies concluded that, **at least during conversation**, hands-free and hand-held performance were equivalent and subsequent analyses collapsed across these variables.

Only one study reported more impairment while using a hand-held phone. Ishida and Matsuura had participants drive an instrumented vehicle on a closed course track while conversing using a hands-free or hand-held phone (Ishida & Matsuura, 2001). They had to follow a lead vehicle and brake whenever the lead vehicle braked. They found that BRT (brake reaction time) while using a hand-held phone was significantly slower than when using the hands-free model. There was also a moderate effect of phone type on lateral control while driving a straight section of road. Similarly, Brookhuis et al. reported that drivers using a hand-held phone had more difficulty controlling the vehicle relative to hands-free users (Brookhuis, de Vries, & de Waard, 1991).

In summary, the data analyzed supported the view that hands-free and hand-held have similar effects. A small number of studies involved and the conditions in them have not allowed for a particularly sensitive test of the differential effects of hand-held units. For example, no study has examined the frequency of signalling or lane position while curve-following or turning, even though both aspects of behaviour should be harder with a hand-held unit. The larger number of hands-free studies is perhaps a reflection of research whose aim was to determine the distraction effects of conversation because legislation seemed to be exclusively focused on hand-held units only.

4.3 Additional Reaction Time Analysis

The capability of drivers to respond to traffic events while using a cell phone has obvious practical relevance. RT was also the most common dependent variable measured across studies.

From the larger set of cell phone studies, 18 studies adequately reported reaction time. A study was included in the analysis if baseline and distraction reaction time means were reported in the text, a table or could be estimated from a figure. The studies that were analyzed are an extension of the research reported in Caird, Lees and Edwards (2004). A number of study characteristics were coded including: the paradigm used (e.g., computer, driving simulator, on-road), conditions tested (e.g., hands-free, hand-held), the distraction task (e.g., conversation, or other, such as listening to radio), stimulus (e.g., sudden pedestrian appearance) and response (e.g., engage brake, press button).

TABLE 4. Mean reaction time increase, standard deviation of study means, number of studies and number of participants

Condition	Mean Increase in Reaction Time (seconds)	Standard Deviation (seconds)	Number of Studies	Number of Participants
All Distraction Tasks	0.23	0.31	18	532
Hand Held Phone	0.20	0.17	4	132
Hands Free Phone	0.21	0.30	14	430

As shown in Table 4, drivers responded about 1/5 of a second later to stimuli in the presence of a cell phone distractor for all studies that were analyzed. At higher speeds a fifth of a second can make a difference between striking another vehicle or a pedestrian and avoiding such a crash. Importantly, the mean RT increase for hand-held and hands-free phones was essentially the same (0.21 versus 0.20).

5 THE EFFECTS OF AGE

This section addresses the last question: *Are some age groups more susceptible to negative influences of cell phone use on driving?*

5.1 Epidemiological Studies

There were too few epidemiological studies found to justify a quantitative analysis of the relationship between age and the effects of cell phone usage on driving risk. There were only three studies (Laberge-Nadeau et al., 2003; Lam, 2002; Redelmeier and Tibshirani, 1997) that reported data in sufficient detail to allow any examination of age effects.

In the Laberge-Nadeau et al. (2003) study, involving 36,078 accident records, users and non-users of cell phones in Québec, five age groups were compared (a) 16 – 24 years, (b) 25 – 34 years, (c) 35 – 44 years, (d) 45 – 54 years, and (e) 55 – 64 years. In all age groups, the risk of a crash was greater for cell phone users. As one would expect, drivers in the 16 – 24 category had the highest risk of crashes. Lam (2002) analyzed 414,136 police records of vehicle crashes in Australia using seven age categories (a) 16 – 19, (b) 20 – 24, (c) 25 – 29, (d) 30 – 39, (e) 40 – 49, (f) 50 – 69, and (g) 70+ yrs. He found that relative to other age groups, only drivers between 25 and 29 years of age had a higher risk of being involved in a crash causing injury or a fatality while using a cell phone. Redelmeier and Tibshirani (1997) collected data from a traffic collision centre in Toronto and classified their participants into four age categories: (a) under 25, (b) 25 – 39, (c) 40 – 54, and (d) greater than 54 yrs. They reported approximately twice the risk (OR = 6.5 vs. 3.3) for 25 – 39 year olds compared to adults over 55 years of age. In summary, there is a consistent, albeit small, trend for the older groups to have the lower risk. This may be due in part to less use of cell phones by older drivers who own them.

5.2 Driving Performance Studies

Among the set of driving performance studies, Ålm & Nilsson, Cooper et al., Green et al., Lyda et al., McCarley et al., McPhee et al., Nilsson & Ålm, Strayer and Drews and Tokunaga et al. included age as a variable of study (Ålm & Nilsson, 1995; Cooper et al., 2003; Green, Hoekstra, & Williams, 1993; Lyda, Osbourne, Coleman, & Rienzi, 2002; McCarley et al., 2001; McPhee et al., 2004; Patten et al., 2004; Nilsson & Ålm, 1991; Strayer & Drews, 2003; Tokunaga, Hagiwara, Kagaya, & Shimojyo, 2000). However, because of errors in data reporting (Lyda et al., 2002) or sufficient statistical information (Cooper et al., 2003; Green et al., 1993), several of these studies could not be considered.

All of the remaining studies compared younger (mean age 29.3 years or less) and older adults (age 45 years or more), with one study including a middle-aged group. In no case was there a significant interaction of age and cell phone usage. In other words, although older adults may have been slower to respond to critical events or less proficient in their driving, these age differences were not exacerbated by the phone conversation. It is important to note, however, that despite this lack of interaction, older adults may still be at greater risk when using cell phones, particularly in time-limited conditions where the additive effects of their cognitive slowing and cell phone usage would prevent them from responding with adequate speed.

5.3 Additional Reaction Time Analysis

Five studies that compared age groups also reported their RT data. The mean increase in RT of younger drivers to a cell phone distractor was 0.19 seconds, whereas it was 0.46 seconds for older drivers (see Table 5). In addition, older driver RT performance was more variable (SD = 0.56 s) than younger drivers (0.19 s). The studies that were analyzed here did not use drivers above the age of 75, who, most likely, would have had even larger performance decrements.

TABLE 5. Mean reaction time increase (i.e., drive with distraction – baseline drive), standard deviation of study means, number of studies and number of participants

Condition	Mean Increase in Reaction Time (seconds)	Standard Deviation	Number of Studies	Number of Participants
All Distraction Tasks	0.23	0.31	18	532
Younger Drivers	0.19	0.26	5	83
Older Drivers	0.46	0.56	5	59

6 OTHER STUDY FINDINGS OF INTEREST

6.1 Results of Previous Reviews

Previous reviews summarizing the scientific literature on the effects of cell phones on driving have come to comparable conclusions. Parkes (1991) examined the data from ten performance-based studies and concluded that the data show that conversing over a cell phone while driving affects driving performance negatively. However, he also clearly states that there is little evidence to suggest, “routine conversations involving little complex information are beyond the capabilities of the normal driving public”.

Goodman et al. reviewed eleven performance-based studies, two epidemiological studies, and five traffic accident databases (Goodman, Bents, Tijerina, Lerner, & Benel, 1997; Goodman, Tijerina, Bents, & Wierwille, 1999). They report that in one study, talking on a cell phone actually improved performance by increasing the arousal level of fatigued drivers. Despite this finding, most studies found that conversing on a phone affected lane-keeping, speed, headway and event detection. They concluded that cell phones negatively affect driving performance in some contexts. However, they point out that the magnitude of the problem is difficult to determine because crash reports rarely indicate whether a phone was in use at the time of the crash.

In a more recent review, Horrey & Wickens (2004) performed a meta-analysis similar to the current project. They reviewed sixteen studies examining only RT data and lane position data. They found that there was a clear detriment to RT when talking on a phone while driving and that the effects of hand-held cell phones were similar to hands-free phones. Interestingly, they did not find that talking on a phone was any more detrimental than talking to other passengers. This contradicts the view that passengers moderate their conversation to the difficulty of the driving task. LaBerge et al. (in press) tested this hypothesis and found that there were no differences in driving performance between a passenger conversation and a conversation over a hands-free phone.

6.2 Quantitative Reaction Time, Cell Phone and Driving Tasks

The quantitative RT data analysis referred to in Sections 4 and 5 was extended to look at the impacts of a number of different cell phone tasks (see Table 6), and driving tasks (see Table 7). The cognitive tasks referred to in Table 6 are those used by experimental psychologists as conversation surrogates and are labelled information processing tasks by Horrey & Wickens (2004). They include such tasks as adding two 1-digit numbers or playing word games. The correspondence of these tasks to real cell phone conversation has been raised by a number of researchers, e.g. (Goodman et al., 1997; Laberge, Scialfa, White, & Caird, 2004; Parkes, 1993).

TABLE 6. **Mean reaction time increase (i.e., drive with distraction – baseline drive), standard deviation of study means, number of studies and number of participants**

Condition	Mean Increase in Reaction Time (seconds)	Standard Deviation	Number of Studies	Number of Participants
All Distraction Tasks	0.23	0.31	18	532
Cognitive Task	0.34	0.40	9	274
Conversation	0.15	0.13	7	65
Dial/Enter Number	0.30	0.16	3	65
Converse with Passenger	0.20	0.13	3	84
Listen to Radio/Other	0.05	0.03	3	88
In-Vehicle Device Operation	0.35	0.36	1	19

Cognitive or information processing tasks produced larger RT increases (0.34 s) than conversations (0.15 s). Horrey & Wickens (2004), in their meta-analysis of 16 studies, report that naturalistic conversation produced greater performance decrements than information processing tasks, which is the opposite of the result found here. The reason for this difference in results is most likely due to differences in which studies were included for analysis.

Dialling or entering a number, conversing with a passenger, and performing in-vehicle tasks (e.g., interacting with heating or the radio) also produced RT increases. Listening, which was included in 3 studies, appeared to have little effect on RT. Mean conversation (0.15) and conversation with a passenger (0.20) increases were similar, which was also found by Horrey & Wickens (2004). Depending on the study, conversation with a passenger could be naturalistic or artificial, which may affect the attention-demanding nature of the conversation and therefore the results.

Reaction time (RT) is a dependent variable category that includes simple reaction time, choice reaction time, perception reaction time and brake reaction time (Olson & Farber, 2003). When the stimulus and response characteristics of the RT category are logically grouped and analyzed, Table 7 results. The RT increase is greatest for lead vehicle braking (0.43 s) and least when responding to a simple stimulus such as the onset of a single LED (0.06 s). BRT/RT to an abstract stimulus response (S-R) includes responses or stimuli that are not usually encountered by drivers. For example, braking to a red square that appears on the left-hand side of the road or flashing a car’s warning lights to traffic lights are not typical driver actions. The authors of these studies argue that these manipulations approximate surprise events, but the novelty of these events may speed responses and/or confuse participants if they cannot remember how to respond (e.g., older adults).

TABLE 7. Mean reaction time increase (i.e., drive with distraction – baseline drive), standard deviation of study means, number of studies and number of participants

Condition	Mean Increase in Reaction Time (seconds)	Standard Deviation	Number of Studies	Number of Participants
All Distraction Tasks	0.23	0.31	18	532
BRT, Lead Vehicle Brakes	0.43	0.46	6	230
BRT, Light Change at Intersection	0.12	0.18	3	78
BRT/RT, Abstract S-R	0.17	0.17	4	104
RT, Simple	0.06	0.19	5	147

A number of individual studies, not listed in Table 7, used unique scenarios that were quite relevant to the impact of cell phone distractions on driver performance. The sudden appearance of a pedestrian on the right while the driver was talking on a hands-free phone produced a 0.14 s increment (LaBerge et al., in press), whereas when a lead vehicle cut in while talking, a 0.77 s increment was found (Ranney, Watson, Mazzae, Papelis, Ahmad, & Wightman, 2004).

The selection of the appropriate contexts in which to test the effects of cell phone distractors on driver performance is over-represented by lead vehicle braking scenarios and under-represented by other crash-likely contexts such as intersections, merging and pedestrians.

6.3 Eye Movements

Absent thus far from the present meta-analysis is the impact of cell phones on eye movements while driving. In an effort to provide performance data for driver modelling, Caird, Lees and Edwards (2004) analyzed 44 cell phone performance studies. Typical measures of eye movements included fixation duration, fixation frequency, pupil diameter, time off road and proportions of gazes to the speedometer and mirrors. Notable studies using these measures included Tijerina et al. and Recarte and Nunes (Tijerina, Kiger, Rockwell, & Tornow, 1996; Recarte & Nunes, 2000; Recarte & Nunes, 2003).

In general, the presence of a cell phone increased the eyes "off road" time when drivers read a display or dialled a number (Tijerina et al., 1996). Conversing or performing an information-processing task tended to change the pattern of eye movements to aspects of the vehicle and traffic environment. For example, fewer glances are made to mirrors and the speedometer, (e.g., Harbluk, Noy, & Eizenman, 2002) and horizontal gaze variability (i.e., left and right scanning) decreased while conversing over a cell phone (Recarte & Nunes, 2000).

In general, eye movement variables are important and desired, but difficult to measure and analyze efficiently. The quality of eye movement results varies and the use of dissimilar measures by different research groups make comparisons across studies difficult. Nevertheless, interaction with a cell phone and/or talking on one, negatively impacts the allocation of attention to the vehicle and roadway in systematic ways.

7 GAPS IN RESEARCH

In the process of reviewing 84 articles on the impact of cell phone use on driving, a number of gaps in the research became evident. These were as follows:

- Insufficient control for exposure to driving in crash studies
- Insufficient control for exposure to cell phone use, confounding age effects
- Insufficient study of hand-held as compared to hands-free cell phones
- Lack of clarity concerning the timing of the cell phone task and a critical driving event and the performance of the cell phone task
- Lack of clarity regarding the meaning of reported driving performance variables with respect to changes in risk

7.1 Exposure, Cell Phone Use and Crash Risk

In studies of crash risk associated with cell phone use there are issues of exposure, which, if not controlled, can confound results. Frequent users of cell phones may be more able to handle the division of attention required, both because of innate skill as well as practice. Behavioural studies should examine this question. On the other hand, they are more likely to be exposed to attention-dividing circumstances, and whether they can handle themselves better than less frequent cell phone users, they may be more likely to have a crash involving the use of a cell phone. Thus, there may be an interaction between driving exposure and cell phone use, with drivers who are more likely to use cell phones, and more likely to use them more often, driving more than other drivers, and therefore having a higher crash risk that is associated with their greater exposure. It would be of interest to examine cell phone use and frequency of use by age, driving exposure, and type of driving exposure (e.g., on highways, in stop and go traffic, etc.).

7.2 Hand-Held vs. Hands-Free Cell Phone Use

It is somewhat surprising that studies examining cell phone use while driving have predominantly focused on hands-free versions of cell phones even though the majority of drivers are using a hand-held cell phone. There are still only a handful of studies that compare the two phone types. This might reflect the belief that there is no difference between the two phone types, (e.g., Strayer and Johnston, 2001). The results of the current meta-analysis suggest that this is true when studies look exclusively at conversation task, but less is known about other forms of interactions.

Given the number of possible functions on modern cell phones, such as camera and video capabilities and text-messaging, it is likely that these tasks will add to the distraction while driving and may have differential effects on maintaining lane position and reacting to critical events. Thus, more studies are needed comparing the differences between hand-held and hands-free cell phones, particularly looking at newer phone interactions that require more visual processing time. Various interfaces should also be researched in greater depth. If new in-vehicle telematics form the next generation of hands-free phones, they may have properties that mitigate some existing problems with hand-held phones. For instance, the legibility and increased screen “real estate” may considerably improve information acquisition.

How a hand-held phone is held to a driver’s ear may restrict head and eye movements. A plausible but untested hypothesis is that fewer hazards are detected by drivers on the same side of the visual field as where the phone is held to the head.

7.3 Cell Phone Use, Age and Driving Experience

The impact of experience using a cell phone while driving and experience at driving has received insufficient attention. Young drivers are more likely than older drivers to be frequent users of cell phones while driving (Laberge-Nadeau et al., 2003; Stutts, Huang, & Hunter, 2002; Taylor, Bennett, Carter, & Garewall, 2003). However, attentional demands of driving are greater for inexperienced than experienced drivers, and for that matter, greater for unfamiliar than for local drivers. A novice driver, who is defined as one who has been driving for less than 6 months, and who is also unfamiliar with a new cell phone is likely to have the highest crash risk (e.g., Chen et al., 2000) and largest performance decrements.

Several studies have examined the impact of cell phone use on the performance of inexperienced and experienced drivers. However, the quality of these studies was not sufficient to determine whether level of driving experience differentially affected driving performance in the presence of a cell phone distractor. Future studies should categorize drivers according to their experience both as drivers and as cell phone users while driving and investigate these effects to determine if such experience mitigates the negative impacts of cell phone use.

7.4 Secondary Task Performance

Conversation, whether with a passenger or on a cell phone, is a distraction task, which is secondary to the primary driving task. The temporal coincidence of primary driving and secondary distraction tasks of conversation, or surrogates for conversation, is rarely described by researchers. Thus, the concurrency of the two tasks is assumed. In addition, the performance of the conversation or cell phone interaction task is rarely described. What the driver does with this distraction task is important to the interpretation of the variety of dependent variables measured. It is desirable that a driver ignores or sheds the distraction task when attention is needed for lane-keeping or hazard response. However, drivers may not be able to protect their driving performance in the face of distracters such as conversation or interacting with a cell phone and this is important to know. Researchers need to report secondary task performance and strategic differences exhibited by drivers to distraction task demands.

7.5 Meaning of Driver Performance Measures

As mentioned above, interpretation of the meta-analysis of cell phone effects on driver performance measures (e.g., lane position) is problematic because of ambiguity in the interpretation of these measures vis-à-vis driver risk. For example, a change in mean lateral lane position may indicate either increased or decreased risk depending on roadway and traffic characteristics. Interpretation is less of a concern for mean headway and speed but, even for these measures, there are conditions where a decrease in a mean does not necessarily imply increased risk. Even measures of variability, such as standard deviation of lane position and headway are not without interpretative difficulties because increased variability may well be an appropriate response to momentary changes in the attentional demands of a distraction in the driving context. At a minimum, future research needs to include more measures of central tendency and variance and should indicate *a priori* the pattern in these measures that is associated with greater risk.

8 CONCLUSIONS

We considered a total of 15 epidemiological and 22 performance studies of cell phone use, and used meta-analysis and a quantitative analysis of RT to answer four questions concerning the safety of cell phone use. There were insufficient epidemiological studies to carry out a meta-analysis for any of those questions. However, there were sufficient driving performance studies to address two of the four questions using meta-analysis. Our findings are summarized below, based on the meta-analysis, the additional analyses of RT, and on a review of the available studies.

8.1 Main Findings

1. *Does conversation on cell phones, both hand-held and hands-free, influence driving performance and crash risk?*

    Yes. The research to date indicates that using a cell phone while driving results in deterioration of driving performance. Both responses to critical events and the ability to maintain vehicular control are hampered. Even under the most conservative analyses, small to moderate effects exist. The negative impact of cell phone usage is larger for responses to critical events than for vehicular control. Driving variables, including lane position and headway variability, showed smaller effects.

    The average RT increase in the presence of a cell phone distraction is about a quarter of a second. This value probably underestimates the behaviour of drivers when not being observed and who are free to adopt typical habits within their own vehicles (Caird et al., 2004). On-road driver behaviour tends to be worse than driver performance assessed in experimental settings (Evans, 2003).

    The effect of conversation on driver performance is to delay recognition and response to important traffic events. To date, research suggests that hands-free cell phones produce similar performance decrements to hand-held phones. Legislation has not necessarily considered the impact that hands-free conversation has on driver performance (Caird et al., 2004).

2. *Are there differences in findings among computer-based tasks, simulator studies and on-road studies?*

    Yes. With respect to study type, laboratory studies found the largest effects. These studies generally focus on a few behaviours, whereas on-road and simulator studies typically sample a larger variety of driving skills. On-road studies also show a moderate effect on behaviour when there is conversation on cell phones. Simulator studies, of which there are the greatest number, show somewhat less of an effect than on-road studies.

    Of the epidemiological studies reviewed, one showed increased crash risk for one of six age groups only (age 25 – 29 years) (Lam, 2002), one showed an increase in risk for both hand-held (OR = 3.9) and hands-free units (OR = 5.9) (Redelmeier and Tibshirani, 1997), and one showed an increase in crash risk for cell phone users (OR = 1.11 for males; 1.21 for females) with increased risk for those who used the phones more frequently (OR = 5.59) (Laberge-Nadeau et al., 2003).

3. *Does performance differ between hand-held and hands-free cell phones?*

   No. Based on the available studies (1 epidemiological, 7 performance), the data indicate no difference between hand-held and hands-free cell phones. This conclusion is tentative, being based on only a single epidemiological study and on studies that did not measure performance in driving situations more likely to be impacted differentially by hand-held and hands-free cell phones.

4. *Are some age groups more susceptible to negative influences of cell phone use on driving?*

   Yes. The research suggests that on a per-kilometre basis, older drivers are more likely to be at risk of a crash because of further decrements in already slowed reaction time found in performance studies. However younger drivers are more likely to use cell phones while driving, and therefore are more likely to be involved in cell phone related crashes. The number of studies that examined age and cell phone use while driving was limited. Of the eight performance studies, not surprisingly, the majority have found that older adults, like younger adults, are slower with respect to reaction time when using a cell phone. However, only one study (Cooper et al., 2003) found that older adults were disproportionately affected when engaged in a hands-free conversation. In addition, none of the studies found that older adults differed from younger adults in lateral or longitudinal vehicular control. Among the three epidemiological studies reviewed, two found it was younger to middle-age rather than older groups who were most at risk. Since these studies did not control for frequency of cell phone use while driving, this may be due to greater use by this age group, rather than increased risk per se (i.e. on a per kilometre driven basis). An analysis combining studies of reaction time found older drivers showing almost a half second delay in response, when cell phones were in use, compared to one fifth of a second for younger drivers.

8.2 Similarity to Findings of Other Reviews

Our conclusions were similar to those of other reviews of the cell phone and driving literature. Additional findings of interest, not included in the meta-analyses, were that the reaction time increase was greater for lead vehicle braking as compared to other reaction time situations, and that use of a cell-phone while driving reduced the eyes-on-road time while driving, and narrowed the area attended.

8.3 Gaps in Research

A number of gaps in research were identified. These were as follows:

- Insufficient control for exposure to driving in crash studies
- Insufficient control for exposure to cell phone use, confounding age effects
- Insufficient study of hand-held as compared to hands-free cell phones
- Lack of clarity concerning the timing of the cell phone task and a critical driving event and the performance of the cell phone task

- Lack of clarity regarding the meaning of reported driving performance variables with respect to changes in risk

In studies of crash risk associated with cell phone use, there are issues of both cell phone exposure (frequency of use while driving) and driving exposure (kilometres driven per year), which can confound results. Frequent users of cell phones may be more able to handle the division of attention required, both because of innate skill as well as practice. Behavioural studies should examine this question. On the other hand, they are more likely to be exposed to attention-dividing circumstances, and whether or not they can handle themselves better than less frequent cell phone users, they may be more likely to have a crash involving the use of a cell phone. Epidemiological studies are required that consider both cell phone and driving exposure. Performance studies are required to examine the impact on driving of cell phone use, for both experienced and inexperienced users of cell phones.

Studies examining cell phone use while driving have predominantly focused on hands-free versions of cell phones even though the majority of drivers are using a hand-held phone. More studies are needed comparing the differences, particularly looking at newer phone interactions, such as text messaging, that require more visual processing time. Various interfaces should also be researched in more depth to determine those that may mitigate some existing problems with hand-held cell phones.

Young drivers are more likely than older drivers to be frequent users of cell phones while driving. However, young drivers are also at higher risk of a crash. Higher frequency of cell phone use while driving, and greater experience as a driver, may both reduce the impact of cell phone use on driving performance. The naïve assumption that either negates the impact of cell phone use on driving needs further investigation.

Studies involving a response to a critical event frequently do not report the timing of the event relative to cell phone use. Furthermore studies do not generally report whether the drivers ignore the cell phone task in other to maintain performance on driving tasks. This information would be helpful in determining safety impacts.

Interpretation of the meta-analysis of cell phone effects on driver performance measures (e.g., lane position) is problematic because of ambiguity in the interpretation of these measures vis-à-vis driver risk. For example, a change in mean lateral lane position may indicate either increased or decreased risk depending on roadway and traffic characteristics. Future research should indicate *a priori* the pattern in these measures that is associated with greater risk.

9 POLICY IMPLICATIONS

With respect to policy implications, four issues arise:

- Legislation concerning cell phone use while driving and the tradeoff of costs and benefits
- The need to consider restrictions on cell phone use for inexperienced drivers
- Private sector response to cell phone crash risk
- Crash reporting and database improvement

Each of these is discussed below.

9.1 Legislation

In the debate to prohibit the use of cell phones while driving, policy makers must weigh the social and economic benefits of using cell phones while driving against the growing literature that suggests that using cell phones while driving is dangerous. Currently, 45 countries have implemented bans on using cell phones while driving including the United Kingdom, Germany, France, Japan, the Netherlands, and Australia (Cellular News, 2004). In Canada, as of April 1st, 2003, only Newfoundland and Labrador had introduced a ban on cell phone use while driving (Transport Canada, 2004).

In the United States, the debate over cell phone use in cars has become a growing issue. At the federal level, in 2001, legislation was proposed to require all states to impose a ban on cell phones while driving. The legislation did not pass Congress and to date, no regulations have been instated prohibiting the use of mobile phones in the car (National Transportation Safety Board, 2003).

New York was the first state to implement a full ban on cell phone use. The effectiveness of the ban is limited. McCartt and Geary examined cell phone usage prior to the ban, immediately after the ban and 1 year after the ban (McCartt & Geary, 2004). They found that immediately after the ban, cell phone use while driving did decrease, but after a year, the level of cell phone use while driving returned to pre-ban levels. The authors suggest that drivers do not take the ban seriously and consistent enforcement will be required for cell phone use to be reduced.

Although the majority of states have looked at the issue (Sundeen, 2003), as of July 2004, only three states (New York, New Jersey, and the District of Columbia) now have full cell phone bans (Cellular News, 2004). Eleven states have partial bans, but the regulations behind the bans vary considerably. For instance, in Pennsylvania, bans vary locally in cities, whereas in Florida, cell phones are permitted as long as they meet certain requirements. Four states are still debating the issue (Cellular News, 2004).

9.2 Inexperienced Drivers and Cell Phone Use

It is not known how many driver-training programs specifically warn new drivers about the possible dangers of using a cell phone while driving. The current handbooks for new drivers provided by the Alberta government predominantly focus on driving manoeuvres and regulations. Only small, infrequent captions warn about the dangers of distractions and these generally refer to distractions from other passengers.

Graduated licensing programs are becoming the norm to licensing new drivers in Canada and the United States. Currently, nine of the Canadian provinces, the Yukon, the District of Columbia, and 47 states have some form of graduated licensing (Williams & Mayhew, 2004). Other sources may report different numbers, because rules governing graduated licensing vary considerably for each jurisdiction. According to Williams and Mayhew (2004), the rules for these in Saskatchewan and Hawaii are negligible and do not qualify as graduated programs.

During the probationary period, drivers are only allowed to operate vehicles under restricted conditions. Common restrictions include limits on passenger numbers, limits on the time of day one can operate a vehicle, and strict zero alcohol rules. Regarding the use of cell phones, only Maine and New Jersey prohibit the use of cell phones during this period (Williams & Mayhew, 2004). This is despite the fact that young people are among the largest users of cell phones, and according to one study, younger drivers are most likely to be involved in distraction related crashes (Reinfurt, Zegeer, Shelton, & Neuman, 1991).

9.3 Private Sector Response

The cell phone industry itself acknowledges that driving while using a cell phone may be a problem. On Nokia's website, warnings target hand-held versions of cell phones: "Always keep your hands free to operate the vehicle while driving. Your first consideration while driving should be road safety". Other cell phone companies have integrated warnings against use while driving into the start-up screens of cell phones. The form that these warnings should take (e.g., text, icon, etc.) for greatest compliance, has not been investigated. Moreover, State Farm Insurance Company now warns customers that driving while using a cell phone will increase the likelihood of being in a crash. Other companies have gone so far as to ban cell phone use while driving while working. For instance, Imperial Oil Ltd. and Exxon Mobil Canada Ltd. recently both instituted this ban for all their workers. Shell Canada Ltd. had already done so last winter (Saunders, 2004).

9.4 Crash Reporting and Database Improvement

Determining how many crashes are actually associated with cell phones is difficult. Most jurisdictions do not require law enforcement officers to specifically determine whether cell phones were involved in crashes. Furthermore, it is up to the crash victims to be forthcoming about using a cell phone while driving. As such, it is likely that the incidence of crashes associated with using a cell phone while driving is under-reported.

In Canada, the data are non-existent. In the U.S., several large databases of crashes are available. In 2000, The NHTSA Fatality Accident Reporting System (FARS) reported only 101 of 37,409 fatal crashes were directly related to cell phone usage while driving. However, only two states (Minnesota and Oklahoma) included cell phone usage in their reporting (National Transportation Safety Board, 2003).

In North Carolina from 1995 – 1999, narrative data suggested that only 8.3% of crashes were associated with distraction and of those, only 1.5% were associated with using a cell phone. In Pennsylvania, only 5.2% of distracted crashes were associated with cell phones. Last, in California, 6% of crashes were associated with distractions and of those, the largest percentage (11%) was associated with using a cell phone (National Transportation Safety Board, 2003).

Yet, there is reason to suspect that the numbers are greater. Royal conducted telephone interviews of drivers asking about cell phone use (Royal, 2002). Approximately 60% of drivers said they had a cell phone, and, of those, about 30% of drivers made calls or received calls on a regular basis while driving.

As of 2003, the Model Minimum Uniform Crash Criteria Guideline specifies that cell phones and other electronic devices such as PDAs are recorded as distractors that may have caused a crash (National Transportation Safety Board, 2003). Thus, future data may be more revealing as to the potential dangers of cell phone use.

10 REFERENCES

Studies that are preceded by an asterisk (*) were included in the meta-analysis, whereas studies included in the quantitative RT analysis are denoted by a number sign (#).

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APPENDIX A

STUDY SUMMARIES

EPIDEMIOLOGICAL STUDIES

REFERENCE	**Chapman, S. & Schofield, W.N. (1998). Lifesavers and Samaritans: Emergency use of cellular (mobile) phones in Australia. *Accident Analysis & Prevention*, 30 (6), 815-819.**						
Objectives	**Features**	**Method**			**Results / Conclusions**		
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Examines the increase in response times in emergency situations as a result of the pervasiveness of cellular phones.	*Hands-free / hand-held* N/A *Age* N/A *Simulator, On Road, Lab* N/A	720 mobile phones users or their family members as participants.	A questionnaire about the potential uses of cell phones in emergency situations was given to 720 mobile phone users or their families in 1997.	National random telephone survey.	Reports frequency from sample and tries to extrapolate to national population as a whole.	62.64% of vehicle cell phone users used their phone to call about being late for an appointment. 12. % had used cell phones to call for help for others needing assistance. 5.97% used their phones to call for non-road emergencies. 2.22% called for help about someone following them.	Argues that there are many situations where cell phones have been used to summon help. People also take more risk because they can call for help. Argues that any policy to reduce cell phone usage must weigh the benefits and the risks.

REFERENCE	Eby, D.W. & Vivoda, J.M. (2003). Driver hand-held mobile phone use and safety belt use. *Accident Analysis & Prevention*, 35, 893-895.							
Objectives	**Features**	**Method**			**Results / Conclusions**			
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**	
Compared hand-held phone use in Michigan between users and non-users of seat belts.	*Hands-free / hand-held* Hand-held *Age* N/A *Simulator, On Road, Lab* N/A	11 863 drivers from Michigan.	Data collected at 168 controlled intersections (40 were exits from freeways) in Michigan. Time of day and day of week were randomized. Data were collected when vehicles were stopped at a stop sign or at a traffic light. Observers recorded hand-held phone use and seat belt use.	N/A	Reports frequency data and converted to rates.	2.70% of drivers used a cell phone while driving. 82.2% non seat belt users used cell phones, compared to 75.83% of seat belt users. This difference was significant.	Suggests a correlation between seat belt use and cell phone use and important to focus safety to this population.	

REFERENCE	Horberry, T., Bubnich, C., Hartley, L., & Lamble, D. (2001). ***Drivers' use of hand-held mobile phones in Western Australia.*** **Transportation Research Part F 4, 213-218.**						
		Method			Results / Conclusions		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
To establish the number of drivers who use hand-held phone while driving and to discover if this number had increased as compared to the year earlier.	*Hands-free / hand-held* Hand-held *Age* N/A *Simulator, On Road, Lab* N/A	Not reported.	Data collected by roadside observers who counted number of drivers using a hand-held phone. Observations were taken between 7:30 a.m. and 6:00 p.m. in the summer in Perth. Observations were held at 19 locations, at least twice per location. In addition, in 4 locations, specific periods of the day were chosen to examine time of day effects. Numbers compared to data collected a year earlier.	N/A	Frequency	1.5% of drivers used their cell phones while driving. 78% of those were males and 64% were less than 40 years old. Cell phone use did not differ as a function of time of day.	Cell phone usage by drivers remained constant over a 1-year period. Phone use varied across locations, but not time of day, even though there are more cars on the road at different times during the day.

REFERENCE	Laberge-Nadeau, C., Maag, U., Bellavance, F., Lapierre, S.D., Desjardins, D., Messier, S., & Saidi, A. (2003). Wireless telephones and the risk of road crashes. *Accident Analysis & Prevention* , 649-660.						
Objectives	Features	Method			Results / Conclusions		
		Participants	Procedure	Data Used Measures Made	Analyses Used	Results	Recommendations
To verify association between cell phone use and road crashes.	*Hands-free / hand-held* N/A *Age* 16 - 64 yrs. *Simulator, On Road, Lab* N/A	Survey Respondents: N = 36078 Male = 22942 Female = 13136	Presented a questionnaire that asked about driving habits, risk exposure, opinions of driving safety, collisions, SES information, and cell phone use. Compared observations with records from insurance, police, and cell phone companies.	Data taken from SAAQ and from those who responded, cell phone records were obtained with their consent from 1 of 4 mobile telephone companies.	Estimated the strength of association between the probability of having at least one car accident and (1) using or not using a cell phone, and (2) different levels of usage of the cell phone among cell phone users. Ran Logistic Normal Regression Models on the data.	Calculated the number of people who would have at least 1 accident out of 100 people. Found that for most age groups, cell phone users had a greater risk for accidents. Older adults were the exception.	Study suggests higher risk for cell phone users and that men have a greater risk than women.

REFERENCE	Lam, L.T. (2002). Distractions and the risk of car crash injury: The effect of drivers' age. *Journal of Safety Research,* 33, 411-419.						
		Method			Results / Conclusions		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Investigated the association between distractions from inside and outside the vehicle, and the increased risk of car crash injury among drivers across different ages.	*Hands-free / hand-held* Hand-held *Age* 16 - 70+ yrs *Simulator, On Road, Lab* N/A	Examined records of 414,136 crash reports from 1996 - 2000 and 2400 were considered due to distraction.	Accidents were classified into 4 groups, (a) in-vehicle, (b) outside vehicle, (c) no distraction, and (d) hand-held phone. Data were stratified by distraction type and age groups.	Traffic Accident Database System by the Roads and Traffic Authority of New South Wales.	Collected frequency data and computed relative risk. Relative Risk based on injury/death rate of each distraction type vs. no distraction	With the exception of those 20 - 24 yrs and those over 70, all age groups showed an elevated risk of accidents with using cell phones. Particularly, those 25 - 29 were especially at risk.	Suggests that in general, hand-held cellular phones will distract a driver. In particular, distraction inside the vehicle is more distracting than distraction occurring outside the vehicle.

REFERENCE	McCartt, A.T. & Geary, L.L. (2004). Longer term effects of New York State's law on drivers' handheld cell phone use. *Injury Prevention*, 10, 11-15.							
Objectives	Features	Method			Results / Conclusions			
		Participants	Procedure	Data Used Measures Made	Analyses Used	Results	Recommendations	
To determine whether substantial short term declines in drivers' use of hand-held cell phones, after a state ban, were sustained one year later.	*Hands-free / hand-held* Hands-free *Age* < 25, 25 - 59, 60 and older *Simulator, On Road, Lab* N/A	50033 drivers in NY and 28307 in CT	Usage of cell phone while driving was measured one month before, immediately after, and 1 year after law banning their usage while driving. Daytime observations at 6 controlled intersections in small to medium-sized communities in NY and CT. Observations	N/A	Logistic regression	In New York, before the law was in place, 2.3% of drivers used cell phones. Immediately after the law, usage was 1.1%. One year later, it increased back to 2.1%. In Connecticut, before the law was in place, 2.9% of drivers used cell phones. Immediately	Short term drop in usage of cell phones was not maintained after one year. Authors recommend that vigorous enforcement was needed along with publicity to encourage long term compliance.	

REFERENCE	Min, S.T., & Redelmeier, D.A. (1998). Car phones and car crashes: An ecologic analysis. *Canadian Journal of Public Health*, 89 (3), 157 - 161.						
Objectives	**Features**	**Method**			**Results / Conclusions**		
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Used an ecological analysis to evaluate cell phone use and accidents in cities without cell phone legislation.	*Hands-free / hand-held* N/A *Age* N/A *Simulator, On Road, Lab* N/A	Estimated users of cell phones based on density of cell phone towers.	Collision data for 75 specific locations in Toronto in 1984 vs. 1993 were compared. Cell phone usage was estimated by the number of cell phone towers in the surrounding area of each of 75 locations. The density of towers in specific areas was then compared to the accident rates in those areas.	Metro Toronto Traffic Data Centre collision data.	Linear regression / multiple regression (multiple regression used estimates of traffic flow and pedestrian flow as covariates)	Total collisions in 1984 were 51925, while in 1993 there were 66500. When all other things were accounted for, the usage of cell phones was negatively associated with accidents.	A negative association between cell phones and accidents was found. However, authors suggest biases of analyses may be misleading.

REFERENCE	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.						
		Method			**Results / Conclusions**		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used / Measures Made**	**Analyses Used**	**Results**	**Recommendations**
To determine if using cellular phones leads to an increase in driving accidents by comparing participants who had accidents while using the phone to times when they were driving and not using the phone.	*Hands-free / hand-held* Hands-free vs. hand-held *Age* < 25, 25 - 39, 40 - 54, > 55 *Simulator, On Road, Lab* N/A	N = 699. Were people who came to a collision reporting centre and had cellular phones.	Questions were demographic and collision related. Cell phone records obtained and police reports of time of accident used. Calculated relative risk based on phone usage before crash vs. chance model based on phone records from previous days.	Surveyed people coming to accident reporting centre in Toronto.	Relative risk estimated using binomial tests and logistic regression.	Relative risk of driving and using a cell phone was elevated for all age groups, gender and phone types.	No difference between hands-free and hand-held. Relative risk of cell phone is argued to be similar to risk of drinking and driving.

REFERENCE	**Stutts, J.C., Huang, H.F., & Hunter, W.W. (2002).** ***Cell phone use while driving in North Carolina: 2002 Update Report*** **. North Carolina Governor's Highway Safety Program.**						
		Method			**Results / Conclusions**		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Performed an extensive study of cell phone use/characteristics while driving in N. Carolina. Paper includes data regarding statewide survey of percentage and characteristics of drivers who use cell phones while driving and cell phone related crashes.	*Hands-free / hand-held* N/A *Age* 5 age groups: 18 - 24, 25 - 39, 40 *Simulator, On Road, Lab* N/A	1006 completed surveys. 650 interviews conducted.	Telephone survey was conducted for 1 month.	N/A	Chi-square test on categorical variables. T-tests and Pearson's r for continuous. Regression for limited multivariate analyses.	Of those surveyed, 550 said they had used cell phone while driving, while 456 did not. Most used a hand-held phone while driving (71.9%) and the majority believed that a hands-free phone was safer (87.7%) and made driving easier (89.9%).	Cannot make clear recommendations since there is no data estimating how much time people spend talking on cell phones while driving. Acknowledges that cell phones can be used in emergencies to call for help and cell phones are one of many distracting acti

REFERENCE	**Taylor, D., Bennett, D., Carter, M., and Garewal, D. (2003). Mobile telephone use among Melbourne drivers: A preventable exposure to injury risk. *Public Health,* 179, 140 - 142.**							
Objectives	**Features**	**Method**			**Results / Conclusions**			
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**	
To determine the rate of hand-held mobile telephone use among motor vehicle drivers.	*Hands-free / hand-held* Hand-held *Age* young, middle, older *Simulator, On Road, Lab* N/A	17023 drivers in Melbourne Australia	Observations done in Melbourne in 2002. At each site type and each time of day, observers recorded all vehicles (except motorcycles) in the closest lane. Observers recorded hand-held phone use, sex, approximate age.	N/A	Chi-square test	Little difference in the percentage of male (19%) and female (17.5%) drivers who use a cell phone. Older drivers use cell phones the leaste while driving (4.8%), relative to younger drivers (21.9-23.2%). Cell phone use increases slightly at after 5 p.m. (23.5%).	Argues that there is an increase in cell phone use and that they are likely a cause of preventable injuries. Interventions should be considered and research is needed.	

REFERENCE	**Violanti (1998). Cellular phones and fatal traffic collisions. *Accident Analysis & Prevention* , 30, 519-524.**						
Objectives	**Features**	**Method**			**Results / Conclusions**		
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
To determine associations between traffic fatalities and the use of cellular phones.	*Hands-free / hand-held* N/A *Age* < 20 - > 50 yrs. *Simulator, On Road, Lab* N/A	223,137 traffic accidents occurring from 1992 - 1995.	Examined accident reports of fatal (experimental group) and non-fatal (control group) accidents and looked at the frequency of cell phone use or simply their presence at the time of accident.	Oklahoma State Dept. of Public Safety database.	Logistic Regression	Results suggest an elevated risk of an accident when a cell phone is in the car or when the cell phone is in use while driving (OR = 9.29).	Drivers with cell phones were twice as likely to be in a vehicle accident.

REFERENCE	Violanti, J.M., & Marshall, J.R. (1996). Cellular phones and traffic accidents: An epidemiological approach. *Accident Analysis & Prevention* , 28, pp. 265-270.						
		Method			**Results / Conclusions**		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
To evaluate the association among cellular phone use, 18 other driver inattention factors (driving experience, gender, age, etc.) and actual traffic accidents.	*Hands-free / hand-held* N/A *Age* N/A *Simulator, On Road, Lab* N/A	Random sample of N = 200 New York State resident drivers. 100 with accident ($1000.00 property damage or personal injury (serious accident). 100 accident free for 10 years.	Mailed survey using blinded researcher approach. Control groups were matched by geographic area.	Department of Motor Vehicles (accident records identifying information and circumstances for accident)	Logistic Regression	Odds ratio of using a cell phone and being involved in an accident was 5.59.	

REFERENCE	Violanti, J.M. (1997). Cellular phones and traffic accidents. *Public Health* , 111, 423-428.						
		Method			Results / Conclusions		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Accident characteristics between drivers with and without cell phones were associated with accident causes, type of collisions, fatalities, age, and gender.	*Hands-free / hand-held* N/A *Age* < 20 years to > 50 years *Simulator, On Road, Lab* N/A	206,639 police reports of traffic accidents between 1992 - 1995. 5292 subjects had a cell phone. 492 were using cell phones at the time of the accident.	Analyzed data from police reports from 1992 - 1995.	State of Oklahoma Dept. of Public Safety.	Used rate-ratio: rate of cell phone possession / use amongst those with accident characteristics compared to those without accident characteristics.	Found that cell phone use was related to inattention accidents, accidents that crashed into fixed objects, overturned vehicle accidents, vehicle off the road accidents and accidents in the city. Cell phones was also related to injury and fatalities in vehicle accidents.	In general, the study finds that cell phone users had more accidents than non-users and that many of the reported accidents that are reported as inattention and accidents where a vehicle goes off the road may be cell phone related.

REFERENCE	**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.**						
		Method			**Results / Conclusions**		
Objectives	**Features**	**Participants**	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
An accident database search was performed to determine the effecs of driver visual allocation on accident rates.	*Hands-free / hand-held* N/A *Age* N/A *Simulator, OnRoad, Lab* N/A	N/A	Did a keyword search on database for potential accidents caused by vision-related accidents for 1989 and some of 1992. All the hits were then screened to ensure they met the criteria that 1) the driver's vision was directed away from the forward scene, and 2) this visual allocation was the primary cause of the accident.	State of North Carolina police-accident reports.	Frequency	Cell phone accounted for 11 of the 203 accidents in 1989 that were due to allocation of vision to the dash, console, or other features of the car's displays. Cell phone accounted for approximately 27 accidents in 1992 that were due to allocation of vision to the dash, console, or other features of the car's displays.	Shows the increase of cell phones in the vehicle will lead to more crashes as cell phones become more prevalent.

REFERENCE	**Wilson, J., Fang, M., Wiggins, S., & Cooper, P. (2003). Collision and violation involvement of drivers who use cellular telephones. *Traffic Injury Prevention*, 4(1), 45 - 52.**						
Objectives	**Features**	**Method**			**Results / Conclusions**		
		Participants	**Procedure**	**Data Used Measures Made**	**Analyses Used**	**Results**	**Recommendations**
Analyzes the association of drivers who use a cell phone while in a vehicle and accident risk.	*Hands-free / hand-held* N/A *Age* N/A *Simulator, OnRoad, Lab* N/A	3869 non-commercial drivers whose data were collected in 1999 in 42 areas around Vancouver, BC.	Observations were made at intersections of people who used cell phones and those who did not. Estimates of age, gender, and vehicle plates were recorded. Data were then matched to information from driver licence records. Accident statistics were then ga	Insurance data on accidents (ICBC from 1997 - 2000.) Also used police records from this same period.	Factor analyses to develop constructs of the 84 different types of violations. Three main factors were found (1) alcohol, (2) aggression, and (3) inattention. Then a logistic regression was performed on various variables (e.g., age, gender, cell phone use	Found that the relative risk of at least one at-fault accident rose for both males and females when using a cell phone. The same was generally found for at least one inattention accident. However, there was no increase in inattention accidents for women.	Argues that those who use cell phones are at a higher risk, not necessarily because of inattention, but maybe because of lifestyle, attitude, and personality factors.

PERFORMANCE ARTICLES

REFERENCE	**Alm, H. & Nilsson, L. (1994). Changes in driver behaviour as a function of hands free mobile phones - a simulator study. *Accident Analysis & Prevention* , 26 (4), 441-451.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To investigate the effects of a mobile phone task while driving on either an easy or difficult curvy route.	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Simulator	N = 40. 20 males and 20 females. Mean age 32.4 (SD 9.4)	Driving Task (straight vs. curved road); Phone Task (exposed to phone task vs. control no phone task)	RT: brake as fast as possible when a visual stimulus appeared. Lateral Position (m): position on the road relative to a zero point. Speed: average speed from onset of cell phone call to 80s afterwards.	Subjects were asked to drive as they normally would along a 2-lane roadway. When the phone rang, they were told to answer it using the hands-free function and to solve the question. The question was always a "X does Y" sentence and subjects had to determ	RT was slower when using a cell phone on straight roads, F (1, 36) = 6.40, p = 0.124. Lateral position was also affected by the cell phone task on straight roads, F (1, 144) = 5.67, p = .0185, and when manoevring curves, F (1, 144) = 22.95, p = .0001. Sp	On RT authors provide several explanations for results. Lateral position shows that in the more difficult driving task, lateral position was more affected by the cell phone task. Drivers tended to stay to the right of the roadway.

REFERENCE	**Alm, H., & Nilsson, L. (1995). The effects of mobile telephone task on driver behaviour in a car following situation. *Accident Analysis & Prevention,* 27(5), 707-715.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Car following with hands-free phone in a simulator.	*Hands-free / hand-held* Hands-free *Age* Young vs. Old *Simulator, On Road, Lab* Simulator	N = 40 (30 males, 10 females) Young (< 60 (M = 29.3, SD = 8.1) Old (M = 67.6, SD = 4.1).	Age (young vs. old); Phone (telephone vs. control)	CRT, headway, lateral position, workload (NASA TLX) and secondary task performance.	Subjects drove a route on a simulator while interacting with Working Memory Span Test on a phone mounted on dash.	Age differences were evident in choice RT, $F(1, 35) = 6.06$, $p = .0189$, as was the cell phone task, $F(1, 35) = 9.36$, $p = .0042$. There were no differences in lateral position, but there were age differences in average headway distance, F(1, 36) = 6.78, p =	CRT to lead vehicle was greater for older drivers than young and in the cell phone conversation conditions. Minimum and average headway was closer in the cell phone than in the control condition. No lateral position differences were found.

REFERENCE	Brookhuis, K.A., de Vries, G., & de Waard, D. (1991). The effect of mobile telephoning on driving performance. *Accident Analysis & Prevention*, 23(4), 309-316.						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
This study examines the effects of driving in various situations while conversing on a hands-free and hand-held cellular telephone.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* On Road	N = 12 (10 males and 2 female). 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.	Subjects were asked to drive on a roadway under various conditions and were instructed to follow a lead car, keeping a constant gap distance. Driving performance was assessed under cell phone and no cell phone conditions in which the PASAT test was given.	There were no differences in BRT when using a cell phone versus not using a cell phone. Although lateral position was greater when using a cell phone, $F(1, 11) = 7.31$, $p < .02$.	When talking in heavy traffic, RT to the lead vehicle increased, but not significantly. Adaptation to changes of the lead vehicle was delayed 600 ms. Steering wheel movement increased before a hand-held cell phone call and afterwards for a hands-free cell phone calls.

REFERENCE	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 & Prevention* , 325, 495–500.						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To investigate the effect of cell phone use on brake reaction time.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* Lab	N = 22 (18 - 27 yrs., M = 21)	Distraction Type: (No distraction, listening to radio, conversing with passenger, conversing with hand-held cell phone, conversing with hands-free cell phone.	BRT to light stimulus.	Subjects were seated in a mock vehicle. They were instructed to brake whenever a red lamp was activated. The lamp was activated every 10 - 20 sec.	Holding a conversation, whether with a passenger or on a cell phone resulted in slower RT, $p < .0001$. However, there were no differences between hands-free and hand-held cell phones and no differences were found between talking to a passenger and talking on a cell phone, $p > .05$.	Cell phone use leads to slower RT performance in braking.

REFERENCE	**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 & Prevention* , 35, 23–35.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
The effect of cell phone use was investigated in difficult driving-related situations (e.g., manoeuvres and decisions were required).	*Hands-free / hand-held* Hands-free *Age* Young, middle-aged, older *Simulator, On Road, Lab* On Road	N = 41(30 male, 11 female), 7 were 19 - 24 yrs., 25 were 25 - 44, and 9 were 45 - 70.	Task (traffic signal, left turn, weaving), road surface (wet, dry), age (young, middle-aged, old), gender, message (no message, hand-held, hands-free), message type, (spatial, verbal).	Velocity at light change to foot on brake (BRT), average deceleration, time-to-collision (TTC) to stop line, speed at trigger.	Subjects drove a closed course while performing 3 tasks (1) responding to a traffic light, (2) weaving through obstacles, and (3) making left turn decisions. During this task, an alerting tone was presented followed by taped instructions and passages and subjects were instructed to respond to the message.	In the short trigger condition, the effect of the message on BRT was not significant F (1, 27) = 0.19, p = 0.67. In the long trigger condition, the effect of message on BRT was significant F(1, 28) = 3.74, p = .06. Younger adults did not suffer from a cell phone message, but older adults did exhibit slower responses when a message was present, F(2, 27) = 4.52, p = .02. Speed did not differ at either of the trigger types. For the short trigger, F(1, 28) = .56, p = .46 and for the long trigger, F(1, 27) = .18, p = .67.	In the short trigger light situation, message presence produced a conservative precautionary effect on RT for the young and middle-aged, but for the older adults, RT was considerably higher when messages were present.

REFERENCE	Gugerty, L., Rando, C., Rakauskas, L., 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.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Analyzed the effect of conversing with a passenger or on a hands-free cell phone on several types of driving awareness.	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Lab	Experiment 1. N = 29 or 58 pairs. One person was the passenger while the other was the driver. Experiment 2. N = 80 pairs.	Driving type (no conversation, conversing on a hands-free cell phone, conversing with a passenger)	Mean location recall, error (distance between recall and actual), % correct scene interpretations, % hazards detected, blocking car detection, RT to hazard detection.	Subjects were placed in a low fidelity simulation to examine awareness. Subjects were presented with a scene (18 to 35 seconds) and were then required to identify hazards and cars in the scene. Subjects performed 18 trials of no conversation and 35 trials of conversation while performing the task. The conversation was a game where the participants had to say words that began with the last letter of a previously stated word.	In both experiments, driving and talking resulted in slower response times relative to driving alone, $p < .05$.	Exp. 1. RT was worse while conversing over baseline. Remote and in-person conversation were equal. Exp. 2. Replicated RT for Exp. 1.

REFERENCE	**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.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To investigate the effects of a mobile hand-held and hands-free phone task while driving in a simulator.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* Simulator	N = 30. 13 males and 17 females. Mean age 26.93 (SD 3.06)	Transmission (automatic vs. manual). Cell phone type (hands-free vs. hand-held). Period (pre-call, during call, post-call)	Speed, variability of accelerator pedal, frequency of driving off the road, number of collisions, heart rate.	Subjects drove 4 scenarios, 2 using manual and 2 using automatic transmissions. Each scenario was broken into pre-, during, and post-call periods. Cell phone type was counterbalanced. The Baddeley grammatical reasoning test was given during a cell phone conversation.	Speed differed as a function of driving period, F(2, 58) = 5.96, p = .005. Speed reduced during a call. There was no difference between hand-held and hands-free phones, F (1, 29) = .06, p > .05.	Increase in heart rate while talking suggests an increased workload. There was no difference in cell phone types, suggesting no increased demands using a hand-held phone. Drivers compensate for increased workload by decreasing their speed.

REFERENCE	**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.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To determine the reaction time to a brake light while engaged in various forms of conversation.	*Hands-free / hand-held* Hand-held *Age* N/A *Simulator, On Road, Lab* Lab	N = 16, 21 - 45 (M = 31.5, SD 9). 8 men and 8 women.	Conversational task: control (1) listen to weather forecast, (2) answer simple questions, (3) respond to questions requiring deeper thought (e.g. route from home to school), and (4) answer questions about beliefs (e.g. abortion). Gender	RT (ms)	Subjects required to brake as quickly as possible to a red light stimulus while performing one of the conversational tasks. Stimulus was activated every 10 - 20 seconds randomly.	Results showed that all types of conversation resulted in slower RT relative to no driving alone, $p < .05$.	Results showed all forms of conversation impact RT but that the different forms did not differ, suggesting intensity of conversation does not affect RT.

REFERENCE	Ishida, T., & Matsuura, T. (2001). The effect of cellular phone use on driving performance. *IATSS Research,* 25(2), 6-14.						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Driver performance while using a hands-free and hand-held phone.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* On Road	N = 50, only one female.	Driving condition (alone, hand-held, hands-free, cassette)	BRT(s), mean fixation duration, fixation frequency, total glance duration, following distance (m), lane keeping, and secondary task performance.	Subjects drove an instrumented vehicle over a test track while using a hands-free cell phone, hand-held cell phone, or manipulating a cassette.	BRT when talking on a cell phone was longer than when driving alone, $p < .001$. BRT was longer when using a hand-held cell phone over a hands-free cell phone, $t(49) = 1.717$, $p < .05$. Steering wheel angle was also greater when talking on a cell phone, $p < .001$ and hand-held cell phone conversations resulted in greater steering wheel angles than hands-free cell phones, $t(49) = 3.593$, $p < .001$. Longitudinal control also showed a difference, but only adjusting a cassette and hand-held conversations were different from driving alone, $F(2, 6) = 51.48$, $p < .05$.	BRT was more variable and longer for all conditions relative to driving alone. Following distance for hand-held cell phones was greater.

REFERENCE	Laberge, J., Scialfa, C., White, C., & Caird, J.K. (in press - 2004). The effect of passenger and cellular phone conversations on driver distraction. *Transportation Research Record.*						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To determine the differential effect of passenger and hands-free cell phone conversation on driving performance.	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Simulator	N = 80 (10 - 27 yrs). Participants randomly assigned to baseline, hands-free, or passenger condition. Subjects also paired such that one was driver and other was a passenger.	Driving difficulty (rural, urban), task condition (baseline, passenger, hands-free). An intersection light (green, yellow, red) occurred 3.5 seconds from intersection once in the rural route and once in the urban routes as did a pedestrian event (walked into the roadway giving drivers 2.5 seconds to respond).	PRT, SD lane position, mean lane position, mean speed, SD speed, speech rate, word complexity, linguistic frequency, word errors, NASA TLX	Study compared passenger and hands-free conversation in a driving simulator while playing a word game between speakers. Rural (easy) and urban (difficult) driving routes were driven.	Talking to a passenger and talking on a hands-free cell phone resulted in a slower PRT, $p < .05$. However, talking to a passenger was not different from talking on a cell phone. Moreover, there were no differences in lateral control when the task was driving alone, or driving while engaged in a conversation. Mean speed was not signficantly different ($p > .15$).	PRTs were slightly faster responding to the pedestrian event in the urban route than the rural route. PRTs were slower to the pedestrian when talking with a passenger and in hands-free condition than driving alone. Conversation did not affect lane position. No differences between conversing with a passenger or with someone on a cell phone.

REFERENCE	**McCarley, J.S., Vais, M., Pringle, H., Kramer, A.F., Irwin, D.E., & Strayer, D.L. (2001). Conversation disrupts visual scanning of traffic scenes. *Vision in Vehicles.* Australia.**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To examine the effects of naturalistic conversation on observers' scanning and consequent representation of visual scenes.	*Hands-free / hand-held* Hands-free *Age* Young vs. older *Simulator, On Road, Lab* Lab	N = 28. 14 younger (M = 21.43 yrs) and 14 older (M = 68.43).	Conversation vs. no conversation. Age: Young vs. old.	Error rate, RT (for change detection). Eye movement data.	Subjects had to perform a change detection task of a traffic scene while performing a conversation or not. Subjects had to press a button if they detected a change as quickly as possible while conversing with a confederate over a speaker/microphone system.	Age differences were found in RT to detect a change, $F(1, 26) = 82.651$, $p < .001$, but there was no difference in RT when conversing on a cell phone, $p > .05$.	Although RT did not increase with conversation, errors did and fixations were reduced.

REFERENCE	**McPhee, L., Ho., G., Dennis, W., Scialfa, C., & Caird, J.K. (in press - 2004). The effects of simulated telephone conversation on visual search for traffic signs. *Human Factors* .**						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Examined the effects of conversation on the search of traffic signs.	*Hands-free / hand-held* Hands-free *Age* Younger and older adults *Simulator, On Road, Lab* Lab	N = 32. 16 younger adults (M = 22.62, range = 17 -33 yrs.) and 16 older adults (M = 64.19 yrs, range = 56 - 71 yrs.)	Age: young vs. old. Conversation: no conversation vs. conversation. Clutter: low vs. high clutter. Target presence: present vs. absent.	RT, errors , visual data, NASA - TLX.	In single-task condition, participants given a search task for traffic signs. Half the target signs were present and participants had to respond "present" on keyboard if they saw the target sign. In the dual task, they did the same task, but they also had to listen to a prose passage and answer questions regarding the passage.	Age differences were evident in RT, F (1, 30) = 25.17, p < .001 and for conversation, F (1,30) = 11.34, p = .002. The interaction was not significant.	Older adults performed more slowly under the divided-attention condition using a two-tailed test, but not one-tailed. Divided-attention condition increased RT for finding target signs.

REFERENCE	Nilsson, L., & Ålm, H. (1991). ***Elderly people and mobile telephone use– including comparisons to younger drivers' behaviour.*** **(Rep. No. 176, DRIVE Project V1017, BERTIE). Gothenburg, Sweden: Swedish Road and Traffic Research Institute.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Effect of hands-free cell phone use on driving with an elderly population.	*Hands-free / hand-held* Hands-free *Age* Older adults *Simulator, On Road, Lab* Simulator	N = 20 (60 -71 yrs.). (M = 65.9, SD 3.4 yrs)	Cell phone task vs. no cell phone task. Age (note that the young data were collected from Ålm & Nilsson, 1990)	Speed, lateral position, variation of lateral position, BRT, workload, cell phone task performance.	Subjects had to drive a simulator route and were given 8 cell phone calls during the course of the experiment. On half of the calls, an unexpected event occurred.	Hands-free cell phone use resulted in slower RT relative to the no conversation condition, $F(1, 36) = 10.13$, $p < .01$. Older adults were slower than younger adults, $F(1, 36) = 9.89$, $p < .01$, but the interaction was not significant. There were no significant differences in any conditions for lateral position, but the standard deviation of lateral position was affected by the conversation, $F(1, 144) = 6.09$, $p = .0147$. Those in the cell phone condition drove slower, $F(1, 28) = 172.55$, $p = 0.0001$.	Elderly RT was slower to react to an external event when engaged in cell phone conversation. Elderly drivers varied their lateral position more.

REFERENCE	Parkes, A.M., & Hooijmeijer, V. (2001). *Driver situation awareness and car phone use.* Proceedings of the 1st Human-Centered Transportation Simulation Conference (ISSN 1538-3288). Iowa City, IA: University of Iowa.						
		Method					
Objectives	Features	Participants	Independent Variables	Dependent Variables	Procedure	Results	Conclusions
Sought to examine the effect of talking in hands-free conversation on driving, particularly looking at its effect on situation awareness.	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Simulator	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 cell phones while 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).	RT, braking profile, lateral position, speed, situation awareness.	Subjects drove a driving simulator over a 15.5 mile rural route with a high level of oncoming traffic. Subjects drove the route once while talking on the phone and once without. Subjects 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). Two unexpected events required immediate responses by subjects: 1) a green square appeared (2 times) on the roadway for 2 seconds and required participants to flash their lights, and 2) a red square appeared on the road (once) and participants were required to make an emergency stop.	For RT, in two conditions, there were no significant differences between the conversation and no conversation conditions. For one condition (1st green square condition), those in the phone task had slower RTs, $t(14) = 2.576$, $p < .05$. Lateral position was not affected by the conversation. Speed was slower for the conversation group only when the speed changed from 80 - 50 km/h, $t(14) = 3.42$. When speed changed from 50 - 80 km/h, there were no differences, $t(14) = 1.13$.	RT to first green square was slower while conversing. RT did not differ on second green square or the red square. Conversing did not affect variability of lateral position.

REFERENCE	Patten, C.J.D., Kircher, A., Ostlund, J., & Nilsson, L. (2004). Using mobile telephones: Cognitive workload and attention research allocation. Accident Analysis and Prevention, 36(3), 341-350.						
		Method					
Objectives	Features	Participants	Independent Variables	Dependent Variables	Procedure	Results	Conclusions
Driver distraction with manual car.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* On Road	N = 40 (21 - 60 yrs., M = 39.6) professional drivers.	Conversation type (hands-free, hand-held, baseline). Conversation task: (complex: addition, simple: repeat digit, no conversation)	LED RT (ms), LED hit rate	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 11 km/h. An array of 6 red LEDs positioned in a HUD (6.8 and 21.8 deg left of steering centre). Each cell phone conversation lasted about 1.5 to 2 min.	Although there were no differences in RT between using a hands-free cell phone and a hand-held cell phone, both cell phone conditions resulted in slower RTs relative to the no conversation condition, $p < .001$. This was true for both the simple conversation and the complex conversation conditions.	Hands-free and hand-held cell phones did not differentially affect detection of LED task, but were higher than baseline. Those in the hands-free condition adopted a higher speed than baseline while those in hand-held dropped their speed.

REFERENCE	Rakauskas, M., Gugerty, L., & Ward, N.J. (in review). ***Effects of cell phone conversations with naturalistic conversations.***						
		Method					
Objectives	**Features**	**Participants**	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To determine the effect of a number of naturalistic conversations on driving performance.	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Simulator	N = 24 (12 male, 12 female) (= 20.4).	Conversation type (easy, hard, none).	Accelerator position, variability, SD speed, mean speed, steering offset, mean lateral speed, collisions, RT (trigger to accelerator = 0; brake > 0; steering > 3 SD; workload (RSME).	Subjects drove a simulator through route. Three hazards were presented - a pull-out vehicle, an oncoming vehicle, and an ambulance that ran a red light.	No differences in RT found between the conversation and no conversation conditions, $t(23) = 0.371$, $p = .357$. No differences were found in lateral position, $p > .05$. Speed variability was greater with conversation, $t(23) = 2.436$, $p = .012$. Average speed decreased with conversation, $t(23) = 2.306$, $p = .015$.	Conversations increased acceleration variability, speed variability, and slightly decreased speed relative to baseline. Workload was rated higher for conversation over baseline and easy and hard conversations rated about the same.

REFERENCE	**Ranney, T., Watson, G., Mazzae, E.N., Papelis, Y.E., Ahmad, O. & Wightman, J.R. (2004).** ***Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator.*** **Preliminary Report on Freeway Pilot Study (Rep. No. DOT 809 737). Washington, DC: NHTSA.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To evaluate distraction effects of using wireless phones while driving. Focus on hands-free and voice-activated technology.	*Hands-free / hand-held* Both *Age* Younger, middle-aged and older drivers *Simulator, On Road, Lab* Simulator	12 participants	Cell phone type (hand-held; hands-free headset; hands-free voice-activated); cell phone status (incoming, outgoing, no call); age (younger, middle, older)	The DVs differed according to the event. Lead vehicle braking used RT; lead vehicle cut in used BRT, accelerator release time. Car following: speed coherence; delay, modulus, headway, lane position variability. Merging used gap stability, time to merge, time to collision, speed at merge, speed range, and lane position variability.	Subjects drove a simulated freeway. Two cell phone calls were initiated, one incoming and one outgoing. Various events occurred while driving: (a) sudden lead vehicle cut in, (b) braking by lead vehicle, (c) a car following event, and (d) a merge event. The conversation was the Baddeley task.	CAR FOLLOW: no statistical differences in cell phone type for coherence. Effect of delay, F(1, 11) = 6.70, p = .025. Effect of modulus F(1, 11) = 9.94, p = .009. Headway F(1, 11) = 4.48, p = .578. No difference in headway between cell phone types. Lane position F(1, 7) = 11.28, p .0121 (in opposite direction). MERGE. Speed. No difference in cell phone call F(1, 11) = .02, p = .88. No difference in cell phone type, F(3, 31) = .069, p =.57. LEAD VEHICLE CUT IN. BRT was significant, F(1, 11) = 25.06, p =.004. No difference in cell phone type.	Only a pilot study and the study warns that data is not definitive. Conclusions suggest hand-held cell phone led to increased headway, larger RMS error in car following, and slower merging behaviour. BRTs were longer during phone use.

REFERENCE	Strayer, D.L., & Drews, F.A.. (2003). ***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.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Examined the effects of hands-free cell phone conversations on simulated driving.	*Hands-free / hand-held* Hands-free *Age* Young vs. old *Simulator, OnRoad, Lab* Simulator	N = 40. 20 younger (M = 20.2, Range = 18 - 25). Twenty older (M = 69.5, Range = 65 - 74)	Age: young vs. old. Conversation: conversation vs. no conversation	Brake onset time, following distance, speed, half-recovery time (the time for subjects to recover 50% of the speed that was lost during braking).	Subjects had to follow a pace car and had to step on the brake if the lead car braked. For half of the driving scenarios, subjects had to carry on a conversation on a hands-free cell phone.	Brake onset time was slower for those in the conversation condition, $F(1,38) = 12.96$, $p < .01$. No age differences in RT were found and no interaction was evident. Following distance was greater for older adults, $F(1,38) = 31.97$, $p < .01$. Conversation produced marginally greater following distance, $F(1,38) = 3.80$, $p < .06$. No interaction was present. Recovery of speed did not differ by conversation condition, $F(1, 38) = .01$, $p = .97$, and did not interact with age $F(1, 38) = 1.53$, $p = .22$.	Suggests that talking on a cell phone impairs driving performance. Older adults are slower, but are not differentially affected by talking and driving.

REFERENCE	**Strayer, D.L., & Johnston, W.A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science,* 12(6), 1-5.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Exp 1.To determine the source of dual-task interference and its effect on surrogate driving performance.	*Hands-free / hand-held* Both *Age* N/A *Simulator, On Road, Lab* Lab	N = 48 (24 male, 24 female), 18 to 30 (M = 21.3).	Task (listen to the radio, listen to a book on tape, hand-held cell phone conversation, hands-free cell phone conversation).	RT (ms), p (miss)	Subjects performed a tracking task. A target light flashed red or green every 10 to 20 seconds (M = 15s). If the light flashed red, subjects were to press the "brake" button while performing tracking task.	There were no differences in RT between hands-held and hands-free cell phones, $F(1, 30) = 0.01$, $p > .90$. However, RT was longer for those conversing, regardless of cell phone type relative to the no conversation condition, $F(1, 30) = 28.9$, $p < .01$.	The RT for red lights while tracking was significantly higher while using the cell phone than baseline (hand-held & hands-free were collapsed). There was no difference in listening to the radio and the baseline condition.

REFERENCE	Strayer, D.L., Drews, F.A., Albert, R.W. & Johnston, W.A. (2002). *Why do cell phone conversations interfere with driving?* Proceedings of the 81st Annual Transportation Research Board Meeting [CD-ROM]. Washington, DC: TRB.						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
Examined the effects of conversing on hand-held and hands-free cell phone on driving. Specifically, misses to traffic signals and accidents. **Note that Experiment 2 is equivalent to Stayer, Drews, & Johnston (2003).	*Hands-free / hand-held* Exp. 1 - Both; Exp. 2 - Hands-free	Exp. 1. N = 64 (32 male, 32 female). Range 18 - 30 yrs (M = 21.2)	Cell phone type (hands-free & hand-held). Task (single vs. dual) listen to radio, listen to book on tape, conversation).	p (miss); RT	Subjects had to perform a pursuit task on a computer. First, they did it in a single task condition, then they engaged in either conversation, radio, or book task.	In Exp. 1, RT did not differ for hands-free or hand-held cell phones. RT was slower when talking on a cell phone, F (1, 31) = 29.8, p < .01.	Subjects engaged in cell phone conversations were more likely to be in accidents, missed more signals and reacted more slowly. Equivalent performance for hand-held and hands-free cell phone types.
	Age N/A *Simulator, On Road, Lab* Exp. 1 - Lab; Exp. 2 - Simulator	Exp. 2. N = 40 (18 male, 22 female). Range 18 - 32 yrs (M = 23.6)	Only hands-free used. Traffic density (high vs. low). Task (single vs. dual).	Accidents, brake onset, brake offset, time to min speed, following distance.	Subjects drove a multi-lane highway on simulator in single task and dual task (on a cell phone). Subjects had to follow lead vehicle and brake when it braked.	In Exp. 2, the dual task resulted in longer RTs relative to the single task, F (1, 38) = 7.3, p < .01 and this interacted with traffic density, t (19) = 2.6, p < .01. Following distance was greater in the dual task condition, F (1, 38) = 17.4, p < .01. Time to reach min. speed was slower for those using a cell phone, F (1, 38) = 8.1, d = .92. This effect did not interact with density, F (1, 38) = 0, d = .02. At low density, t(19) = 2.4, d = .29 and at high density, t(19) = 3.2, d = .58.	

REFERENCE	Strayer, D.L., Drews, F.A., & Johnston, W.A. (2003). Cell phone-induced failures of attention during simulated driving. *Journal of Experimental Psychology: Applied* , 9(1), 23-32.						
		Method					
Objectives	Features	Participants	Independent Variables	Dependent Variables	Procedure	Results	Conclusions
Experiment 1:To replicate findings of Strayer & Johnston (2001) in a simulator. Examined hands-free cell phone conversations on simulated driving. Note that this experiment is identical to Experiment 2 of Strayer, Drews, Albert, & Johnston (2002).	*Hands-free / hand-held* Hands-free *Age* N/A *Simulator, On Road, Lab* Simulator	N = 40 (18 males, 22 female), 19 to 32 (M = 23.6)	Density (high vs. low). Conversation type (hands-free vs. no conversation)	Brake onset time (BRT), brake offset time, collisions, following distance, time to reach minimum speed	Subjects followed a lead car and had to brake when the lead car braked. Half of the scenarios were driven under no conversation while the other half were driven while talking on a cell phone.	Conversation slowed BRT, F = 7.3, d = 0.88 and interacted with traffic density, F = 3.8, d = 0.64. Following distance was also greater for those in the conversation conditions, F = 17.4, d = 1.4. Time to reach min. speed was slower for those using a cell phone, F (1, 38) = 8.1, d = .92. This effect did not interact with density, F (1, 38) = 0, d = .02. At low density, t(19) = 2.4, d = .29 and at high density, t(19) = 3.2, d = .58.	Hands-free cell phone conversation impairs driving performance and this impairment increases with traffic density.

REFERENCE	**Tijerina, L., Kiger, S., Rockwell, T., & Tornow, C. (1996).** ***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 7A*** **(Rep. No. DOT HS 808 467 7B). Washington, DC: NHTSA.**						
Objectives	**Features**	**Method**					
		Participants	**Independent Variables**	**Dependent Variables**	**Procedure**	**Results**	**Conclusions**
To determine the effects of cell phones and text messaging on heavy vehicle driver workload.	*Hands-free / hand-held* Hand-held *Age* N/A *Simulator, On Road, Lab* On Road	N = 16. (M = 47.2)	Lighting (dark vs. light), road type (divided vs. undivided), traffic density (high vs. low). Task type (visual text messaging, manual dialing, cognitive). Only the cognitive task will be summarized. It was comprised of biographical questions, arithmetic questions, and no questions.	Several visual measures and driving performance measures were provided. For our purposes, steering wheel angle, mean lane position, lane position variance, lane exceedances.	Subjects were told to drive a predetermined route and were told that they would perform extra driving tasks. In the cognitive task, messages were recorded on a voice answering system which asked the driver specific questions: 1) Biographical, 2) Arithmetic, and 3) Open Road Driving	Results showed that lane position, standard deviation of lane position, and steering position were all non-significant, $p > .05$.	The effects of various cell phone tasks on driving varied from substantial to trivial. For lane position, simple conversation tasks had little effect.