Research Article

Psychological Science
2014, Vol. 25(12) 2136–2146

DOI: 10.1177/0956797614549774
pss.sagepub.com

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

**John G. Gaspar[1,2], Whitney N. Street[2], Matthew B. Windsor[2], Ronald Carbonari[1], Henry Kaczmarski[1], Arthur F. Kramer[1,2], and Kyle E. Mathewson[1,3]**

[1]Beckman Institute for Advanced Science and Technology, University of Illinois; [2]Department of Psychology, University of Illinois; and [3]Department of Psychology, University of Alberta

**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

**Corresponding Author:**
Kyle E. Mathewson, P-217 Biological Sciences Building, 116 St. and 85 Ave., Edmonton, Alberta T6G 2E9, Canada
E-mail: kyle.mathewson@ualberta.ca

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 (Horrey, Lesch, & Garabet, 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 could 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

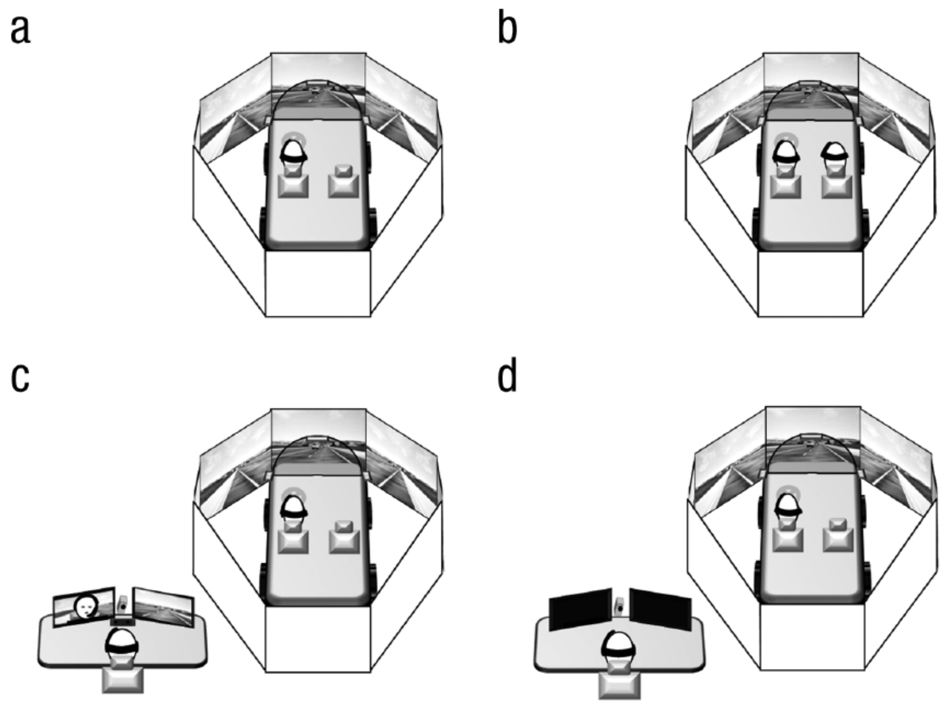


**Fig. 1.** Diagram of the four conversation conditions. In the drive-alone condition (a), the driver was alone in the simulator and did not converse. In the passenger condition (b), the partner was in the car with the driver, and the two conducted a conversation. In the videophone condition (c), the driver and partner conducted a remote conversation while the partner received video feed of the driver's face and the driving scene. In the cell-phone condition (d), the driver and partner conducted a remote conversation via a cell phone, with no video feed.

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

| Measure | Condition: Drive alone | Passenger | Videophone | Cell phone | Effect of condition: Test statistic | $p$ | $\eta_p^2$ |
|---|---|---|---|---|---|---|---|
| Collisions per merging event | .018 (.042) | .031 (.056) | .034 (.054) | .065 (.081) | $F(3, 69) = 4.22$ | .008 | .38 |
| Collisions per braking event | .070 (.153) | .035 (.120) | .074 (.257) | .052 (.128) | $F(3, 69) = 0.31$ | > .250 | .01 |
| Correct exits taken (%) | 91.7 | 100 | 91.7 | 79.2 | $\chi^2(3, N = 24) = 5.67$ | .129 | .08 |
| Average speed (miles/hr) | 56.6 (3.8) | 56.5 (3.8) | 56.9 (3.1) | 56.5 (3.6) | $F(3, 69) = 0.40$ | > .250 | .02 |
| Standard deviation in speed (miles/hr) | 6.6 (1.9) | 7.9 (2.8) | 7.1 (2.0) | 6.9 (1.1) | $F(3, 69) = 1.4$ | > .250 | .18 |
| Standard deviation in lane position (m) | 0.36 (0.09) | 0.34 (0.10) | 0.35 (0.08) | 0.36 (0.12) | $F(3, 69) = 0.99$ | > .250 | .13 |
| Average following distance (m) | 58.8 (21.7) | 58.1 (17.6) | 59.5 (18.5) | 55.4 (19.0) | $F(3, 69) = 0.08$ | > .250 | .004 |
| Sign memory (% correct) | 63.3 (11.5) | 70.9 (12.6) | 70.8 (13.1) | 69.5 (10.5) | $F(3, 69) = 5.15$ | .003 | .44 |

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. We also calculated the mean duration of all utterances (whether or not traffic related) for both the driver and the partner in each of the conversation conditions. Shorter utterances indicate less complex, and thus less distracting, conversations. Finally, raters coded conversation partners' looking behavior (i.e., whether the partner looked at the driver vs. the driving scene), and we used these data to examine the distribution of the conversation partners' attention in the passenger and videophone 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, $F(3, 69) = 4.22$, $p = .008$, $\eta_p^2 = .38$. Planned comparisons with the cell-phone condition revealed that collision likelihood was significantly reduced in both the passenger condition, $t(23) = -2.49$, $p = .021$, $\eta_p^2 = .21$, and, most important, the videophone condition, $t(23) = -2.47$, $p = .021$, $\eta_p^2 = .21$. There was no reliable difference between the passenger and drive-alone conditions, $t(23) = 0.946$, $p > .250$, $\eta_p^2 = .04$, though there were more collisions per event in the videophone condition compared with the drive-alone condition, $t(23) = 5.916$, $p = .023$, $\eta_p^2 = .205$.

**Table 2.** Conversation and Gaze Measures: Means and Effects of Condition

| Measure | Condition | | | Effect of condition | | |
|---|---|---|---|---|---|---|
| | Passenger | Videophone | Cell phone | Test statistic | $p$ | $\eta_p^2$ |
| Number of traffic references | | | | | | |
| Total | 14.35 (8.92) | 8.43 (7.71) | 6.43 (6.51) | $F(3, 57) = 11.17$ | < .001 | .46 |
| Driver initiated | 9.04 (7.12) | 5.91 (6.45) | 5.52 (5.53) | $F(3, 57) = 2.99$ | .038 | .22 |
| Partner initiated | 5.30 (3.23) | 3.22 (2.15) | 0.91 (1.47) | $F(3, 57) = 19.24$ | < .001 | .53 |
| Turns per traffic reference | 3.13 (1.81) | 3.29 (2.80) | 2.59 (1.87) | $F(3, 57) = 1.34$ | > .250 | .21 |
| Duration of traffic references (s) | 10.63 (5.53) | 12.37 (7.70) | 8.14 (5.74) | $F(3, 57) = 3.44$ | .023 | .18 |
| Number of exit references by partner | 0.43 (0.73) | 0.43 (1.47) | 0.04 (0.21) | $F(3, 57) = 5.17$ | .003 | .33 |
| Number of traffic references within 10 s of event | 0.062 (0.08) | 0.004 (0.02) | 0.039 (0.07) | $F(3, 57) = 5.30$ | .003 | .194 |
| Utterance duration (s) | | | | | | |
| Driver initiated | 2.39 (1.04) | 2.38 (1.19) | 2.73 (1.19) | $F(3, 60) = 2.56$ | .063 | .11 |
| Partner initiated | 2.35 (0.86) | 2.46 (0.84) | 3.05 (1.65) | $F(3, 60) = 4.21$ | .009 | .17 |
| Looking time (%) | | | | | | |
| Road | 80.32 (9.58) | 36.13 (21.80) | — | $t(19) = 71.59$ | < .001 | .79 |
| Driver | 11.39 (9.11) | 48.18 (20.87) | — | $t(19) = 50.25$ | < .001 | .73 |

Note: Standard deviations are given in parentheses.

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 $p$s < .014), and the passenger, videophone and cell-phone conditions did not differ significantly ($p$s > .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, $t(19) = 8.69$, $p < .001$, $\eta_p^2 = .28$, or the cell-phone condition, $t(19) = 18.17$, $p < .001$, $\eta_p^2 = .45$. There were also more traffic references in the videophone condition than in the cell-phone condition, $t(19) = 2.46$, $p = .024$, $\eta_p^2 = .10$.

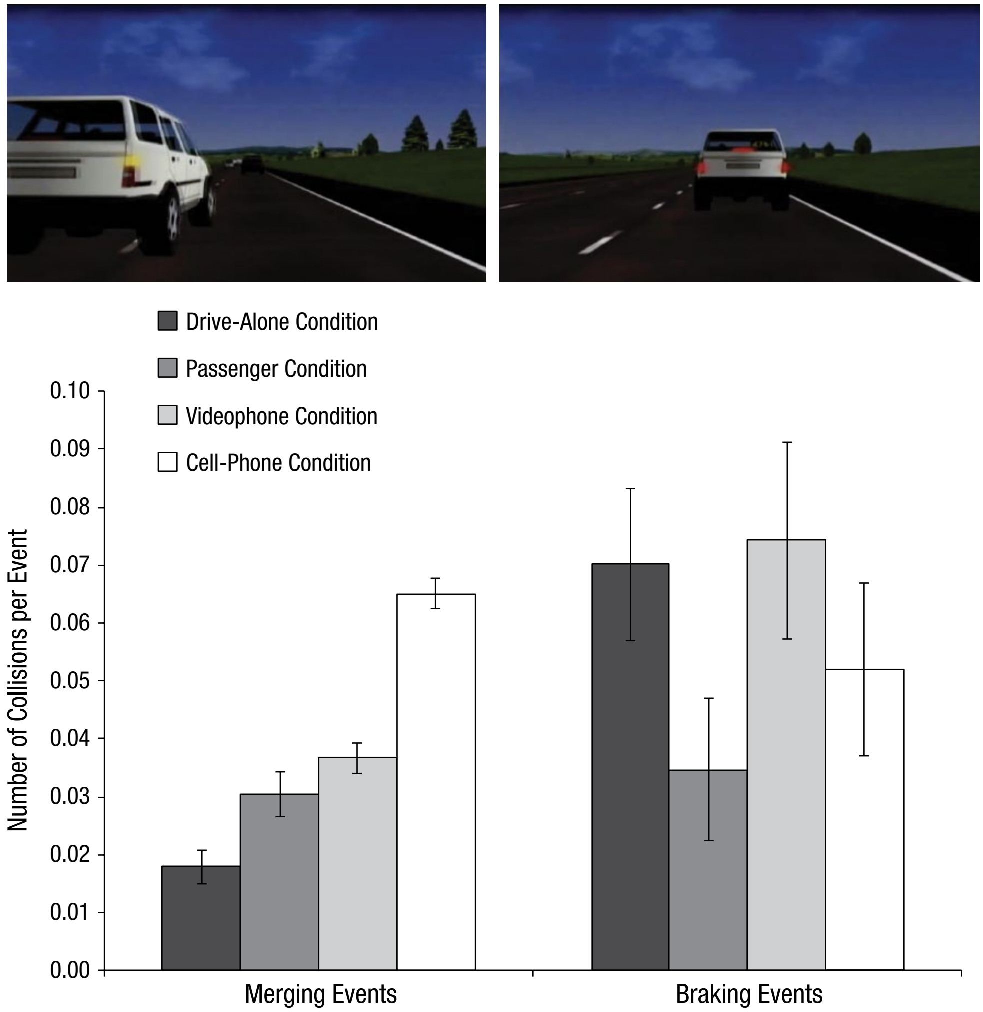


**Fig. 2.** Collision likelihood (number of collisions per event) for merging and braking events in each of the four conditions. Error bars represent 95% within-subjects confidence intervals (Franz & Loftus, 2012). Screenshots for the event types are displayed above the graphs.

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.

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

| Condition | Conversation |
|---|---|
| Passenger | Partner: "Are you looking at the signs?" |
| | Driver: "Kinda." |
| | Partner: "What did that one say?" |
| | Driver: "That one with speed limit 50?" |
| | Partner: "The one, the sign in front of it." |
| | Driver: "Nope, that is it." |
| | Partner: "It said 'DJ food.'" |
| Videophone | Partner: "Oh, my God." |
| | Driver: "Ah, of course, it is the guy driving a Lexus." |
| | Partner: "Why don't you speed up and flip them off. Can you see them on the side?" |
| | Driver: "Mother#*%$&@, get out of here!" |
| Cell phone | Partner: "Are you crashing?" |
| | Driver: "No, I just went into the grass." |
| | Partner: "Why?" |

There was a main effect of condition on number of exit-related traffic references initiated by the partner, $F(3, 57) = 5.17$, $p = .003$, $\eta_p^2 = .33$. These navigation words were said more by partners in the passenger condition than by partners in the cell-phone condition, $t(19) = 2.87$, $p = .010$, $\eta_p^2 = .28$, but the difference between the videophone condition and the cell-phone condition was not significant, $t(19) = 1.28$, $p = .216$, $\eta_p^2 = .07$.

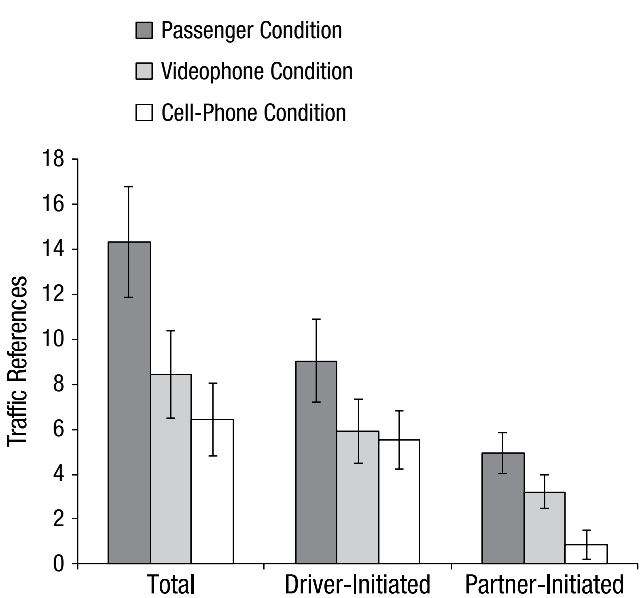


**Fig. 3.** Total number of traffic references and number of driver-initiated and partner-initiated traffic references in each conversation condition. Error bars represent 95% within-subjects confidence intervals (Franz & Loftus, 2012).

Following merging events, partners initiated significantly more traffic references in the passenger condition, $t(19) = 3.31$, $p = .004$, $\eta_p^2 = .34$, and videophone condition, $t(21) = 2.54$, $p = .020$, $\eta_p^2 = .24$, than in the cell-phone condition. Following braking events, partners initiated marginally more traffic references in the videophone condition than the cell-phone condition, $t(19) = 1.94$, $p = .067$, $\eta_p^2 = .15$, but the difference between the passenger and cell-phone conditions was not significant, $t(19) = 1.30$, $p = .210$, $\eta_p^2 = .07$.

***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, $F(3, 60) = 2.56$, $p = .063$, $\eta_p^2 = .11$. Planned comparisons revealed that drivers made marginally shorter utterances in the videophone condition than in the cell-phone condition, $t(20) = 1.63$, $p = .119$, $\eta_p^2 = .20$. The difference between the passenger and cell-phone conditions was not significant, $t(20) = 1.33$, $p = .199$, $\eta_p^2 = .07$.

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, $F(3, 60) = 4.21$, $p = .009$, $\eta_p^2 = .17$. Planned comparisons revealed that partners made significantly shorter utterances in the passenger condition than in the cell-phone condition, $t(20) = 2.72$, $p = .013$, $\eta_p^2 = .25$, and marginally shorter utterances in the videophone condition than in the cell-phone condition, $t(20) = 1.85$, $p = .078$, $\eta_p^2 = .14$.

## *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, $t(19) = 71.59$, $p < .001$, $\eta_p^2 = .79$, and less time looking at the driver, $t(19) = 50.25$, $p < .001$, $\eta_p^2 = .73$, 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, $t(19) = 303.82$, $p < .001$, $\eta_p^2 = .94$. In the videophone condition, however, partners' overt attention was evenly distributed between the screens displaying the driver and the driving scene, $t(19) = 1.94$, $p = .180$, $\eta_p^2 = .09$.

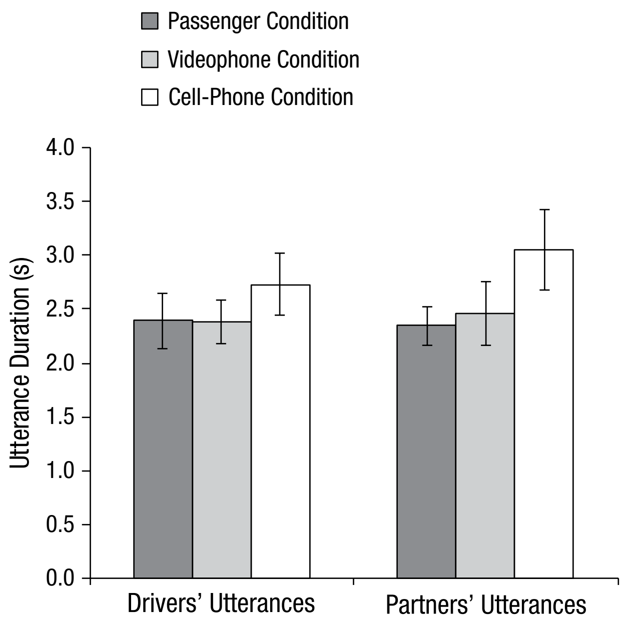


**Fig. 4.** Average duration of drivers' and partners' utterances in each of the three conversation conditions. Error bars represent 95% within-subjects confidence intervals (Franz & Loftus, 2012).

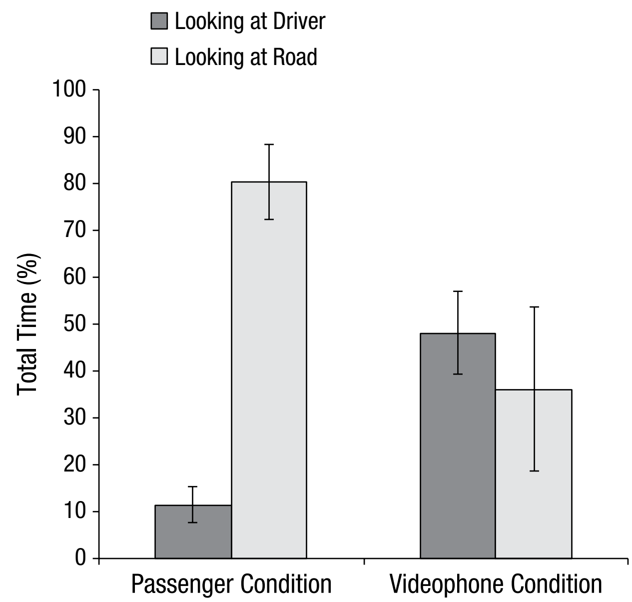


**Fig. 5.** Average percentage of the total drive time during which conversation partners looked at the driver and looked at the driving scene in the passenger and videophone conditions. Error bars represent 95% within-subjects confidence intervals (Franz & Loftus, 2012).

## Discussion

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 themselves as passengers and to pick up on the drivers' nonverbal cues. The ability to see the driver's face may also have increased engagement in the task.

Our findings are of theoretical importance in understanding 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 condition 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 possibility 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 navigational benefit in the videophone condition may have resulted from the fact that it was difficult for the conversation partners to see the streets and signs on the monitor, as their view was restricted to the front eighth of the scene. This is an important point: It is likely that the videophone 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 conversation partner to provide the same level of benefit for strategic or navigational assistance, it can serve to increase situational awareness, helping to reduce costly distraction-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., Crundall, Bains, Chapman, & Underwood, 2005; Drews et al., 2008), their conversations show a safety benefit compared 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 suggestion 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 highway task was very challenging and resulted in high collision rates, as the primary goal was to determine whether a videophone interface could be effective in reducing crashes in the most demanding circumstances, such as heavy traffic. Furthermore, we used a high-fidelity simulator to test driving performance. Although the simulator allowed us to study driving under very dangerous conditions, 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 conversation partners in our study were able to utilize information 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 conversation 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 partners 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 provided 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.


## References


Amado, S., & Ulupinar, P. (2005). The effects of conversation on attention and peripheral detection: Is talking with a passenger and talking on the cell phone different? *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*, 383–395. doi:10.1016/j.trf.2005.05.001

Charlton, S. G. (2009). Driving while conversing: Cell phones that distract and passengers who react. *Accident Analysis & Prevention*, *41*, 160–173. doi:10.1016/j.aap.2008.10.006

Cooper, J. M., Vladisavljevic, I., Medeiros-Ward, N., Martin, P. T., & Strayer, D. L. (2009). An investigation of driver distraction near the tipping point of traffic flow stability. *Human Factors*, *51*, 261–268. doi:10.1177/0018720809337503

Crundall, D., Bains, M., Chapman, P., & Underwood, G. (2005). Regulating conversation during driving: A problem for mobile telephones? *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*, 197–211. doi:10.1016/j.trf.2005.01.003

Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied*, *14*, 392–400. doi:10.1037/a0013119

Foss, R. D., Goodwin, A. H., McCartt, A. T., & Hellinga, L. A. (2009). Short-term effects of a teenage driver cell phone restriction. *Accident Analysis & Prevention*, *41*, 419–424. doi:10.1016/j.aap.2009.01.004

Franz, V. H., & Loftus, G. R. (2012). Standard errors and confidence intervals in within-subjects designs: Generalizing Loftus and Masson (1994) and avoiding the biases of alternative accounts. *Psychonomic Bulletin & Review*, *19*, 395–404. doi:10.3758/s13423-012-0230-1

Gaspar, J. G., Neider, M. B., & Kramer, A. F. (2013). Falls risk and simulated driving performance in older adults. *Journal of Aging Research*, *2013*, Article 356948. Retrieved from http://www.hindawi.com/journals/jar/2013/356948/

Gugerty, L., Rakauskas, M., & Brooks, J. (2004). Effects of remote and in-person verbal interactions on verbalization rates and attention to dynamic spatial scenes. *Accident Analysis & Prevention*, *36*, 1029–1043. doi:10.1016/j.aap.2003.12.002

Heenan, A., Herdman, C. M., Brown, M. S., & Robert, N. (2014). Effects of conversation on situation awareness and working memory in simulated driving. *Human Factors*, *56*, 1077–1092. doi:10.1177/0018720813519265

Horrey, W. J., Lesch, M. F., & Garabet, A. (2008). Assessing the awareness of performance decrements in distracted drivers. *Accident Analysis & Prevention*, *40*, 675–682. doi:10.1016/j.aap.2007.09.004

Horrey, W. J., & Wickens, C. D. (2006). Examining the impact of cell phone conversations on driving using meta-analytic techniques. *Human Factors*, *48*, 196–205. doi:10.1518/001872006776412135

Insurance Institute for Highway Safety. (2013). *State cellphone and texting laws*. Retrieved from http://www.iihs.org/iihs/topics/laws/cellphonelaws?topicName=distracted-driving

Kramer, A. F., Cassavaugh, N., Horrey, W. J., Becic, E., & Mayhugh, J. L. (2007). Influence of age and proximity warning devices on collision avoidance in simulated driving. *Human Factors*, *49*, 935–949. doi:10.1518/001872007X230271

Ma, R., & Kaber, D. B. (2005). Situation awareness and workload in driving while using adaptive cruise control and a cell phone. *International Journal of Industrial Ergonomics*, *35*, 939–953. doi:10.1016/j.ergon.2005.04.002

McCarley, J. S., Vais, M. J., Pringle, H., Kramer, A. F., Irwin, D. E., & Strayer, D. L. (2004). Conversation disrupts change detection in complex traffic scenes. *Human Factors*, *46*, 424–436. doi:10.1518/hfes.46.3.424.50394

Pickrell, T. M., & Ye, T. J. (2013). *Driver electronic device use in 2011* (Report No. DOT HS 811 719). Washington, DC: National Highway Traffic Safety Administration.

Recarte, M. A., & Nunes, L. M. (2000). Effects of verbal and spatial-imagery tasks on eye fixations while driving. *Journal of Experimental Psychology: Applied*, *6*, 31–43. doi:10.1037/1076-898X.6.1.31

Rueda-Domingo, T., Lardelli-Claret, P., Luna-del-Castillo, J. D. D., Jiménez-Moleón, J. J., García-Martín, M., & Bueno-Cavanillas, A. (2004). The influence of passengers on the risk of the driver causing a car collision in Spain: Analysis of collisions from 1990 to 1999. *Accident Analysis & Prevention*, *36*, 481–489. doi:10.1016/S0001-4575(03)00043-5

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS ONE*, *8*(1), Article e54402. Retrieved from http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0054402

Singh, S. (2010). *Distracted driving and driver, roadway, and environmental factors* (Report No. DOT HS-811 380). Washington, DC: National Highway Traffic Safety Administration.

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*, 23–32. doi:10.1037/1076-898X.9.1.23