

CELL PHONE INDUCED PERCEPTUAL IMPAIRMENTS DURING SIMULATED DRIVING

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Summary: Our research assessed the effects of cellular phone conversations on driving performance. When subjects were deeply involved in cellular phone conversations using either a hand-held or hands-free device, they were more than twice as likely to miss simulated traffic signals presented at the center of fixation 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. One might argue that when subjects were conversing on a cell phone that they detected the simulated traffic signals, but that the responses to them were suppressed. To assess this, we examined the implicit perceptual memory for items that were presented at fixation but called for no response. Implicit perceptual memory was strong when subjects were not engaged in a cell-phone conversation but impaired when they were so engaged. 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 118 million subscribers in the United States as of July 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 attempted to further localize the source of cell phone interference on driving. In particular, one might argue that when subjects were conversing on a cell phone that they detected the simulated traffic signals, but that the responses to them were suppressed. To assess this, we examined the perceptual memory for words that were presented at fixation while subjects performed the simulated driving task and conversed with a confederate using a hands-free cell phone. Implicit perceptual memory was measured using a dot-clearing procedure in a session immediately following the simulated driving task. In the dot-clearing procedure, words were initially masked and then slowly faded into view as the mask was gradually removed. We estimated the perceptual memory for an item by the time taken by subjects to report the identity of that item. Researchers using the dot-clearing procedure have found that words previously attended to are identified faster than new words (e.g., Hawley & Johnston, 1991).

Methods

Subjects. Thirty undergraduates (17 male and 13 female) from the University of Utah participated in the experiment. Subjects ranged in age from 18 to 25, with an average age of 19.6. All had normal or corrected-to-normal vision and perfect color vision.

Stimuli and Apparatus. In addition to the materials used in the first study, the stimuli included 330 four-to-five letter words selected from the Kucera and Francis (1967) word norms. The latency of the subject's responses in the dot-clearing task was measured using a voice-activated response device and response accuracy was manually recorded at the end of each trial.

Procedure. There were two phases to the study. The first phase was identical to the simulated driving task used in the first study, with the exception that the simulated traffic signals were replaced with 4-5 letter words that were presented for 500 msec at the center of fixation. Subjects were asked to press a button on the joystick if the word was an animal name. Three percent of the words were animal names and these items were not included in the second phase of the study.

The second phase of the study used the dot-clearing procedure to measure the perceptual memory for words presented in the single and dual-task conditions during the first phase of the study. In addition, words not presented in the first phase of the study were also included to provide a baseline measure for the dot-clearing task. The words from the three categories (i.e., single-task, dual-task, and new) were presented in a randomized order in the dot-clearing phase of the study.

Results and Discussion

Table 2 presents the data from the dot-clearing phase of the study. Subjects were able to identify words presented in single-task conditions faster than new words, $F(1,29)=24.7$, $p<.01$, providing a baseline measure of the perceptual memory effect. Words presented while subjects were engaged in conversation on a cell phone were identified faster than new words, $F(1,29)=5.3$,

$p < 0.03$, but slower than words presented in single-task conditions, $F(1,29) = 5.7$, $p < 0.02$. These data indicate that the implicit perceptual memory for items presented at fixation was strong when subjects were not engaged in a cell-phone conversation but impaired when subjects were so engaged. That is, when subjects were conversing on the cell phone, their ability to attend to information in the driving environment was impaired. This impairment was observed even when objects were presented directly where subjects were looking.

Table 2. Mean identification reaction time in the dot-clearing phase of the Experiment 2

Single-Task	Dual-Task	New Words
3114 (444)	3176 (460)	3252 (385)

GENERAL DISCUSSION

The principal findings are that: (1) subjects that engaged in cell phone conversations missed twice as many simulated traffic signals as when they were not talking on the cell phone, (2) subjects took longer to react to those signals that they did detect, (3) these deficits were equivalent for both hand-held and hands-free cell phone users, and (4) perceptual memory for words presented at fixation was impaired when subjects were conversing on the cell phone.

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. The impairments to perceptual memory demonstrate that the attention subjects devote to visual objects in driving environment is adversely affected by conversations on a cell phone. Thus, the simulator studies described in this report and the correlational studies of real traffic accidents (e.g., Redelmeier and Tibshirani, 1997) provide converging evidence on the locus of interference.

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 than 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.
- Hawley, K. J., & Johnston, W. A. (1991). Long-term perceptual memory for briefly exposed words as a function of awareness and attention. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 807-815.
- 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.
- Redelmeier, D. A., & Tibshirani, R. J. (1997) Association between cellular-telephone calls and motor vehicle collisions. *The New England Journal of Medicine*, *336*, 453-458.