A Comparison of the Cell Phone Driver and the Drunk Driver

David L. Strayer, Frank A. Drews, and **Dennis J. Crouch,** University of Utah, Salt Lake City, Utah

Objective: The objective of this research was to determine the relative impairment associated with conversing on a cellular telephone while driving. **Background:** Epidemiological evidence suggests that the relative risk of being in a traffic accident while using a cell phone is similar to the hazard associated with driving with a blood alcohol level at the legal limit. The purpose of this research was to provide a direct comparison of the driving performance of a cell phone driver and a drunk driver in a controlled laboratory setting. **Method:** We used a high-fidelity driving simulator to compare the performance of cell phone drivers with drivers who were intoxicated from ethanol (i.e., blood alcohol concentration at 0.08% weight/volume). **Results:** When drivers were conversing on either a handheld or hands-free cell phone, their braking reactions were delayed and they were involved in more traffic accidents than when they were not conversing on a cell phone. By contrast, when drivers were intoxicated from ethanol they exhibited a more aggressive driving style, following closer to the vehicle immediately in front of them and applying more force while braking. **Conclusion:** When driving conditions and time on task were controlled for, the impairments associated with using a cell phone while driving can be as profound as those associated with driving while drunk. **Application:** This research may help to provide guidance for regulation addressing driver distraction caused by cell phone conversations.

INTRODUCTION

Although they are often reminded to pay full attention to driving, people regularly engage in a wide variety of multitasking activities when they are behind the wheel. Indeed, data from the 2000 U.S. census indicates that drivers spend an average of 25.5 min each day commuting to work, and there is a growing interest in trying to make the time spent on the roadway more productive (Reschovsky, 2004). Unfortunately, because of the inherent limited capacity of human attention (e.g., Kahneman, 1973; Navon & Gopher, 1979), engaging in these multitasking activities often comes at a cost of diverting attention away from the primary task of driving. There are a number of more traditional sources of driver distraction. These "old standards" include talking to passengers, eating, drinking, lighting a cigarette, applying makeup, and listening to the radio (Stutts et al., 2003). However, over the last decade many new electronic devices have been developed, and they are making their way into the vehicle. In many cases, these new technologies are engaging, interactive information delivery systems. For example, drivers can now surf the Internet, send and receive E-mail or faxes, communicate via a cellular device, and even watch television. There is good reason to believe that some of these new multitasking activities may be substantially more distracting than the old standards because they are more cognitively engaging and because they are performed over longer periods of time.

The current research focuses on a dual-task activity that is commonly engaged in by more than 100 million drivers in the United States: the concurrent use of cell phones while driving (Cellular Telecommunications Industry Association, 2006; Goodman et al., 1999). Indeed, the National Highway Transportation Safety Administration

estimated that 8% of drivers on the roadway at any given daylight moment are using their cell phone (Glassbrenner, 2005). It is now well established that cell phone use impairs the driving performance of younger adults (Alm & Nilsson, 1995; Briem & Hedman, 1995; Brookhuis, De Vries, & De Waard, 1991; I. D. Brown, Tickner, & Simmonds, 1969; Goodman et al., 1999; McKnight & McKnight, 1993; Redelmeier & Tibshirani, 1997; Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001). For example, drivers are more likely to miss critical traffic signals (traffic lights, a vehicle braking in front of the driver, etc.), slower to respond to the signals that they do detect, and more likely to be involved in rear-end collisions when they are conversing on a cell phone (Strayer et al., 2003). In addition, even when participants direct their gaze at objects in the driving environment, they often fail to "see" them when they are talking on a cell phone because attention has been directed away from the external environment and toward an internal, cognitive context associated with the phone conversation. However, what is lacking in the literature is a clear benchmark with which to evaluate the relative risks associated with this dual-task activity (e.g., Brookhuis, 2003).

In their seminal article, Redelmeier and Tibshirani (1997) reported epidemiological evidence suggesting that "the relative risk [of being in a traffic accident while using a cell phone] is similar to the hazard associated with driving with a blood alcohol level at the legal limit" (p. 456). These estimates were made by evaluating the cellular records of 699 individuals involved in motor vehicle accidents. It was found that 24% of these individuals were using their cell phone within the 10-min period preceding the accident, and this was associated with a fourfold increase in the likelihood of getting into an accident. Moreover, these authors suggested that the interference associated with cell phone use was attributable to attentional factors rather than to peripheral factors such as holding the phone. However, there are several limitations to this important study. First, although the study established a strong association between cell phone use and motor vehicle accidents, it did not demonstrate a *causal* link between cell phone use and increased accident rates. For example, there may be self-selection factors underlying the association: People who

use their cell phone while driving may be more likely to engage in risky behavior, and this increase in risk taking may be the cause of the correlation. It may also be the case that being in an emotional state may increase one's likelihood of driving erratically and may also increase the likelihood of talking on a cell phone. Finally, limitations on establishing an exact time of the accident lead to uncertainty regarding the precise relationship between talking on a cell phone while driving and increased traffic accidents.

If the relative risk estimates of Redelmeier and Tibshirani (1997) can be substantiated in a controlled laboratory experiment and there is a causal link between cell phone use and impaired driving, then these data would be of immense importance for public safety and legislative bodies. Here we report the result of a controlled study that directly compared the performance of drivers who were conversing on either a handheld or hands-free cell phone with the performance of drivers with a blood alcohol concentration at 0.08% weight/volume (wt/vol). Alcohol has been used as a benchmark for assessing performance impairments in a variety of other areas, including aviation (Billings, Demosthenes, White, & O'Hara, 1991; Klein, 1972), anesthesiology (Thapar, Zacny, Choi, & Apfelbaum, 1995; Tiplady, 1991) nonprescription drug use (Burns & Moskovitz, 1980), and fatigue (Williamson, Feyer, Friswel, & Finlay-Brown, 2001). Indeed, the World Health Organization recommended that the behavioral effects of drugs be compared with those of alcohol under the assumption that performance on drugs should be no worse than that at the legal blood alcohol limit (Willette & Walsh, 1983).

We used a car-following paradigm (see also Alm & Nilsson, 1995; Lee, Vaven, Haake, & Brown, 2001; Strayer et al., 2003) in which participants drove on a multilane freeway following a pace car that would brake at random intervals. We measured a number of performance variables (e.g., driving speed, following distance, brake reaction time, time to collision) that have been shown to affect the likelihood and severity of rear-end collisions, the most common type of traffic accident reported to police (T. L. Brown, Lee, & McGehee, 2001; Lee et al., 2001). Three counterbalanced conditions were studied using a within-subjects design: single-task driving (baseline condition), driving while conversing on a

cell phone (cell phone condition), and driving with a blood alcohol concentration of 0.08% wt/vol (alcohol condition). The driving tasks were performed on a high-fidelity driving simulator.

METHOD

Participants

Forty adults (25 men, 15 women), recruited via advertisements in local newspapers, participated in the Institutional Review Board approved study. Participants ranged in age from 22 to 34 years, with an average age of 25 years. All had normal or corrected-to-normal vision and a valid driver's license with an average of 8 years of driving experience. Of the 40 participants, 78% owned a cell phone, and 87% of the cell phone owners reported that they have used a cell phone while driving. A further requirement for inclusion in the study was that participants were social drinkers, consuming between three and five alcoholic drinks per week. The experiment lasted approximately 10 hr (across the three days of the study), and participants were remunerated at a rate of $10/hr.

A preliminary comparison of male and female drivers found greater variability in following distance for female drivers, $F(1, 38) = 10.9, p < .01$; however, this gender effect was not modulated by alcohol or cell phone use. No other effects of gender were significant in the current sample. Additional analyses comparing the driving performance of participants who owned a cell phone with that of those who did not own a cell phone failed to find any significant differences (all $ps > .60$). Similarly, there was no significant difference in driving performance between participants who reported that they used a cell phone while driving and those who did not use a cell phone while driving (all $ps > .70$).

Stimuli and Apparatus

A PatrolSim high-fidelity driving simulator, illustrated in Figure 1 and manufactured by GE-ISIM, was used in the study. The simulator is composed of five networked microprocessors and three high-resolution displays providing a 180° field of view. The dashboard instrumentation, steering wheel, gas pedal, and brake pedal are from a Ford Crown Victoria® sedan with an automatic transmission. The simulator incorporates proprietary vehicle dynamics, traffic scenario, and road surface software to provide realistic scenes and traffic conditions.

A freeway road database simulated a 24-mile (38.6-km) multilane interstate with on- and off-ramps, overpasses, and two- or three-lane traffic in each direction. Daytime driving conditions with good visibility and dry pavement were used. A pace car, programmed to travel in the right-hand

Figure 1. A participant talking on a cell phone while driving in the GE-ISIM driving simulator.
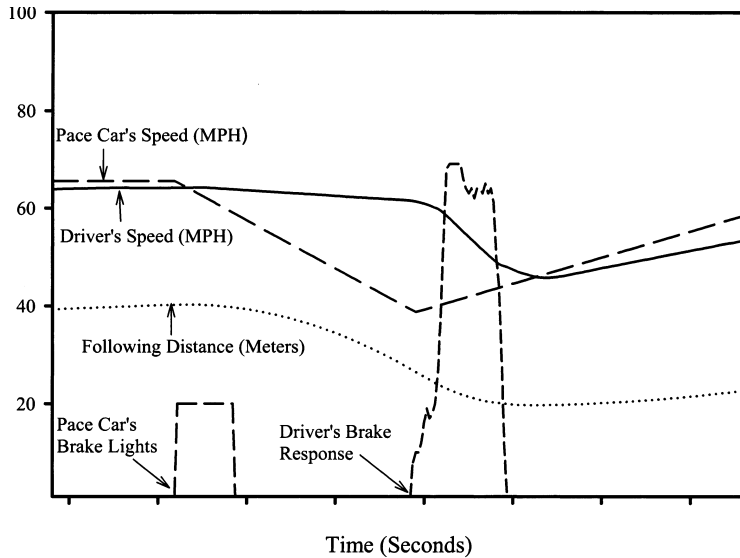
Figure 2. An example of the sequence of events occurring in the car following paradigm.

lane, braked intermittently throughout the scenario. Distractor vehicles were programmed to drive between 5% and 10% faster than the pace car in the left lane, providing the impression of a steady flow of traffic. Unique driving scenarios, counterbalanced across participants, were used for each condition in the study. Measures of real-time driving performance, including driving speed, distance from other vehicles, and brake inputs, were sampled at 30 Hz and stored for later analysis. Cellular service was provided by Sprint PCS. The cell phone was manufactured by LG Electronics Inc. (Model TP1100). For hands-free conditions, a Plantronics M135 headset (with earpiece and boom microphone) was attached to the cell phone. Blood alcohol concentration levels were measured using an Intoxilyzer 5000, manufactured by CMI Inc.

Procedure

The experiment used a within-subjects design and was conducted in three sessions on different days. The first session familiarized participants with the driving simulator using a standardized adaptation sequence. The order of subsequent alcohol and cell phone sessions was counterbalanced across participants. In these latter sessions, the participant's task was to follow the intermittently braking pace car driving in the right-hand lane of the highway. When the participant stepped on the brake pedal in response to the braking pace car, the pace car released its brake and accelerated to normal highway speed. If the participant failed to depress the brake, he or she would eventually collide with the pace car. That is, as in real highway stop-and-go traffic, the participant was required to react in a timely and appropriate manner to a vehicle slowing in front of them.

Figure 2 presents a typical sequence of events in the car-following paradigm. Initially both the participant's car (solid line) and the pace car (long-dashed line) were driving at about 62 miles/hr (mph) with a following distance of 40 m (dotted line). At some point in the sequence, the pace car's brake lights illuminated for 750 ms (short-dashed line) and the pace car began to decelerate at a steady rate. As the pace car decelerated, following distance decreased. At a later point in time, the participant responded to the decelerating pace car by pressing the brake pedal. The time interval between the onset of the pace car's brake lights and the onset of the participant's brake response defines the brake onset time. Once the participant depressed the brake, the pace car began to accelerate, at which point the participant removed his or her foot from the brake and applied pressure to the gas pedal. Note that in this example, following distance decreased by about 50% during the braking event.

In the alcohol session, participants drank a mixture of orange juice and vodka (40% alcohol by volume) calculated to achieve a blood alcohol

concentration of 0.08% wt/vol. Blood alcohol concentrations were verified using infrared spectrometry breath analysis immediately before and after the alcohol driving condition. Participants drove in the 15-min car-following scenario while legally intoxicated. Average blood alcohol concentration before driving was 0.081% wt/vol and after driving was 0.078% wt/vol.

In the cell phone session, three counterbalanced conditions, each 15 min in duration, were included: single-task baseline driving, driving while conversing on a handheld cell phone, and driving while conversing on a hands-free cell phone. In both cell phone conditions, the participant and a research assistant engaged in naturalistic conversations on topics that were identified on the first day as being of interest to the participant. As would be expected with any naturalistic conversation, they were unique to each participant. The task of the research assistant in our study was to maintain a dialog in which the participant listened and spoke in approximately equal proportions. However, given that our cell phone conversations were casual, they probably underestimate the impact of intense business negotiations or other emotional conversations conducted over the phone. To minimize interference from manual components of cell phone use, the call was initiated before participants began driving.

RESULTS

In order to better understand the differences between conditions, we created driving profiles by extracting 10-s epochs of driving performance that were time locked to the onset of the pace car's brake lights. That is, each time that the pace car's brake lights were illuminated, the data for the ensuing 10 s were extracted and entered into a 32 × 300 data matrix (i.e., on the jth occasion that the pace car brake lights were illuminated, data from the 1st, 2nd, 3rd, …, and 300th observations following the onset of the pace car's brake lights were entered into the matrix $X_{[j,1]}, X_{[j,2]}, X_{[j,3]},...X_{[j,300]}$, in which j ranges from 1 to 32 reflecting the 32 occasions in which the participant reacted to the braking pace car). Each driving profile was created by averaging across j for each of the 300 time points. We created profiles of the participant's braking response, driving speed, and following distance.

Figure 3 presents the braking profiles. In the baseline condition, participants began braking within 1 s of pace car deceleration. Similar braking profiles were obtained for both the cell phone and alcohol conditions. However, compared with baseline, when participants were intoxicated they tended to brake with greater force, whereas participants' reactions were slower when they were conversing on a cell phone.

Figure 4 presents the driving speed profiles. In the baseline condition, participants began decelerating within 1 s of the onset of the pace car's brake lights, reaching minimum speed 2 s after the pace car began to decelerate, whereupon participants began a gradual return to prebraking driving speed. When participants were intoxicated they drove slower, but the shape of the speed
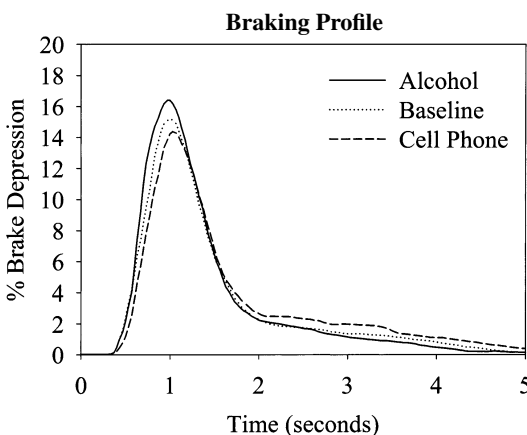

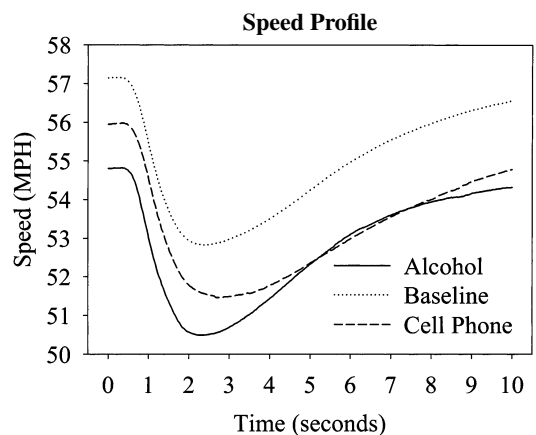
Figure 3. The braking profile.

Figure 4. The speed profile.

profile did not differ from baseline. By contrast, when participants were conversing on a cell phone it took them longer to recover their speed following braking.

Figure 5 presents the following distance profiles. In the baseline condition participants followed approximately 28 m behind the pace car, and as the pace car decelerated the following distance decreased, reaching nadir approximately 2 s after the onset of the pace car's brake lights. When participants were intoxicated, they followed closer to the pace car, whereas participants increased their following distance when they were conversing on a cell phone.

Table 1 presents the nine performance variables that were measured to determine how participants reacted to the vehicle braking in front of them. *Brake reaction time* is the time interval between the onset of the pace car's brake lights and the onset of the participant's braking response (i.e., defined as a minimum of 1% depression of the participant's brake pedal). *Maximum braking force* is the maximum force that the participant applied to the brake pedal in response to the braking pace car (expressed as a percentage of maximum). *Speed* is the average driving speed of the participant's vehicle (expressed in miles per hour). *Mean following distance* is the distance prior to braking between the rear bumper of the pace car and the front bumper of the participant's car. *SD following distance* is the standard deviation of following distance.

Time to collision (TTC), measured at the onset of the participant's braking response, is the time

remaining until a collision between the participant's vehicle and the pace car if the course and speed were maintained (i.e., had the participant failed to brake). Also reported are the frequency of trials with TTC values below 4 s, a level found to discriminate between cases in which the drivers find themselves in dangerous situations and those in which the driver remains in control of the vehicle (e.g., Hirst & Graham, 1997). *Half recovery time* is the time for participants to recover 50% of the speed that was lost during braking (e.g., if the participant's car was traveling at 60 mph [96.5 km/hr] before braking and decelerated to 40 mph [64.4 km/hr] after braking, then half recovery time would be the time taken for the participant's vehicle to return to 50 mph [80.4 km/hr]). Also shown in the table is the total number of collisions in each phase of the study. We used a multivariate analysis of variance (MANOVA) followed by planned contrasts (shown in Table 2) to provide an overall assessment of driver performance in each of the experimental conditions.

We performed an initial comparison of participants driving while using a handheld cell phone versus a hands-free cell phone. Both handheld and hands-free cell phone conversations impaired driving. However, there were no significant differences in the impairments caused by these two modes of cellular communication (all $ps > .25$). Therefore, we collapsed across the handheld and hands-free conditions for all subsequent analyses reported in this article. The observed similarity between handheld and hands-free cell phone conversations is consistent with earlier work *(*e.g., Patten, Kircher, Ostlund, & Nilsson, 2004; Redelmeier & Tibshirani, 1997; Strayer & Johnston, 2001) and calls into question driving regulations that prohibit handheld cell phones and permit hands-free cell phones.

MANOVAs indicated that both cell phone and alcohol conditions differed significantly from baseline, $F(8, 32) = 6.26$, $p < .01$, and $F(8, 32) = 2.73$, $p < .05$, respectively. When drivers were conversing on a cell phone, they were involved in more rear-end collisions, their initial reaction to vehicles braking in front of them was slowed by 9%, and the variability in following distance increased by 24%, relative to baseline. In addition, compared with baseline, participants who were talking on a cell phone took 19% longer to recover the speed that was lost during braking.
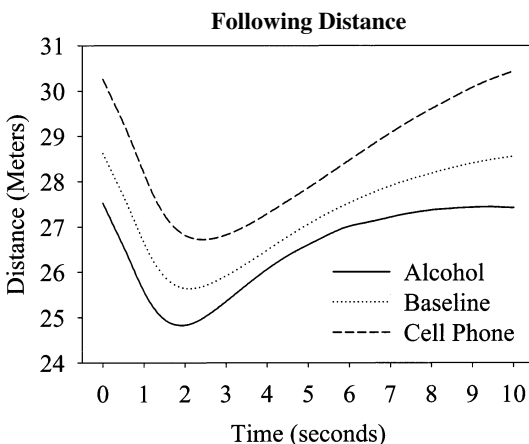

Figure 5. The following distance profile.

TABLE 1: Means and Standard Errors (in Parentheses) for the Alcohol, Baseline, and Cell Phone Conditions

	Alcohol	Baseline	Cell Phone
Total accidents	0	0	3
Brake reaction time (ms)	779 (33)	777 (33)	849 (36)
Maximum braking force	69.8 (3.7)	56.7 (2.6)	55.5 (3.0)
Speed (mph)	52.8 (2.0)	55.5 (0.7)	53.8 (1.3)
Mean following distance (m)	26.0 (1.7)	27.4 (1.3)	28.4 (1.7)
SD following distance (m)	10.3 (0.6)	9.5 (0.5)	11.8 (0.8)
Time to collision (s)	8.0 (0.4)	8.5 (0.3)	8.1 (0.4)
Time to collision < 4 s	3.0 (0.7)	1.5 (0.3)	1.9 (0.5)
Half recovery time (s)	5.4 (0.3)	5.3 (0.3)	6.3 (0.4)

By contrast, when participants were intoxicated, neither accident rates, nor reaction time to vehicles braking in front of the participant, nor recovery of lost speed following braking differed significantly from baseline. Overall, drivers in the alcohol condition exhibited a more aggressive driving style. They followed closer to the pace vehicle, had twice as many trials with TTC values below 4 s, and braked with 23% more force than in baseline conditions. Most importantly, our study found that accident rates in the alcohol condition did not differ from baseline; however, the increase in hard braking and the increased frequency of TTC values below 4 s are predictive of increased accident rates over the long run (e.g., T. L. Brown et al., 2001; Hirst & Graham, 1997).

The MANOVA also indicated that the cell phone and alcohol conditions differed significantly from each other, $F(8, 32) = 4.06$, $p < .01$. When drivers were conversing on a cell phone, they were involved in more rear-end collisions and took longer to recover the speed that they had lost during braking than when they were intoxicated. Drivers in the alcohol condition also applied greater braking pressure than did drivers in the cell phone condition.

To sharpen our understanding of the differences between the cell phone and alcohol conditions, we

TABLE 2: T Test Values for the Pair-Wise Comparisons

		Alcohol	Baseline
Brake reaction time (ms)	Alcohol		0.34
	Cell phone	1.74*	5.46***
Maximum braking force	Alcohol		4.40***
	Cell phone	4.13***	0.67
Speed (mph)	Alcohol		1.41
	Cell phone	0.47	1.69*
Mean following distance (m)	Alcohol		0.87
	Cell phone	1.11	1.06
SD following distance (m)	Alcohol		1.25
	Cell phone	1.59	4.18***
Time to collision (s)	Alcohol		1.18
	Cell phone	0.16	1.76*
Time to collision < 4 s	Alcohol		2.06**
	Cell phone	1.44	1.10
Half recovery time (s)	Alcohol		0.32
	Cell phone	1.96*	3.68***

Note. All comparisons have a df of 39 and are evaluated with a two-tailed significance level.

*p < .10. **p < .05. ***p < .01.

entered the driving performance measures obtained for each participant into a discriminant function analysis. The discriminant analysis determines which combination of variables maximally discriminates between the groups. The larger the standardized coefficient, the greater the contribution of that variable to the discrimination between the groups. Three of the obtained coefficients were negative, affected primarily by alcohol consumption: maximum braking force (–0.674), mean following distance (–0.409), and TTC less than 4 s (–0.311). Four of the obtained coefficients were positive, affected primarily by cell phone conversations: speed (0.722), *SD* of following distance (0.468), half recovery time (0.438), and brake reaction time (0.296). Average TTC did not differentiate between groups (coefficient = 0.055). Taken together, the discriminant analysis indicates that the pattern of impairment associated with the alcohol and cell phone conditions is qualitatively different.

Finally, the accident data were analyzed using a nonparametric chi-square statistical test. The chi-square analysis indicated that there were significantly more accidents when participants were conversing on a cell phone than in the baseline or alcohol conditions, $\chi^2(2) = 6.15$, $p < .05$.

DISCUSSION

Taken together, we found that both intoxicated drivers and cell phone drivers performed differently from baseline and that the driving profiles of these two conditions differed. Drivers using a cell phone exhibited a delay in their response to events in the driving scenario and were more likely to be involved in a traffic accident. Drivers in the alcohol condition exhibited a more aggressive driving style, following closer to the vehicle immediately in front of them, necessitating braking with greater force. With respect to traffic safety, the data suggest that the impairments associated with cell phone drivers may be as great as those commonly observed with intoxicated drivers.

However, the mechanisms underlying the impaired driving in the alcohol and cell phone conditions clearly differ. Indeed, the discriminant function analysis indicates that the driving patterns of the cell phone driver and the drunk driver diverge qualitatively. On the one hand, we found that intoxicated drivers hit the brakes harder, had shorter following distances, and had more trials with TTC values less than 4 s. On the other hand, we found that cell phones drivers had slower reactions, had longer following distances, took longer to recover speed lost following a braking episode, and were involved in more accidents. In the case of the cell phone driver, the impairments appear to be attributable, in large part, to the diversion of attention from the processing of information necessary for the safe operation of a motor vehicle (Strayer et al., 2003; Strayer & Johnston, 2001). These attention-related deficits are relatively transient (i.e., occurring while the driver is on the cell phone and dissipating relatively quickly after attention is returned to driving). By contrast, the effects of alcohol persist for prolonged periods of time, are systemic, and lead to chronic impairment.

Also noteworthy was the fact that the driving impairments associated with handheld and hands-free cell phone conversations were not significantly different. This observation is consistent with earlier reports *(*e.g., Patten et al., 2004; Redelmeier & Tibshirani, 1997; Strayer & Johnston, 2001) and suggests that legislative initiatives that restrict handheld devices but permit hands-free devices are not likely to eliminate the problems associated with using cell phones while driving. This follows because the interference can be attributed in large part to the distracting effects of the phone conversations themselves, effects that appear to be attributable to the diversion of attention away from driving. It should be pointed out that our study did not examine the effects of dialing or answering the phone on driving performance; however, Mazzae, Ranney, Watson, and Wightman (2004) compared handheld with hands-free devices and found the former to be answered more quickly, dialed faster, and associated with fewer dialing errors than the latter.

Our study also sheds light on the role that experience plays in moderating cell-phone-induced dual-task interference. Participants' self-reported estimates of the amount of time spent driving while using a cell phone averaged 14.3% with a range from 0% to 60%. When real-world usage was entered as a covariate into analyses comparing baseline and cell phone conditions, there was no evidence that practice altered the pattern of dual-task interference (i.e., all main effects and interactions associated with real-world

usage had ps > .40). That is, practice in this dual-task combination did not result in improved performance. Given the attentional requirements of these two activities, it is not surprising that practice failed to moderate the dual-task interference. Because both naturalistic conversation and driving (at least reaction to unpredictable or unexpected events) have task components that are variably mapped, there are likely to be few benefits from practicing these two tasks in combination. Indeed, there is overwhelming evidence in the literature that performance on components of a task with a variable mapping do not benefit from practice (e.g., Shiffrin & Schneider, 1977).

Furthermore, the lack of differences in dual-task interference as a function of real-world usage suggests that drivers may not be aware of their own impaired driving. Indeed, when we debriefed participants at the end of the experiment, many of the drivers with higher levels of real-world cell phone usage while driving indicated that they found it no more difficult to drive while using a cell phone than to drive without using a cell phone. Thus, there appears to be a disconnect between participants' self-perception of driving performance and objective measures of their driving performance. Elsewhere, we have suggested that one consequence of using a cell phone is that it may make drivers insensitive to their own impaired driving behavior (Strayer et al., 2003).

One factor that is often overlooked when considering the overall impact of cell phone driving is the effect these drivers have on traffic flow. In our study, we found that drivers using a cell phone took 19% longer (than baseline) to recover the speed that was lost following a braking episode. In situations where traffic density is high, this pattern of driving behavior is likely to decrease the overall traffic flow, and as the proportion of cell phone drivers increases, these effects are likely to be multiplicative. That is, the impaired reactions of a cell phone driver make them less likely to travel with the flow of traffic, potentially increasing overall traffic congestion.

In the current study, the performance of drivers with a blood alcohol level at 0.08% differed significantly from their performance in both the cell phone and baseline conditions. In particular, when participants were in the alcohol condition, they followed the pace car more closely, had a greater frequency of trials with TTC less than 4 s,

and depressed the brake with more vigor when the lead vehicle began to decelerate. However, the difference in brake onset time between the alcohol and baseline conditions was not significant in the current study. The precise reason for the lack of an effect on reaction time is unclear; although the literature on the effects of alcohol on reaction time has produced mixed results (see Moskovitz & Fiorentino, 2000). One possibility is that drivers in the alcohol condition may have reacted with alacrity out of necessity; given their shorter following distance, they may have been pressed into action sooner than in the other conditions. Indeed, an examination of the relationship between reaction time and following distance yielded significant correlations for the baseline (r = .47, p < .01) and cell phone (r = .56, p < .01) conditions, but not for the alcohol condition, (r = .07, ns). That is, for both the baseline and cell phone conditions, reaction time tended to increase with following distance, but this pattern was not observed in the alcohol condition.

No accidents were observed in the alcohol sessions of our study. Nevertheless, alcohol clearly increases the risk of accidents in real-world settings. For example, the U.S. Department of Transportation (2002) estimated that alcohol was involved in 41% of all fatal accidents in 2002; however, it is important to note that in 81% of these cases the blood alcohol level was higher than 0.08% wt/vol and that the average blood alcohol level of drivers involved in a fatal crash was twice the legal limit (i.e., 0.16% wt/vol). For cases in which the blood alcohol level was at or below the legal limit, the total number of fatalities in 2002 was 2818.

Another way to determine the effect of alcohol on driving is to estimate the risk of an accident when driving with a specific blood alcohol concentration as compared with baseline conditions when the driver is not under the influence of alcohol. Using odds ratios, Zandor, Krawchuk, and Voas (2000) estimated the relative risk of a passenger vehicle accident for drivers 21 to 34 years old. At blood alcohol concentrations between 0.05% and 0.79%, the odds ratio was estimated to be 3.76, and at blood alcohol concentrations between 0.08% and 0.99%, the odds ratio was estimated to be 6.25. Unfortunately, the precise odds ratio for a blood alcohol concentration of 0.08% is not readily discernable from the tabular

information in the Zandor et al. (2000) study, but presumably it falls somewhere between 3.76 and 6.25.

By comparison, this is the third in a series of studies that we have conducted evaluating the effects of cell phone use on driving using the car-following procedure (see also Strayer & Drews, 2004; and Strayer et al., 2003). Across these three studies, 120 participants performed in both baseline and cell phone conditions. Two of the participants in our studies were involved in an accident in baseline conditions, whereas 10 participants were involved in an accident when they were conversing on a cell phone. A logistic regression analysis indicated that the difference in accident rates for baseline and cell phone conditions was significant, $\chi^2(1) = 6.1$, $p = .013$, and the estimated odds ratio of an accident for cell phone drivers was 5.36, a relative risk similar to the estimates obtained by Zandor et al. (2000) for drivers with a blood alcohol level of 0.08% wt/vol.

One factor that may have contributed to the absence of accidents in the alcohol condition of our study is that the alcohol and driving portion of the study was conducted during the daytime (between 9:00 a.m. and noon). Data from the National Highway Transportation Safety Administration (National Highway Traffic Safety Administration, 2001) indicates that only 3% of fatal accidents on U.S. highways occur during this time interval. In fact, in the real world there is a natural confounding of alcohol consumption and fatigue such that nearly 80% of all fatal alcohol-related accidents on U.S. highways occur between 6:00 p.m. and 6:00 a.m. In the current study, participants were well rested prior to the consumption of alcohol, potentially lowering the relative risk factors.

The objective of the present research was to help to establish a clear benchmark for assessing the relative risks associated with using a cell phone while driving. We compared the cell phone driver with the drunk driver for two reasons. First, there are now clear societal norms associated with intoxicated driving, and laws in the United States expressly prohibit driving with a blood alcohol level at or above 0.08%. Logical consistency would seem to dictate that any activity that leads to impairments in driving equal to or greater than the drunk driving standard should be avoided (Willette & Walsh, 1983). Second, the epidemiological study by Redelmeier and Tibshirani

(1997) suggested that "the relative risk [of being in a traffic accident while using a cell phone] is similar to the hazard associated with driving with a blood alcohol level at the legal limit" (p. 456). The data presented in this article are consistent with this estimate and indicate that when driving conditions and time on task are controlled for, the impairments associated with using a cell phone while driving can be as profound as those associated with driving with a blood alcohol level at 0.08%. With respect to cell phone use, clearly the safest course of action is to not use a cell phone while driving. However, regulatory issues are best left to legislators who are provided with the latest scientific evidence. In the long run, skillfully crafted regulation and better driver education addressing driver distraction will be essential to keep the roadways safe.

ACKNOWLEDGMENTS

REFERENCES

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

Billings, C. E., Demosthenes, T., White, T. R., & O'Hara, D. B. (1991). Effects of alcohol on pilot performance in simulated flight. *Aviation, Space, and Environmental Medicine, 62,* 233–235.

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

Brookhuis, K. A. (2003 July). *On the Assessment of Criteria for Driver Impairment: In search of the Golden Yardstick for Driving Performance.* Presented at Driving Assessment 2003: International Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Park City, UT.

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

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

Brown, T. L., Lee, J. D., & McGehee, D. V. (2001). Human performance models and rear-end collision avoidance algorithms. *Human Factors, 43,* 462–482.

Burns, M. & Moskovitz, H. (1980). Effects of diphenhydramine and alcohol on skills performance. *European Journal of Clinical Pharmacology, 17,* 259–266.

Cellular Telecommunications Industry Association. (2006). *Background on CTIA's semi-annual wireless industry survey.* Retrieved April 11, 2006, from http://files.ctia.org/pdf/CTIAEndYear2005Survey.pdf

Glassbrenner, D. (2005). Driver cell phone use in 2004 – Overall results. In *Traffic safety facts: Research note* (DOT HS 809 847). Washington, DC: U.S. Department of Transportation.

Goodman, M. F., Bents, F. D., Tijerina, L., Wierwille, W., Lerner, N., & Benel, D. (1999). *An investigation of the safety implications of wireless communication in vehicles: Report summary* (Department of Transportation electronic publication). Retrieved April 11, 2006, from http://www.nhtsa.dot.gov/people/injury/research/wireless/#rep

Hirst, S., & Graham, R. (1997). The format and presentation of collision warnings. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 203–319). Hillsdale, NJ: Lawrence Erlbaum.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice Hall.

Klein, K. (1972). Prediction of flight safety hazards from drug induced performance decrements with alcohol as a reference substance. *Aerospace Medicine, 43,* 1207–1214.

Lee, J. D., Vaven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effects of speech-based E-mail on drivers' attention to the roadway. *Human Factors, 43,* 631–640.

Mazzae, E. N., Ranney, T. A., Watson, G. S., & Wightman, J. A. (2004). Hand-held or hands-free? The effects of wireless phone interface type on phone task performance and driver performance. In *Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting* (pp. 2218–2221). Santa Monica, CA: Human Factors and Ergonomics Society.

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

Moskovitz, H., & Fiorentino, D. (2000). *A review of the literature on effects of low doses of alcohol on driving-related skills* (U.S. DOT/NHTSA Report). Retrieved April 11, 2006, from http://www.nhtsa.dot.gov/people/injury/research/pub/Hs809028/Title.htm#Contents

National Highway Traffic Safety Administration. (2001). *Alcohol and highway safety 2001: A review of the state of knowledge* (NHTSA DOT HS 809 383). Retrieved April 11, 2006, from http://www.nhtsa.dot.gov/people/injury/research/AlcoholHighway/index.htm#Contents

Navon, D., & Gopher, D. (1979). On the economy of the human processing system. *Psychological Review, 86,* 214–255.

Patten, C. J. D., Kircher, A., Ostlund, J., & Nilsson, L. (2004). Using mobile telephones: Cognitive workload and attention resource allocation. *Accident Analysis and Prevention, 36,* 341–350.

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *New England Journal of Medicine, 336,* 453–458.

Reschovsky, C. (2004). *Journey to work: 2000, Census 2000 brief.* Retrieved April 11, 2006, from http://www.census.gov/prod/2004pubs/c2kbr-33.pdf

Shiffrin, R., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127–190.

Strayer, D. L. & Drews, F. A. (2004). Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers. *Human Factors, 46,* 640–649.

Strayer, D. L., Drews, F. A., & Johnston, W. A. (2003). Cell phone induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied, 9,* 23–52.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular phone. *Psychological Science, 12,* 462–466.

Stutts, J., Feaganes, J., Rodgman, E., Hamlett, C., Meadows, T., Reinfurt, D. Gish, K., Mercadante, M., & Staplin, L. (2003). *Distractions in everyday driving.* Washington, DC: AAA Foundation for Traffic Safety.

Thapar, P. J., Zacny, J. P., Choi, M., & Apfelbaum, J. L. (1995). Using alcohol as a standard to assess the degree of impairment induced by sedative and analgesic drugs used in ambulatory surgery. *Anesthesiology and Analgesia, 80,* 1092–1098.

Tiplady, B. (1991). Alcohol as a comparator. In I. D. Keepler, L. D. Sanders, & M. Rosen (Eds.), *Ambulatory anesthesia and sedation* (pp. 26–37). Malden, MA: Blackwell Scientific.

U.S. Department of Transportation. (2002). *Traffic safety facts 2002: Alcohol* (DOT HS 809 606). Retrieved April 11, 2006, from http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2002/2002alcfacts.pdf

Willette, R. E., & Walsh, J. M. (1983). *Drugs, driving, and traffic safety.* Geneva: World Health Organization.

Williamson, A., Feyer, A. M., Friswel, R., & Finlay-Brown, S. (2001). Developing measures of fatigue using an alcohol comparison to validate the effects of fatigue on performance. *Accident Analysis and Prevention, 33,* 313–326.

Zandor, P. L., Krawchuk, S. A., & Voas, R. B. (2000). *Relative risk of fatal crash involvement by BAC, age, and gender* (DOT HS 809 050). Washington, DC: U.S. Department of Transportation.

David L. Strayer is a professor of psychology at the University of Utah. He received his Ph.D. in psychology from the University of Illinois at Urbana-Champaign in 1989.

Frank A. Drews is an assistant professor of psychology at the University of Utah. He received his Ph.D. in psychology from the Technical University of Berlin, Germany, in 1999.

Dennis J. Crouch is a research associate professor of pharmacology and toxicology at the University of Utah. He received his M.B.A. from Utah State University in 1989.