Providing Views of the Driving Scene to Drivers’ Conversation Partners Mitigates Cell-Phone-Related Distraction

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Abstract
Cell-phone use impairs driving safety and performance. This impairment may stem from the remote partner’s lack of awareness about the driving situation. In this study, pairs of participants completed a driving simulator task while conversing naturally in the car and while talking on a hands-free cell phone. In a third condition, the driver drove while the remote conversation partner could see video of both the road ahead and the driver’s face. We tested the extent to which this additional visual information diminished the negative effects of cell-phone distraction and increased situational awareness. Collision rates for unexpected merging events were high when participants drove in a cell-phone condition but were reduced when they were in a videophone condition, reaching a level equal to that observed when they drove with an in-car passenger or drove alone. Drivers and their partners made shorter utterances and made longer, more frequent traffic references when they spoke in the videophone rather than the cell-phone condition. Providing a view of the driving scene allows remote partners to help drivers by modulating their conversation and referring to traffic more often.

Keywords
divided attention, dual-task performance, distracted driving

Received 3/16/14; Revision accepted 8/9/14

At any given time in the United States, an estimated 5% of drivers are using mobile devices (Pickrell & Ye, 2013), even though distraction was implicated in 18% of all automobile crashes and 3,000 fatal crashes from 2005 through 2007 (Singh, 2010). Research strongly supports the link between distraction and crash risk. Both simulator and on-road studies have shown that cell-phone conversations slow drivers’ response times and increase the likelihood of collisions (see Horrey & Wickens, 2006, for a meta-analysis). Such disruption is theorized to result (at least in part) from conversations drawing the driver’s attention away from the driving scene, thereby causing inattentional blindness. Even when looking right at important information, drivers are more likely to miss it if they are conversing on cell phones than if they are not (Strayer, Drews, & Johnston, 2003). Similarly, cell-phone conversations impair drivers’ ability to notice large changes in driving scenes (McCarley et al., 2004) and reduce drivers’ situational awareness, that is, their understanding of the current driving context and ability to predict what will happen next (Heenan, Herdman, Brown, & Robert, 2014; Ma & Kaber, 2005).

To date, this mounting research has prompted 12 U.S. states to ban use of handheld cell phones during driving, and 37 states to ban all novice drivers’ cell-phone use in the car (Insurance Institute for Highway Safety, 2013). Of course, limiting only handheld-phone conversation ignores

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much of the problem, as research suggests that cognitive limitations are to blame for much of the cost associated with distracted driving (e.g., Strayer et al., 2003).

Despite the research and legislation, drivers continue to use cell phones at an alarming rate. A recent study by the Insurance Institute for Highway Safety found that following North Carolina’s complete cell-phone ban for teen drivers, teens’ use of cell phones in the car did not decrease (Foss, Goodwin, McCartt, & Hellinga, 2009). One reason that drivers may continue to use cell phones is that they misestimate their ability to multitask; Sanbonmatsu, Strayer, Medeiros-Ward, and Watson (2013) found a negative correlation between perceived and actual multitasking ability. Furthermore, drivers underestimate the extent to which a demanding task will impair their driving performance (Drews, Pasupathi, & Strayer, 2008). Therefore, novel interventions may be needed to decrease the distracting effects of conducting a cell-phone conversation while driving.

All conversations do not disrupt driving performance equally. Conversing with an in-car passenger is less detrimental to driving than conversing on a cell phone (for experienced drivers). Epidemiological data show that experienced drivers are 1.49 times more likely to be involved in a collision when driving alone than when driving with an in-car passenger (Rueda-Domingo et al., 2004). In a driving simulator experiment, drivers conversing on a cell phone with remote partners missed a larger percentage of highway exits and showed poorer lateral lane keeping compared with drivers conversing with in-car passengers (Drews, Pasupathi, & Strayer, 2008). The critical difference between the driver conversing on a cell phone and conversing with a passenger is believed to center on the partner’s increased understanding of the driving context. An in-car passenger is able to monitor the driving situation as well as the driver’s responses and can provide assistance by alerting the driver (e.g., “Here comes your exit”). Furthermore, a passenger can dynamically restrict conversation during times when the driver’s full attention is needed.

The contents of conversations during driving provide evidence for increased situational awareness among in-car passengers compared with remote conversation partners. Conversations with a driver are more likely to reference the surrounding driving scene when the conversation partner is in the car with the driver rather than conversing with the driver on a cell phone (Drews et al., 2008). Passengers, but not cell-phone partners, also support drivers by modulating the pace of the conversation (e.g., number of syllables per minute), which suggests that in-car passengers possess enhanced situational awareness compared with partners talking on a cell phone (Drews et al., 2008).

In the present study, we tested the hypothesis that enhancing conversation with a remote partner to simulate conversation with an in-car passenger would increase the partner's situational awareness and thereby reduce the driver’s distraction. Only one prior study has investigated whether driver distraction can be offset by providing remote partners views of the driving scene (Charlton, 2009). In-car passengers, but not remote conversation partners who viewed the driving scene through a window behind the simulator, were less distracting than cell-phone partners, contrary to our prediction. In the present study, however, the remote conversation partners who viewed the driving scene saw both the driver’s face and the scene from a perspective similar to what they would see as an in-car passenger. We predicted that this would make it easier to assist the driver.

Specifically, we recruited pairs of participants and assigned one member of each pair to be the driver and the other to be the conversation partner. Each pair engaged in naturalistic conversations in three different conditions: remotely in a hands-free cell-phone condition, together in the simulator, and in a novel videophone condition in which the driver spoke hands free and the remote conversation partner could see live video of the driver’s face and the driving scene ahead of the driver. We compared driving performance in these situations with performance in a condition in which the driver drove alone. If the lack of shared situational awareness is partially responsible for the negative effects of using a cell phone while driving, remote conversation partners who receive video information about the driver and driving scene should use their increased knowledge to modulate the conversation, which should improve the driver’s performance considerably.

To preview the results, we found that providing video to a remote conversation partner reduces the likelihood of collisions in certain situations, offsetting driver distraction much as having the conversation partner in the vehicle does. Furthermore, the results for measures of conversation and navigation suggest that cell-phone distraction arises from a lack of awareness on the part of the remote partner, which we ameliorated through the presentation of remote views of the driving scene.

Method

Participants

Twenty-four pairs of friends, all young adults, were recruited from the Urbana-Champaign community (mean age = 20.4 years, $SD = 1.7$), and each participant was paid $8 per hour. All participants had a valid driver’s license, 2 or more years of driving experience, normal or corrected-to-normal visual acuity, and normal color vision. The
institutional review board at the University of Illinois Urbana-Champaign approved the procedure, and all participants provided written consent prior to participating. The target sample size was estimated on the basis of previous simulator studies (e.g., Gaspar, Neider, & Kramer, 2013), and data collection was stopped when the order of conditions had been counterbalanced across pairs.

**Apparatus**

Driving performance was assessed in a high-fidelity DriveSafety simulator (DriveSafety, Salt Lake City, UT) at the Illinois Simulator Lab using a 1995 General Motors Saturn SL automobile surrounded by eight projection screens. Traffic environments and experimental scenarios were developed using DriveSafety’s HyperDrive Authoring Suite. Driving data were recorded at 60 Hz.

**Driving task**

The driving task involved navigating a 12-mile, three-lane highway. Participants started each trial by merging onto the roadway. They were instructed to maintain the posted speed, which changed during the drive (50, 55, and 60 miles/hr), and to pass slower-moving vehicles when necessary. On each trial, the driver was instructed to exit the highway at one of four named exits, randomly chosen without replacement over the course of the experiment; the trial ended when the driver exited the highway. Ambient traffic in each lane was programmed to assume a range of speeds within the posted speed limit, with slower vehicles in the right lane and faster vehicles in the left lane. These vehicles were also programmed to change lanes periodically, which created dense simulated traffic.

To test the effects of conversation conditions on hazard avoidance, we included unexpected and potentially hazardous events in the task. In *merging events*, a vehicle in an adjacent lane, within 20 m of the front of the participant’s vehicle, suddenly signaled and then, 200 ms after the signal’s offset, entered the driver’s lane. These events simulated times when drivers of other cars change lanes without noticing a vehicle in their blind spot. In *braking events*, the vehicle directly in front of the driver braked suddenly and then, 100 ms after the onset of the brake light, began to decelerate by 10 m/s$^2$. Braking events were triggered when the lead vehicle was within 20 m of the front of the driver’s car and its speed differed from that of the driver’s car by less than 5 m/s.

During each third of a 12-mile trial, four merging and two braking events could be triggered if the criteria for these events were satisfied, with the constraint that two events could not be triggered in the same 10-s period. If the criteria were not met, no event occurred. The order of events was randomized for each 4-mile driving segment. On average, drivers experienced 9.37 ($SD = 2.52$) merging events and 3.94 ($SD = 1.48$) braking events over the course of a trial.

**Procedure**

After the members of a pair provided informed consent, a coin flip randomly determined who was to be the driver and who was to be the conversation partner; these roles did not change over the course of the experimental session. The driver completed a 5-min adaptation sequence in the driving simulator to gain familiarity with the controls. Each member of the dyad was then asked to individually recall three stories of trips he or she had taken that the other member of the pair had not heard before; these stories served as conversation starters in the three conditions in which the driver and partner conversed.

The experiment had a within-subjects design consisting of four conversation conditions (see Fig. 1):

- **Drive alone**: In this condition, the driver drove without conversing.
- **Passenger**: In this condition, the partner was beside the driver (i.e., an in-car passenger), and the driver and partner conversed during the drive.
- **Videophone**: The driver and conversation partner conversed remotely in this condition, via hands-free microphones and speakers. The partner, who was located in a separate room, could see live video on two 19-in. displays: The screen on the left showed the driver, and the screen on the right showed the driving scene. The driver feed was from a live camera mounted unobtrusively on the car’s dashboard. The driving-scene feed replicated what the driver saw in the front simulator image.
- **Cell phone**: The driver and conversation partner also conversed remotely in this condition, using the same microphones and speakers as in the videophone condition. The partner was located in the same room as in the videophone condition, but in this case would not see the driver or the driving simulator. From the driver’s perspective, the videophone and cell-phone conditions were identical.

In each of the four conditions, the driver completed one 12-mile driving trial lasting roughly 15 min. The order of the conversation conditions was counterbalanced across pairs, and pairs had the chance to rest between drives.

At the start of each trial, one member of the pair, selected by coin flip, was instructed to begin telling a story. In all cases, the conversations quickly became lively and naturalistic. In the drive-alone condition, the simulator sounds were recorded onto DVD with
simultaneous video feeds of the driver (from a camera on the left side of the dashboard) and the road (from the simulator). In the passenger, videophone, and cell-phone conditions, the conversation audio, and video of the partner, were included in these recordings. The camera that recorded the partner was on the right side of the dashboard in the passenger condition, and on the desk between monitors in the videophone and cell-phone conditions. The synchronized audio and video recordings were used for coding the conversations and the partner’s looking behavior.

Measures

Driving performance. To assess whether providing video to a remote partner affects driving performance, we tested both discrete and continuous driving behavior. Discrete performance entailed hazard avoidance (i.e., the likelihood of collisions with merging and braking vehicles) as well as navigation accuracy (i.e., whether the driver took the specified exit). A collision was recorded any time a neighboring vehicle occupied the same space as any portion of the driver’s vehicle. Our measures of continuous driving behavior focused on ongoing vehicle control during the portion of the drive when the driver was not responding to programmed merging and braking events. Specifically, we analyzed speed, following distance, and lateral lane keeping (i.e., standard deviation in lateral lane position) over the course of the drive, excluding the 10 s after programmed merging and braking events. Following distance was calculated as the average distance from the front of the driver’s vehicle to the back of the vehicle directly ahead, and included only periods when a vehicle was within 60 m of the driver’s vehicle, in the same lane, and the driver was not changing lanes (Cooper, Vladisavljevic, Medeiros-Ward, Martin, & Strayer, 2009).

To determine whether the conversation conditions affected visual attention and memory, we also tested recognition memory for 24 unique road signs the driver passed during each trial. The order in which these signs were presented was randomized within each trial. After the drive, the driver was presented with 48 randomly ordered signs, half of which had been passed, and asked whether he or she had seen each sign. Four unique sets of 48 signs were used (one for each drive), and the order in which the sets were presented across trials was counterbalanced across participants.
Table 1. Driving Measures: Means and Effects of Condition

<table>
<thead>
<tr>
<th>Measure</th>
<th>Condition</th>
<th>Effect of condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drive alone</td>
<td>Passenger</td>
</tr>
<tr>
<td>Collisions per merging event</td>
<td>.018 (.042)</td>
<td>.031 (.056)</td>
</tr>
<tr>
<td>Collisions per braking event</td>
<td>.070 (.153)</td>
<td>.035 (.120)</td>
</tr>
<tr>
<td>Correct exits taken (%)</td>
<td>91.7</td>
<td>100</td>
</tr>
<tr>
<td>Average speed (miles/hr)</td>
<td>56.6 (3.8)</td>
<td>56.5 (3.8)</td>
</tr>
<tr>
<td>Standard deviation in speed</td>
<td>6.6 (1.9)</td>
<td>7.9 (2.8)</td>
</tr>
<tr>
<td>Standard deviation in lane position (m)</td>
<td>0.36 (0.09)</td>
<td>0.34 (0.10)</td>
</tr>
<tr>
<td>Average following distance (m)</td>
<td>58.8 (21.7)</td>
<td>58.1 (17.6)</td>
</tr>
<tr>
<td>Sign memory (% correct)</td>
<td>63.3 (11.5)</td>
<td>70.9 (12.6)</td>
</tr>
</tbody>
</table>

Note: Standard deviations are given in parentheses.

**Situational awareness.** Situational awareness was operationalized as the number of traffic references (both driver and partner initiated) and the degree of turn taking between driver and partner per traffic reference. Independent raters who were unaware of the experimental predictions coded the drive recordings for references to traffic, including any time either member of a pair discussed the visible driving scene or the driving task (e.g., other cars around the driver). Turn taking within traffic references (i.e., average number of turns per reference) and duration of these references served as measures of their complexity. To test whether partners were of assistance to the drivers when it came to taking the correct exit, and whether this assistance varied across conditions, we searched the transcriptions of the partner-initiated traffic references to tally the number of times the conversation partners made exit-related references specifically (i.e., used the words exit or turn, or any of the four possible exit names: Springfield, Main, Broadway, and Sunset). We tested whether conversation partners in the passenger and videophone conditions were more likely than conversation partners in the cell-phone condition to alert drivers to hazardous events by calculating the average number of partner-initiated traffic references in the 10 s following an event. When appropriate, two-tailed planned comparisons were used to compare simple effects between conditions.

**Results**

Unless otherwise indicated, all analyses were conducted as repeated measures analyses of variance (ANOVAs) with conversation condition (drive alone vs. passenger vs. videophone vs. cell phone) as a within-subjects factor. When appropriate, two-tailed planned comparisons were used to compare simple effects between conditions. Driving-simulator data for a single pair in the drive-alone condition were not recorded because of a technical error, so summary statistics for that pair were replaced with the mean for the rest of the group. Table 1 summarizes results for the driving measures, and Table 2 summarizes results for the conversation and gaze measures.

**Driving performance**

**Collisions.** Of primary concern was the effect of conversation condition on drivers’ ability to avoid collisions due to unexpected events. Because all drivers did not trigger the same number of events, we computed the likelihood of a collision per event for merging and braking separately (Fig. 2). For merging events, there was a main effect of conversation condition on collision likelihood, $F(3, 69) = 4.22, p = .008, \eta^2 = .38$. Planned comparisons with the cell-phone condition revealed that collision likelihood was significantly reduced in both the passenger condition, $t(23) = -2.49, p = .021, \eta^2 = .21$, and, most important, the videophone condition, $t(23) = -2.47, p = .021, \eta^2 = .21$. There was no reliable difference between the passenger and drive-alone conditions, $t(23) = 0.946, p > .250, \eta^2 = .04$, though there were more collisions per event in the videophone condition compared with the drive-alone condition, $t(23) = 5.916, p = .023, \eta^2 = .205$. 
For braking events, there were no reliable differences between conditions, $F(3, 69) = 0.31, p > .250, \eta_p^2 = .01$.

**Navigation accuracy.** We compared the number of times drivers successfully took the specified exit in the four conditions. Drivers were significantly more likely to take the correct exit in the passenger condition than in the cell-phone condition, $\chi^2(1, N = 24) = 5.58, p = .018, \eta_p^2 = .23$. Though in the predicted direction, the difference in navigation accuracy between the videophone and cell-phone conditions was not significant, $\chi^2(1, N = 24) = 1.51, p = .220$.

**Continuous vehicle control.** Conversation condition had no impact on average speed, $F(3, 69) = 0.40, p > .250, \eta_p^2 = .02$, or speed variability, $F(3, 69) = 1.4, p > .250, \eta_p^2 = .18$. Following distance was also unaffected by conversation condition, $F(3, 69) = 0.08, p > .250, \eta_p^2 = .004$. Contrary to expectation (Drews et al., 2008), conversation condition also did not significantly affect lateral vehicle control, $F(3, 69) = 0.99, p > .250, \eta_p^2 = .13$.

**Sign memory.** Conversation condition had a significant effect on memory accuracy in the postdrive test, $F(3, 69) = 5.15, p = .003, \eta_p^2 = .44$. Planned comparisons revealed that drivers were less accurate in the drive-alone condition compared with the other three conditions (all $ps < .014$), and the passenger, videophone and cell-phone conditions did not differ significantly ($ps > .250$).

### Conversations

We next examined the coded conversations (for examples, see Table 3) to determine whether the videophone condition improved joint situational awareness relative to the cell-phone condition. Because of technical issues, no utterance information was recorded for three pairs, and traffic references specifically were not coded from one additional pair; data from these pairs were not included in the relevant analyses. Utterance length in the passenger condition was missing for two additional pairs, and utterance length in the videophone condition was missing for one additional pair; these missing data were replaced with the group averages.

### Traffic references

The average number of traffic references, whether initiated by the driver or the partner, was computed for each condition as an index of how focused the pairs were on the driving scene (Fig. 3). Overall, there was a significant main effect of conversation condition on the total number of traffic references, $F(3, 57) = 11.17, p < .001, \eta_p^2 = .46$. Planned comparisons revealed that pairs referenced traffic more in the passenger condition than in the videophone condition, $t(19) = 7.15, p < .001, \eta_p^2 = .79$. Traffic references in the videophone condition was missing for one additional pair; these missing data were replaced with the group averages.
We specifically predicted, however, that the conversation partner’s situational awareness would benefit in the videophone condition relative to the cell-phone condition, so we next analyzed driver- and partner-initiated traffic references separately (Fig. 3).

There was a main effect of conversation condition on the number of driver-initiated traffic references, $F(3, 57) = 2.99, p = .038, \eta_p^2 = .22$, driven by the greater number of driver-initiated references in the passenger condition compared with the cell-phone condition, $t(19) = 6.14, p < .001, \eta_p^2 = .22$; the videophone and cell-phone conditions did not differ. As we predicted, for partner-initiated traffic references, there was a strong main effect of conversation condition, $F(3, 57) = 19.24, p < .001, \eta_p^2 = .53$. Partner-initiated traffic references were again more frequent in the passenger condition than in the cell-phone condition, $t(19) = 37.90, p < .001, \eta_p^2 = .63$. Critically, conversation partners initiated more traffic references in the videophone condition than in the cell-phone condition, $t(19) = 13.16, p < .001, \eta_p^2 = .37$.

To further investigate shared situational awareness, we looked at the average number of turns between the driver and conversation partner per traffic reference. More turns per reference would indicate that the pair spent more time conversing about traffic once a traffic reference began. However, there was no difference between conditions, $F(3, 57) = 1.34, p > .250, \eta_p^2 = .21$. Furthermore, we tested the mean length (in seconds) of these traffic references. There was a main effect of condition, $F(3, 57) = 3.44, p = .023, \eta_p^2 = .18$, and planned comparisons revealed that traffic references were longer in the passenger condition, $t(19) = 1.38, p = .183, \eta_p^2 = .091$, and the videophone condition, $t(19) = 3.28, p = .004, \eta_p^2 = .34$, compared with the cell-phone condition.
Following merging events, partners initiated significantly more traffic references in the passenger condition, \( \kappa(19) = 3.31, p = .004, \eta^2_p = .34 \), and videophone condition, \( \kappa(21) = 2.54, p = .020, \eta^2_p = .24 \), than in the cell-phone condition. Following braking events, partners initiated marginally more traffic references in the videophone condition than the cell-phone condition, \( \kappa(19) = 1.94, p = .067, \eta^2_p = .15 \), but the difference between the passenger and cell-phone conditions was not significant, \( \kappa(19) = 1.30, p = .210, \eta^2_p = .07 \).

**Utterance duration.** To examine whether the conversation conditions changed the pattern of conversation, we computed the average utterance duration for all types of conversation in each condition, separately for drivers and conversation partners (Fig. 4). For drivers’ utterances, the main effect of conversation condition did not reach significance, \( F(3, 60) = 2.56, p = .063, \eta^2_p = .11 \). Planned comparisons revealed that drivers made marginally shorter utterances in the videophone condition than in the cell-phone condition, \( \kappa(20) = 1.63, p = .119, \eta^2_p = .20 \). The difference between the passenger and cell-phone conditions was not significant, \( \kappa(20) = 1.33, p = .199, \eta^2_p = .07 \).

Of great importance was whether partners’ conversation patterns were affected by conversation condition. There was a significant main effect of condition on the duration of partners’ utterances, \( F(3, 60) = 4.21, p = .009, \eta^2_p = .17 \). Planned comparisons revealed that partners made significantly shorter utterances in the passenger condition than in the cell-phone condition, \( \kappa(20) = 2.72, p = .013, \eta^2_p = .25 \), and marginally shorter utterances in the videophone condition than in the cell-phone condition, \( \kappa(20) = 1.85, p = .078, \eta^2_p = .14 \).

**Conversation partners' looking behavior**

We examined conversation partners’ distribution of attention when they had access to views of the driver and driving scene by analyzing their looking behavior in the passenger and videophone conditions (Fig. 5). Technical issues prohibited coding of looking direction for 4 partners, so their data were not included in the analysis. Conversation partners spent significantly more time looking at the road, \( \kappa(19) = 71.59, p < .001, \eta^2_p = .79 \), and less time looking at the driver, \( \kappa(19) = 50.25, p < .001, \eta^2_p = .73 \), in the passenger condition compared with the videophone condition. In the passenger condition, conversation partners spent nearly all their time looking ahead at the driving scene, \( \kappa(19) = 305.82, p < .001, \eta^2_p = .94 \). In the videophone condition, however, partners’ overt attention was evenly distributed between the screens displaying the driver and the driving scene, \( \kappa(19) = 1.94, p = .180, \eta^2_p = .09 \).

### Table 3. Coded References to Traffic for a Representative Pair (#123)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger</td>
<td>Partner: “Are you looking at the signs?”</td>
</tr>
<tr>
<td></td>
<td>Driver: “Kinda.”</td>
</tr>
<tr>
<td></td>
<td>Partner: “What did that one say?”</td>
</tr>
<tr>
<td></td>
<td>Driver: “That one with speed limit 50.”</td>
</tr>
<tr>
<td></td>
<td>Partner: “The one, the sign in front of it.”</td>
</tr>
<tr>
<td></td>
<td>Driver: “Nope, that is it.”</td>
</tr>
<tr>
<td></td>
<td>Partner: “It said ‘DJ food.’”</td>
</tr>
<tr>
<td></td>
<td>Driver: “Why?”</td>
</tr>
<tr>
<td></td>
<td>Partner: “The one, the sign in front of it.”</td>
</tr>
<tr>
<td></td>
<td>Driver: “That one with speed limit 50.”</td>
</tr>
<tr>
<td></td>
<td>Partner: “The one, the sign in front of it.”</td>
</tr>
<tr>
<td></td>
<td>Driver: “Nope, that is it.”</td>
</tr>
<tr>
<td></td>
<td>Partner: “It said ‘DJ food.’”</td>
</tr>
<tr>
<td></td>
<td>Driver: “Why?”</td>
</tr>
</tbody>
</table>

There was a main effect of condition on number of exit-related traffic references initiated by the partner, \( F(3, 57) = 5.17, p = .003, \eta^2_p = .33 \). These navigation words were said more by partners in the passenger condition than by partners in the cell-phone condition, \( \kappa(19) = 2.87, p = .010, \eta^2_p = .28 \), but the difference between the videophone condition and the cell-phone condition was not significant, \( \kappa(19) = 1.28, p = .216, \eta^2_p = .07 \).
The goal of this study was to determine if it would be possible to ameliorate distracted driving by providing conversation partners views of the driver and driving scene. Indeed, we found that collision risk during dangerous merging events was reduced when partners had such visual information (passenger and videophone conditions), relative to when they did not (cell-phone condition). Moreover, this reduction was significant; collisions involving merging were about half as frequent in the passenger and videophone conditions as in the cell-phone condition. Note that crash risk was reduced just by changing what the partner could see, even though the driver's visual environment did not differ between these conditions.

Partners made important modifications of their conversations in the passenger and videophone conditions, and these changes likely played a critical role in crash reduction. Conversation partners made shorter utterances and were more likely to initiate traffic references in these conditions than in the cell-phone condition. This suggests that access to views of the driving scene led to greater situational awareness on the part of conversation partners, and increased awareness, in turn, allowed partners to modify their conversation according to what was happening on the road. Furthermore, when partners had visual information, their conversation functioned much like a collision-warning system (e.g., Kramer, Cassavaugh, Horrey, Becic, & Mayhugh, 2007), in that they could alert drivers to unexpected events. In Table 3, for example, the excerpt from a conversation in the videophone condition illustrates a case in which the partner's exclamation in reaction to a merging vehicle may have directed the driver's attention to the hazard. Indeed, the number of partner-initiated references to traffic in the 10 s following merging and braking events was larger in the videophone condition than in the cell-phone condition.

These types of warnings from passengers and videophone partners were probably most effective for localizing targets outside drivers' typical gaze pattern, which may be why the only measures of driving performance that showed benefits in the passenger and videophone conditions relative to the cell-phone condition were collision likelihood in merging events and navigation accuracy. Drivers tend to focus their attention straight ahead, effectively reducing their visual inspection window (Recarte & Nunes, 2000). Having another set of eyes monitoring the visual periphery likely helped drivers “see” more peripheral information they would have otherwise missed, such as a merging car or important sign.

Although passengers spent most of their time looking out the windshield at the roadway, conversation partners in the videophone condition distributed their gaze evenly between the driver's face and the driving scene. Perhaps one way to optimize such a videophone for driving would be to provide visual information about the driving scene only. However, conversation partners may also find a videophone engaging because they can see the driver’s face and read nonverbal communication. More research is needed to address these issues. Regardless, partners...
were evidently able to attend considerably more to the
Driving scene in both the passenger and videophone
conditions than in the cell-phone condition.

Our results differ from those of Charlton (2009), who
found that showing conversation partners in another
room views of the simulator through a window did not
benefit driving performance. However, our videophone
interface differed from the equipment Charlton used in
many important ways. Conversation partners in our task
saw a view of the road that was similar to what their view
would be if they were in the vehicle, and they could also
see an image of the driver’s face. This may have made it
easier for the conversation partners to imagine them-

selves as passengers and to pick up on the drivers’ non-
verbal cues. The ability to see the driver’s face may also
have increased engagement in the task.

Our findings are of theoretical importance in under-
standing shared attention. In particular, access to shared
contextual information appears to play a critical role in

team situational awareness. The mechanisms of this benefit
in the videophone condition relative to the cell-phone con-

dition appear to have been (at least) twofold. First, partners
could provide direct cues to alert drivers. Second, an
increase in team situational awareness may have caused
drivers to alter their general attentional allocation. This pos-
sibility is supported by the observed reduction in collisions
due to peripheral events in the passenger and videophone
conditions. Our findings also highlight the conversation
partner’s important influence on the distraction a driver
experiences when using a cell phone, thus revealing
important avenues by which distraction may be mitigated.

Our results extend those of Drews et al. (2008) by
demonstrating a reduction in collision risk when drivers
converse with in-car and videophone partners rather
than cell-phone partners. The smaller-than-expected nav-
igational benefit in the videophone condition may have
resulted from the fact that it was difficult for the conver-
sation partners to see the streets and signs on the moni-
tor, as their view was restricted to the front eighth of the
scene. This is an important point: It is likely that the vid-
eophone setup did not engender the full benefit (relative
to the cell-phone condition) associated with having an
in-car passenger. However, our results suggest that
although a videophone may not allow a remote conver-
sation partner to provide the same level of benefit for
strategic or navigational assistance, it can serve to increase
situational awareness, helping to reduce costly distrac-
tion-related crashes.

It is also important to note that not all measures
showed a benefit for conversations with a passenger over
conversations on a cell phone. This may be due in large
part to the nature of the conversations. When passengers
and drivers are allowed to converse freely (e.g., Grundall,
Bains, Chapman, & Underwood, 2005; Drews et al.,
2008), their conversations show a safety benefit com-
pared with cell-phone conversations. However, when
conversation partners do not have control over the pace
or content of the conversation, conversations conducted
in person and over a cell phone often do not differ in the
associated distraction (Amado & Ulupinar, 2005; Gugerty,
Rakauskas, & Brooks, 2004). Our results support the sug-

gestion that modulations of the pace, topic, or timing of
conversation are crucial to the observed benefit for in-car
and videophone conversations over traditional cell-
phone conversations.

Several limitations of our study should be noted, as they
may be useful in guiding future research. First, the high-
way task was very challenging and resulted in high colli-
sion rates, as the primary goal was to determine whether
a videophone interface could be effective in reducing
155 crashes in the most demanding circumstances, such as
heavy traffic. Furthermore, we used a high-fidelity simu-
lar to test driving performance. Although the simulator
allowed us to study driving under very dangerous condi-
tions, more research is needed to determine how these
results translate to on-road behavior. Future research
should also explore potential implementation issues,
including the size of videophone displays. Although con-
versation partners in our study were able to utilize infor-
mation presented via two 19-in. monitors, smaller displays
(e.g., cell-phone screens) may limit partners’ field of view
and consequently limit detection of peripheral events.

Ideally, drivers should remain distraction free. For the
foreseeable future, however, drivers will continue to talk,
and a large portion of accidents will result from driver
distraction. Our results provide clear evidence for the
efficacy of a promising new strategy for ameliorating
driver distraction due to cell-phone conversations. In the
real world, use of videophones might also lead conversa-
tion partners to simply end their conversations should
they see traffic becoming too demanding. Future research
should explore the efficacy of the videophone in varied
real-world driving situations, among at-risk groups of
drivers (e.g., novice teens), and with conversation part-
ners in various situations.

Author Contributions
K. E. Mathewson and W. N. Street developed the study concept.
All authors contributed to the study design. Data collection was
performed by J. G. Gaspar. Data were analyzed by J. G. Gaspar,
W. N. Street, M. B. Windsor, and K. E. Mathewson, who also
drafted the manuscript. A. F. Kramer and H. Kaczmarski pro-
vided critical revisions. All authors approved the final version of
the manuscript for submission.

Acknowledgments
We thank Daniel Simons for comments and Kory Mathewson
for conversations.
Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This research was supported by a grant from the Office of Naval Research to A. F. Kramer and by a Beckman Institute fellowship to K. E. Mathewson.

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