# Calling While Driving: Effects of Providing Remote Traffic Context


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## ABSTRACT

Cell phone conversations distract drivers. This research explores the possibility of reducing distracting by providing callers with remote information about the driver's traffic. We asked whether providing such contextual information would change the caller's conversation such that drivers would be less distracted. In Experiment 1 we examined this question in a low-fidelity driving simulator; in Experiment 2 we examined this question in a higher fidelity simulator. In both experiments, remote callers and passengers were distracting. Providing traffic information to the remote caller significantly reduced crashes in the low fidelity tests and significantly reduced passing in the high fidelity tests, compared with the control conditions. We consider the implications for development of remote displays or signals to promote driving safety.



### Author Keywords

Cell phones, driving, distraction, cognitive load, attention, interruption, contextual information, contextual displays.

### ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.


## INTRODUCTION

Cell phones are becoming ubiquitous around the world and on the road. In the United States, cell phone use increased from 4.3 million people in 1990 to 134.5 million people in 2002 [11]. Possibly because driving is usually easy and leaves attentional resources free, many people make and answer cell phone calls while they drive. In a recent study of videotaped drivers, one-third of the drivers talked by cell phone while they were driving [1].

Driving while talking on a cell phone is risky. In one study using epidemiological methods, researchers found that 24% of the 669 individuals involved in accidents during the study period had used their cell phones during the 10 minutes preceding the accident [18]. The authors estimated a quadrupling of the risk of a collision during the period of a call, comparable to the increased risk of driving while legally drunk.

Proposed strategies for reducing the risk of cell phone use in cars have focused on ways to change drivers' cell phone use. Currently, two states, New York and New Jersey, and the District of Columbia, completely ban the use of cell phones while driving, and 11 states have partial bans. Worldwide, at least 46 countries have similar bans [4]. In this paper, we propose and test a different method for reducing the risk of cell phone calls. Our approach involves influencing the remote caller's behavior. We argue that if remote callers are provided information about a driver's road and traffic situation, they may moderate their conversations to reduce their disruptiveness. For example, remote callers might cease talking if they know there is busy traffic facing the driver. We tested this approach in two controlled experiments.

### Attentional Resources and Cell Phone Disruption

Researchers have found consistently that the mental engagement of the driver in conversation, rather than visual focus away from the road or hands off the wheel, is the major factor that increases the dangerousness of talking on a cell phone while driving. For example, Redelmeier & Tibshirani [18] found no safety advantage of hands-free phones over hand-held phones. The authors argued that the increased interference of cell phone calls was due to the cognitive demands of the conversation, rather than to other factors such as manual manipulation of the phone. In support of this thesis, Baddeley [2] and others have shown that people can far more easily divide attention between motor and cognitive tasks (e.g., eating while driving) than they can divide their attention between two demanding cognitive tasks (solving arithmetic problems and driving in traffic).

Laboratory experiments using driving simulators and instrumented cars have documented that cell phone conversations reduce driving performance. In these studies, researchers required drivers to perform a secondary cognitive task imposed by the experimenter (such as conversation or a mental processing task), and then they measured the impact of the secondary task on driving performance. Strayer, Drews, and Johnston [21] found that a cell phone conversation significantly increased a driver's reaction time to a car ahead that was braking. They also demonstrated a causal link with the attentional resources required by conversation. They found conversations reduced by nearly half the rate of perception and recall of objects presented to the driver during the driving task. Similarly, Trbovich & Harbluk [22] found drivers made significantly fewer glances to traffic lights and fewer glances to the environment around an intersection when they were performing mental arithmetic problems while driving (a form of tunnel vision).

McKnight & McKnight [15] studied participants who watched pre-recorded videos of actual driving situations and drove using simulated controls. They compared a control condition of no distractions with casual conversation (light conversation with the experimenter) and a more intense task of mental arithmetic (to simulate more intense conversation). Their results showed both casual and intense conversation tasks to be significantly more distracting than no secondary task, and the intense math task to be significantly more distracting than the casual conversation task.

### Providing Traffic Context Information for Callers

We know drivers respond to driving conditions they notice. Could we provide callers with contextual information about the road and traffic? In a previous paper [14], we proposed that if remote cell phone callers had some road and traffic information such as that available to passengers who are monitoring the road, callers might moderate or time their conversations so as to reduce the disruptiveness of conversation on the driver. In one experiment, focused on remote callers, we tested whether participants, acting as remote callers to a driver, would moderate their conversational behavior if they were reminded of a driver's road situation. We found callers did cease talking when they heard beeping, sounds of traffic, or a message that the driver was busy. They did not cease talking if the driver only stopped talking.

In a second experiment, focused on the driver, we tested whether drivers would perform better if they drove with no conversation, a remote caller, or a remote caller who withheld conversation during critical driving periods. In that study, drivers using a driving simulator made nearly twice the number of driving errors when conversing on a phone compared to driving with no conversation, but when the caller's conversation ceased during critical driving periods, the number of crashes was reduced to the same level as the no-call control condition.

The results of our previous studies suggest that when the driver and caller have access to shared information about the traffic situation, then they can coordinate their behavior in ways that might be difficult without this shared information. This idea is consistent with theories and research on common ground [e.g, 5] and mutual knowledge 6, 12] in communication, which show that interacting people coordinate their behavior to achieve effective interaction and that shared expectations and knowledge aid this coordination. Thus, we argue that a remote caller and driver collaborate to communicate, and that mutual knowledge of the traffic situation can aid this collaboration. For instance, the caller should cease talking when the driver is stopping to allow a pedestrian to cross the road, acknowledging the driver's state of concentration. In the absence of co-presence, a shared visual display or information signaling the traffic situation could aid such mutual understanding. We think that shared mutual knowledge of the traffic situation would not only aid communication of content but also would improve safety because it would moderate the caller's behavior.

Our previous study of driving suggested that if remote callers moderated their talking during critical driving periods, drivers' performance would improve over the situation where the remote callers kept talking regardless of the driving situation. When testing the impact on driving of remote contextual information in that study, we employed a confederate instructed to stop talking when the driver encountered a critical driving situation. The current studies went beyond that study by examining whether actual remote callers with contextual information about the driving situation would change their conversational behavior such that the driver's performance improved.

To examine this question, we conducted two experiments, each with a different sample of participants. We tested naïve participants in pairs, one acting as driver and one as the caller. Using a simulator, we examined driving performance in four conditions: driving alone (no conversation) (Figure 1); driving while talking with a passenger sitting next to the driver (Figure 2); driving while talking with a remote caller (Figure 3), and driving while talking with a remote caller who saw a replica of the driver's dynamic road and traffic display (Figure 4).

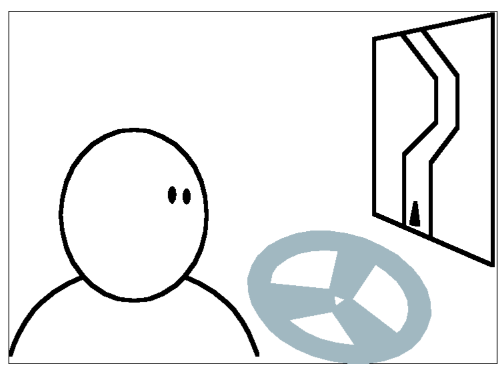

**Figure 1: Driver Only condition.**

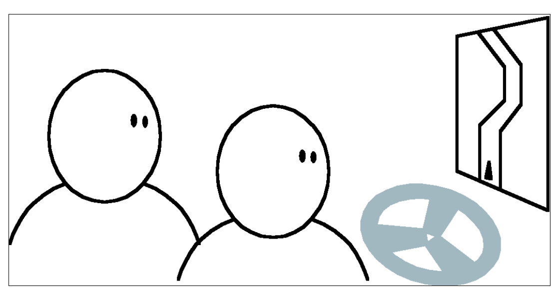

**Figure 2: Passenger condition.**

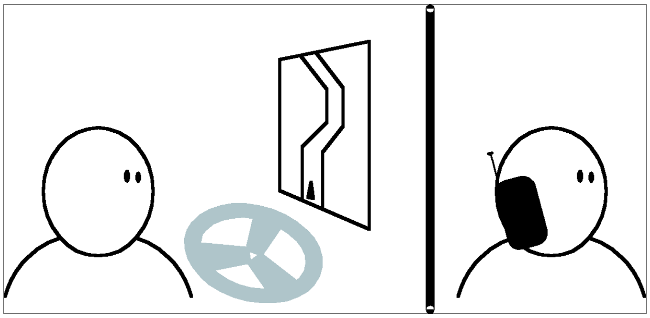

**Figure 3: Remote Caller condition.**

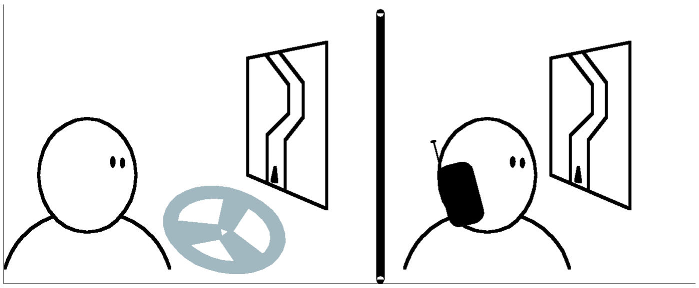

**Figure 4: Remote Caller With Traffic Display condition.**

The main dependent measures of driving performance in the studies were the driver's avoidance of accidents on a curved road with changes in traffic and pedestrian behavior (Experiments 1 and 2) and passing in heavy traffic (Experiment 2). We hypothesized that when a remote caller was provided information about the driver's context, the driver's performance would improve in comparison to a situation in which the remote caller had no such information.

### *Hypotheses*

As noted above, there were four conditions.

*Driver only*. The "driver only" condition involved a driver with no caller and no conversation. We expected driving performance to be best in that condition. The driver-only condition is our main control condition.

*Remote caller*. In accord with previous research, we expected driving to deteriorate because of mental distraction when the driver had a conversation with a remote caller.

*Remote caller with traffic display*: From the arguments above, we predicted that the remote caller with a display of the driver's traffic situation would moderate his or conversation, causing the driver to drive better than when the remote caller did not have such a display. In other words, driving in this condition should be more like the driving in the driver only condition.

*Passenger*. The passenger condition requires some elaboration. In this condition a second participant sat next to the driver and conversed with the driver. When we began this research we thought that a passenger would be less distracting than a remote caller because the passenger has a view of the road and traffic situation. Drivers also believe that conversing with a passenger is less effortful than talking on the phone [13]. However, several studies of real driving suggest that passengers do not necessarily watch the road and traffic when they are talking with a driver and that passengers distract drivers. For example, passengers are likely to gesture to aid their dialogue [3] and they may call attention to themselves. Fairclough et al. [7] tested driving ability in an instrumented car under three experimental conditions: normal driving, driving while talking on a hands-free cell phone with the experimenter, and driving while talking with the experimenter in the front seat. The authors measured driving performance using objective measures (time to completion, heart rate, eye movements) and subjective measures of perceived workload. The conversational task performed by drivers involved a verbal negotiation, for example, booking a vacation or buying a used car. The authors reported that the driver's heart rate increased significantly in the phone condition compared to the passenger condition, suggestive of greater effort for phone conversations. However, they found no significant differences between the phone and passenger conditions in measures of driving outcome.

Nunes & Recarte [16] also compared passengers and callers by giving drivers laboratory distraction tasks (repeating lists of numbers and performing mental arithmetic) rather than conversing with them. The phone task produced higher mental interference effects than the side-by-side task, but the authors did not find a difference in driving performance.

In sum, the literature to date does not lead to a clear prediction that passengers improve driving performance as compared with remote callers. In this study we employed a passenger control condition to examine this question. That is, do passengers affect driving performance? On the one hand, passengers could use traffic information to adjust their conversation [8, 20], which should aid the driver. On the other hand, previous research [e.g., 1, 16] suggests that passengers are distracting. Passengers may attend to the driver instead of the road, and their presence or their behavior (such as gestures) could be distracting to the driver.

In sum, we expected driving performance in this order: driver only (best), remote caller with display, remote caller (worst). The passenger condition remained an open question.

## METHOD

We performed two experiments. The first experiment used a low-fidelity PC-based driving simulator of the first author's construction. The second experiment was conducted with a commercial pc-based driving simulator with much higher fidelity. The experimental design was otherwise identical.

### Experimental Design

We used a within-subjects one-way factorial experiment design, with four conditions: driver only, remote caller, remote caller with traffic information, and passenger. Participants worked in teams of two. Initially one member of the pair drove on four tracks of about the same length and difficulty, one in each condition. The other member of the pair acted as the caller and passenger as needed. Then the participants switched positions and the experiment was repeated. Order of condition and track were counterbalanced using a Latin Square design.

### Participants

In the first (low fidelity) experiment there were thirty participants (20 female, 10 male) from the Carnegie Mellon University community. Their age ranged from 20 to 66 with an average of 34.4 and median of 33.5.

In the second (high fidelity) experiment there were 44 participants (16 female and 28 male), also from Carnegie Mellon University. Their age ranged from 18 to 77 with an average 25.3 and median of 22. All analyses were performed only on licensed drivers.

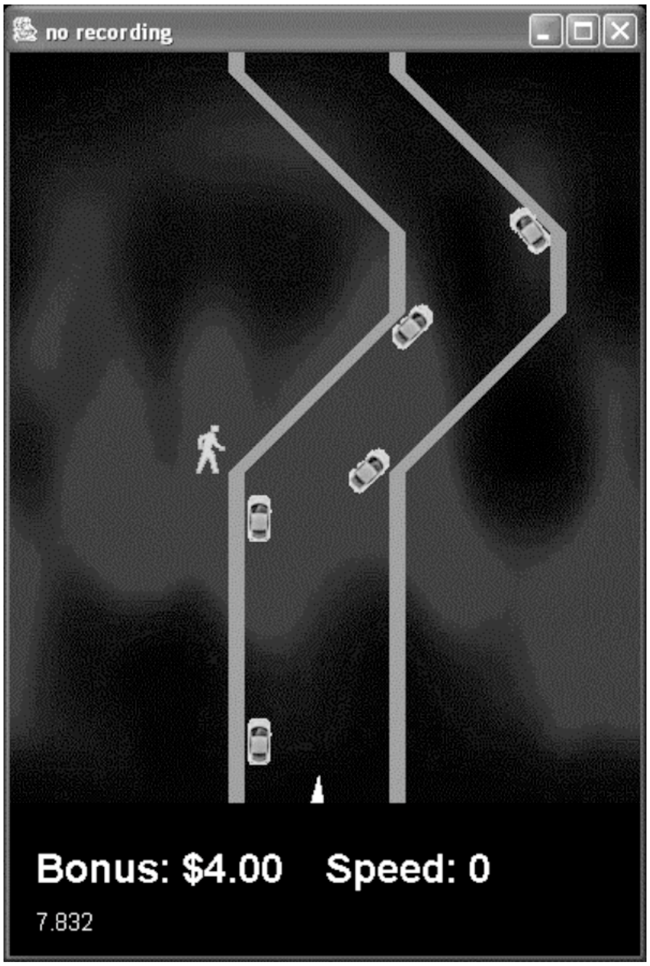


**Figure 5: Screenshot of low-fidelity simulator from Experiment 1 with parked cars and a pedestrian about to walk into the road.**

### Apparatus

#### *Experiment 1*

For the first experiment we constructed a simple 2-D driving game with a top-down display (Figure 5). Participants used a Microsoft Sidewinder steering wheel attached to a PC running Windows XP. They navigated through the course by steering their car through the winding track. Parked cars to be avoided were located on either side of the road at random intervals. Additionally, pedestrians would occasionally walk out into the road, and the participants were required to stop and wait for the pedestrian to cross the road completely. Tracks A, B, C, and D had 35, 34, 38, and 30 cars and 7, 12, 7, and 12 pedestrians respectively. Every track had 7 curves. Each participant drove each track once (in counterbalanced order) and the tracks did not vary between participants. The driver spoke on a speaker phone (hands-free) and the passenger spoke on an ordinary handset phone during the remove conditions.

#### *Experiment 2*

For the second experiment we used a commercial off-the-shelf pc driving simulator called StiSim Drive [19], which has been used extensively for driving research, for example [8, 10]. (See Figures 6, 7 and 8.) The driving task was different for this experiment. Drivers were put on a 2-lane highway-type road. Spaced out over the next few miles were 5 to 6 large trucks in the same lane as the driver. The driver's task was to pass as many of the trucks as possible, while avoiding regular but intermittent oncoming traffic in the other lane. They drove four tracks of approximately equal difficulty with an equal number of cars in both lanes. The driver spoke on a speaker phone (hands-free) and the passenger spoke on an ordinary handset phone during the remove conditions.

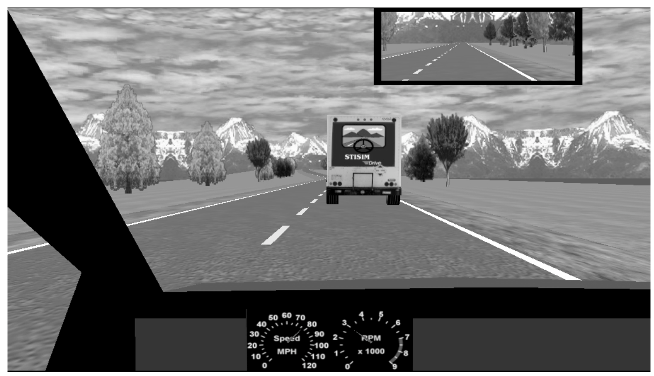

**Figure 6: Screenshot of high-fidelity simulator from Experiment 2, showing the driver approaching a truck that he will attempt to pass.**

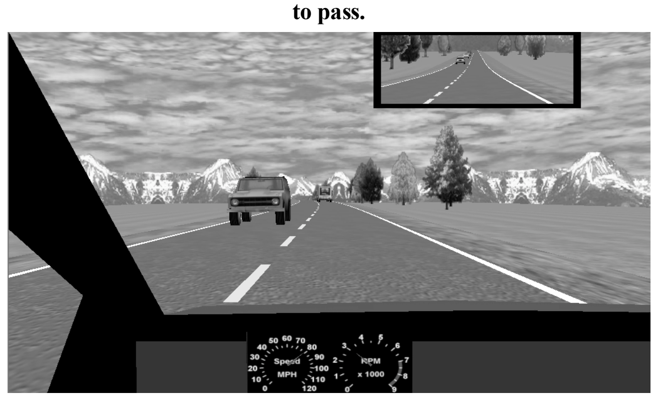

**Figure 7: Screenshot of high-fidelity simulator from Experiment 2, showing a vehicle in the opposite lane, which he must avoid, and a truck in the distance that he will attempt to pass.**

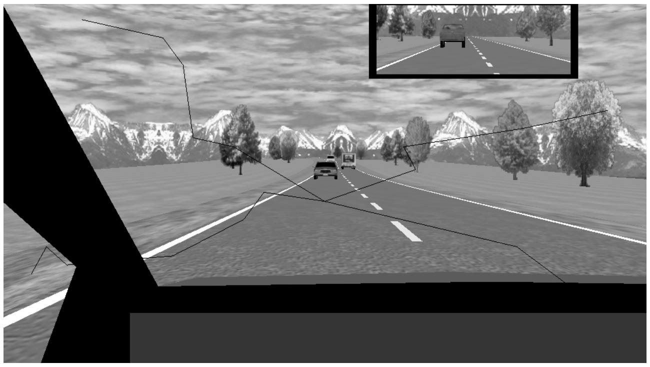

**Figure 8: Screenshot of high-fidelity simulator from Experiment 2, immediately after the driver crashes into a vehicle in the opposite lane.**

### Procedure

To enhance the ecological validity of our experiment, we asked the remote callers and passengers to engage in a type of discussion that could occur in everyday life, as in our previous study [14] and similar to the approach of Fairclough et al. [7].

Participants arrived two at a time to the experimental laboratory. One participant was randomly assigned to be the driver, and to role-play a landlord with three apartments to rent. The other participant was asked to role-play an apartment seeker, who would talk with the driver about the apartments for rent remotely using a phone, and while sitting next to the driver. After completing each condition of the experiment, the roles were reversed and the experimental session was run again. The landlord's task was to drive the course one time alone and three other times while answering the questions of the apartment seeker (corresponding to the remote caller, remote caller with traffic display, and passenger conditions).

The apartment seeker was provided a list of information about the apartments to obtain from the landlord. The apartment seeker was encouraged but not required to ask about every item on the list. The information to be obtained included the rental price, neighborhood, condition of the apartment, availability of washer/dryer, air conditioning, and parking. The apartment seeker was specifically reminded to ask the landlord for directions from the apartment to the university to require spatial cognitive processing by the landlord. The landlord was asked to make up his or her responses to the apartment seeker's questions.

After the experimenter told the two participants about the study and obtained informed consent, a short questionnaire was given asking their age, sex, if they were a currently licensed driver, and if they were a native English speaker. The experimenter explained the procedure and demonstrated the driving task one time. Then the first driver/landlord was given one practice run before beginning the experiment.

### Incentives

In many driving studies, because it is necessary in most cases to use a simulator, there is some concern that participants will not care about accidents. To ensure that the driver and the caller/passenger each had an incentive for good driving, the experimenter offered a monetary bonus to each pair of participants.

For the first experiment, the payment was computed with the following formula: $4 – $1 * (number of pedestrians hit) – $0.50 * (number of cars hit) – $0.25 * (number of times car left road). The bonuses were averaged within each pair of participants to ensure equal incentives for the driver and the caller. With perfect driving, each participant could receive a bonus of up to $2 per run or $16 for the experiment.

For the second experiment the participants received a $1 bonus for each truck they passed, and a $1 penalty for each time they crashed. Participants were guaranteed a minimum of $5 for participating in the experiment. The bonuses were averaged within each pair of participants to ensure equal incentives for the driver and the caller. With perfect driving a participant could earn $36 (4 tracks * 6 trucks/track) although no drivers did that well.

## RESULTS

### Experiment 1

In the first experiment using the low fidelity simulator, our main measure of driving performance was calculated as the total number of crashes, that is, collisions with cars or pedestrians, or running off the road. We also calculated total money earned because the formula weighted crashes by severity. However, the two measures were essentially equivalent ($r = -.90$). There were few pedestrian hits (mean = .1 per run) as compared with crashes with parked cars or going off the road (both means = .7 per run).

We tested the hypothesis that a remote caller with driver context information would interfere with the driver less than a remote caller without this information. Each of these conditions was compared with a no conversation situation—the Driver Only condition in which we expected the best performance. We also examined the effects of talking with a passenger. The analyses were conducted as within-subjects analyses of variance using participant as a random factor, order of condition, age and gender included as control variables, and condition as the independent variable.

#### *Driving Performance*

Figure 9 shows the mean number of crashes per run (leaving the road or striking an object). The effect of condition on the number of crashes is significant ($F [3, 82] = 5.2$, $p < .001$). We used the Tukey test to compare individual conditions with each other. This test showed that when the driver was talking with a remote caller or a passenger, he or she had more crashes ($p < .01$) and the remote caller and passenger conditions did not differ. However, as predicted, when the driver talked with a remote caller who used the traffic display, he or she crashed somewhat less. That is, the decrement in driving performance from conversation, while far from perfect, was mitigated and was not significantly different from the driver's performance in the Driver Only condition.

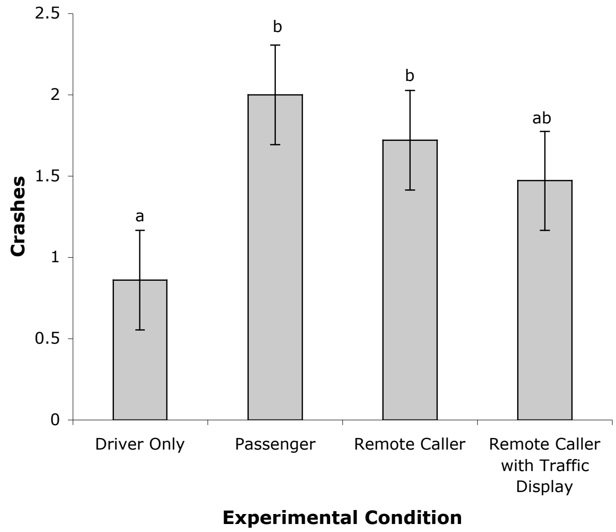


**Figure 9. Driving performance in Experiment 1. (Bars with different subscripts show conditions are significantly different.)**

*Caller Behavior*

We have argued that remote callers with context information can moderate their conversational behavior as they view the driving situation. To explore this process, we examined the effect of the three conversation conditions on the number of words spoken by callers by the first 24 participants. These analyses do not include the Driver Only condition. We found strong effects of condition ($F$ [2, 39] = 6.5, $p < .01$). As passengers, the participants spoke the least, possibly because they were able to use gestures and visual feedback to communicate with the driver and because they could hear the driver clearly; they spoke an average of 130.8 words. As remote callers with context information, the participants spoke an average of 141.4 words. As remote callers with no context information, participants spoke an average of 151.8 words per run. There was no effect of condition on the drivers' number of words.

We then tested whether the number of words spoken was associated with accidents. We found that the number of words spoken by the caller had a marginally significant effect and increased crashes, controlling for participant, order of condition, age, and gender (F [1, 40] = 2.8, p = .10). These analyses suggest that the caller's talking in a conversation while someone else is driving is a partial predictor of deteriorated driving performance.

Overall, these results replicate others' work insofar as we have shown that remote callers and passengers interfered with driving performance. Our results suggest, in addition, that the disruption from phone calls while driving can be mitigated in part using a remote contextual display. We also have some evidence that talking is negatively related to performance, and that the display reduced the remote caller's amount of talk.

**Experiment 2**

In the second experiment using the high fidelity simulator we measured the number of trucks passed and the number of crashes as dependent variables. We again tested the hypothesis that a remote caller with driver context information would interfere with the driver less than a remote caller without this information. Each of these conditions was compared with a no conversation situation—the Driver Only condition in which we expected the best performance. The analyses were conducted as within-subjects analyses of variance using participant as a random factor, order of condition, age, and gender included as control variables, and condition as the independent variable.

Our analyses show that crashes did not differ across any of the conditions. Perhaps the high fidelity nature of the simulator made drivers more careful. Note that we also rewarded drivers for good driving. In general, drivers who crashed did so in the early runs of the experiment and then drove more carefully. We were able to test the amount of caution the drivers adopted while driving by counting the number of trucks they passed. Passing trucks on the road was quite difficult due to frequent oncoming traffic. Thus, more caution should entail passing less if one is talking with another person.

Using passing as a dependent variable, we found a significant effect across conditions ($F$ [3, 44] = 2.8, $p = .04$). We again used the Tukey test to compare individual conditions with each other. The driver in the Driver Only condition passed the most, as would be expected without any distraction. However, when the same drivers were talking in the Passenger and Remote Caller conditions, they passed as much as they did without conversation. Only when the driver was talking with a Remote Caller with the Traffic Display did he or she pass less (see Figure 10).

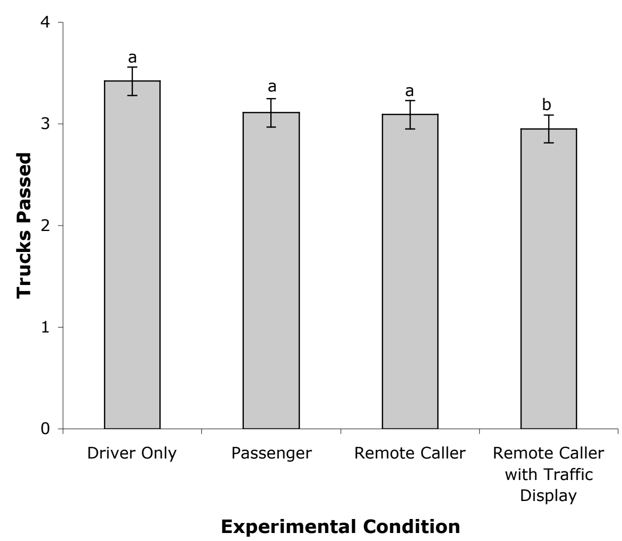


**Figure 10. Passing in Experiment 2. (Bars with different subscripts show conditions are significantly different.)**

There are at least two possible explanations for these results. One explanation is that the caller, on seeing traffic approaching or dangerous situations, perhaps restrained or cautioned the driver. Another possibility is that for some reason the drivers in this condition were driving were more distracted by the display. To check this possibility, we ran the same analysis controlling for crashes. We found that crashes did predict passing (those who crashed more passed less,) but the effect of the Remote Caller with the Traffic Display was just as strong nonetheless ($F$ [3, 43] = 2.9, $p$ = .03). These results lend some credence to the argument that drivers while talking with a caller who had a remote display exerted more caution than they did when they talked with a passenger or with a remote caller having no display.

## DISCUSSION

Our results replicated previous findings that show a distracting effect of conversations on driving ability. Drivers crashed more often in the first experiment and passed less often in the second experiment while engaged in conversation. We also replicated the findings of a few studies [9, 12] showing that passengers talking with the driver can be just as distracting to the driver as a remote caller. The unique contribution of this paper is our exploration of the effects on driving of providing context information to a remote conferee. In both experiments we found that when the caller had access to context information about the driver's traffic situation, there were measurable differences in driving performance.

In Experiment 1 using the low-fidelity simulator, when the remote caller had a traffic display, crashes by the driver were reduced significantly as compared to when the driver conversed with a passenger or a remote caller without a display, and approached the number of crashes in the driver-only condition. We also found some evidence that the callers' amount of talking was related to the number of crashes. In the second experiment with the high-fidelity simulator, we found no condition differences in crashing (lending some credence to the idea that higher fidelity increases caution). Yet there were behavioral differences in passing. The driver passed nearly as much in the passenger and the remote caller conditions as when he or she had no conversation, indicating a lack of caution in those conditions. However, the driver passed significantly less when the remote caller had access to a remote traffic display.

One might argue that the caution shown by drivers with a remote caller with a traffic display could have been caused by their being more rather than less distracted in this condition. That is, drivers with a remote caller using the traffic display, for some reason, might have been driving poorly or were too distracted to pass. However, the reduced passing in this condition remained significantly depressed even when we controlled statistically for driving quality (by adding number of crashes and time to finish the course into the regression equation). Thus, it seems plausible that the driver talking to the remote caller with a traffic display was encouraged by the caller's behavior to be cautious. We will need to conduct more research to discover whether this interpretation of our results is correct or not.

### Future Use Scenarios

Any system designed to increase driver safety will only be of use if it can be deployed practically for real users. We argue that a system for providing contextual traffic information to remote conferees, such as we simulated in the laboratory, could be adapted using technology which, if not available today, will certainly be feasible in 5-10 years.

The first step would be to collect relevant contextual traffic information. Live streaming video with frame rates of 5 – 10 frames per second or information interpreted from lower bandwidth sensors might be used. For instance, sensors are being used in Pittsburgh to detect pedestrians in the roadway and convey an alarm to bus drivers. Similarly, such information could be collected for remote conferees. The second step would be to convey this contextual information to remote conferees in a reasonable manner.

Our laboratory situation was unrealistic in the sense that viewing live video while trying to converse on a cell phone could make such a scenario impractical. Instead, Figures 11 and 12 present possible usage scenarios for remote conferees.


**Figure 11: Proposed usage scenario 1. Caller hears signal conveying traffic situation confronted by the remote driver.**

In Figure 11 a caller is shown in conversation with a driver. The caller cannot see the driver or the driver's traffic but instead obtains this contextual information via simulated traffic noise such as honking or tire squeals when the system detects a dangerous level of traffic or obstacles in the roadway. We tested an aspect of this scenario in [11], showing that remote callers reduced their talking when they heard traffic noises on the phone.

Another usage scenario, shown in Figure 12, would be applicable to dispatchers and others talking to drivers while these callers sit at a remote console. Such persons might be 911 operators, car emergency dispatchers, first responder coordinators, and police. A camera mounted in the driver's car for purposes of helping the driver also could provide real-time images to the caller. In this latter scenario, we have replicated the essential aspects of the system tested in our experiments above. One possible obstacle to actual use is if the system used a reduced frame rate due to low bandwidth; in this situation, the images of traffic might be uninformative or uninfluencial.

**Figure 12: Proposed usage scenario 2. The view from a police patrol car is shown to the dispatcher on the left-most screen.**

An obstacle to usage in both scenarios would be false positives if the system caused callers or drivers to be too cautious or overly concerned about others' responses to their driving. More generally, the major obstacle might be user acceptance. As this is a very novel way of driving and communicating remotely, users would need a powerful argument why they should use such a technology. (Witness the extremely long period people drove cars in the United States before they began to wear seat belts consistently.) Strong repeated results showing increased safety of such as system will be needed before people and organizations are likely to adopt such a system.

### Limitations

As do other experimental studies of driving, this study had several important limitations. In real driving, there are millions of people on the road and comparatively few accidents per driving mile. For an experiment to simulate driving and to study distraction effects, the driving task and secondary cognitive (or other) task must be controlled and made sufficiently difficult to observe variations in performance within a short period of time. In achieving this aim, we attempted to use a conversation task drawn from real life, but it was necessarily contrived.

Another problem with our experimental setup in Experiment 1 was a lack of discriminatory power among the most skilled operators. Five out of 36 participants in Experiment 1 did not commit any driving errors (crashes) during their session, and seven out of 36 committed only one driving error during their session. Thus, among those participants, we could not discriminate who performed better or worse than the others. This problem was due to the binary nature of the dependent measure used (i.e. they either crashed or they didn't), and due to the relative ease of driving the course. In Experiment 2, the simulator was far more difficult, and the incentive structure ensured that nearly everyone crashed at least a few times, but even so, due to low variability we did not find condition differences in crashes.

## CONCLUSION

Our studies suggest that callers with having remote traffic information change drivers' behavior, and our analyses of callers' behavior in Experiment 1 (as well as in our previous study [14]) suggest that this change comes about because callers alter the amount or timing of their speech. Because drivers are increasingly offered new ways to communicate in cars, and because conversation can be a serious distraction, we argue that the possible use of remote displays or signaling systems for callers should be pursued further. Direct effects on callers and drivers must be established empirically in very high fidelity driving scenarios, and the technology for remote traffic information input and display must be further developed and tested.


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