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Passenger and Cell Phone Conversations in Simulated Driving

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This study examines how conversing with passengers in a vehicle differs from conversing on a cell phone while driving. We compared how well drivers were able to deal with the demands of driving when conversing on a cell phone, conversing with a passenger, and when driving without any distraction. In the conversation conditions, participants were instructed to converse with a friend about past experiences in which their life was threatened. The results show that the number of driving errors was highest in the cell phone condition; in passenger conversations more references were made to traffic, and the production rate of the driver and the complexity of speech of both interlocutors dropped in response to an increase in the demand of the traffic. The results indicate that passenger conversations differ from cell phone conversations because the surrounding traffic not only becomes a topic of the conversation, helping driver and passenger to share situation awareness, but the driving condition also has a direct influence on the complexity of the conversation, thereby mitigating the potential negative effects of a conversation on driving.

Keywords: shared attention, driver distraction, cell phone conversation, passenger conversation

Driving is a complex perceptual and cognitive task. There is ample evidence that driving performance is negatively affected by simultaneously conversing on a cell phone. Previous studies found that cell phone use impairs the driving performance of younger (Alm & Nilsson, 1995; Briem & Hedman, 1995; Brookhuis, De Vries, & De Waard, 1991; Brown, Tickner, & Simmonds, 1969; Goodman et al., 1999; McKnight & McKnight, 1993; Redelmeier & Tibshirani, 1997; Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001), and older drivers (Alm & Nilsson, 1995; Strayer et al., 2003). These impairments have been studied using a wide range of methodological paradigms including computer-based tracking tasks (Strayer & Johnston, 2001), high-fidelity simulation (Strayer et al., 2003), driving of vehicles on a closed circuit (Treffner & Barrett, 2005), on-road studies (Crudall, Bains, Chapman, & Underwood, 2005), and epidemiological studies of car crashes (McEvoy et al., 2005; Redelmeier & Tibshirani, 1997). The level of impairment is comparable to being intoxicated at a blood alcohol level of .08 (Strayer, Drews, & Crouch, 2006).

Considering Distracted Driving Impairment With Greater Specificity

To understand the implications of performing a secondary task while driving, it is useful to apply a conceptualization of the

driving task that can guide the analysis of performance deficits. In his task analysis of driving, Groeger (1999) described three levels of performance (see Michon, 1979, 1985, for similar proposals). The first level of performance is an *operational* or control level, which involves elements that serve the task of keeping a vehicle on a predetermined course. A deficit at this level is shown, for example, in a reduction of lateral control, that is, the vehicle may drift to the side of the road. A number of studies demonstrated that this operational level is negatively affected by performing an additional task like conversing on a cell phone (Alm & Nilsson, 1995; Haigney & Westerman, 2001; Stein, Parseghian, & Allen, 1987).

The second level of performance involves skills needed for maneuvering the vehicle in traffic. This level is called *tactical* behavior and examples for deficits at this level are approaching other vehicles too closely or ignoring approaching vehicles while turning left at an intersection. Studies that have found deficits on this level of driving performance describe changes in speed (Burns, Parkes, Burton, & Smith, 2002; Horberry, Anderson, Regan, Triggs, & Brown, 2006), changes in acceleration (Strayer & Drews, 2006), and delayed reaction times (Consiglio, Driscoll, Witte, & Berg, 2003) when drivers are engaged in a cell phone conversation. The characterization of driving behavior as “sluggish” (Strayer et al., 2003) refers to both operational and tactical levels of driving behavior with driving performance changing such that drivers drive and accelerate slower and show longer reaction times when braking (see Drews & Strayer, 2008; Svenson & Patten, 2005, for reviews).

The third level involves more executive, goal-directed aspects of driving and reflects *strategic* performance (Barkley, 2004). Examples for problems at this level are failures in the execution of navigation tasks or trip-related planning tasks. Currently, there is only indirect evidence that deficits on this level can be observed when drivers converse on a cell phone. In their simulator study Ma and Kaber (2005) measured situation awareness—a precondition

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for strategic performance—of drivers conversing on a cell phone while driving compared to a group using an adaptive cruise control system. The authors found that the use of a cell phone while driving significantly reduced driver situation awareness and significantly increased the perceived mental workload relative to no phone and adaptive cruise control conditions. The application of Groeger's (1999) framework highlights a gap of empirical work investigating the strategic level of performance of drivers engaged in a cell phone conversation. Thus, at this point it is unclear if the deficits observed on the operational and tactical level also extend to the strategic level, or if this level of performance is unaffected by a cell phone conversation. Based on the assumptions of Michon (1979, 1985), lower level deficits ought to affect higher level performance, and we would expect the suggestive findings of Ma and Kaber to be evident in a task that is more representative of typical driving.

Allocation of Attention and the Distracted Driver

Most work on driver distraction focused on the assessment of the impairment rather than on a delineation of the cognitive mechanisms underlying deficits in driving performance. The small number of studies that has focused on this theoretically important question point to a reduction in attention directed toward the driving task as partly responsible for the deficits. Strayer et al. (2003) examined the hypothesis that the observed impairment could be attributed to a withdrawal of attention from the visual scene resulting in a form of inattention blindness (i.e., a fixated object is not being processed resulting in either an incomplete or no mental representation of the object). Their findings indicated that cell phone conversations impaired both implicit and explicit recognition memory of visual information even when participants had fixated upon it. Strayer et al. suggested that the impairment of driving performance resulting from cell phone conversations is mediated, at least in part, by reduced attention to visual inputs in the driving environment. More evidence was presented recently by Strayer and Drews (2007) demonstrating a reduction in the amplitude of the P300 as a result of a cell phone conversation in response to the onset of braking lights of a car that had to be followed. The P300 component of event-related brain potentials (ERP) is sensitive to the attention that is allocated to a task (Sirevaag, Kramer, Coles, & Donchin, 1989), and has been shown to allow discrimination between levels of task difficulty, decreasing as the task demand increases (Kramer, Sirevaag, & Braun, 1987). Finally, more evidence for deficits in allocation of attention comes from investigations of scanning behavior of traffic scenes. McCarley et al. (2004) showed that conversations result in higher error rates for change detection and higher numbers of saccades to locate a changing item. The authors also found reduced fixation times under dual-task conditions and interpret this as evidence that a conversation while scanning traffic scenes impacts the peripheral guidance of attention.

To summarize, the allocation of attention to the driving task is central to the issues related to driving performance deficits observed in the context of cell phone use. Thus, the literature appears to suggest that nearly any task that diverts attention away from the driving task will cause impairment. Indeed, supporting this assertion are epidemiological studies (see McEvoy et al., 2005; Redelmeier & Tibshirani, 1997) that indicate that the relative risk of

being in a motor vehicle accident quadruples when a driver converses on a cell phone (i.e., odds ratio of an accident when conversing on a cell phone is 4.2). By contrast, other epidemiological studies (Rueda-Domingo et al., 2004; see also Vollrath, Meilinger & Krüger, 2002) have found a strikingly different pattern for situations in which an adult passenger is in the vehicle. In particular, when drivers have a passenger in the vehicle, the relative risk of a motor vehicle accident is lower than when the driver drives by him or her self (i.e., the odds ratio of an accident with a passenger in the vehicle is 0.7). Given that in many instances the passenger and the driver are conversing, these findings appear to be at odds with the suggestion that any task that diverts attention away from driving causes impairment. What accounts for the seemingly paradoxical finding that a conversation on a cell phone interferes with driving, whereas having a conversation with a passenger in the vehicle improves driving performance? Are differences in the allocation of attention partly responsible for these differences?

How passenger and cell phone conversations differ in their implications for attention and driving performance is a question of theoretical and applied importance. It is of theoretical importance because a comparison between cell phone and passenger conversation revolves around the similarities or differences between the two contexts' impact on the attentional resources of a driver. In this paper we suggest that the different contexts affect the ability to allocate attention to a task differently, that is, the allocation of attention is not independent of contextual variables, even if the task at the onset seems identical. The question is also of applied importance because it may help to understand better what contexts have an impact on a driver's ability to allocate attention to the task of driving.

Conversing

From one vantage point a conversation is a conversation. Conversations require attention from their participants for monitoring the topic and content, coordinating turn taking, and so on (Clark, 1996). Thus, all conversations are presumably diverting attention from a driving task and should create at least some impairment.

An alternative perspective, drawn from psycholinguistics, emphasizes conversations as joint activities that involve shared attention from all participants, and as dynamic activities that unfold over time (Clark, 1996). This perspective emphasizes that participants in a conversation move forward in the joint activity of conversing by adding to their shared understandings of what is being talked about. This process is called *grounding* (Clark & Schaefer, 1989) and it involves establishing that all parties in a conversation share relevant knowledge, beliefs, and assumptions. It also includes awareness of the current context that provides many cues that can aid in grounding, such as shared visual attention (Richardson, Dale, & Kirkham, 2007) and shared awareness of distractions. The critical difference between a cell phone conversation and an in-vehicle conversation revolves around this shared awareness of the driving context. That shared awareness leads to the prediction that in-vehicle conversation will not have the same detrimental impact on driving performance that cell phone conversations have. It also opens the possibility for in-vehicle conversation to have a positive impact on driving performance, as is suggested by epidemiological data. Moreover, in

pointing to conversation as a joint activity unfolding over time, it suggests two nonexclusive proposals about how conversations affect the allocation of the driver's attention to the driving task. One is simply that an in-vehicle passenger responds to the demands of the driving context by reducing demand for the conversation task (e.g., by changing the production rate—a modulation hypothesis, see Gugerty, Rakauskas, & Brooks, 2004). The second is that the passenger adopts the driving task as part of the overall joint activity in which driver and passenger are mutually engaged. In both cases, the assumption is that this is not likely or possible for a cell phone conversational partner because they do not have direct access to the real-time driving conditions.

Another point about this perspective on conversation bears mention, and it is that many tasks employed to simulate conversation in studies of cell phone use while driving suffer from serious ecological validity concerns. Some investigators used putative conversations in which the participants and a confederate alternately generated a word and the other person had to generate a word that began with the last letter of the previous spoken word (Gugerty et al., 2004). Treffner and Barrett (2004) had participants perform summations or categorizations. Others identified topics of interest for the participant by questionnaire and had an experimenter converse with the participant about such topics (Strayer et al., 2003). These approaches are limited because they fail, to a larger or smaller extent, to mimic the coordinated, joint activity features of naturalistic conversations. In a meta-analysis, Horrey and Wickens (2006) found that more naturalistic conversations produced greater interference with driving than did more "synthetic" information processing tasks, suggesting a greater engagement for the former. Although not a central aim of this study, we made a serious effort to develop a conversational task that was truly applicable to the applied context. Following Bavelas, Coates, and Johnson (2000), close-call stories as the topic of the conversation were used in studying the impact of conversations on driving. Bavelas et al. defined close-call stories as stories about times when your life was threatened. The advantage of using such close-call conversations is that they involve the kinds of stories that are often told among friends and produce a conversation that is engaging. In addition, unlike in other studies in which at least one of the partners of the conversation was a confederate, we asked participants to bring friends with the intention of having them converse about previously untold close-call stories.

Few authors have studied how passenger conversations affect driving performance. In their on road study, Crundall et al. (2005) provided initial evidence that passenger and driver responded to changes in the cognitive demand of driving when playing a "competitive [word] game between driver and the partner" (Crundall et al., 2005, p. 201) that simulated a conversation. For example, passenger conversations were suppressed during more demanding urban driving and there was no impact of the driving context on the conversation during cell phone conversations. It appears as if the cell phone task imposed a cognitive load independent of the cognitive demand resulting from the driving conditions, making it likely that the driver's cognitive limits were exceeded.

Gugerty et al. (2004) investigated the impact of passenger conversations on driving performance in a low-fidelity driving simulator. To simulate a conversation the authors used a word game task in which the participants took turns saying words with the constraint that a new word had to begin with the last letter of

the word spoken by the partner. Gugerty et al. tested driving performance by assessing the driver's situation awareness for the surrounding traffic but also measured performance on the verbal task. Overall there was no evidence that passengers slowed the verbal task more than remotely communicating participants, and in Experiment 1 the opposite effect was found, despite the fact that only the passengers shared visual information about the driving conditions. Also, the verbal interaction negatively affected situation awareness in both the passenger and the cell phone condition, equally impacting a precursor for strategic performance.

More interesting, Amado and Ulupinar (2005) reported a negative impact of passenger conversation on a driving surrogate: The authors compared the impact of a hands-free cell phone conversation, a passenger conversation, and a control condition on attention in a peripheral detection task that simulated driving. To simulate the cognitive demand of a conversation, the authors asked participants questions of low or high complexity. Both simulated conversation conditions had a similar negative impact on performance in a peripheral detection task as compared to the control condition. The lack of a difference between the cell phone conversation condition and the passenger conversation condition is notable. One potential reason for the absence of a difference is that in this study the conversation pace was kept constant artificially not allowing for modulation. Moreover, the perceptual detection task is much less complex than the driving task, indicating data limits in this study.

The limited literature on cell phone and passenger conversations suggests that modulation (i.e., slowing) of a conversation is possible, and may occur under natural driving conditions. However, one of the problems of the existing studies is that the conversations were highly scripted and often simulated only the cognitive demand of a conversation. Driving performance seems to be affected by passenger conversations by reduced situation awareness and a reduction in the ability to detect peripheral objects. It appears that there is no difference between passenger conversations compared to remote conversations in their negative impact on driving performance.

In the present paper we examined the impact of cell phone and passenger conversations on driving performance, applying Groeger's (1999) conceptualization to guide the operationalization of driving. Consequently, we used measures of driving performance that reflect the operational, the tactical, and the strategic level of driving behavior. In addition, we examined features of the conversation that shed light on how conversations on cell phones and conversations with a passenger differ in ways that bear on attention allocation. We hypothesize that a passenger—provided he or she has at least minimal driving expertise—monitors the driving environment. Consequently, when a driver faces an increasing demand of the driving task, both passenger and driver may respond by reducing the cognitive demand of the conversation. These changes can manifest themselves in switching the topic of the conversation to the driving conditions and the surrounding traffic (e.g., by pointing out potential hazards) that directs the driver's attention toward the surrounding traffic. Also, it is possible that a reduction of the production rate of speech or its complexity reflects a response to increases in the cognitive demand for the driver.

In sum, the goal of this research is to increase our understanding of how conversing on a cell phone while driving compares with

conversing with a passenger while driving. This research uses naturalistic conversations and measures driving performance at the operational, tactical, and strategic levels, and also focuses on measures that reflect changes in the dynamics of the conversation.

Method

Participants

Ninety six adults were recruited in a total of 48 friend dyads and received course credit for participation. Participants ranged in age from 18 to 49 with 20 being the average age. Forty-seven participants were women and 49 participants were men. All participants had normal or corrected-to-normal visual acuity, normal color vision (Ishihara, 1993), and a valid Utah driver's license.

Stimuli and Apparatus

A PatrolSim™ high-fidelity driving simulator, manufactured by L3 Communications I-Sim (Salt Lake City, UT, USA) was used in the present study (see Figure 1). The simulated vehicle is based on the vehicle dynamics of a Crown Victoria® model with automatic transition built by the Ford Motor Company.

A freeway road database simulated a 24-mile multilane beltway with on- and off-ramps, overpasses, and two-lane traffic in each direction. Participants were driving under an *irregular-flow* driving condition (Drews, Strayer, Uchino, & Smith, in press). The irregular-flow driving condition can be characterized as a situation in which other vehicles, in compliance with traffic laws, changed lanes and speeds. This traffic requires the participant to pay attention to the surrounding traffic as opposed to a situation in which the driver can minimize the attentional requirements and the cognitive demand by driving exclusively in one lane of travel. In addition, slow-moving vehicles were sometimes unsuccessfully attempting to pass vehicles on the left side, significantly slowing

down the overall traffic flow. The speed limit was 65 mph. Visibility in all scenarios was optimal.

Procedure

After providing informed consent, participants were familiarized with the driving simulator using a standardized 15-min adaptation sequence. The adaptation sequence consisted of three 5-min driving scenarios, one being located in a rural area at night, another one located in a downtown area, involving some minimal navigation around traffic barricades, and a final scenario located on a highway with optimal driving conditions at daytime. After familiarization, one participant of a dyad was randomly selected to drive the vehicle, the other, based on experimental condition, was either the passenger or talking on the cell phone to the driver from a different location. The assignment of speaker and listener was counterbalanced over driver and nondriving interlocutor, and the speaker provided the close-call story. Participants were instructed to provide a story they had not shared with the partner in the past. In the single-task condition, the driver was instructed to drive safely and to follow all the traffic rules. In addition, in the dual-task condition they were instructed that their task was having a conversation about a close-call story with their friend who was either seated next to them as a passenger or conversing on a cell phone. Finally, the drivers were instructed to leave the highway once they arrived at a rest area located approximately eight miles after the beginning of the drive. The passenger/cell phone interlocutor was instructed to participate actively in the conversation and told that the driver had the task of leaving the highway when approaching a rest area. In the dual-task portion of the experiment, half of the driving participants were either conversing on a cell phone or talking to a passenger while driving; in the single-task condition, participants were driving only. The order of the single and dual-task conditions was counterbalanced and the assignment to cell phone and in-person conversation was randomized. The individual driving sequences (single/dual task) took about 10 min to finish. The entire experiment took approximately 60 min to completion.

Measures

Driving performance. Multiple measures of driving performance were taken, distinguishing between measures dealing with the operational level, the tactical level, and those reflecting more strategic processes involved in driving. A measure of the operational level was how well participants stayed in the center of the lane without lateral movements and drifting. For this purpose, we defined the lane center of the road and calculated the root mean standard error (RMSE) between center and the center position of the car. On the tactical level, we analyzed speed and following distance. Speed was measured as the average speed of the driver for the road segment they were driving until they reached the rest area exit, whereas following distance was measured as the average distance between the driver's car and a car that was directly ahead of them. On the strategic level of performance we were interested in participants' ability to follow the instruction of a navigation task—more specifically—did they take the correct exit?

Conversation. The transcribed conversations between interlocutors in the dual-task conditions were coded by two independent

Navigation task

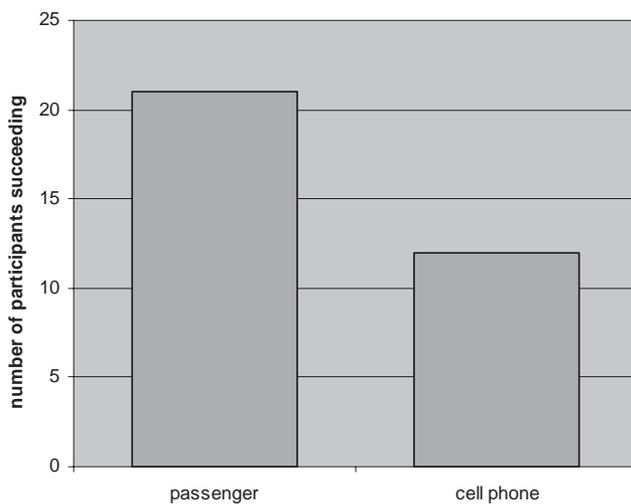


Figure 1. Frequency of successful task completion in the navigation task.

coders. Though the instruction for participants was for one person to tell a story about close calls, in all cases after a short time both participants were lively engaged in the conversation. The coding of the conversations focused on the number of references to traffic, intercoder-reliability Pearson's $r(47) = .92$; who initiated the reference (driver and nondriver; Cohen's $\kappa(47) = 1$), and the number of turn takes with reference to the traffic event after a reference to traffic was made, intercoder-reliability Pearson's $r(47) = .98$. All conversations were analyzed from transcripts of the conversations by trained coders who were blind to the condition under which the conversation took place.

The rationale for analyzing traffic references was that referring to the surrounding traffic is an attempt to create shared situation awareness and indicates support for the driving task. The number of turn takes after a reference to traffic was made was analyzed because it is a reflection of the willingness of both partners to engage in a conversation about traffic rather than the close-call story. Included in this analysis were only turn takes with statements about the event that provoked the initial traffic reference.

A second analysis focused on the impact of the driving environment. Because the impact on driving has been well documented in the past (e.g., Brookhuis et al., 1991) this analysis focuses on the impact of traffic complexity on the conversation. For this purpose two independent coders coded the traffic as low or moderately demanding, intercoder-reliability Cohen's $\kappa(47) = .98$. Low demanding traffic was defined as a situation in which the participant's vehicle was surrounded by maximally one vehicle (either in front, behind, or on the left lane), in which a situation of moderately demanding traffic involved more than one other vehicle in close proximity to the participant's vehicle. For both types of driving situations, the speech production rate of the driver and the interlocutor in syllables per second was analyzed. The production rate of the driver and the passenger in this context reflects the degree to which the cognitive demand imposed by the traffic context has an impact on the conversation, potentially leading to some modulation of the conversation (see Berthold, 1998; Müller, Großmann-Hutter, Jameson, Rummer, & Wittig, 2001). As an additional measure, the number of syllables per word for the driver and the interlocutor was analyzed. The number of syllables per word is thought to measure the complexity of an utterance (Berthold, 1998). Production rate and complexity of utterance are used to test the hypothesis that both conversation partners in the passenger condition adjust their conversation in response to changes in the cognitive demand of the traffic imposed on the

driver, reflecting implicit collaboration on the driving task (see Crundall et al., 2005). Due to the lack of situation awareness of the interlocutor on a cell phone, modulation is unlikely in the cell phone condition.

Design

The design of the study was a between-subject design with dual-task condition (cell phone vs. passenger conversation) as a between-subjects factor. Each participant's driving performance was also assessed in the single-task condition (driving only). To control for any between-subject variability we analyzed driving behavior using the difference scores between single- and dual-task performance for each participant.

Results

Driving Performance

The following analyses of driving performance include data from 41 dyads (21 passenger conversation) due to technical problems with data collection in the driving simulator. Counterbalancing of the task order for both conditions was not affected by this data loss, because these dyads had identical task sequences. All of the following driving performance analyses that compare the cell phone and passenger conversation use difference scores between the single- and dual-task condition for each participant, thus reflecting the difference in impact of the two dual-task conditions. The use of difference scores was indicated because the initial analyses revealed some minor differences in single-task driving performance between groups (see Table 1). Analyses of the demographic variables revealed that the average age of driving participants in the cell phone condition was 19.6 years (range 18 to 23) and in the passenger condition was 20.1 years (range 18 to 26). In the cell phone condition, 10 female and 10 male drivers participated, whereas in the passenger conversation condition, 11 female and 10 male drivers participated. Thus, it is possible that the initial differences in driving performance as reported in Table 1 can be attributed to slight differences in driving experience.

Operational level of driving performance. The first analysis focused on the drivers' ability to stay in the center of the lane without drifting sideways. Focusing on the RMSE between actual vehicle position and center of the lane, we analyzed the differences between cell phone and passenger conversation condition using a

Table 1
Means and Standard Deviations for Lane Keeping, Driving Speed, and Distance for Both Experimental Conditions and Single and Dual Task

	Passenger		Cell phone	
	Single task	Dual task	Single task	Dual task
	<i>M</i> (<i>SD</i>)			
Lane keeping (RMSE)	0.4 (0.8)	0.4 (1.0)	0.5 (0.5)	1.0 (0.9)
Mean speed (mph)	63.8 (4.2)	63.9 (3.8)	65.8 (3.5)	65.9 (3.7)
Mean distance (meters)	72.3 (27.4)	62.1 (21.0)	63.9 (17.8)	85.3 (47.0)

Note. RMSE = root mean standard error; mph = miles per hour.

t test. The analysis revealed a significant difference between conditions, $t(39) = -2.1$, $p < .05$, Cohen's $d = 0.7$, with drivers showing a more pronounced tendency to drift during cell phone conversations compared to the passenger conversation condition (see Table 1).

Tactical level of driving performance. We used a *t* test identical to the one described above to analyze the differences for average speed. The analyses revealed no changes in driving speed, $t(39) < .1$ in both conditions (see Table 1).

The next analysis focused on the distance drivers kept between their own vehicle and vehicles ahead of them. The *t* test revealed a significant difference between the two conditions, $t(39) = 2.4$, $p < .05$, Cohen's $d = 0.8$, with following distance being greater in the cell phone condition (see Table 1).

Strategic level of driving performance: Navigation. The last part of the analysis of driving performance focused on behavior on the strategic level (i.e., successfully accomplishing the driving task by exiting the highway at the rest area). Figure 2 shows the number of participants who finished the task successfully. Analyzing task completion for cell phone conversation and passenger conversation condition revealed a difference between the two conditions, $\chi^2(1, N = 40) = 7.9$, $p < .05$, $w = 0.6$: drivers in the cell phone condition were four times more likely to fail task completion than drivers in the passenger condition.

Conversation

References to traffic and turn taking. The transcripts of the conversations were analyzed for references to traffic and number of turns taken following an initial traffic reference that still centered on the traffic topic. The latter indicates the extent to which the driving task became a conversational topic in its own right, temporarily superseding the close-call stories. The number of traffic references in the passenger conversation condition and the cell phone conversation condition are shown in Table 2. Clearly, fewer references to traffic were made in the cell phone condition, $t(46) = 3.0$, $p < .01$, Cohen's $d = 0.9$.

To determine who initiated the reference to traffic, we analyzed the number of initializations made in the cell phone conversation

Table 2

Means and Standard Deviations of References to Traffic and Turns for Both Experimental Conditions

	Passenger	Cell phone
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
References	3.8 (2.4)	2.1 (1.6)
Turns at speech	19.2 (13.8)	8.6 (6.7)

condition and the passenger conversing condition using *t* tests. The number of references by the driver did not differ, $t(46) = 1.7$, $p > .1$, although there was a reliable difference in the number of references initiated by the nondriving interlocutor, $t(46) = 2.4$, $p < .05$, Cohen's $d = 0.7$; with fewer references initiated in the cell phone condition.

The next analysis focused on the number of turns between the interlocutors who continued conversing about traffic after an initial reference to traffic was made. The number of turns for both conditions is shown in Table 2. Overall more than twice as many turns occurred in the passenger condition as compared to the cell phone condition, $t(46) = 3.4$, $p < .01$, Cohen's $d = 1.0$.

Production rate and complexity of speech. The final analyses focused on the production rate of the driver and interlocutor and the complexity of their speech (see Table 3) as a function of the demand of the driving conditions. Because driving condition (low and moderate demand) is added to the analyses as independent variable analyses of variance (ANOVA) were performed. In moderately demanding driving conditions, the production rate of the driver decreased when talking to a passenger but increased when talking on a cell phone as indicated by a significant interaction between driving condition and conversation condition, $F(1, 39) = 4.3$, $p < .05$, partial $\eta^2 = 0.1$. No differences were observed in the nondriving interlocutors production rates for conversation condition, demand, and the interaction (the *F* values for the main effects and the interaction were all $< .16$ and effect sizes, partial $\eta^2 < .03$). Analyzing the complexity of speech indicated that both driver, $F(1, 43) = 5.5$, $p < .05$, partial $\eta^2 = 0.1$ and interlocutor, $F(1, 43) = 4.8$; $p < .05$; partial $\eta^2 = 0.1$, responded to an increase in the cognitive demand of driving by reducing the number of syllables per word. Neither the main effect of conversation condition nor the interaction reached significance.

Discussion

The present study investigated how conversing with a passenger differs from talking on a hands-free cell phone in terms of its impact on driving performance at the operational, tactical, and strategic level and how the dynamics of the conversations are affected by contextual factors elicited by the driving task.

Michon (1979, 1985) suggested that lower level deficits of driving behavior ought to affect higher level performance. The present study provides evidence in support of this hypothesis under dual-tasking conditions. For the cell phone condition, the data suggest that deficits on lower levels of driving behavior also are present (though in different form) at higher levels. For example, drivers conversing on a cell phone showed more lane keeping variability (operational level) than participants conversing with a passenger.



Figure 2. Participant talking on a cell phone in the I-Sim driving simulator.

Table 3
Means and Standard Deviations for Production and Complexity for Driver and Passenger in Both Experimental Conditions and Low Demand and Moderate Demand Driving Scenarios

		Passenger		Cell phone	
		Low demand	Moderate demand	Low demand	Moderate demand
		<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Driver	Production ^a	4.1 (1.0)	3.6 (1.0)	3.8 (0.9)	4.2 (1.8)
	Complexity ^b	1.3 (0.2)	1.1 (0.3)	1.2 (0.1)	1.0 (0.4)
Passenger	Production ^a	3.7 (1.6)	4.0 (1.2)	3.8 (1.4)	3.6 (0.9)
	Complexity ^b	1.2 (0.1)	1.1 (0.3)	1.3 (0.2)	1.1 (0.4)

^a Given in syllable per second. ^b Given in syllable per word.

Similarly, on the tactical level, cell phone drivers do differ from participants in the passenger condition on some measures (e.g., changes in following distance). However, no changes in driving speed were observed in the dual-task condition, seemingly at odds with previous findings of slower driving cell phone drivers (e.g., Strayer & Drews, 2007; Strayer et al., 2003). One explanation for this discrepancy could be procedural differences, with studies demonstrating slower driving speed using a car following paradigm as opposed to the free driving paradigm that was used here.

On the strategic level of performance, cell phone drivers performed poorly at the navigation task. Two nonmutually exclusive explanations can be provided for this deficit: First, drivers conversing on a cell phone may experience problems with keeping the intention of exiting at the rest area in working memory, or second, drivers may not sufficiently process information from the driving environment (exit signs). Some support for the latter hypothesis comes from studies demonstrating inattention blindness in cell phone drivers (Strayer et al., 2003). The performance of participants in the passenger conversation condition indicates that these drivers may have paid more attention to the navigation task, partly due to the passenger. Indeed, examination of the video taped driving segments found several instances in which the passenger helped the driver navigate to the rest area.

Overall, the study clearly documents that relative to a driving only condition, cell phone use negatively impacts lane keeping, increases the headway and leads to an impairment in a navigation task while passenger conversations have only little effect on all of the three measures.

Contrary to prior suggestions (e.g., Crundall et al., 2005; Gugerty, Rando, Rakauskas, Brooks, & Olson, 2003), we did not find evidence that in-vehicle drivers and passengers were better able to modulate their production speed to match changes in the complexity of the driving task. Instead, we found some evidence of modulation of the complexity of speech, indicated by syllables-per-word, in response to the demand of the driving task. Thus, the present findings suggest a process of modulation, but this process is not tied to production rate as it is in the original proposal of Gugerty et al. (2003). Contrary to Gugerty et al. this study reports an increase in performance on the strategic level in the passenger condition, which should not have been observed if situation awareness had been negatively affected in both conversation conditions. Also, quite surprisingly drivers conversing on the cell phone increased their production rate when talking on the cell phone,

which is contrary to the predictions of the modulation hypothesis. More interesting, this happened even as those drivers in the passenger condition tended to reduce their production rate.

Some of the differences in findings may be explained by important methodological differences related to the study of conversation behavior in the context of driving. To realistically measure the impact of a conversation on driving performance, tasks that are not conversation tasks but traditional information processing tasks may miss central compensatory mechanisms of conversations, thus underestimating a conversations complex nature. Also, the use of low-fidelity simulations in passenger conversations may have a significant impact on the process of grounding in a conversation, thereby not reflecting a conversation's context that is central for processes of allocation of attention. One issue in naturalistic conversation revolves around managing turn-taking—and these differential changes in production rates for drivers, changes that depended on the nature of the conversation—may reflect differences in how participants attempted to manage turn-taking. Drivers on cell phones may have attempted to dominate the conversation to avoid having to engage in speech comprehension, whereas with in-vehicle partners, it may be easier to relinquish control, given that the partner can be relied on to accommodate with his or her contributions.

The conversation data suggest that passengers take an active role in supporting the driver as indicated by passengers more frequently talking about the surrounding traffic. It seems likely that a passenger supports the driver by directing attention to the surrounding traffic when perceived necessary. As mentioned above, this conclusion is also supported by the analysis of the video recordings (in some cases passengers mentioned the exit sign or pointed to the exit). Thus, the higher driving performance in the passenger condition is due in part to the shared situation awareness between driver and passenger due to grounding. This interpretation is also supported by the reliable difference in traffic references initiated by the passenger and the cell phone interlocutor.

In addition, the results provide evidence for even more subtle support between interlocutors. In both dual-task conditions, there is evidence that interlocutors respond to an increase in the cognitive demand from the driving context by reducing the complexity of their utterances. This difference seems to be driven by changes in the complexity of utterances by the driver because the conversation partner on the cell phone cannot be aware of changes in the driving environment.

The results also draw an intriguing picture about the allocation of attention under dual-tasking conditions: Two similar situations with identical tasks and instructions lead to fundamentally different performance outcomes indicating that contextual variables can have a significant impact on overall performance.

The present findings are of theoretical and applied importance. On the theoretical side they raise general questions about how much current models of attention predict performance of dyads or groups in complex environments with regard to the allocation of attention (see Cooke, Salas, Cannon-Bowers, & Stout, 2000). Models of attention traditionally focus on individuals; however, conceptualizing shared attention is of importance for any general theory of attention. Of more specific theoretical importance here, is the question of the mechanisms involved in the above processes: Does a passenger just provide cues that help to optimize the allocation of attention or does the passenger qualitatively change the way that a driver allocates attention, thereby creating a form of joint or distributed attention?

On the practical side, the findings allow predictions about how contexts can negatively affect dual-task performance. On one hand, passengers not engaged in the driving task either because they are not able to direct the attention of the driver toward traffic, or do not know how to identify important events in the driving environment (e.g., children in the vehicle) have a potentially negative impact on driving performance. On the other hand, it is possible that overengagement can also have a potentially negative impact. For example a passenger who is too "supportive" by constantly commenting and directing attention in an overcontrolling fashion has a potentially negative impact on performance.

In conclusion, the data indicate that cell phone and passenger conversation differ in their impact on a driver's performance and that these differences are apparent at the operational, tactical, and strategic levels of performance. The difference between these two modes of communication stems in large part from the changes in the difference in the structure of cell phone and passenger conversation and the degree to which the conversing dyad shares attention.

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