

Cell-Phone–Induced Driver Distraction

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ABSTRACT—*Our research examined the effects of hands-free cell-phone conversations on simulated driving. We found that even when participants looked directly at objects in the driving environment, they were less likely to create a durable memory of those objects if they were conversing on a cell phone. This pattern was obtained for objects of both high and low relevance, suggesting that very little semantic analysis of the objects occurs outside the restricted focus of attention. Moreover, in-vehicle conversations do not interfere with driving as much as cell-phone conversations do, because drivers are better able to synchronize the processing demands of driving with in-vehicle conversations than with cell-phone conversations. Together, these data support an inattention-blindness interpretation wherein the disruptive effects of cell-phone conversations on driving are due in large part to the diversion of attention from driving to the phone conversation.*

KEYWORDS—*driver distraction; inattention blindness; attention; cell phones*

This article focuses on a dual-task activity that over 100 million drivers in the United States currently engage in: the concurrent use of a cell phone while operating a motor vehicle. It is now well established that cell-phone use significantly impairs driving performance (e.g., McEvoy et al., 2005; Redelmeier & Tibshirani, 1997; Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001). For example, our earlier research found that cell-phone conversations made drivers more likely to miss traffic signals and react more slowly to the signals that they did detect (Strayer & Johnston, 2001). Moreover, equivalent deficits in driving performance were obtained for users of both hand-held and hands-free cell phones (see also Strayer, Drews, & Crouch, 2006). By contrast, listening to radio broadcasts or books on tape did not impair driving. These findings are important because

they demonstrate that listening to verbal material, by itself, is not sufficient to produce the dual-task interference associated with using a cell phone while driving. The data indicate that when a driver becomes involved in a cell-phone conversation, attention is withdrawn from the processing of the information in the driving environment necessary for safe operation of the motor vehicle.

EVIDENCE OF INATTENTION BLINDNESS

The objective of this article is to muster evidence in support of the hypothesis that cell-phone conversations impair driving by inducing a form of inattention blindness in which drivers fail to see objects in their driving environment when they are talking on a cell phone. Our first study examined how cell-phone conversations affect drivers' attention to objects they encounter while driving. We contrasted performance when participants were driving but not conversing (i.e., single-task conditions) with that when participants were driving and conversing on a hands-free cell phone (i.e., dual-task conditions). We used an incidental-recognition-memory paradigm to assess what information in the driving scene participants attended to while driving. The procedure required participants to perform a simulated driving task without the foreknowledge that their memory for objects in the driving scene would be subsequently tested. Later, participants were given a surprise recognition-memory test in which they were shown objects that had been presented while they were driving and were asked to discriminate these objects from foils that had not been in the driving scene. Differences in incidental recognition memory between single- and dual-task conditions provide an estimate of the degree to which attention to visual information in the driving environment is distracted by cell-phone conversations.

Each of the four studies we report here used a computerized driving simulator (made by I-SIM; shown in Fig. 1) with high-resolution displays providing a 180-degree field of view. (The dashboard instrumentation, steering wheel, gas, and brake pedal are from a Ford Crown Victoria sedan with an automatic transmission.) The simulator incorporates vehicle-dynamics,

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Fig. 1. A participant talking on a hands-free cell phone while driving in the simulator.

traffic-scenario, and road-surface software to provide realistic scenes and traffic conditions. We monitored the eye fixations of participants using a video-based eye-tracker (Applied Science Laboratories Model 501) that allows a free range of head and eye movements, thereby affording naturalistic viewing conditions for participants as they negotiated the driving environment.

The dual-task conditions in our studies involved naturalistic conversations with a confederate on a cell phone. To avoid any possible interference from manual components of cell-phone use, participants used a hands-free cell phone that was positioned and adjusted before driving began (see Fig. 1). Additionally, the call was begun before participants began the dual-task scenarios. Thus, any dual-task interference that we observed had to be due to the cell-phone conversation itself, as there was no manual manipulation of the cell phone during the dual-task portions of the study.

Our first study focused on the conditional probability of participants recognizing objects that they had fixated on while driving. This analysis specifically tested for memory of objects presented where a given driver's eyes had been directed. The conditional probability analysis revealed that participants were more than twice as likely to recognize roadway signs encountered in the single-task condition than in the dual-task condition. That is, when we focused our analysis on objects in the driving scene on which participants had fixated, we found significant differences in recognition memory between single- and dual-task conditions. Moreover, our analysis found that even when participants' eyes were directed at objects in the driving environment for the same duration, they were less likely to remember them if they were conversing on a cellular phone. The data are consistent with the inattention-blindness hypothesis: The cell-phone conversation disrupts performance by diverting attention from the external environment associated with the driving task to an engaging context associated with the cell-phone conversation.

Our second study examined the extent to which drivers who engage in cell-phone conversations strategically reallocate attention from the processing of less-relevant information in the driving scene to the cell-phone conversation while continuing to give highest priority to the processing of task-relevant information in the driving scene. If such a reallocation policy were observed, it would suggest that drivers might be able to learn how to safely use cell phones while driving. The procedure was similar to that of the first study except that we used a two-alternative forced-choice recognition-memory paradigm to determine what information in the driving scene participants attended to while driving. We placed 30 objects varying in relevance to safe driving (e.g., pedestrians, cars, trucks, signs, billboards, etc.) along the roadway in the driving scene; another 30 objects were not presented in the driving scene and served as foils in the recognition-memory task. There were different driving scenarios for different participants and target objects for some participants were foil objects for others. Objects in the driving scene were positioned so that they were clearly in view as participants drove past them, and the target and foils were counterbalanced across participants. Here again, participants were not informed about the memory test until after they had completed the driving portions of the study.

As in the first study, we computed the conditional probability of recognizing an object given that participants fixated on it while driving. Like the first study, this analysis specifically tested for memory of objects that were located where the driver's eyes had been directed. We found that participants were more likely to recognize objects encountered in the single-task condition than in the dual-task condition and that this difference was not affected by how long they had fixated on the objects. Thus, when we ensured that participants looked at an object for the same amount of time, we found significant differences in recognition memory between single- and dual-task conditions.

After each forced-choice judgment, participants were also asked to rate the objects in terms of their relevance to safe driving, using a 10-point scale (participants were initially given an example in which a child playing near the road might receive a rating of 9 or 10, whereas a sign documenting that a volunteer group cleans a particular section of the highway might receive a rating of 1). Participants' safety-relevance ratings ranged from 1.5 to 8, with an average of 4.1. A series of regression analyses revealed that there was no association between recognition memory and traffic relevance. In fact, traffic relevance had absolutely no effect on the difference in recognition memory between single- and dual-task conditions, suggesting that the contribution of an object's perceived relevance to recognition-memory performance is negligible. This analysis is important because it indicates that drivers do not strategically reallocate attention from the processing of less-relevant information in the driving scene to the cell-phone conversation while continuing to give highest priority to the processing of task-relevant information in the driving scene.

The studies discussed thus far have relied on explicit-memory measures taken after the driving session to test the hypothesis that cell-phone conversations interfere with the initial encoding of information in the driving scene. However, an alternative possibility is that there are no differences in the initial encoding but rather differences in the retrieval of the information during subsequent memory tests. This distinction is more than academic, because the former has direct implications for traffic safety whereas the latter does not (i.e., failing to recognize an item at a later point in time does not necessarily imply an impairment in encoding and reaction to an object in the driving environment).

Our third study tested the inattention-blindness hypothesis by recording on-line measures of brain activity elicited by events in the driving environment. Prior research has found that the amplitude of the P300 component of the event-related brain potential (ERP) is sensitive to the attention allocated to a task (e.g., Sirevaag, Kramer, Coles, & Donchin, 1989; Wickens, Kramer, Vanasse, & Donchin, 1983) and, further, that memory performance is superior for objects eliciting larger-amplitude P300s during encoding (e.g., Fabiani, Karis, & Donchin, 1986; Otton & Donchin, 2000). Moreover, ERPs recorded in flight simulation revealed that the P300 component discriminates between different levels of task difficulty, decreasing as the task demands increased (e.g., Kramer, Sirevaag, & Braun, 1987; Sirevaag et al., 1993).

In this study, we used a car-following paradigm in which participants drove on a simulated multilane freeway. Participants followed a pace car that would brake at random intervals and ERPs were time-locked to the onset of the pace-car brake lights in both single- and dual-task conditions. If the impairments in memory performance are due to differences in the initial encoding of objects in the driving scene, then P300 amplitude should be smaller in dual-task conditions than in single-task conditions. By contrast, if the memory differences are due to impaired retrieval of information at the time of the recognition-memory test but not at the time of encoding, then we would not expect to find differences in P300 amplitude between single- and dual-task conditions.

The average ERPs are presented in Figure 2. Visual inspection reveals a large positive potential between 250 and 750 milliseconds (the P300 component of the ERP). Our analysis indicated that the amplitude of the P300 component of the ERPs was reduced by 50% when the drivers were talking on the cell phone. Thus, drivers using a cell phone fail to see information in the driving scene because they do not encode it as well as they do when they are not distracted by the cell-phone conversation. These data suggest that drivers using a cell phone will be less able to react with alacrity in situations that demand it because of the diversion of attention from driving to the phone conversation (see also Strayer, Drews, & Johnston, 2003).

Our fourth study contrasted two modes of conversation commonly engaged in while driving: Conversation with a friend via a

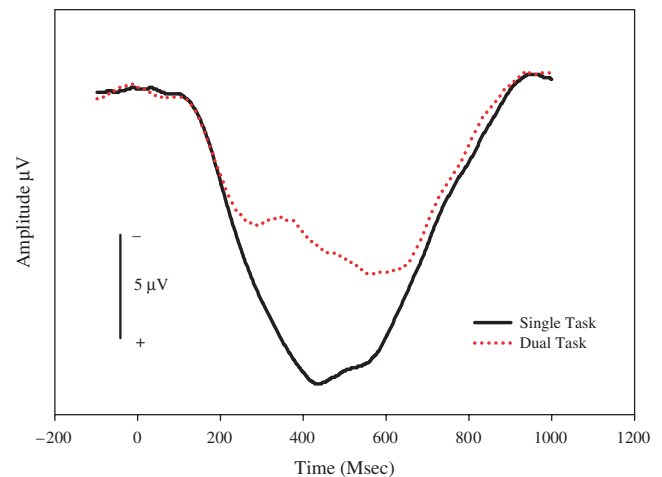


Fig. 2. Event-related potentials (ERPs) elicited by the onset of a pace car's brake light when talking on a cell phone (dual-task condition) and when not talking on a cell phone (single-task condition). The amplitude of the P300 component of the ERP (which is a manifestation of higher cognitive processing such as memory encoding) was reduced by 50% when participants were conversing on a hands-free cell phone.

hands-free cell phone versus conversation with a friend seated in the passenger seat located next to the driver in the vehicle. We hypothesized that these two conversations would differ because passengers tend to adjust their conversation based on driving difficulty; often helping the driver to navigate and identify hazards on the roadway and pausing the conversations during difficult sections of the drive. By contrast, this real-time adjustment based upon traffic demands is not possible with cell-phone conversations.

Participants were instructed to drive on a multilane freeway and exit at a rest stop approximately 8 miles down the road. We found that the majority of drivers (88%) who were conversing with a passenger successfully completed the task of navigating to the rest area, whereas 50% of the drivers talking on a cell phone failed to navigate to the rest area. Analysis of the video recordings indicated that a primary difference between these two modes of communication was that the passenger helped the driver in the navigation task by reminding them to exit at the rest stop. Moreover, our analysis of the content of the conversation indicated that references to traffic conditions were more likely with passenger conversations than they were with cell-phone conversations.

THEORETICAL CONSIDERATIONS AND FUTURE DIRECTIONS

What are the implications of these findings for the architecture of cognition? Multiple-resource models of dual-task performance (e.g., Wickens, 1984) have been interpreted as suggesting that an auditory/verbal/vocal cell-phone conversation may be performed concurrently with little or no cost to a visual/spatial/manual driving task. That is, given the apparent lack of overlap

in processing resources, the cell phone and driving dual-task combination should be performed with little degradation in performance. However, given the clear and consistent interference between cell-phone and driving tasks, it would appear that multiple-resource models do not apply well to this dual-task combination.

One alternative possibility that we are currently exploring is that the dual-task interference stems from a central-processing bottleneck, wherein attending to the cell-phone conversation temporarily blocks or impedes the processing of information in the driving environment (cf. Levy, Pashler, & Boer, 2006). We hypothesize that the central-processing bottleneck forces serial processing of these two sources of information (i.e., the information necessary for the safe operation of a motor vehicle and the cell-phone conversation) and that the cell-phone conversation may not lend itself to parsing in ways that are compatible with driving (cf. Strayer & Johnston, 2001). That is, a conversation on the phone cannot be successfully broken into arbitrary units, but instead is composed of “turns” that engage the central-processing bottleneck for prolonged periods of time (e.g., pausing in mid-sentence/thought impedes the flow of the conversation); moreover, this turn-taking is often asynchronous with the processing demands of driving. Supporting this idea is the observation that in-vehicle conversations do not interfere with driving as much as cell-phone conversations do because there is a greater ability to synchronize an in-vehicle conversation with the processing demands of driving than there is with a cell-phone conversation.

The findings reported here highlight the need for sharpening our theoretical understanding of multitasking in complex naturalistic environments. The usefulness of such theory increases with the ever-increasing prevalence of new technologies allowing people to engage in concurrent activities. Theory development will improve our ability to determine why some tasks are successfully performed in combination whereas others are incompatible.

In sum, the data indicate that cell-phone conversations place demands upon the driver that differ qualitatively from those of other auditory/verbal/vocal tasks commonly performed while operating a motor vehicle. Even when cell-phone drivers direct their gaze at objects in the driving environment, they often fail to “see” them because attention has been diverted to the cell-phone conversation.

Recommended Reading

- Redelmeier, D.A., & Tibshirani, R.J. (1997). (See References)
 Strayer, D.L., & Johnston, W.A. (2001). (See References)
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REFERENCES

- Fabiani, M., Karis, D., & Donchin, E. (1986). P300 and recall in an incidental memory paradigm. *Psychophysiology*, *23*, 298–308.
- Kramer, A.F., Sirevaag, E.J., & Braun, R. (1987). A psychophysiological assessment of operator workload during simulated flight missions. *Human Factors*, *29*, 145–160.
- Levy, J., Pashler, H., & Boer, E. (2006). Central interference in driving: Is there any stopping the psychological refractory period? *Psychological Sciences*, *17*, 228–235.
- McEvoy, S.P., Stevenson, M.R., McCartt, A.T., Woodward, M., Haworth, C., Palamara, P., & Cercarelli, R. (2005). Role of mobile phones in motor vehicle crashes resulting in hospital attendance: A case-crossover study. *British Medical Journal*, *331*, 428–433.
- Ottom, L.J., & Donchin, E. (2000). Relationship between P300 amplitude and subsequent recall for distinctive events: Dependence on type of distinctiveness attribute. *Psychophysiology*, *37*, 644–661.
- 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.
- Sirevaag, E.J., Kramer, A.F., Coles, M.G.H., & Donchin, E. (1989). Recourse reciprocity: An event-related brain potential analysis. *Acta Psychologica*, *70*, 77–97.
- Sirevaag, E.J., Kramer, A.F., Wickens, C.D., Reisweber, M., Strayer, D.L., & Grenell, J.H. (1993). Assessment of pilot performance and mental workload in rotary wing aircraft. *Ergonomics*, *9*, 1121–1140.
- Strayer, D.L., Drews, F.A., & Crouch, D.J. (2006). Comparing the cell-phone driver and the drunk driver. *Human Factors*, *48*, 381–391.
- 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.
- Wickens, C.D. (1984). Processing resources in attention. In R. Parasuraman & R. Davies (Eds.), *Varieties of Attention*. (pp. 63–101). New York: Academic Press.
- Wickens, C.D., Kramer, A.F., Vanasse, L., & Donchin, E. (1983). Performance of concurrent tasks: A psycho-physiological assessment of the reciprocity of information-processing resources. *Science*, *221*, 1080–1082.