Why do Cell Phone Conversations Interfere with Driving?

David L. Strayer, Frank A. Drews, Robert W. Albert, & William A. Johnston
Department of Psychology
University of Utah
Salt Lake City, Utah USA
E-mail: David.Strayer@psych.utah.edu

Summary: This research assessed the effects of cell phone conversations on driving. Our first study found that subjects engaged in cell phone conversations using either a hand-held or hands-free device, were more than twice as likely to miss simulated traffic signals than when they were not distracted by the cell phone conversation. By contrast, performance was not disrupted by listening to radio broadcasts or listening to a book on tape. Our second study, using a high-fidelity driving simulator, found that subjects conversing on a hands-free cell phone were more likely to get into traffic accidents. Analysis of driving profiles revealed that cell phone users exhibited a sluggish response to changing traffic patterns and attempted to compensate by increasing their following distance. We suggest that active participation in a cell phone conversation disrupts performance by diverting attention to an engaging cognitive context other than the one immediately associated with driving.

The use of cellular phones has skyrocketed in recent years, with more than 123 million subscribers in the United States as of November 1, 2001 (CTIA, 2001). This increase has been accompanied by an increase in the number of individuals concurrently driving and talking on the cell phone. Recent estimates suggest that cell phone users spend 60% of their cell phone time while driving (Hahn, et. al., 2000). The precise effects of cell phone use on public safety are unknown. However, because of the possible increase in risks associated with the use of cell phones while driving, several legislative efforts have been made to restrict cell phone use on the road. In most cases, the legislation regarding cell phones and driving makes the tacit assumption that the source of any interference from cell phones use is due to peripheral factors such as dialing and holding the phone while conversing. Among other things, our research evaluates the validity of this assumption.

Prior research has established that the manual manipulation of equipment (e.g., dialing the phone, answering the phone, etc.) has a negative impact on driving (e.g., Brookhuis, et. al., 1991; Briem & Hedman, 1995). However, the effects of the phone *conversation* on driving are not as well understood, despite the fact that the duration of a typical phone conversation may be up to two orders of magnitude greater than the time required to dial or answer the phone. Briem & Hedman (1995) found that simple conversations did not adversely affect the ability to maintain road position. On the other hand, several studies have found that working memory tasks (Alm & Nilsson, 1995; Briem & Hedman, 1995), mental arithmetic tasks (McKnight & McKnight, 1993), and reasoning tasks (Brown, et. al., 1969) disrupt simulated driving performance.

The current research focused on the cell phone conversation, because it comprises the bulk of the time engaged in this dual-task pairing. Our studies sought to determine the extent to which cell phone conversations interfere with driving and, if so, the precise nature of the interference. In particular, the “peripheral interference” hypothesis attributes interference from cell phones to peripheral factors such as holding the phone while conversing. By contrast, the “attentional hypothesis” attributes interference to the diversion of attention from driving to the phone conversation itself.

EXPERIMENT 1

Our first study was designed to contrast the effects of hand-held and hands-free cell phone conversations on responses to traffic signals in a simulated driving task (viz., pursuit tracking). We also included control groups who either listened to the radio or listened to a book on tape while performing the simulated driving task. As subjects performed the simulated driving task, occasional red and green lights were flashed on the computer display. If subjects saw a green light, they were instructed to continue as normal. However, if a red light was presented they were to make a braking response as quickly as possible. This manipulation was included to determine how quickly subjects could react to the red light as well as to determine the likelihood of detecting these simulated traffic signals, under the assumption that these two measures would contribute significantly to any increase in the risks associated with driving and using a cell phone.

Methods

Subjects. Sixty-four undergraduates (32 male, 32 female) from the University of Utah participated in the experiment. Subjects ranged in age from 18 to 30, with an average age of 21.2. All had normal or corrected-to-normal vision and perfect color vision. Subjects were randomly assigned to one of the radio control, book-on-tape control, hand-held cell phone, or hands-free cell phone groups.

Stimuli and Apparatus. Subjects performed a pursuit tracking task in which they used a joystick to maneuver the cursor on a computer display to keep it aligned as closely as possible to a moving target. The target position was updated every 33 msec and was determined by the sum of three sine waves (0.07 hz, 0.15 hz, and 0.23 hz). The target movement was smooth and continuous, yet essentially unpredictable. At intervals ranging from 10 to 20 sec (mean = 15 sec), the target flashed red or green and subjects were instructed to press a “brake button” located in the thumb position on top of the joystick as rapidly as possible when they detected the red light. Red and green lights were equiprobable and were presented in an unpredictable order.

Procedure. An experimental session consisted of three phases. The first phase was a warm-up interval that lasted 7 minutes and was used to acquaint subjects with the tracking task. The second phase was the single-task portion of the study and was comprised of the 7.5 minute segment immediately preceding and the 7.5 minute segment immediately following the dual-task portion of the study. During the single-task phase, subjects performed the tracking task by itself. The third phase was the dual-task portion of the study, lasting 15 minutes. Dual-task conditions required the subject to engage in a conversation with a confederate (or listen to a radio broadcast of their choosing or a book on tape) while concurrently performing the tracking task. Subjects in the phone conversation groups were asked to discuss either the then on-going Clinton presidential impeachment or the Salt Lake City Olympic Committee bribery scandal (conversations were counterbalanced across subjects). The confederate's task was to facilitate the conversation and also to ensure that the subject listened and spoke in approximately equal proportions during the dual-task portions of the experiment. Subjects in the radio control group listened to a radio broadcast of their choosing during the dual-task portions of the experiment. Subjects in the book-on-tape control group listened to selected portions from a book on tape during the dual-task portions of the experiment.

Results and Discussion

A preliminary analysis of detection rates and reaction times to traffic signals indicated that there were no reliable differences between hands-free and hand-held cell phone groups (all p's > .80). Neither were there reliable differences between radio control and book-on-tape control groups (all p's > .30). Therefore, the data were aggregated to form a 2 (Group: Cell Phone vs. Control) X 2 (Task: Single vs. Dual) factorial design. Table 1-A presents the probability of missing simulated traffic signals. Overall, miss rates were low; however, the probability of a miss significantly increased when subjects were engaged in conversations on the cell phone, $F(1,31)=8.8$, $p<0.01$. By contrast, the difference between single and dual-task conditions was not reliable for the control group, $F(1,31)=0.9$, $p>0.36$. The reaction time to the simulated traffic signals is presented in Table 1-B. Analysis of the RT data revealed that subjects in the cell phone group responded slower to simulated traffic signals while engaged in conversation on the cell phone, $F(1,31)=29.8$, $p<0.01$. There again was no indication of a dual-task decrement for the control group, $F(1,31)=2.7$, $p>0.11$

Table 1. Table 1-A presents the probability of missing the simulated traffic signals in single and dual-task conditions for the cell phone and control groups. Table 1-B presents the mean reaction time to the simulated traffic signals in single and dual-task conditions for the cell phone and control groups. Standard deviations are presented in parentheses.

Table 1-A	Single-Task	Dual-Task
Cell Phone	0.028 (.05)	0.070 (.09)
Control	0.027 (.04)	0.034 (.04)

Table 1-B	Single-Task	Dual-Task
Cell Phone	534 (67)	585 (90)
Control	543 (65)	533 (65)

These data demonstrate that the phone conversation itself resulted in significant slowing in the response to simulated traffic signals, as well as an increase in the likelihood of missing these signals. Moreover, the fact that hand-held and hands-free cell phones resulted in equivalent dual-task deficits indicates that the interference was not due to peripheral factors such as holding the phone while conversing. These findings also rule out interpretations that attribute the deficits associated with a cell phone conversation to simply attending to verbal material, because dual-task deficits were not observed in the book-on-tape control. Active engagement in the cell phone conversation appears to be necessary to produce the observed dual-task interference.

EXPERIMENT 2

Our second study was designed to replicate and extend the findings of Experiment 1 using a high fidelity driving simulator. Subjects drove on a multi-lane freeway in single-task (i.e., driving only) and dual-task (i.e., driving and conversing on a cell phone) conditions. In both conditions, subjects followed a pace car that would, on occasion, brake in response to unexpected events. We measured a number of real-time performance variables to determine how subjects reacted to the car braking in front of them. To rule our any potential interference from the manual components of cell phone use, subjects used a hands-free cell phone and the call was initiated before they began driving. *Thus, any difference between single and dual-task conditions can be attributed to the cell phone conversation itself and not to manual manipulation of the phone.*

Methods

Subjects. Forty undergraduates (18 male and 22 female) from the University of Utah participated in the experiment. Subjects ranged in age from 18 to 32, with an average age of 23.6. All had normal or corrected-to-normal vision and perfect color vision.

Stimuli and Apparatus. The PatrolSim high-fidelity driving simulator manufactured by GE Capital I-SIM (www.i-sim.com) was used in the study. The simulator, illustrated in Figure 1, is composed of 5 networked microprocessors and three high resolution computer displays providing a 180 degree field of view. The dashboard instrumentation, steering wheel, gas, and brake pedals are adapted from a Ford Crown Victoria® sedan. The simulator incorporates proprietary vehicle dynamics, traffic scenario, and road surface software to provide accurate stimuli for the driver. Measures of real-time driving performance, including driving speed, distance from other vehicles, brake, gas, and steering wheel inputs, were sampled at 30 Hz and stored on disk for off-line analysis.

A freeway road database was used to create the scenarios for the experiment. The freeway road database simulates a 40-mile multi-lane beltway with on and off ramps, overpasses, and two and three-lane traffic in each direction (separated by a grass median). All scenarios used day time dry-pavement driving conditions. In the low-density driving condition, a pace car and the subject's car were the only vehicles on the roadway. The pace car was programmed to stay in the right-hand lane throughout the scenario. In the high-density driving condition, 32 "distractor" vehicles were added to the highway scenario. These 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 in the left-hand lane. In each scenario, the pace car was programmed to brake at 32 randomly selected intervals and would continue to decelerate until the subject depressed the brake pedal, at which point the pace car would begin to accelerate to normal freeway speeds. Thus, each scenario provided 32 opportunities to measure the subject's response to a car braking in front of them.

Procedure. When subjects arrived for the experiment, they completed a questionnaire that assessed various aspects of their driving behavior and also assessed their interest in potential topics of cell phone conversation. Subjects were then familiarized with the driving simulator using a standardized 15 minute adaptation sequence. Subjects then drove four ten-mile sections on a multi-lane highway. Half of the scenarios were used in single-task driving conditions and half were used in dual-task (i.e., driving and cell phone conversation) conditions. The order of conditions and scenarios was counterbalanced across subjects using a Latin square design, with the constraint that both single and dual-task conditions were performed in the first half of the experiment and both single and dual-task conditions were performed in the last half of the experiment. For data analysis purposes, we collapsed across scenario for both the single and dual-task conditions.

The subject's task was to follow a pace car that was driving in the right-hand lane of the highway. The pace car was programmed to brake at 32 randomly selected intervals throughout the course. When the subject depressed the brake in response to the pace car deceleration, the pace car released its brake and accelerated to normal highway speed. If the subject failed to depress the brake, they would eventually collide with the pace car. That is, like real highway stop and go traffic, the subject was required to react in a timely and appropriate manner to vehicles slowing in front of them. We also manipulated driving density by manipulating the number of vehicles on the highway. In the low-density driving condition, only two cars were present on the highway (the subject's car and the pace car). In the high-density driving condition, 32 distractor vehicles were added to the scenario, providing the impression of a steady stream of traffic moving in the left-hand lane. Thus, the increase in driving density was due to an increase in perceptual load; neither the subject nor the pace car directly interacted with these distractor vehicles.

The dual-task condition involved conversing on a cell phone with a confederate. The subject and the confederate discussed material that was identified in the pre-experiment questionnaire as topics of interest to the subject. To avoid any possible interference from manual components of cell phone use, subjects used a hands-free cell phone that was positioned and adjusted before driving began. Additionally, the call was initiated before subjects began the dual-task scenarios. Thus, any dual-task interference that we observe must be due to the cell phone conversation itself, because there was no manual manipulation of the cell phone during the dual-task portions of the study.

The data were analyzed using a 2 (Driving Density: Low vs. High) X 2 (Task: Single vs. Dual) split-plot Analysis of Variance (ANOVA). Driving density was a between subjects factor and single versus dual-task condition was a within-subjects factor. In addition, a Multivariate Analysis of Variance (MANOVA) was used to provide an overall assessment of driving performance as a function of experimental condition.

Results and Discussion

Table 2 presents the accident rates and several of the driving profile parameters for Experiment 2. There were no accidents in the low-density condition. However, subjects were more likely to be involved in traffic accidents while conversing on a cell phone in the high-density condition. In order to better understand this increased incidence of traffic accidents, we examined the subject's driving profile in response to the braking pace car. Driving profile were created by extracting 10 second 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 seconds of driving performance were extracted and entered into a 32 X 300 data matrix (i.e., on the j^{th} 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 $X_{[j,1]}, X_{[j,2]}, X_{[j,3]} \ldots X_{[j,300]}$; where j ranges from 1 to 32 reflecting the 32 occasions in which the subject 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 driver’s speed, brake response, and the distance from the pace car.

Table 2. Table 2 presents the average performance data from Experiment 2. Standard deviations are presented in parentheses.

Traffic Accidents	**Low Driving Density**	**High Driving Density**
Single Task	0	0
Dual Task	0	3
Brake Onset (msec)		
Single Task	928 (373)	933 (309)
Dual Task	957 (286)	1112 (346)
Brake Offset (msec)		
Single Task	1549 (647)	1513 (520)
Dual Task	1645 (541)	1756 (570)
Time to Min Speed (msec)		
Single Task	1833 (500)	1920 (433)
Dual Task	2130 (416)	2430 (466)
Following Distance (meters)		
Single Task	23.6 (8.6)	25.8 (5.6)
Dual Task	26.0 (8.0)	29.3 (6.4)

Figure 2: Braking Profile

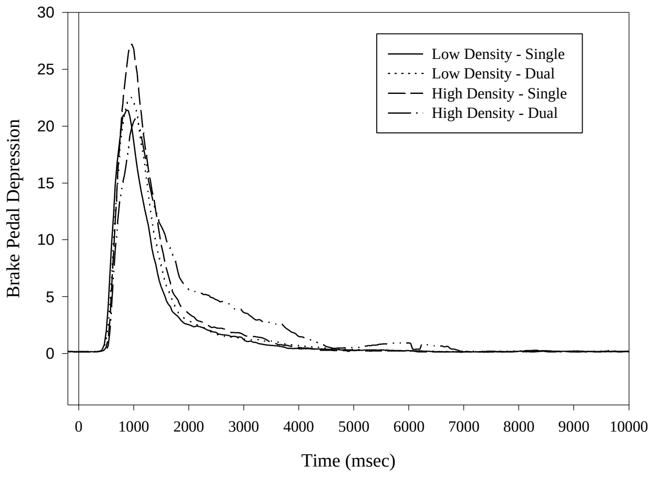

Figure 2 presents the braking profile for Experiment 2. Inspection of Figure 2 reveals that subjects initiated their braking response approximately 1 second after the pace car’s brake lights were illuminated and that the subject continued to depress the brake for several seconds following brake onset. It is evident in Figure 2 that both brake onset time and brake offset time varied as a function of experimental condition. The brake onset times, presented in Table 2, were longer in dual-task than in single-task conditions, $F(1,38)=7.3$, $p<.01$. There was also a modest interaction with driving density, $F(1,38)=3.8$, $p<.06$. Planned comparisons revealed that the difference between single and dual-task conditions was not reliable in low-density condition, but differed significantly in high-density condition, $t(19)=2.6$, $p<.01$.

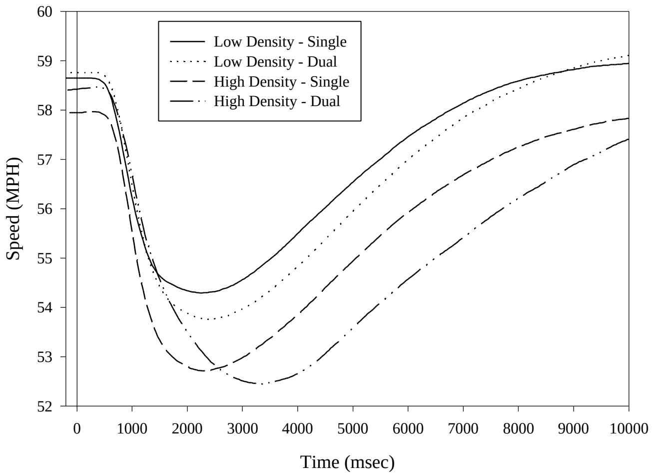

Figure 3: Speed Profile

These data indicate that subjects conversing on a cell phone were slower to initiate their braking response than when they were driving in single-task conditions.

Brake offset times, presented in Table 2, were longer in dual than in single-task conditions, F(1,38)=8.1, p<.01. Neither the main effect of driving density nor the interaction of driving density with single/dual-task condition were reliable. However, planned comparisons revealed that the difference between single and dual-task conditions was marginally reliable in the low-density condition, t(19)=1.8, p<.08, whereas this difference was significant in the high-density conditions, t(19)=2.3, p<.03. These data indicate that subjects pressed the brake pedal longer when conversing on a cell phone than when they were driving in single-task conditions.

Figure 3 presents the driving speed profile for Experiment 2. Inspection of Figure 3 reveals that the subject's vehicle began to decelerate approximately 1 second after the pace car's brake lights illuminated and that the subject's continued to decelerate for 2-4 seconds, thereafter gradually accelerated to normal freeway speeds. As indicated in Table 2, it took subjects longer to reach their nadir of their speed in dual-task conditions, F(1,38)=8.1, p<.01. There again, neither the main effect of driving density nor the interaction of driving density with single/dual-task conditions were reliable. However, planned comparisons revealed that the difference between single and dual-task conditions was not reliable in the low-density condition, but was reliable in the high-density condition, t(19)=3.6, p<.01.

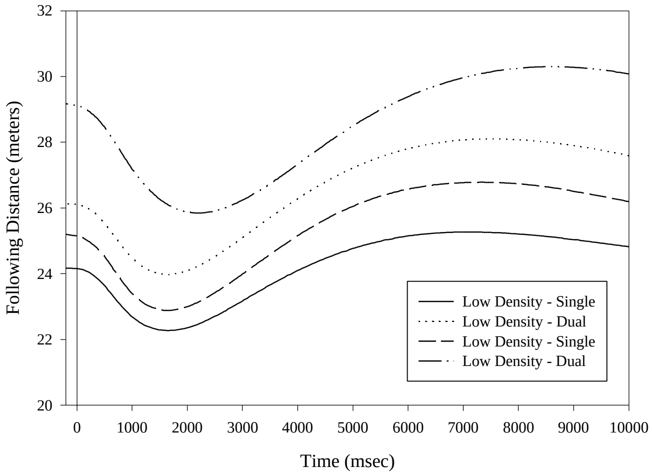

Figure 4: Following Distance Profile

Figure 4 presents the following distance profile for Experiment 2. Inspection of Figure 4 reveals that subjects increased the separation between themselves and the pace car from single to dual-task conditions, F(1,38)=17.4, p<.01. Neither the main effect of driving difficulty nor the interaction with single/dual-task conditions were reliable. Indeed, planned comparisons revealed that the increase from single to dual-task conditions was reliable for both the low-density, t(19)=2.4, p<.02 and high-density conditions, t(19)=3.5, p<.01.

The 4 dependent measures described above were entered into a MANOVA to provide an overall profile of the subject's response as a function of experimental condition. The MANOVA revealed a reliable main effect of single versus dual-task, F(4,35)=4.8, p<.01, indicating that when subjects were conversing on the cell phone, their reactions were sluggish when compared to their single-task baseline. Subjects attempted to compensate for this sluggish behavior by increasing the separation between themselves and the pace car. In addition the difference between single and dual–task conditions was exacerbated by driving density, F(4,35)=2.6, p<.05. Thus, conversing on a hands-free cell phone impaired driving performance and this impairment became more pronounced as driving difficulty increased. Consistent with this interpretation, subjects were more likely to be involved in traffic accidents when they were using the cell phone in the high density driving conditions.

GENERAL DISCUSSION

The principal findings are that subjects engaged in cell phone conversations were more likely to be involved in traffic accidents, missed more traffic signals, and reacted more slowly to events in the driving environment than when they were not engaged in cell phone conversations. Equivalent deficits in driving performance were obtained for hand-held and hands-free cell phone users. Indeed, performance decrements were obtained in Experiment 2 even when there was no possible contribution from the manual manipulation of the cell phone.

An analysis of the driving profiles revealed that the reactions of cell phone users were sluggish and that subjects attempted to compensate for this sluggish behavior by increasing the distance from the vehicle they were following. However, the observed incidence of traffic accidents suggests that this compensatory strategy was inadequate. Moreover, as driving difficulty increased, the costs of cell phone use were exacerbated. These data are consistent with an attention-based interpretation in which the disruptive effects of cell phone conversations on driving are due primarily to the diversion of attention from driving to the phone conversation itself.

In sum, we found that conversing on either a hand-held or hands-free cell phone led to significant decrements in simulated driving performance. We suggest that the cellular phone use disrupts performance by diverting attention to an engaging cognitive context other that the one immediately associated with driving. Our data further suggest that legislative initiatives that restrict hand-held devices but permit hands-free devices are not likely to reduce interference from the phone *conversation*, because the interference is, in this case, due to central attentional processes.

References

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

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

Brookhuis, K. A., De Vries, G., & De Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis & 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*(5), 419-424.

Cellular Telecommunications Industry Association,1250 Connecticut Avenue, NW Suite 800 || Washington, DC 20036, Phone : (202) 785 - 0081. (http://www.ctia.org/).

Hahn, R. W., Tetlock, P. C., & Burnett, J. K. (2000). Should you be allowed to use your cellular phone while driving? *Regulation*, *23*, 46-55.

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

Radeborg, K., Briem, V., & Hedman, L. R. (1999). The effect of concurrent task difficulty on working memory during simulated driving. *Ergonomics*, *42*, 767-777.