Distractive effects of cellphone use
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Abbreviations and acronyms

ADTC	Accelerator distance-to-collision
ART	Accelerator reaction time
ATTC	Accelerator time-to-collision
BDTC	Braking distance-to-collision
BRT	Braking reaction time
BTTC	Braking time-to-collision
SA	Situation awareness

Contents

Executive summary

A range of studies has shown that the use of cellphones has adverse consequences on a driver's probability of being involved in a crash. One of the most consistent findings is that drivers' use of cellphones increases their reaction times to vehicles braking ahead although other adverse changes in driver behaviour have been reported as well, including: impaired gap judgements; an increased number of traffic violations; failure to maintain appropriate headway distances; higher curve speeds; impaired eye scanning; reduced checking of rearview mirrors; striking pedestrians; impairment of vehicle control actions; and poor speed management. Of considerable practical interest is whether or not the cognitive demands and consequent changes in driver behaviour are unique to cellphone conversations or are an inevitable result of drivers' concurrent processing of verbal material. For example, a frequently posited response to the finding that both handheld and hands-free cellphones increase drivers' crash risk is that, if conversations are distracting regardless of phone type, then conversations with in-car passengers must be equally dangerous.

The purpose of the present study was to investigate the differences between passenger and hands-free cellphone conversations in a controlled manner. The study compared the driving performance and conversational characteristics that occurred when drivers engaged in realistic conversations with: 1) passengers physically present in the car; 2) cellphone conversors; and 3) remote passengers (who could see the driver's situation but were not physically present in the car). Of interest was whether visual access to the driver's situation was sufficient to produce the conversation suppression and references to the immediate driving task found with in-car passengers. The goal of the study was to identify any differences between drivers' cellphone conversations and conversations with passengers in terms of their effects on driving performance. The participants drove a 25.3 km-long simulated road containing five hazards and an overtaking lane using the University of Waikato driving simulator.

The results clearly indicated that driving while talking to an in-car passenger was appreciably different from conversing over a cellphone. Drivers talking on a cellphone often failed to take any action to reduce their speed as they approached the hazards, resulting in the highest crash rates obtained. Similarly, many of these drivers also failed to manage the overtaking scenario by increasing their speeds when appropriate. Drivers with passengers were more likely to anticipate hazards and reduce their speeds, performing nearly as well as the no-conversation Control group. Differences in discourse measures gave some insight into why these two groups may have performed so differently. Drivers and their passengers made shorter utterances, had more frequent pauses, and were more likely to be talking about the upcoming hazard than the other conditions. Drivers and their cellphone conversors made the longest utterances, were less likely to mention the hazards, had the poorest recall of the hazards and the highest crash rate. The remote passengers tended to have shorter utterances and more utterances about the hazards than cellphone conversors, but did not display the same number of conversational pauses as in-car passengers and driver performance was nearly as bad as in the cellphone condition. Drivers who were not conversing (Control group) were the safest by most measures. These drivers displayed cautious speeds, rapid deceleration reactions to hazards, good speed management leading to safe overtaking, the fewest crashes and good recall of the hazards after the drive. The drivers in the Passenger group displayed a higher number of crashes than the no-conversation drivers indicating that there is a penalty associated with driving while conversing (perhaps because not all passengers suppress their conversations when they should).

A second experiment investigated whether a cellphone modified to emit warning tones could alleviate some of the adverse effects typically associated with cellphone conversations. The underlying concept is that radio frequency ‘tags’ could be placed on hazard warning signs, or GPS-capable cellphones could be programmed with maps containing the locations of known road hazards. In either case, the cellphone would emit a series of warning beeps as a driver conversing on a cellphone approached a potential hazard. The results showed that the alerting cellphone was associated with driving performance nearly as good as that of the no-conversation controls from the previous experiment. The drivers’ deceleration responses were faster, earlier and further away from the hazard than those of the Cellphone group. The discourse produced during the cellphone alerts contained more frequent pauses, more often referred to the driving situation and had shorter utterances than the Cellphone group. The low number of crashes observed in this experiment suggested that the alerting cellphone was at least as effective as passengers at helping drivers prepare for, and respond to, road hazards. In sum, the alerting cellphone demonstrated an appealing technological possibility for overcoming many of the unsafe effects associated with drivers conversing on cellphones as they approach certain types of hazard locations. Additional research examining other methods of presenting alerting information to drivers regardless of their cellphone use (eg via in-car navigation aids such as GPS) would be required before any one technological solution is pursued. Further, future research exploring and comparing the self-paced and externally paced aspects of other in-car distractions of various durations would be very useful.

Abstract

The research systematically compared the driving performance and conversational patterns of drivers speaking with in-car passengers, hands-free cellphones, and remote passengers who could see the driver's current driving situation (via a window into a driving simulator). Driving performance suffered during cellphone and remote passenger conversations as compared with in-car passenger conversations and no-conversation controls in terms of their approach speeds, reaction times, and avoidance of road and traffic hazards. Of particular interest was the phenomenon of conversation suppression, the tendency for passengers to slow their rates of conversation as the driver approached a hazard. On some occasions these passengers also offered alerting comments, warning the driver of an approaching hazard. Neither conversation suppression nor alerting comments were present during cellphone conversations. Remote passengers offered some alerting comments but did not display conversation suppression. The data suggested that conversation suppression is a key factor in maintaining driving performance and that visual access to the driver's situation is not sufficient to produce conversation suppression. A second experiment investigated whether a cellphone modified to emit warning tones could alleviate some of the adverse effects typically associated with cellphone conversations. The modified cellphone produced discourse patterns that were similar to passenger conversations and driving performance nearly as good as that of drivers who were not conversing.

1. Introduction

A range of studies has shown that the use of cellphones has adverse consequences on a driver's probability of being involved in a crash. Epidemiological research has shown that as little as one hour per month of cellphone use while driving increases a driver's crash risk 400–900% (McEvoy et al 2005; Violanti 1998; Violanti and Marshall 1996). A widely reported case-crossover study found that the risk attached to cellphone conversations by drivers is comparable to that of alcohol intoxication at the maximum legal limit (0.08 blood alcohol concentration) (Redelmeier and Tibshirani 1997, 2001).

The reasons for the heightened crash risk associated with the use of cellphones have been examined in a number of laboratory and field studies. One of the most consistent findings is that drivers' use of cellphones increases their reaction times to vehicles braking ahead (Ålm and Nilsson 1994, 1995; Brookhuis et al 1991; Lamble et al 1999; Strayer and Drews 2004) and responding to stop signs and stop lights (Beede and Kass 2006; Hancock et al 2003). A meta-analysis of the research findings in this area (Caird et al 2008) reported a mean increase in drivers' reaction times of 0.25 s (although the authors noted that this value was probably an underestimate of on-road decrements). A range of other adverse changes in driver behaviour have been reported as well, including: impaired gap judgements (Brown et al 1969; Cooper and Zheng 2002); an increased number of traffic violations (Beede and Kass 2006); failure to maintain appropriate headway distances (Ålm and Nilsson 1995; Rosenbloom 2006); higher curve speeds (Charlton 2004); impaired eye scanning (Harbluk et al 2007; Maples et al 2008); reduced checking of rearview mirrors (Brookhuis et al 1991); striking pedestrians (Kass et al 2007); impairment of vehicle control actions (Treffner and Barrett 2004); and poor speed management (Ålm and Nilsson 1994; Horberry et al 2006; Rakauskas et al 2004; Törnros and Bolling 2005, 2006).

Several mechanisms have been proposed to account for the adverse effects of cellphone conversations on driver performance. Manipulation of handheld cellphones certainly produces some adverse effects via interference with control actions (Brookhuis et al 1991). Many of the negative effects associated with cellphone conversations, however, do not appear to be the result of impaired driver control actions. Further, the findings that use of hands-free cellphones may be just as detrimental as handheld (Horrey and Wickens 2006; Matthews et al 2003; Patten et al 2004) suggest that cellphone interference results from cognitive demands of the conversation rather than distraction due to manipulation. It has been suggested that the cognitive demands of conversing while driving result in reduced attention to visual inputs (Strayer et al 2003), a form of inattentional blindness. This suggestion would appear to be supported by findings of impaired recognition memory for billboards and words presented visually to drivers conversing on hands-free cellphones (Strayer et al 2003).

Other researchers have argued that concurrent verbal interactions have the effect of degrading drivers' situation awareness and as a result, their ability to identify and respond quickly to hazards (Gugerty et al 2004; Kass et al 2007). This interpretation is in concordance with findings that drivers engaged in a concurrent hands-free verbal task displayed degraded performance on a range of situation awareness probes (Gugerty et al 2004) and that conversing drivers' failure to maintain situation awareness was associated with an increase in range of driving errors (Kass et al 2007). There have also been a wide range of studies showing that drivers' ratings of their mental workload increase as a result of concurrent cellphone tasks and coincide with decrements in their driving performance (Horberry et al 2006; Lamble et al 1999; Patten 2004; Törnros and Bolling 2006). These studies suggest that the dual task situation of conversing can exceed a driver's momentary attentional capacity, resulting in a tendency to switch attention between the two tasks. When a driver's attention is diverted to the conversation task, performance on those aspects of the driving task that require explicit attentional processing (eg detection of hazards and decision-making) are impaired, resulting in higher detection thresholds and longer reaction times (Beede and Kass 2006; Brookhuis et al 1991; Brown et al 1969; Patten et al 2004).

Of considerable practical interest is whether or not the cognitive demands and consequent changes in visual attention, situation awareness and mental workload are unique to cellphone conversations or are an inevitable result of drivers' concurrent processing of verbal material. For example, a frequently posited response to the finding that both handheld and hands-free cellphones increase drivers' crash risk is that, if conversations are distracting regardless of phone type, then conversations with in-car passengers must be equally dangerous. This line of argument goes on to maintain that inasmuch as conversations between a driver and passenger cannot reasonably be prohibited, neither should drivers' use of cellphones. Unfortunately, the research literature on this point is somewhat ambiguous. Epidemiological studies have found that carrying two or more passengers in the car does increase a driver's risk of a crash (a two-fold increase), albeit not as much as talking on a cellphone (a four-fold increase), but there is the suggestion that this may be primarily an issue for young drivers (McEvoy et al 2007; Neyens and Boyle 2007).

A laboratory experiment examining drivers engaged in verbal tasks (eg answering general knowledge and arithmetic questions) failed to find any significant differences between remote and in-car verbal sources (Amado and Ulupinar 2005). Similarly, a field study in which drivers completed a range of secondary cognitive tasks, either over the phone or with an in-car experimenter, failed to detect any differences in visual search patterns or ratings of mental demand (Nunes and Recarte 2002). Another laboratory experiment compared participants performing a driving scene monitoring task and a concurrent word game with a partner who either could not see the driving task display (equivalent to a remote cellphone conversor) or could see the driving task display (an in-person passenger equivalent) (Gugerty et al 2004). The researchers did not find any differences in the drivers' situation awareness in the two conditions, but there was evidence that the drivers found conversing with the 'in-person' partners easier than with the 'remote' partners. Interestingly, when the remote and in-person partners were both able to see the driver (independent of the driving scenes) the additional difficulty associated with the remote condition was removed (Gugerty et al 2004). In contrast, experiments employing more naturalistic conversations and measuring driving performance have reported that conversations with passengers are not as cognitively demanding as cellphone conversations and are associated with fewer driver errors and crashes (Drews et al 2004, Hunton and Rose 2005).

There are several logical reasons why drivers' conversations with passengers may not be as cognitively demanding or impair their driving performance to the same degree as conversations over cellphones. Drivers conversing with passengers have access to a range of nonverbal cues (eg facial expressions, gestures and posture) that are not available when conversing over a cellphone (Gugerty et al 2004, Hunton and Rose 2005). This additional information can make it easier to parse the speech stream and process the meaning of a speaker's utterances, as well as provide cues for turn-taking and other pragmatic aspects of discourse. A related finding is that good speech quality (intelligibility and fidelity) is important in reducing the mental workload of drivers (Matthews et al 2003). Passenger conversations undoubtedly enjoy greater fidelity and intelligibility compared with any sort of cellphone and thus require less attention and effort by the driver to process the conversation, allowing more attention to remain with the primary driving task.

There is also the suggestion that the form and content of passenger conversations are fundamentally different from conversations over hands-free and handheld cellphones (Haigney and Westerman 2001; McKnight and McKnight 1993; Strayer and Johnston 2001). The logic of this argument is that, because passengers can see what the driver sees, they are able to modulate the timing and complexity of their speech to match the driving conditions. As a result, drivers talking to passengers are less likely to become overloaded in difficult driving conditions and may avoid many of the adverse consequences associated with cellphone conversations (Crundall et al 2005, Hunton and Rose 2005). In support of this line of argument, one study comparing the conversations of drivers with in-car passengers to cellphone conversations found that the in-car conversors reduced their rate of speech when approaching particularly demanding or hazardous driving situations, and some stopped talking altogether (Crundall et al 2005). This demonstration of conversation suppression, which was absent in the cellphone conversations, may help to explain why cellphone conversations are more cognitively demanding than passenger conversations. Although the study did not examine driving performance, the underlying logic was that an in-car passenger's ability to see the momentary demands of the traffic and road situation led to a modulation of their speech, which in turn, freed the driver to allocate more attention to the driving task.

Even more compelling evidence for the advantage of passenger conversations over cellphone conversations can be taken from the finding that the content of conversations with in-car passengers includes more turn-taking, more references to the driving situation, and may actually help maintain driver situation awareness, compared with cellphone conversations (Drews et al 2004). Drivers engaged in a cellphone conversation spent less time discussing the surrounding traffic and were more likely to miss important elements of the driving task. When passengers are conversationally involved in the driving task, their participation may even increase the driver's situation awareness of upcoming hazards, and alleviate the potential adverse effects of driving while conversing (Drews et al 2004).

The purpose of the present study was to investigate the differences between passenger and cellphone conversations in a controlled manner. The study compared the driving performance and conversational characteristics that occurred when drivers engaged in realistic conversations with: 1) passengers physically present in the car; 2) cellphone conversors; and 3) remote passengers (who could see the driver's situation but were not physically present in the car). Of interest was whether visual access to the driver's situation was sufficient to produce the conversation suppression and references to the immediate driving task found with in-car passengers. Also of interest was the degree to which these conversational aspects were associated with drivers' speed management, reaction times to driving hazards, recall of those hazards and ratings of mental effort across the three conversation conditions. The goal of the study was to address whether, and in what ways, drivers' conversations with passengers were able to avoid the harmful effects on driving performance found with cellphone conversations.

2. Experiment 1

This experiment compared four driving conditions: drivers conversing with in-car passengers; drivers conversing over a hands-free cellphone; drivers conversing with remote passengers (who could see the driving situation) by means of a hands-free cellphone; and a no-conversation control group. Several aspects of driving performance were measured including drivers' speeds and deceleration and braking reactions on the approach to hazardous road situations. In addition, the pacing and content of the discourse in the three conversation groups was recorded along with drivers' ratings of driving difficulty and conversational interference, and the accuracy of their recall of the hazards they encountered.

2.1 Method

2.1.1 Participants

A sample of 119 participants, 56 male and 61 female, were recruited from the local area via notices placed in professional newsletters, university bulletin boards and newspapers. The participants ranged from 17 to 59 years of age with an average age of 27.65 years (SD = 10.55). Participants were required to possess a current New Zealand driver licence and were asked to wear any corrective lenses during the experiment if they were required to do so as a condition of their driver licence. Seven participants did not complete the experiment due to either mechanical failures (5) or participant reports of eyestrain or dizziness (2). The remaining sample of 112 was composed of equal numbers of male (56) and female (56) participants. Of the 64 participants in this sample who were drivers in the experiment (the other 48 served as conversors for the drivers), 87% indicated they owned a cellphone. Of those drivers who owned a cellphone, 78.6% admitted they used it to converse as they drove and 51.8% said they used it weekly or more often. Also of note, 66.1 % of the drivers who owned a cellphone said they used their cellphone to send and receive text messages while they drove, 51.8% of them weekly or more often.

2.1.2 Apparatus

The experimental apparatus was the University of Waikato driving simulator consisting of a complete automobile (BMW 314i) positioned in front of three angled projection surfaces (shown in Figure 2.1). The centre projection surface was located 2.42 m in front of the driver's seat with two peripheral surfaces connected to the central surface at 62 degree angles. The entire projection surface was angled back away from the driver at 14 degrees (from the bottom to the top of the projection surface) and produced a 175 degree (horizontal) by 41 degree (vertical) forward view of the simulated roadway from the driver's position. The image projected on the central surface measured 2.64 m wide by 2.10 m high (at a resolution of 1280 by 1024 pixels) and each of the two peripheral images measured approximately 2.65 m by 2.00 m (at resolutions of 1024 by 768 pixels). In addition, two colour LCDs with an active area of 12.065 cm by 7.493 cm each at a resolution of 640 by 480 pixels were mounted at the centre rear-view mirror and driver's wing mirror positions to provide views looking behind the driver's vehicle. The simulated vehicle's dashboard displayed accurate speed and engine RPM data and vehicle performance was determined by a multi-body vehicle dynamics model configured as an automobile with automatic transmission, 3-litre engine (making 170 kW power) and power steering. The projected images and vehicle model were updated at a minimum rate of 100 frames per sec. The steering wheel provided tactile feedback to simulate the forces produced when steering the vehicle. Four speakers located inside the car and a sub-woofer underneath the car presented realistic engine and road noises as appropriate. The simulation software recorded the participant's speed, lane position and control actions automatically throughout designated sections of the simulation scenario. A digital video camera was mounted in the rear seat of the simulated vehicle to record the participants' conversations during the experimental sessions.

Figure 2.1 The University of Waikato driving simulator.

2.1.3 Simulation scenario

The simulated road created for this study was a 25.3 km-long section of rural road containing a combination of straights and gentle horizontal and vertical curves. The road geometry was an accurate representation of a rural two-lane state highway in New Zealand and was based on the surveyed 3-dimensional road geometry of the highway. The lane widths, road markings, sight distances and other road engineering characteristics were incorporated in the simulation using road survey data obtained from the road controlling authority and by comparing the simulations to video recordings of the highway taken from the driver's perspective. Road signs and roadside objects were modelled as 3-dimensional objects and placed in the simulations to match the video recordings of the highway. Other traffic was placed in the scenario to depict a representative mixture of cars, light trucks and heavy trucks at a volume of approximately 8,000-10,000 passenger car units per day. Special care was taken to introduce heading traffic at key points in the scenario to control each participant's progress through a series of driving hazards described below. The speed limits of the simulated road were changed from those present on the actual highway: the first 4.75 km of the simulated road had a posted speed limit of 60 km/hr; followed by 19.5 km of road with a 100 km/h speed limit; returning to a 60 km/h speed zone for the final 1.05 km of road.

The simulated road was also altered from the veridical road to contain five traffic hazards and an overtaking lane, located at approximately 4–5 min intervals as shown in Figure 2.2. The first hazard was a busy ‘T’ intersection with several turning vehicles as shown in Figure 2.3a. On the approach to the intersection the participant’s vehicle was preceded by two vehicles travelling at 52 km/h. When the participant reached a point 150 m before the intersection, the car immediately ahead began indicating a left turn and then decelerated and moved left into a left-turn lane. The other leading car briefly illuminated its brake lights and then proceeded though the intersection which contained a truck signalling a turn across the participant’s path (moving towards the participant’s vehicle at 1 m per sec) and a vehicle emerging from the road to the left also preparing to turn across the participant’s path.

Approximately 2 km later the participants reached the second hazard, a car pulling out of a curb parking area as the participant approached (see Figure 2.3b). When the participant’s vehicle was 60 m away, the parked car began to blink its right indicator light. When the participant was 30 m away the parked vehicle pulled into the participant’s lane, accelerating to 60 km/h.

The third hazard was a one-lane bridge located 4.24 km later, in the 100 km/h speed area (see Figure 2.3c). A hazard warning sign for the bridge was located 272.5 m in advance of the bridge; with a second warning sign accompanied by a supplementary right of way plate (giving right of way to the participant’s vehicle) located 42.5 m ahead of the bridge entrance (at the beginning of the roadway taper). As the participant’s vehicle approached the bridge a large truck was exiting the bridge and two cars were beginning to cross. A fourth vehicle arriving at the far end of the 48 m bridge slowed to a rolling stop (1 m per sec) to wait for the participant’s vehicle to cross.

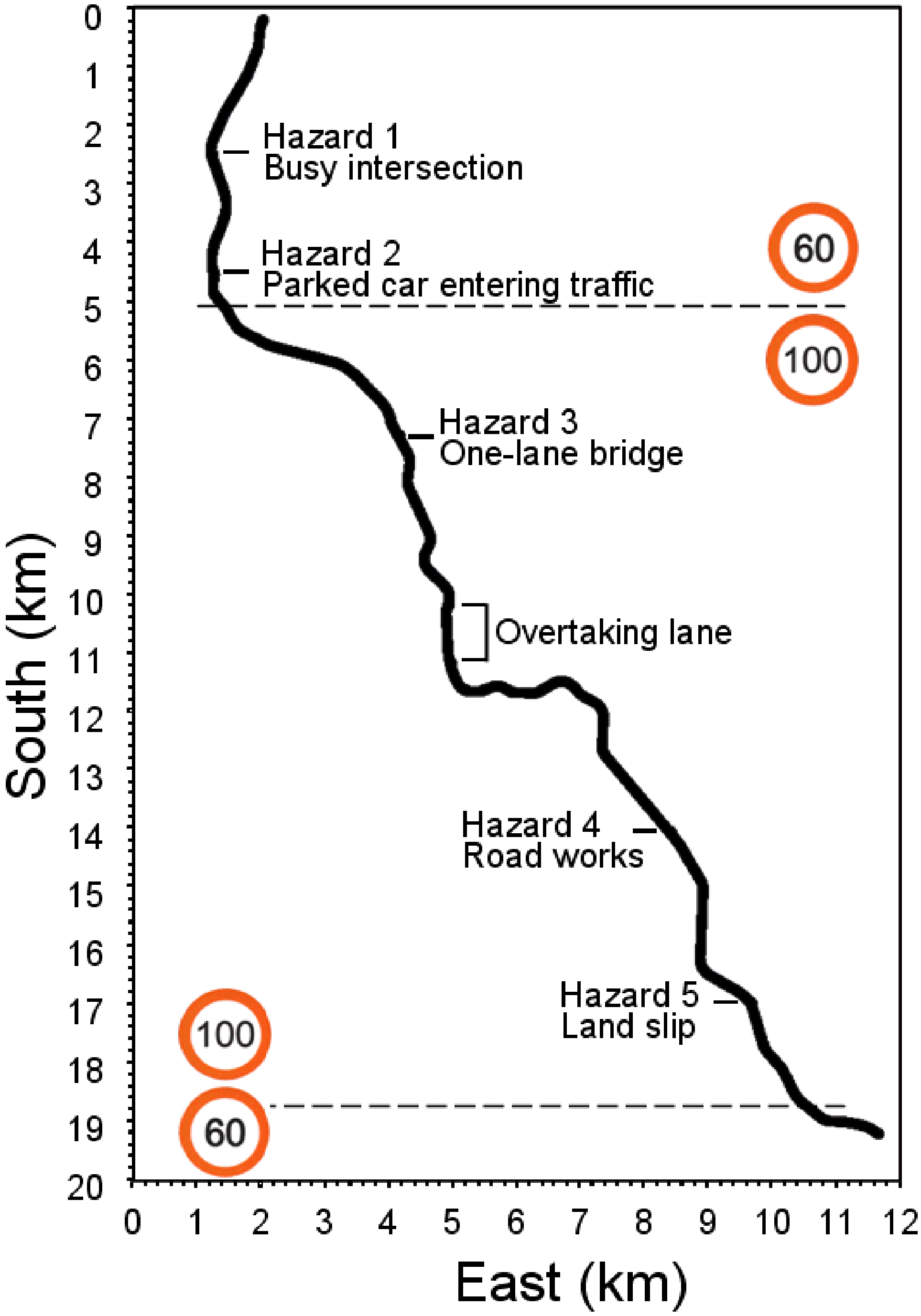
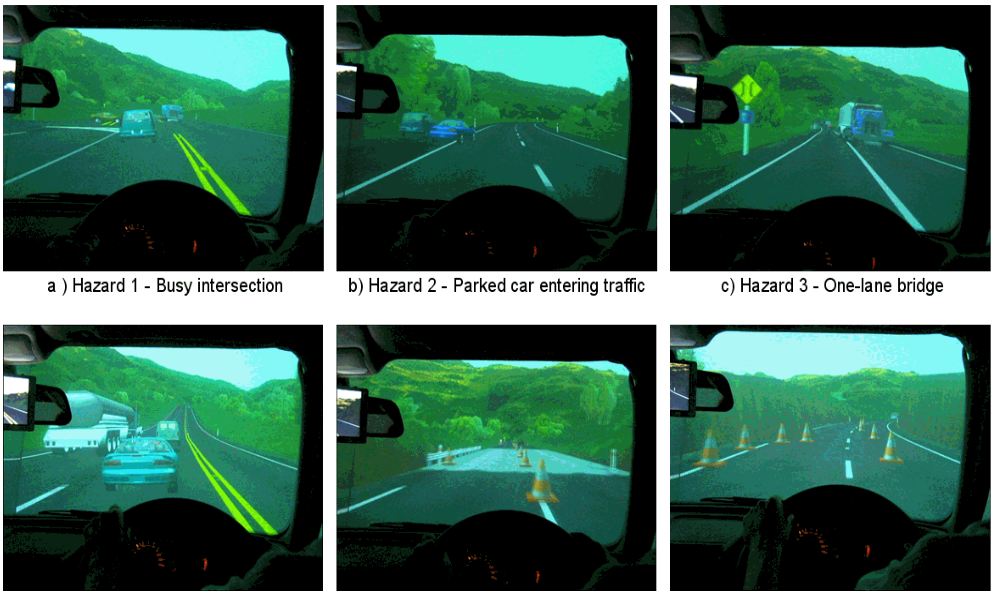


Figure 2.2 A map of the simulated road showing the five hazard locations and overtaking lane.



a) Hazard 1 - Busy intersection
b) Hazard 2 - Parked car entering traffic
c) Hazard 3 - One-lane bridge
d) Overtaking lane
e) Hazard 4 - Road works
f) Hazard 5 - Land slip

Figure 2.3 Participants' views of the five hazards and overtaking lane.

An overtaking lane approximately 1 km in length was located 3.15 km after the bridge hazard. Although not specifically designed to constitute a hazard, it was included to present a challenging driving task for the participants. The overtaking lane was preceded by a series of advisory/warning signs located 2 km, 1 km and 400 m before the start of the lane. As the participant's car approached the 1 km advisory sign it encountered a series of leading vehicles; a car travelling 95 km/h which slowed to follow a van travelling 87 km/h, both of them slowing further to follow a tanker truck travelling 78 km/h. At the beginning of the overtaking lane all three leading vehicles stayed in the left (slow) diverge lane. Almost immediately, the car and the van indicated a change to the right (fast) lane and accelerated to 96 km/h. After the van overtook the truck it indicated and moved to the left lane while the car accelerated to 106 km/h and overtook the truck and van (see Figure 2.3d). Approximately 250–300 m of the overtaking lane remained at this point and an advisory warning sign indicating the lane merge was located 200 m before the merge taper. If the participant did not overtake the truck or van during the overtaking lane, the car and van indicated a left turn and pulled into a left-turn lane at an intersection located 560 m after the overtaking lane.

The fourth hazard location was a road works site preceded by a road works hazard warning sign (240 m prior), a temporary 30 km/h speed restriction sign (60 m prior), and a loose seal (gravel) hazard sign 30 m prior. The road works site itself consisted of a series of road cones located in the centre of the road leading through a 38.5 m stretch of loose seal and an 85 m section of road with no road markings (see Figure 2.3e). The road works terminated with a 'works end–100 km/h' sign.

The final hazard was located 3.5 km later and was composed of a temporary 'slip' hazard warning sign followed by a series of road cones in the centre and along the left of the road leading traffic around a land slip that extended approximately 1.5 m into the participant's lane (100 m after the initial warning sign). The posted speed limit returned to 60 km/h 2.28 km after the final road cone and led to a Stop sign indicating the end of the simulation scenario 1.05 km later.

2.1.4 Procedure

At the time of scheduling an appointment for the experiment the participants were randomly assigned to one of four experimental groups. Group 1 was a no-conversation control group containing 16 participants (8 male and 8 female) that completed the simulation scenario individually. Group 2 was a passenger conversation group in which 16 pairs of participants (8 male pairs and 8 female pairs) completed the simulation scenario together, one member of each pair driving the simulated car while the other sat in the front passenger seat. Group 3 was a cellphone conversation group that contained 16 pairs of participants (8 male and 8 female pairs) in which one person drove the simulated car and the other was seated in an adjoining room conversing with the driver by means of a hands-free cellphone. Another 16 participant pairs (8 male and 8 female) were assigned to Group 4, a remote passenger condition in which the conversor was seated in an adjoining room while communicating with the driver over the hands-free cellphone but was able to view the driver's progress through the simulation scenario via a large window located just behind the right rear (driver's side) of the simulation vehicle (the remote passengers' view is shown in Figure 2.1). From this position the remote passenger could see the simulation, but not the driver's facial expression. In most cases, the members of each participant pair were acquainted with one another from their workplace, university classes, or membership in professional organisations.

Upon arrival, the participants were given an overview of the activities involved and the time required for the experiment, and were asked to complete an informed consent agreement and a brief questionnaire about their driving background and cellphone use. After completion of the questionnaire each participant was given a short practice session and allowed to drive until they felt comfortable operating the simulator. Participants in Groups 2, 3 and 4 then self-selected which member of the pair would be the driver and which would be the conversor. The pairs were told that they were free to converse about any topics they chose to. The conversor in each pair was also provided with a set of conversation cards containing topics that could be used if they had any difficulty finding subjects to discuss (eg a list of 10 items they would agree to take to a deserted tropical island for a two-week stay; a list of 10 songs to put on a mix tape to listen to on a long car trip; etc.)

Once the driver and conversor were seated in their positions, a voice check was conducted with the hands-free cellphone for the participants in Groups 3 and 4, the video recorder was switched on and the simulation scenario was begun. The average time required to complete the simulation scenario was approximately 24 min. During this time, the participants' self-paced conversations continued without prompting from the experimenter. Although a conversation duration of 24 min may have been somewhat atypical when compared with drivers' normally occurring cellphone conversations, the continuous self-paced conversation was desirable in order to examine whether any conversation modulation occurred in the vicinity of the hazards. Only one of the participants commented that they felt it unusual or difficult to maintain a conversation of that length. Following completion of the simulation scenario the drivers were asked to rate the difficulty of driving the simulated road on a seven-point mental workload/driving difficulty scale ranging from 1 = easy; no difficulty at all to 7 = extremely difficult; unsafe (Charlton 2004) and recall as many hazards or difficult situations from their drive as possible. Drivers in Groups 2, 3 and 4 were also asked to rate the amount of interference their conversation had on their driving on a seven-point scale (1 = no interference, 7 = complete interference).

2.2 Results

2.2.1 Vehicle speeds

Shown in Figure 2.4 are the mean vehicle speeds for the four experimental groups as they approached and passed through each of the five simulated hazard sites. As can be seen in the figure, drivers in the Control (no conversation) and Passenger groups generally reduced their speeds as they approached and drove past each hazard point, whereas the average speeds of drivers in the Cellphone and Remote Passenger groups decreased only slightly or not at all.

A one-way multivariate analysis of variance (General Linear Models procedure, SPSS, Inc, Chicago IL) comparing the groups' vehicle speeds at the five hazard points indicated a statistically reliable difference between the groups [Wilks' Lambda = .470, $F_{(15,154.99)} = 3.246$, $p < 0.001$]. Examination of the univariate group comparisons at each hazard site showed group differences at Hazard 1 (busy intersection) [$F_{(3, 60)} = 5.577$, $p < 0.01$], Hazard 3 (one-lane bridge) [$F_{(3, 60)} = 4.543$, $p < 0.01$], Hazard 4 (road works) [$F_{(3, 60)} = 4.924$, $p < 0.01$], and Hazard 5 (land slip) [$F_{(3, 60)} = 11.026$, $p < 0.001$]. The group differences in speeds at the second hazard point (parked car entering traffic) were not statistically reliable [$F_{(3, 60)} = 1.938$, $p > 0.05$].

Post hoc pair-wise comparisons of individual group means at each hazard point were made using a Bonferroni adjustment for experiment-wise error rate. At the busy intersection the mean speeds of drivers in the Passenger group were significantly lower than the speeds in the Cellphone and Remote Passenger groups [ps < 0.05] and the Control group was slower (marginally significant) than the Cellphone and Remote Passenger groups [$p < 0.06$ & $p < 0.07$ respectively]. The comparison of the Cellphone and Remote Passenger groups failed to indicate any reliable difference in their mean speeds; nor was there any reliable difference in the speeds of the Control and Passenger groups.

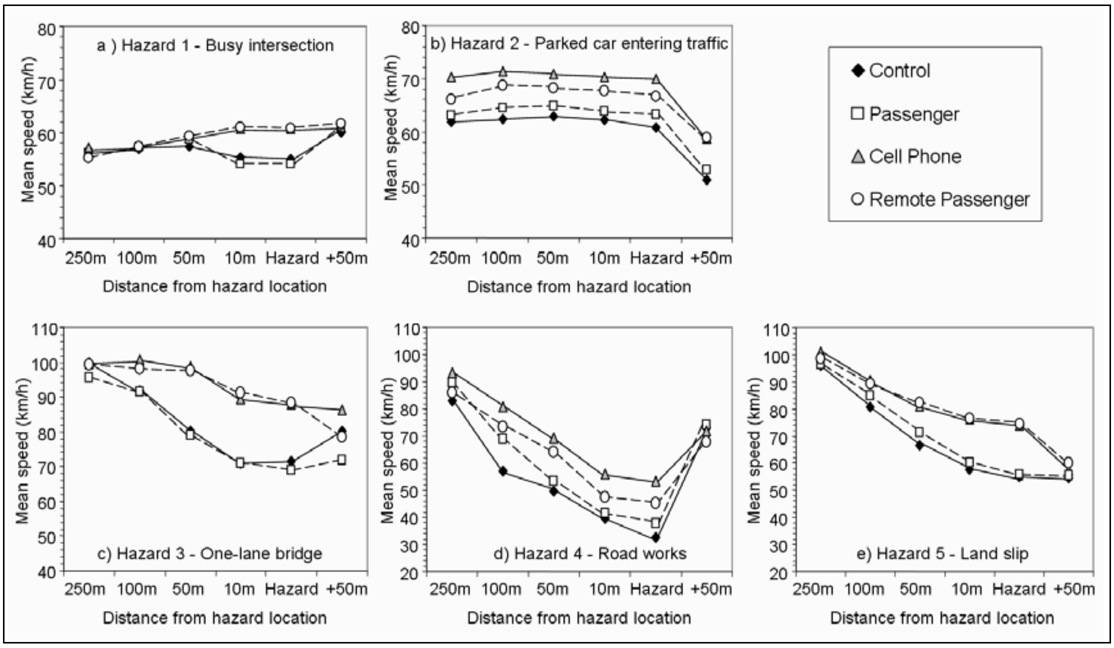


Figure 2.4 Participants' mean speeds through each of the five hazards.

At the one-lane bridge the mean speeds of the Passenger group were reliably lower than the speeds for the Cellphone and Remote Passenger groups [ps < 0.05], but none of the other groups' mean speeds were reliably different [ps > 0.10]. At the road works site the Control group's mean speed was reliably lower than the Cellphone group [p < 0.01] and the Passenger group's speed was marginally lower than the Cellphone group [p < 0.055]. None of the other pair-wise comparisons were statistically reliable at this site. Finally, at the land-slip hazard, the both the Control and Passenger groups displayed reliably lower speeds than the Cellphone and Remote Passenger groups [ps < 0.01].

2.2.2 Reaction times

Six measures of the participants' decelerating and braking reactions were calculated at each hazard location. Three deceleration measures were calculated from the time each driver removed their foot from the accelerator pedal (began decelerating): accelerator reaction time (ART) measured in seconds from a point 250 m prior to each hazard; accelerator time-to-collision (ATTC) measured in seconds to reach the hazard at the current velocity; and accelerator distance-to-collision (ADTC) measured in metres distant from the hazard. Similarly, three braking measures were calculated from the time each driver pressed the brake pedal: braking reaction time (BRT); braking time-to-collision (BTTC); and braking distance-to-collision (BDTC).

Figure 2.5 shows the significant differences in the participants' deceleration and braking reactions as they approached the hazards. As can be seen in Figure 2.5, drivers in the control group had the fastest deceleration reaction times, removing their foot from the accelerator earlier and further away from the hazards than other drivers. Drivers conversing with passengers were somewhat slower than non-conversing drivers, but still registered deceleration responses considerably earlier and further away than drivers in the Cellphone and Remote Passenger groups.

Hazard 3, the one-lane bridge, which displayed some of the largest between-group differences in speed, is shown in the top panel of Figure 2.5. As can be seen, a greater proportion of the participants in the Control and Passenger groups reacted on the approach to the one-lane bridge by removing their foot from the accelerator and/or braking, compared with the Cellphone and Remote Passenger groups where only 31.3% and 43.8% of the drivers braked. A one-way multivariate analysis of variance comparing the four groups across the three deceleration measures indicated a reliable effect of group at Hazard 3 [Wilks' Lambda = .582, $F_{(9, 99.93)} = 2.768$, $p < 0.01$]. Univariate comparisons for each of the three deceleration measures indicated significant group differences for ART [$F_{(3, 43)} = 6.353$, $p < 0.001$], ATTC [$F_{(3, 43)} = 5.300$, $p < 0.01$], and ADTC [$F_{(3, 43)} = 5.613$, $p < 0.01$]. Post hoc pair-wise comparisons revealed that the Control group was reliably different from the Passenger and Remote Passenger groups on all three deceleration measures [ps < 0.01], but none of the other group means were reliably different from one another.

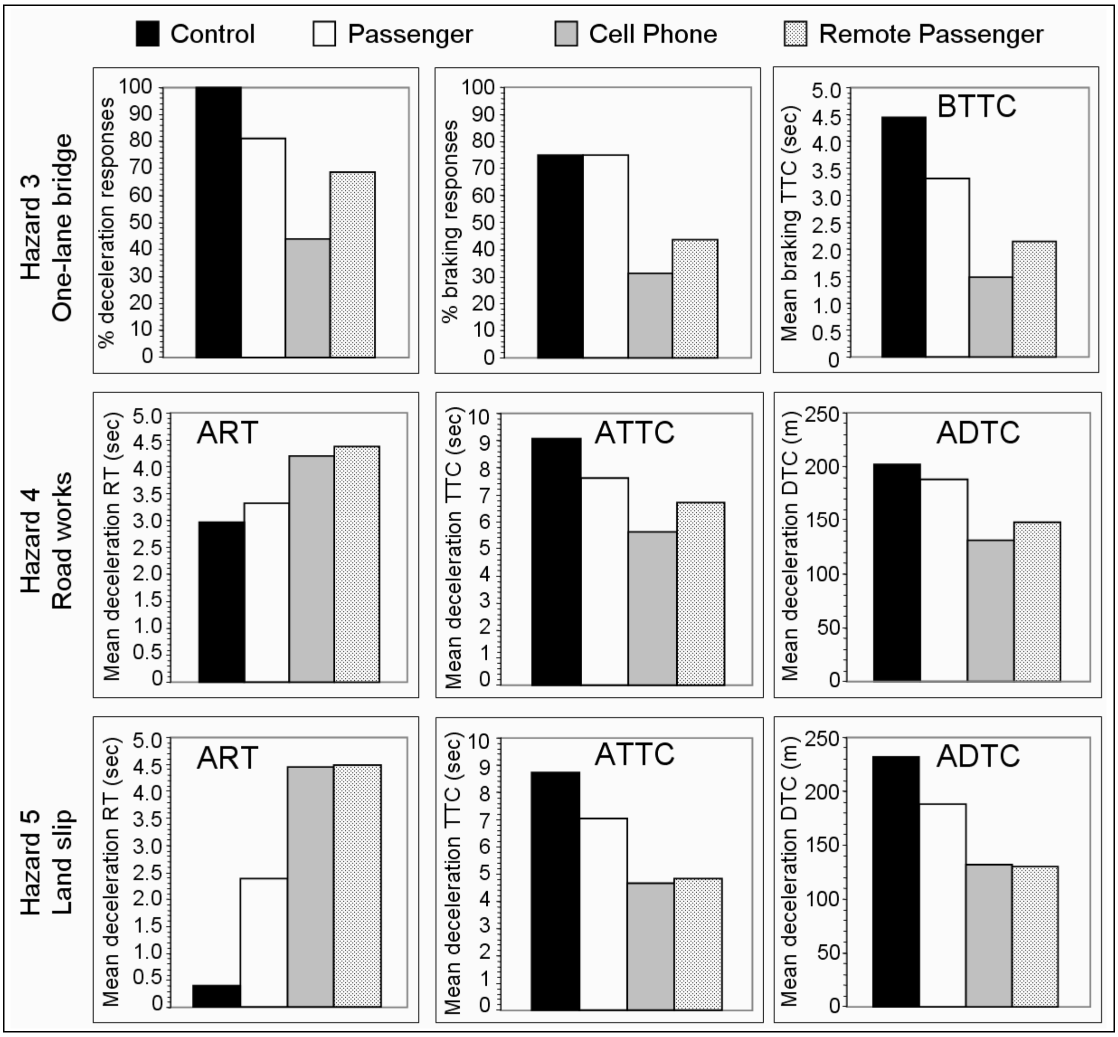


Figure 2.5 Proportion of participants' deceleration and braking reactions at Hazards 3 (top row) and deceleration times and distances at Hazards 4 and 5 (bottom two rows).

A comparison of the groups across the three braking measures at Hazard 3 also indicated a reliable difference between the groups [Wilks' Lambda = .470, $F_{(9, 73.16)} = 2.953$, $p < 0.01$]. Univariate comparisons revealed that the source of this effect was due to group differences for the BTTC measure [$F_{(3, 32)} = 3.702$, $p < 0.05$] as shown in Figure 2.5. Post hoc pair-wise comparisons of the group BTTC means using a Bonferroni adjustment indicated that the Control group braked significantly earlier than the Cellphone group [$p < 0.05$]; none of the other groups differed reliably [$ps > 0.05$]. It should be noted that the one-lane bridge was apparently the most challenging driving situation in the experimental scenario. Examination of the drivers' lateral positions as they crossed the bridge revealed that a sizable number of drivers would have sideswiped or collided with the bridge rails, another vehicle, or both; 11 drivers (68.8%) in each of the Cellphone and Remote Passenger groups displayed vehicle trajectories that intersected with other objects, while only three drivers (18.8%) in the Passenger group and one driver (6.3%) in the Control group did.

At Hazard 4 (road works), shown in the middle panel of Figure 2.5, all of the participants registered a deceleration response and a majority of them also registered a braking response. A one-way multivariate analysis of variance comparing the four groups across the three deceleration measures indicated a reliable effect of group at Hazard 4 [Wilks' Lambda = .573, $F_{(9, 141.31)} = 4.031$, $p < 0.001$]. Univariate comparisons for the three deceleration measures indicated significant group differences for ATTC [$F_{(3, 60)} = 7.292$, $p < 0.001$], ADTC [$F_{(3, 60)} = 7.719$, $p < 0.001$], but not for ART [$F_{(3, 60)} = 1.560$, $p > 0.05$]. Post hoc pair-wise comparisons revealed that the Control group responded earlier and further away than the Cellphone and Remote Passenger groups [ps < 0.01]. The Passenger group was earlier (marginally significant) than the Cellphone group on the ATTC measure [$p < 0.06$] and further away from the bridge than the Cellphone group on the ADTC measure [$p < 0.01$]. A one-way multivariate analysis of variance for the three braking response measures failed to detect a significant difference across the four groups [Wilks' Lambda = .729, $F_{(9, 114.54)} = 1.761$, $p > 0.05$].

Most of the participants registered a deceleration response at Hazard 5, the land slip (all of the Control and Passenger groups and 75% of those in the Cellphone and Remote Passenger groups). The group differences in the deceleration reactions were even more pronounced at this hazard location, as shown in the bottom panel of Figure 2.5. A multivariate analysis of variance indicated that the timing of the deceleration responses were reliably different across the four groups [Wilks' Lambda = .687, $F_{(9, 121.84)} = 2.255$, $p < 0.05$]. Univariate tests on each of the deceleration measures indicated significant group differences for ART [$F_{(3, 52)} = 5.232$, $p < 0.01$], ATTC [$F_{(3, 52)} = 6.483$, $p < 0.001$], and ADTC [$F_{(3, 52)} = 5.731$, $p < 0.01$]. Post hoc pair-wise comparisons revealed that the Control group responded more quickly, earlier, and further away than the Cellphone and Remote Passenger groups (ps < 0.01), but none of the other groups differed reliably. Fewer than 50% of the drivers in the Cellphone and Remote Passenger groups registered a braking response at the land slip and although there was a significant multivariate group effect across the three braking measures [Wilks' Lambda = .614, $F_{(9, 85.331)} = 2.100$, $p < 0.05$], none of the individual univariate tests produced a sufficiently reliable result, perhaps because of the rate of braking by the Cellphone and Remote Passenger drivers.

During the approach to the busy intersection site (Hazard 1), only 31.3 % of the drivers in the Cellphone and Remote Passenger groups registered a deceleration response (removed their foot from the accelerator) compared with the Control and Passenger groups (56.3% and 68.8% respectively). None of the drivers in the Cellphone and Remote Passenger groups undertook a braking response whereas 18.8% of the Control group drivers and 31.3% of the Passenger group did. The relatively low numbers of participants registering a deceleration or braking response made statistical comparison of reaction time differences between the groups impracticable. A greater proportion of the drivers decelerated and braked at Hazard 2 (parked car entering traffic). Nearly all of the drivers in the Control group (93.8%) and Passenger group (81.3%) registered a deceleration response and 62.5% of both the Cellphone and Remote Passenger groups did likewise. Although there was a trend for drivers in the Control and Passenger groups to decelerate earlier and further away from the car ahead of them than drivers in the Cellphone group, the pattern was not statistically reliable [Wilks' Lambda = .800, $F_{(9, 99.93)} = 1.065$, $p >$

0.05]. Only 25% of the Control group, 37.5% of the Cellphone group and 43.8% of the Passenger and Remote Passenger groups registered a braking response, too few for a reliable comparison of group differences for the braking response measures.

2.2.3 Discourse measures

The conversations of the participants in the Passenger, Cellphone and Remote Passenger groups were recorded throughout the experiment. The portions of these conversations corresponding to the 15 sec prior to, and 5 sec after each hazard point were transcribed and several measures of conversational performance were calculated: the number of utterances (Brown and Yule 1983) made by the driver and conversor; the mean utterance length (the total number of words divided by the number of utterances) for the driver and conversor; the number of utterances where the topic was the immediate driving situation (defined as situation awareness utterances or simply SA utterances); and the number of pauses longer than 2 sec that occurred within clause boundaries.

The top panel of Figure 2.6 shows the discourse measures for the three conversation groups at Hazard 1, the busy intersection. As can be seen in the figure, participants in the Cellphone group had fewer pauses in their discourse (particularly the conversors) and did not discuss the driving situation (SA utterances). Drivers and conversors in the Passenger group tended to have shorter utterances. A multivariate analysis of variance of the six discourse measures indicated a significant difference between the three groups [Wilks' Lambda = .420, $F_{(12, 80)} = 3.623$, $p < 0.001$]. The univariate analyses indicated significant group differences for four of the measures: number of driver pauses [$F_{(2, 45)} = 4.452$, $p < 0.05$], number of conversor pauses[$F_{(2, 45)} = 6.559$, $p < 0.01$], percent of driver SA utterances [$F_{(2, 45)} = 9.602$, $p < 0.001$], and percent of conversor SA utterances [$F_{(2, 45)} = 8.556$, $p < 0.001$]. There was also a marginally significant result for conversor utterance length [$F_{(2, 45)} = 2.758$, $p < 0.07$] with Cellphone conversors displaying the longest utterances.

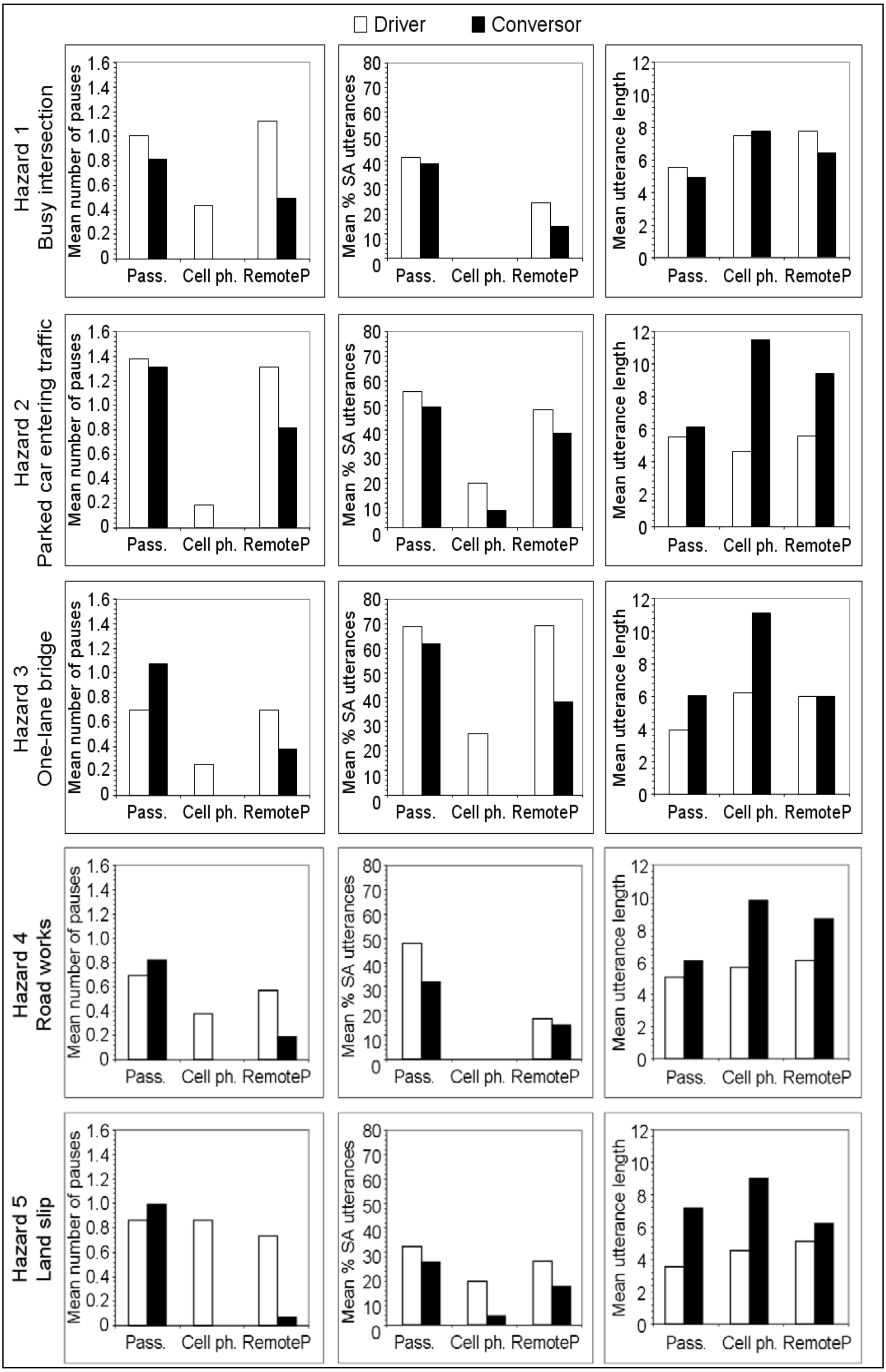


Figure 2.6 Participant's discourse measures at Hazards 1–5.

The second panel of Figure 2.6 shows the same data for Hazard 2, the parked car entering traffic. It can be seen that a similar pattern of discourse was present: participants in the Cellphone group had fewer pauses and tended not to discuss the driving situation. Conversors in the Cellphone and Remote Passenger groups also produced longer utterances than their driving partners and participants in the other groups. Statistical analyses revealed a significant group effect in the multivariate analysis [Wilks' Lambda = .262, $F_{(12, 80)} = 6.353$, $p < 0.001$], and significant univariate group differences for five of the six measures: number of driver pauses [$F_{(2, 45)} = 7.146$, $p < 0.001$], number of conversor pauses [$F_{(2, 45)} = 22.770$, $p < 0.001$], percent of driver SA utterances [$F_{(2, 45)} = 9.760$, $p < 0.001$], percent of conversor SA utterances [$F_{(2, 45)} = 8.962$, $p < 0.001$], and for conversor utterance length [$F_{(2, 45)} = 3.872$, $p < 0.05$].

As can be seen in the middle panel of Figure 2.6, this pattern of discourse was repeated at the one-lane bridge (Hazard 3), albeit with an even higher proportion of conversation about the driving situation for participants in the Passenger group and drivers in the Remote Passenger group. Statistical analyses confirmed the pattern with significant group effect in the multivariate analysis [Wilks' Lambda = .154, $F_{(12, 80)} = 10.325$, $p < 0.001$], and significant univariate group differences for all six of the discourse measures: number of driver pauses [$F_{(2, 45)} = 3.868$, $p < 0.05$], number of conversor pauses [$F_{(2, 45)} = 44.600$, $p < 0.001$], percent of driver SA utterances [$F_{(2, 45)} = 16.765$, $p < 0.001$], percent of conversor SA utterances [$F_{(2, 45)} = 32.822$, $p < 0.001$], driver utterance length [$F_{(2, 45)} = 4.091$, $p < 0.05$], and conversor utterance length [$F_{(2, 45)} = 8.024$, $p < 0.05$]. Table 2.1 shows some of the contents of the conversations at the one-lane bridge, the road works and land slip hazards. As can be seen in the conversation excerpts, the conversations between drivers and their in-car passengers contain more references to the hazards (ie SA utterances) and more frequent pauses than the Cellphone and Remote Passenger groups.

The final two hazards, road works (Hazard 4) and land slip (Hazard 5), produced the same discourse patterns as those found in the other hazards (shown in the lower two panels of Figure 2.6). Conversors in the Cellphone group didn't pause, didn't discuss what the driver was doing and produced long utterances. This appeared to affect the drivers in the Cellphone group as well; they also tended to make fewer utterances about what they were doing than the drivers in the other two groups. Once again, the statistical analyses confirmed that the differences between the groups were reliable. Multivariate analysis results were significant for both Hazard 4 [Wilks' Lambda = .394, $F_{(12, 80)} = 3.954$, $p < 0.001$] and Hazard 5 [Wilks' Lambda = .301, $F_{(12, 80)} = 5.475$, $p < 0.001$]. The univariate results indicated significant group effects for four of the six measures at Hazard 4 (number of conversor pauses [$F_{(2, 45)} = 14.683$, $p < 0.001$], percent of driver SA utterances [$F_{(2, 45)} = 13.070$, $p < 0.001$], percent of conversor SA utterances [$F_{(2, 45)} = 7.807$, $p < 0.001$], and conversor utterance length [$F_{(2, 45)} = 3.615$, $p < 0.05$]), but only two of the six measures displayed reliable group differences at Hazard 5; number of conversor pauses [$F_{(2, 45)} = 32.670$, $p < 0.001$] and percent of conversor SA utterances [$F_{(2, 45)} = 3.674$, $p < 0.05$].

Table 2.1 Discourse excerpts from Hazards 3–5.

Hazard 3 One-lane bridge	Passenger	Pair 5F. Conv 'He's got the right of way'. Driv 'It's just thin'. Conv 'Nah, didn't you see back there?' Driv. 'No, I didn't' Conv 'Well red usually means (pause) stop'. Driv 'I didn't see no red'. Pair 26F. Conv '...New Zealand bands (pause) Che Fu'. Driv 'I like... (pause) Oh sh*t'. Conv 'It's a one-lane bridge'. Driv 'Oh, I didn't even realise it was a one lane bridge. Ooops'. Pair 14M. Conv 'Think they'd know how to do it by now, but still they tend to scream'. Driv 'Narrow bridge'. Conv 'Yeah, damn narrow'. Driv 'Where's the sign? There was no sign'. Conv 'I'm sure there was'. Driv 'You sure?' Conv 'No, maybe I should have been paying attention'. Pair 43M. Conv '...and bloody hell it is'. Driv 'Really'. Conv 'Yeah, it's (pause) oohh aye'. Driv 'Yiyiyiyiyi! You guys are waiting for me. Yeah, thanks a lot pal. Oh looks like he is gonna give way. Geez eh?' Conv 'Far out. New Zealand drivers eh?'
	Cellphone	Pair 28F. Conv '...Waikeria prison is?' Driv 'No'. Conv 'I was going to say its kind near there, like it's about half an hour out of Te Awamutu' Driv 'OK'. Conv 'So it's quite close really, its only like an hour and a bit drive here and so cause I'm in the halls at the moment so if I go home I just go home for the weekends'. Pair 29F. Driv 'Yeah, Mt Karori'. Conv 'Yeah, that's the one'. Driv 'Oh cool'. Conv 'So, I'm probably gonna die, I'm a smoker'. Driv 'I just died, ahhh'. Conv 'I'm not sure how I'm gonna go'. Driv 'I just died and crashed the car'. Pair 45M. Driv 'You'll, you'll struggle Aaron cause you'll be wanting to do (pause) Guy that's bloody skinny'. Conv 'What (unintell)'. Driv 'Oh the road got narrow. You'll be wanting to do hand brakes and drive 200 kilometres an hour'. Conv 'Why's that?' Driv 'Well that's the way you drive isn't it?' Conv 'Am I, am I a boy racer?' Driv 'You're a boy racer'. Pair 56M. Driv '...before that my golf is shocking and after that I get exhausted'. Conv 'And what's your handicap?' Driv 'I don't have a handicap. That was a narrow bridge'. Conv 'Do you have any handicaps?' Driv 'I didn't see it. I didn't see that narrow bridge'.
	Remote passenger	Pair 4F. Conv 'What's that called again?' Driv 'I can't remember'. Conv 'Try and think'. Driv 'Whoa, people on the wrong side of the road'. Conv (laugh) Driv 'I think that was a one-way bridge actually, whoopsies'. Conv 'Okay, what's the new one on C4 right now? By Brooke Frasier?' Driv 'Can't remember'. Pair 42F. Conv '...were supposed to be in love and you know others were supposed to be (pause)'. Driv 'Oh, I'm going to crash into the bridge'. Conv 'Ouch. Isn't uh' Driv 'Karen, Karen I just died, your cellphone's right'. Conv 'I'll mourn you. Do you want me to mourn you?' Pair 9M. Driv 'Oh, yeah'. Conv 'Because I went over, came over on the 18th'. Driv 'Whoa, a (pause) oh a one-way bridge'. Conv 'Good job'. Driv 'That was your fault, I blame that squarely on you'. Conv 'I'm sorry for being such a distraction'. Pair 33M. Conv 'Yeah, no I haven't even touched that textbook I bought eh?' Driv 'True, Ohh (pause) Far out I've just had a head-on collision with a truck. Was that a one-way road?' Conv 'Yeah, a one-lane bridge'. Driv 'Totally missed it eh?' Conv 'I don't know if you had right of way, I didn't see'.

Table 2.1 cont Discourse excerpts from Hazards 3 - 5.

Hazard 4 Road works	Passenger	Pair 5F. Driv 'I remember the thin one, the uh (pause) whatchacallit, the sausage rolls that you made with bread and sausage stuff'. Conv 'How do you do those?' Driv 'Huh?' Conv 'How do you do those? Sausage rolls with bread'. Pair 38F. Driv 'Distance 200, oh'. Conv 'Sorry?' Driv 'Sorry I've got to slow down there's some road, men on the road down here. They might be worth a look'. Conv (laugh) 'Yeah'. Driv 'Get ready for the jump the (pause) going over the (pause)' Pair 14M. Driv 'There's gonna be works'. Conv 'Yeah'. Driv 'Road works, oouhhh. 30, nah'. Conv 'Nah'. Driv 'I never drop my car to 30 on the road works. Probably maybe 50 at most. And the cars super slide if you go over 100'. Pair 55M. Driv, 'Oh road works, cool'. Conv 'Oh what happens here? We're back down to (pause) Oh down to 30. There's no stop-go man'. Driv 'Just tap the brakes now'. Conv 'Did ya come down to 30 allr… (pause) oh yeah'. Driv 'Down to 40'. Conv 'I was expecting to feel bumps in the road'.
	Cellphone	Pair 11F. Driv 'Not noodles, just lasagne sheets'. Conv 'Yeah, that's what I mean, yeah those sheets'. Driv 'Yeah'. Conv 'Ok and um some more tomato I suppose eh, some cheese?' Driv 'Yeah'. Conv 'And has that got a cheesy sort of a sauce in-between too, isn't there?' Driv 'Yeah'. Pair 28F. Driv '…else, but I'm not sure if I'm going to be going on to something else or if I'm going to go in a completely different direction or whatever, so' Conv 'Yeah, I mean I can't really see what I'm gonna be like down, 3 years down the track'. Driv 'Yeah'. Pair 45M. Conv 'Still buying land at the moment'. Driv 'Oh right. So you're busy designing anyway'. Conv 'Pretty much that's all right and been working on the old Avalon drive'. Driv 'Oh yeah'. Conv 'That's what I've been doing and trying to work with our old, old M_____ plans, which are crap'. Pair 53M. Conv 'You cook all the meals at home don't ya?' Driv 'Yeah right'. Conv 'Oh yeah, um now I am going to want some butter chicken. For one night so that means chicken. umm'.
	Remote passenger	Pair 39F. Conv '…at least one of their songs somewhere'. Driv 'You'd have to have old school eh when you were like going places'. Conv 'Yeah'. Driv 'Oh, road works, aaah!. Gosh, ooo!' Conv 'I think we just crashed'. Driv 'Oh my gosh, I suck'. Pair 42F. Driv '…in the other direction, I don't know'. Conv 'Yeah, have you heard from Gemma today?' Driv 'Have I heard from Gemma today?' Conv 'Mmm'. Driv 'No'. Conv 'No'. Driv 'Have you?' Conv 'No, I was just wondering'. Pair 9M. Driv 'Oh, Ok. Oh yeah cause we gotta tha, we gotta go back and study all that stuff that that um (pause)'. Conv 'Do you know if its multi-choice as well?' Driv 'Yeah'. Conv 'Um, so yeah that'll make things a bit easier'. Driv 'We gotta go back and study all that stupid stuff that that stupid woman talked about'. Pair 34M. Conv 'Yeah and then you can follow up with a phone call, that's always good'. Driv 'A phone call, yeah right'. Conv 'Coming up to a work site'. Driv 'Yeah'. Conv 'Is that 30 k the first sign you've come across?'

Table 1 cont Discourse excerpts from Hazards 3–5.

Hazard 5 Land slip	Passenger	Pair 38F. Driv 'Home cooked meals?' Conv 'Yeah. And what do you, what do you put in (pause)'. Driv 'Oh, something with mince (pause) Oh! Made it, I'm so glad'. Pair 40F. Conv 'I haven't been there for vears, since (pause)'. Driv 'Yeah. I wanna go because (pause) last time I went was years ago'. Conv 'Yeah'. Driv 'Um and (pause) I'm sure I could still enjoy it'. Pair 50M. Driv 'I mean it was five months out of its guarantee so (pause)' Conv 'That's very good service eh?. Because most of the time once you um (pause) Might have hit that one'. Driv 'Don't think so, didn't hear anything'. Conv 'What about the rear view mirror?' Pair 47M. Driv 'You want a gas bottle fridge?' Conv 'Can't you get one of those?' Driv 'I don't know. I've never had one. Bloody road works. What's going on here? Oh, bit of a slip'.
	Cellphone	Pair 11F. Conv 'Curry, you'd use the curry powder eh?' Driv 'Yeah'. Conv 'Yeah, ok some saussies, some curry powder. What do you have with it?' Driv 'Onion'. Conv 'Yeah'. Driv 'Um (pause) Oh dear'. Conv 'You're not doing it again are you?' Driv 'Oh dear. What's that?' Conv 'You're not crashing again are you?' Driv 'No, almost'. Pair 48F. Conv '…which is strange'. Driv 'Oh! (pause) Had to concentrate then, I had to stop talking'. Conv 'You what?' Driv 'I had to concentrate then, I couldn't talk'. Pair 45M. Conv 'Well you need to convince her then'. Driv 'Well I recon we could go for like 2 or 5 years and then come back and I'd be able to bloody buy a house outright, just about'. Conv 'Have you crashed?' Driv 'No, I just braked a bit excessively'. Conv 'I can hear all sorts of clanking going on'. Pair 53M. Driv 'Sausages, how're ya gonna cook sausages?' Conv 'Sausages cooked in oil, we need sausages, bit of mashed potato with it so we need potato, a bit of seasoning to mix the potato with, some tea on top of it, we'll have some gravy…'
	Remote passenger	Pair 4F. Driv 'Oh I love it, parmesan cheese'. Conv 'Yeah'. Driv 'It's yum'. Conv 'Whatd I say before, after spaghetti bolognese?' Driv 'Ahh, wahh, wahh' Conv 'Do you remember?' Driv 'Sorry I'm kinda swerving things'. Pair 12F. Conv 'One's doing their PhD, one's doing their masters, and the other one works for NIWA'. Driv 'Oh, ok'. Conv 'Mmmm'. Driv 'So they're all studying hard out'. Conv 'Yeah, they're like, they help me with everything'. Driv 'That's good'. Conv 'Like if I don't understand anything I just ask em'. Driv 'Ahhh! (laugh)'. Conv 'what was that?' Driv 'Ah this road slip like'. Pair 9M. Conv '…like 39 ks earlier'. Driv 'Yeah'. Conv 'Look I'm sure I've seen this hill before'. Driv 'Ha. That tree, I know that tree. Slip'. Conv 'However the road does change'. Driv 'Ahhh!' Pair 54M. Conv 'I really really enjoyed going there. You, you certainly feel very safe over there though don't you?' Driv 'Yeah, yeah'. Conv 'What's that um that quay against, along the river um' Driv 'Oh'. Conv 'Its not, its not Lambton quay or Frankton quay or something like that'. Driv 'I can't remember'.

2.2.4 Difficulty ratings, hazard recall and crashes

Comparison of the participants' ratings of driving difficulty and degree of interference produced by the conversations are shown in Figure 2.7. There was wide variation in the driving difficulty ratings and no reliable group differences were obtained from the statistical analysis [$F_{(3, 60)} = 2.138$, $p > 0.05$] There was, however, a significant difference in the ratings of conversation interference [$F_{(2, 45)} = 6.394$, $p < 0.01$] with post hoc comparisons indicating that the Cellphone group suffered considerably more interference than the Passenger group [$p < 0.01$]. There were also substantial group differences in the number of hazards correctly recalled and in the number of crashes that occurred at the five hazard sites. Also shown in Figure 2.7, drivers in the Control group had the highest percentage of hazards correctly recalled (76.25%) and drivers in the Cellphone group had the lowest (46.25%). A one-way analysis of variance indicated this difference was reliable [$F_{(3, 60)} = 3.817$, $p < 0.05$]. The most memorable hazard for the participants was the land slip (recalled by 84.38% of the participants), perhaps indicative of a recency effect inasmuch as this was the last hazard to appear. The hazard associated with the greatest difficulty for the participants (as reflected in their crash rates), the one-lane bridge, was recalled by 68.75% of the participants whereas the parked car entering traffic was recalled by 78.13% of the participants. The roadworks site was mentioned by 62.5% of the participants while the busy intersection was recalled by only 20.31% of the participants. The total number of crashes is also shown in Figure 2.7, the bulk of them occurring at the one-lane bridge (62%). As can be seen in Figure 2.7, the Cellphone and Remote Passenger groups recorded the highest numbers of crashes, the Control group the lowest. In order to evaluate the group differences in crash rate a Chi-squared analysis was calculated for the proportion of drivers having one, two or no crashes at the five hazard sites. This analysis indicated a significant difference between the four groups [Chi-square = 27.042, df = 6, $p < 0.001$].

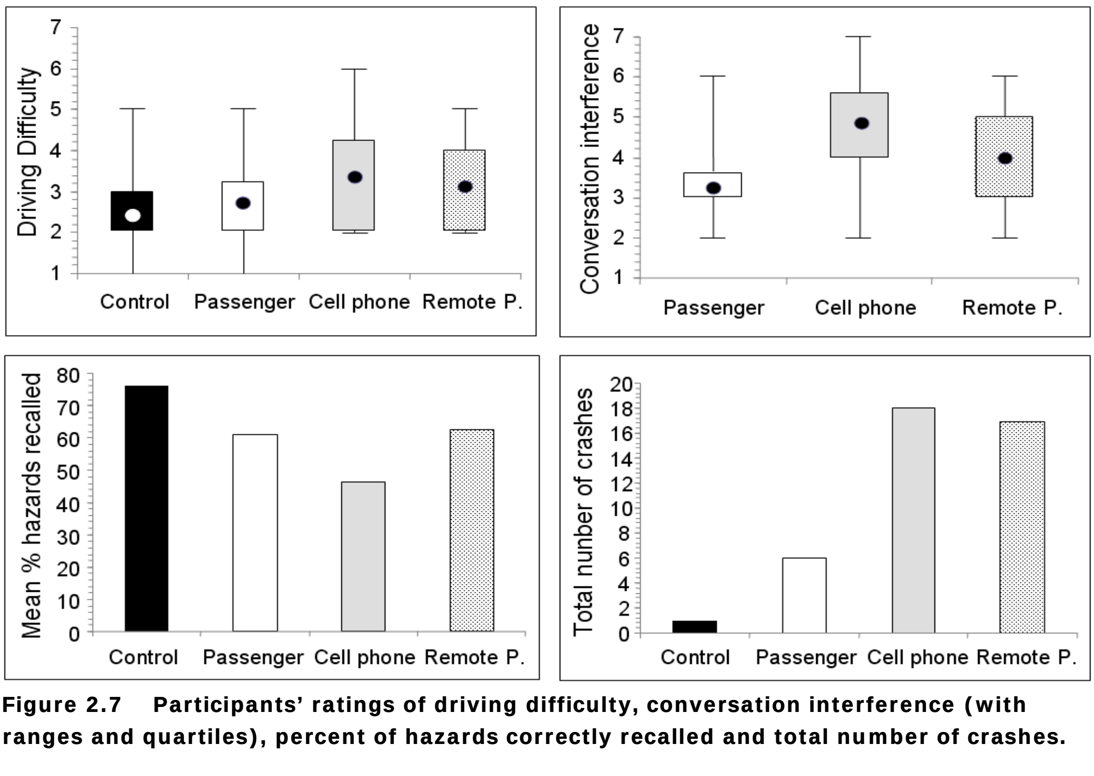


Figure 2.7 Participants' ratings of driving difficulty, conversation interference (with ranges and quartiles), percent of hazards correctly recalled and total number of crashes.

2.2.5 Overtaking

A final point of interest was the participants' driving performance at the overtaking lane. There were no significant group differences in the drivers' speeds measured at four points along the overtaking lane [Wilks' Lambda = .737, $F_{(12, 143.62)} = 1.462$, $p > 0.05$]. There were, however, differences in the number of vehicles overtaken by the participants. In the overtaking scenario the maximum number of vehicles that could be overtaken was three; however, the optimal number that could be safely overtaken (without excessive speed or crossing into oncoming traffic) was two vehicles. Figure 2.8 shows the proportion of drivers in each group successfully overtaking one, two, three or no vehicles. The Control group had the highest proportion of drivers overtaking two vehicles (68.8%) whereas 50% of the drivers in the Cellphone group did not overtake any of the vehicles. In this context, the failure to overtake can be construed as poor or delayed speed management; drivers in the Cellphone group were less likely to accelerate to the speed required to overtake the vehicles ahead of them. A Chi-squared analysis of the proportion of drivers overtaking one, two, three or no vehicles indicated a marginally significant group difference [Chi-square = 16.119, df = 9, $p < 0.064$].

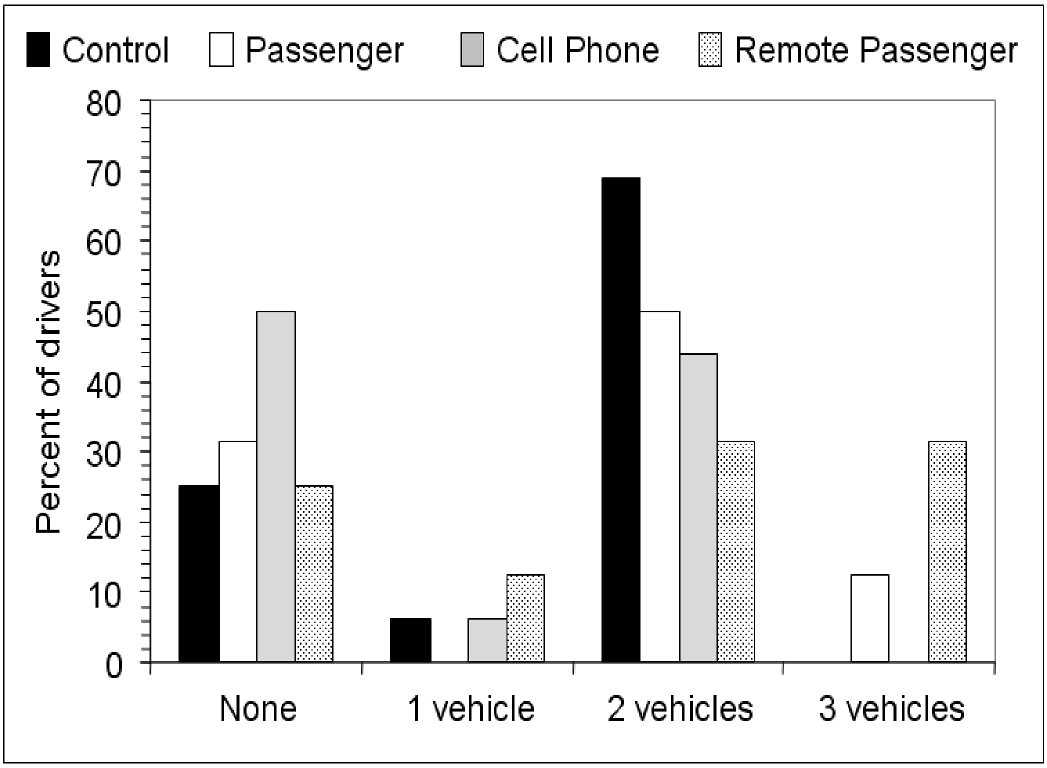


Figure 2.8 Number of vehicles overtaken by drivers in each group.

2.3 Discussion

Drivers talking on a cellphone often failed to take any action to reduce their speed as they approached the hazards, resulting in the highest crash rates obtained (68.8% of participants). Similarly, many of these drivers also failed to manage the overtaking scenario by increasing their speeds when appropriate. Drivers with passengers were more likely to anticipate hazards and reduce their speeds, performing nearly as well as the no-conversation Control group. The differences in the discourse measures give some insight into why these two groups may have performed so differently. Passengers talking to drivers made shorter utterances, had more frequent pauses and were more likely to be talking about the upcoming hazard than cellphone conversors. Drivers and their cellphone conversors tended to make longer utterances than the other participants, were less likely to mention the hazards, had the poorest recall of the hazards, and had the highest crash rate.

The findings clearly indicate that driving while talking to an in-car passenger is appreciably different from conversing over a cellphone. Conversation suppression did occur in the Passenger group (relative to the Cellphone and Remote Passenger groups) as indicated by the number of pauses and the shorter length of conversor utterances. Topic shifts to the hazards also occurred, potentially improving the drivers' awareness of the hazards. Cellphone conversors displayed none of these conversational features. In this context it is interesting that the Remote Passenger group wasn't appreciably better than the Cellphone group as regards their driving performance. The remote passengers did engage in some discussion of the hazards, albeit not to the degree that the passengers did, but they were not as likely to stop talking (pause) as the in-car passengers, or even their driving partners. Apparently the ability to see what the driver can see doesn't lead to the same degree of conversation suppression, and is thus associated with only slightly better performance on the driving task than drivers talking to conversors who are blind to their situation. Of even greater significance, the drivers conversing with remote passengers displayed much poorer performance than drivers conversing with in-car passengers, highlighting the fact that cellphone conversations are significantly more detrimental than passenger conversations.

Regardless of how well the drivers talking to passengers performed relative to the drivers talking on cellphones, it should be noted that drivers who were not conversing (Control group) were the safest by most measures. These drivers displayed cautious speeds, rapid deceleration reactions to hazards, good speed management leading to safe overtaking, the fewest crashes and good recall of the hazards after the drive. The drivers in the Passenger group displayed a higher number of crashes than the no-conversation drivers indicating that there is a penalty associated with driving while conversing (perhaps because not all passengers suppress their conversations when they should). Drivers in both the Passenger and Remote Passenger groups showed good recall of the hazards after the drive, indicating that their discussion of the hazards may have given them a recall advantage over drivers in the Cellphone group, although that advantage in memory performance did not appear to confer any advantage in driving performance to the Remote Passenger group.

3. Experiment 2

Regardless of the wealth of information available about the risks associated with driving while conversing on a cellphone, many drivers continue to engage in the practise and resist restrictions on their use (McCartt and Geary 2004; Rajalin et al 2005). The findings of the previous experiment indicate that conversations per se are not inherently a problem for drivers; conversation rates that are inflexible and incompatible with momentary traffic demands are a problem however. Passenger conversations that contain shorter utterances and pauses during difficult driving situations, and offer comments alerting drivers to the presence of hazards, enable quite satisfactory levels of driver performance.

A reasonable question to ask is whether there are any technological modifications to cellphones that could introduce some of the same features of passenger discourse into a cellphone conversation? One study that addressed this proposition tested a cellphone modified to present three short beeps followed by a suspension of the conversation (Wood and Hurwitz 2005). The researchers reported that the modified cellphone counteracted some of the negative effects typically associated with cellphone conversations, decreasing drivers' workload ratings and their reaction times to vehicles decelerating ahead of them.

The present experiment explored a somewhat different technological modification in the form of a cellphone that provided alerting tones as a driver approached a hazard location. The purpose of this trial was to investigate whether the introduction of alerting beeps would produce conversational pauses similar to those seen in passenger conversations and whether these 'artificial' pauses would result in similar driving performance. The underlying concept is that radio frequency 'tags' could be placed on hazard warning signs, or GPS-capable cellphones could be programmed with maps containing the locations of known road hazards. In either case, the cellphone would emit a series of warning beeps as a driver conversing on a cellphone approached a potential hazard. This experiment was conducted to examine what effects the alerting signals would have on drivers' behaviour. There were two possibilities predicted for the alerting cellphone design: 1) the alerting beeps would add another source of distraction and workload making driving performance worse; and 2) the alerting beeps would interrupt the conversation and alert the driver, artificially replicating the role of an in-car passenger.

3.1 Method

3.1.1 Participants

A sample of 40 participants, 14 male and 26 female, were recruited from a third-year university course in applied cognitive psychology. The participants ranged from 19 to 40 years of age with an average age of 23. 5 years (SD = 5.54). Participants were required to possess a current New Zealand driver licence and asked to wear any corrective lenses during the experiment if they were required to do so as a condition of their driver licence. Two participant pairs did not complete the experiment due to eyestrain or dizziness leaving a final sample of 36 (18 participant pairs) that was composed of 13 male and 23 female participants. In this sample all of the drivers indicated they owned a cellphone and of those, 55.6% admitted they conversed on it while they drove, with 22.3% using it weekly or more often. In comparison, 77.8% of the participants said they used their cellphone to send and receive text messages while they drove, with 61.1% of the participants using it weekly or more often.

3.1.2 Apparatus

The University of Waikato driving simulator hardware, software and video recording equipment described in the previous experiment was used unchanged.

3.1.3 Simulation scenario

The 25.3 km simulated road created for the previous study was again used for the present experiment. The simulation scenario was changed so that the software produced a series of beeps at each of the five hazard sites. As the driver reached a point 300 m away from the hazard a single beep 100 msec in length was sounded. At 200 m from the hazard three beeps were sounded at 400 msec intervals. At 100 m and 50 m from the hazard a series of five beeps (at 250 msec intervals) were sounded.

3.1.4 Procedure

At the time of scheduling an appointment for the experiment the participants self-selected into pairs. All of the pairs experienced the same experimental condition, the alerting cellphone. As in the cellphone conversation group from the previous experiment, one member of each pair drove the simulated car and the other was seated in an adjoining room conversing with the driver by means of a hands-free cellphone. The participants were given the same overview of activities as in the previous experiment and asked to complete an informed consent agreement and a brief questionnaire about their driving background and cellphone use. As with the previous experiment, each participant was given a short practice session and then each pair self-selected which person of the pair would be the driver. The pairs were told that they were free to converse about any topics they chose to and the conversor in each pair was provided with the conversation cards used in the previous experiment. Following completion of the simulation scenario the drivers were asked to rate the driving difficulty of the simulated road, recall as many hazards or difficult situations from their drive as possible, and to rate the amount of interference their conversation had on their driving.

3.2 Results

Figure 3.1 shows the participants' speeds at each of the five hazard locations. The speeds from the Cellphone and Control groups from the previous experiment have been included alongside for comparison. As can be seen, the Alerting Cellphone condition was associated with the lowest speeds at every hazard, even lower than the no-conversation control condition in some cases. A multivariate analysis of variance indicated a reliable difference between the groups across the entire scenario [Wilks' Lambda = .348, $F_{(10, 86)} = 5.972$, $p < 0.001$] and univariate group differences were reliable for each hazard [$F_{(2, 47)} = 6.435$, $p < 0.01$ for

Hazard 1; $F_{(2, 47)}$ = 3.960, $p < 0.05$ for Hazard 2; $F_{(2, 47)}$ = 15.227, $p < 0.001$ for Hazard 3; $F_{(2, 47)}$ = 9.501, $p < 0.001$ for Hazard 4; and $F_{(2, 47)}$ = 11.620, $p < 0.001$ for Hazard 5]. Post hoc pair-wise comparisons (Bonferroni adjusted) indicated that the Alerting Cellphone condition produced reliably lower speeds than the Cellphone group at each hazard location and lower than the Control group at Hazard 3, the one-lane bridge [ps < 0.05].

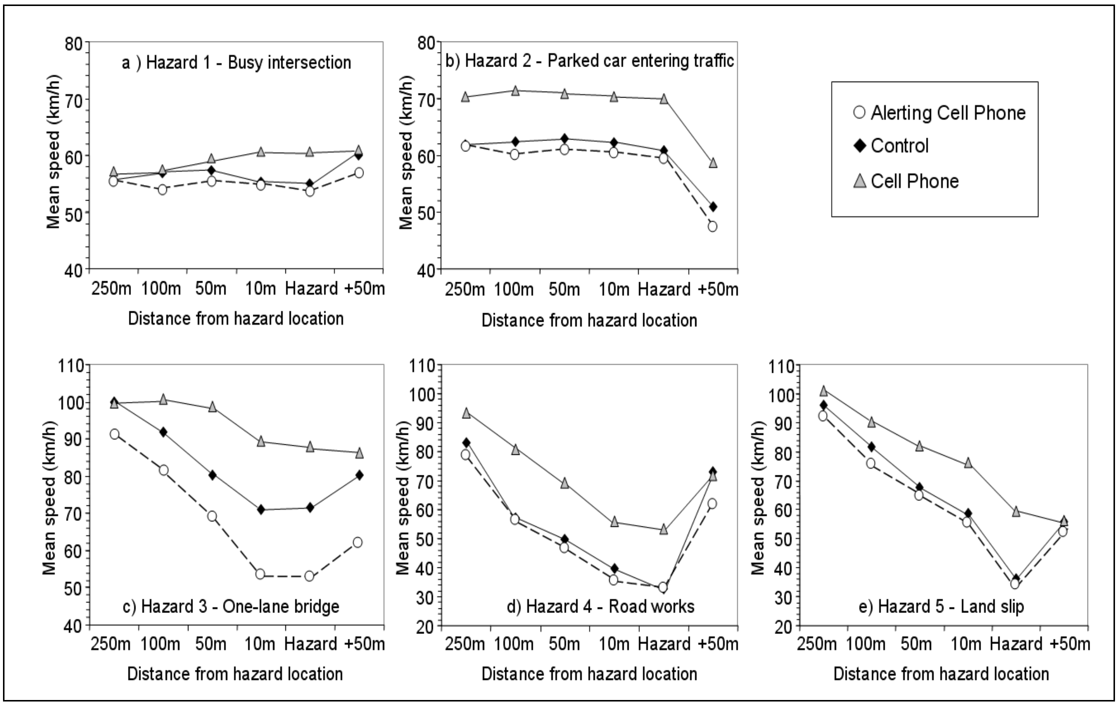


Figure 3.1 Participants' mean speeds through each of the five hazards.

Figure 3.2 shows the deceleration measures for the present experiment compared with the Cellphone and Control groups from the previous experiment. The alerting cellphone was associated with the fastest deceleration reaction times and ATTC and ADTC values equivalent to the no-conversation control condition. All of the Alerting Cellphone drivers registered a deceleration response at Hazards 1, 2, 4 and 5, and all but one driver at Hazard 3. The percentage of Alerting Cellphone drivers registering a braking response were 22.2% at Hazard 1, 100% at Hazard 2, 88.9% at Hazard 3, 77.8% at Hazards 4 and 5. This proportion of drivers braking was higher than that shown by any group except the Passenger group in Experiment 1 (and was even higher than the Passenger group at Hazards 2 and 3). Multivariate analyses of variance comparing the three deceleration measures indicated significant group differences at Hazards 2, 3, 4 and 5 [Wilks' Lambda = .494, $F_{(6, 76)}$ = 5.348, $p < 0.001$, Wilks' Lambda = .453, $F_{(6, 70)}$ = 5.666, $p < 0.001$, Wilks' Lambda = .476, $F_{(6, 90)}$ = 6.737, $p < 0.001$, and Wilks' Lambda = .433, $F_{(6, 82)}$ = 7.105, $p < 0.001$, respectively] (too few Cellphone drivers registered a deceleration response to obtain a reliable multivariate result for Hazard 1). Post hoc pair-wise comparisons confirmed that the drivers in the Alerting Cellphone condition responded earlier (ATTC) and further away (ADTC) than the drivers in the Cellphone condition at every hazard location [ps < 0.05] and also had faster RTs at hazard locations 1, 2 and 5 [ps < 0.05]. The alerting cellphone was also significantly better than the no-conversation control condition on all of the deceleration measures at Hazard 2, had faster RTs and responded further away (ADTC) at Hazard 1 [ps < 0.05], and had longer ATTCs at Hazards 1 and 5 [$p < 0.06$ & $p < 0.05$ respectively]. Multivariate analyses of the braking responses produced reliable group effects at Hazards 3 [Wilks' Lambda = .455, $F_{(6, 56)} = 4.505$, $p < 0.001$] and 5 [Wilks' Lambda = .588, $F_{(6, 56)} = 2.843$, $p < 0.05$]. However, no reliable group differences in braking responses were detected in the post hoc comparisons at these two locations (and thus are not included in Figure 3.2).

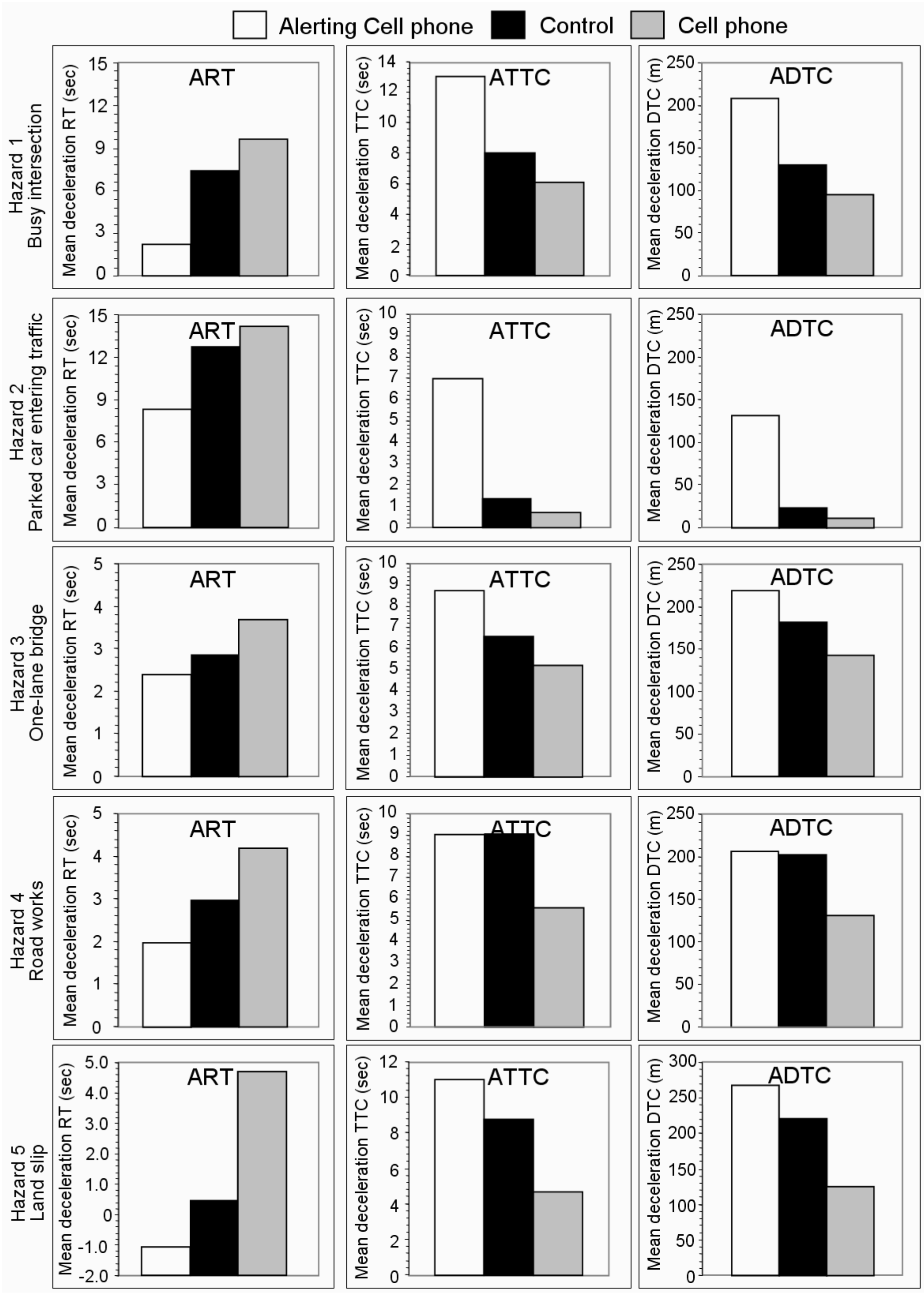


Figure 3.2 Participants' deceleration reactions at the five hazards (compared to the control and cellphone participants from Experiment 1).

Figure 3.3 shows the discourse measures for the present experiment compared with the Cellphone and Control groups from the previous experiment. As can be seen in Figure 3.3, the Alerting Cellphone group produced many more driver and conversor pauses than the Cellphone group; had a much higher proportion of SA utterances; and their mean conversor utterance length was shorter. Multivariate analyses of the discourse measures indicated significant group differences [$ps < 0.001$] at every hazard location except the land slip (which was marginally significant at $p < 0.07$). The univariate comparisons (Bonferroni adjusted) confirmed that the Alerting Cellphone group had more conversor pauses and conversor SA utterances at every location (an exception was conversor SA at Hazard 2 which was $p < 0.059$); more driver pauses and driver SA utterances at every location except Hazard 5 (which was $p < 0.058$ for pauses); and shorter conversor and driver utterance lengths at Hazards 2, 3 and 4, [$ps < 0.01$]. Table 3.1 contains some excerpts from the participants' conversations at the five hazard sites. As with the driver-passenger conversations in the first experiment, the conversations over the alerting cellphone contain frequent pauses and more references to the hazard (SA utterances), as well as references to the alerting tones themselves.

The mean driving difficulty rating for drivers in the Alerting Cellphone condition was 2.89, which was lower than the Cellphone group in Experiment 1 (mean of 3.38) and higher than the control drivers and drivers with passengers (2.44, and 2.75). Post hoc comparisons indicated that the Alerting Cellphone group's ratings were not reliably different from those of either the Control or Cellphone groups [$p > 0.05$]. Similarly, the participants' ratings of driving interference produced by their conversations (mean rating of 4.22) were lower than the Cellphone group (4.88) and higher than the Passenger group (3.28), but did not yield reliably different post hoc mean differences.

The 18 drivers had a total of four crashes in Experiment 2 (22% of participants), all but one of them at the one-lane bridge (the other was at the land slip). This was more than the single crash that occurred for the 16 no-conversation participants in Experiment 1 (6% of participants), but fewer than the five drivers who crashed while conversing with a passenger (31%) and far fewer than the 75% of participants in the Cellphone group who had one or more crashes (for a total of 18 crashes). A Chi-Squared analysis comparing the Alerting Cellphone and Cellphone groups' proportion of drivers having one, two, or no crashes at the five hazard sites indicated a significant group difference [Chi-square = 11.879, $df = 2$, $p < 0.01$]. Finally, at the end of the experimental session the Alerting Cellphone group correctly recalled 74.44% of the hazards, which was equivalent to the Control group in Experiment 1 (76.25%) and significantly better than the 46.25% correctly recalled by the Cellphone group [$p < 0.001$].

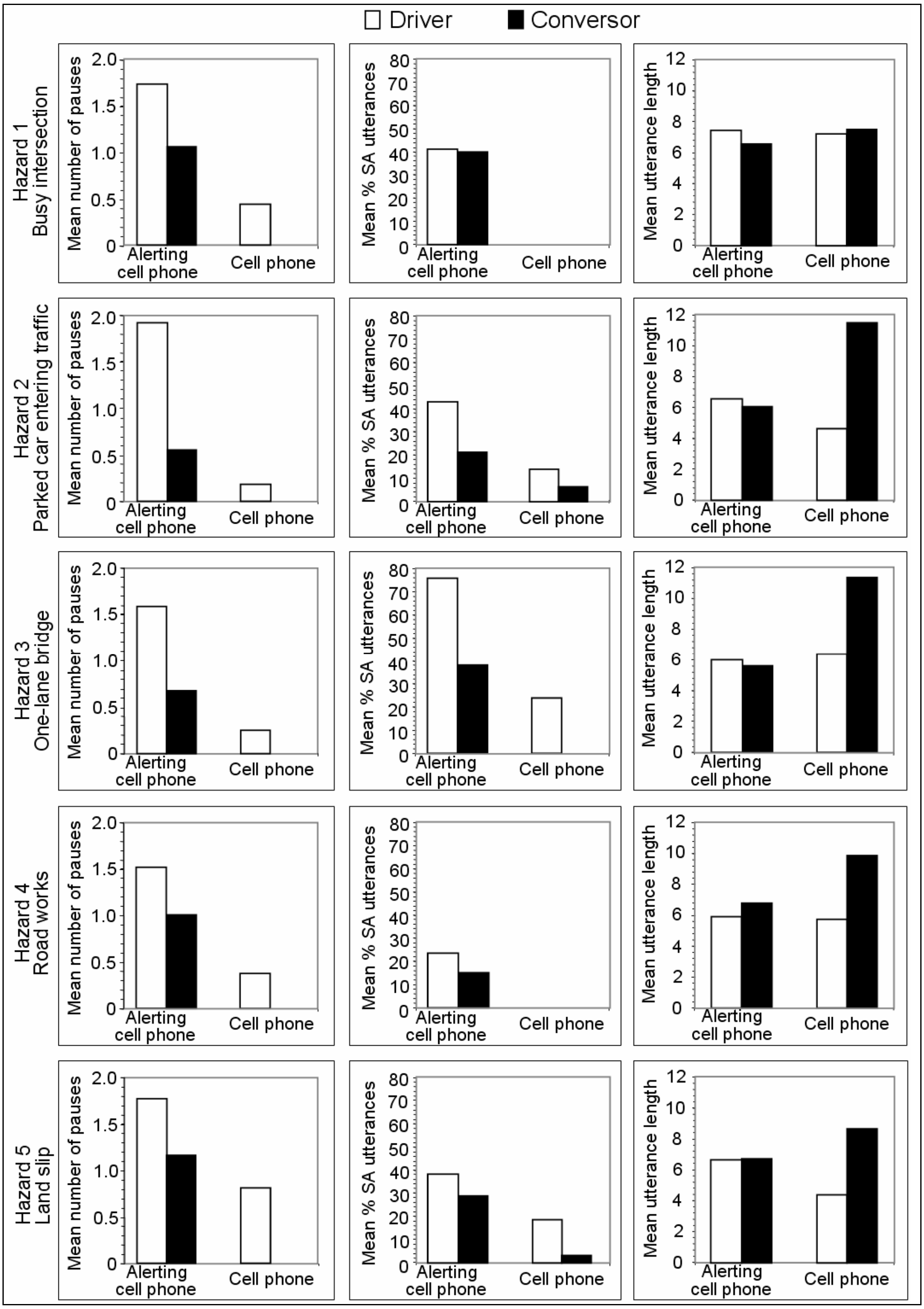


Figure 3.3 Participant's discourse measures at the five hazards (compared with the control and cellphone participants from Experiment 1).

Table 3.1 Discourse excerpts from Alerting Cellphone group.

Hazard 1 Busy intersection	Pair 3F. Conv 'I heard a beep'. Driv 'Yeah I heard a beep too'. Conv 'Think there is some trouble ahead'. Driv 'Hazard must be the intersection'. Conv 'Good thing to notice'. Driv 'Is it beeping because of the hazard or because I'm doing something wrong?' C. 'Think it's just warning you- you're not doing anything wrong'. Pair 21 F. Driver 'That was my resolution to (pause)…ahh I doubt it's (pause) really going to come true with these test results (pause) oh well'. Conv 'Is it hard to drive with the beeping?' Driver 'Ahh, a little, its real hard to talk'.
Hazard 2 Parked car entering traffic	Pair 9F. Driv 'Yeah, but I failed English'. Converser 'Are you busy again?' Driv 'Yeah. Uh… Just watching'. Conv 'Yeah? All good?' Driv 'Yip. There's a car coming'. Conv 'So, did you see the stage production with Lawrence Olivier?' Pair 12M. Driv 'Yeah, I've just been playing a few on that'. Conv 'Oh yeah I (pause) sounds like you've encountered a few hazards then'. Driv 'Looks like it yeah, some car just pulled out in front of me!' Conv (laughs). Driv 'Quite suddenly might I add'.
Hazard 3 One-lane bridge	Pair 16M. Conv 'What's the hazard now?' Driv 'It looks like a bridge, oh it's a one lane bridge'. 'yea (pause) it's a one way bridge'. Conv: 'Oh yea'. Driv 'Hey! Oh this is weird (laughs) It's just hard to judge, I couldn't really tell what the car was doing but it was stopping'. (laughs) Conv 'Oh'. Pair 24F. Driv '…matches and lighters [pause] ok it's beeping at me'. Conv 'Yeah it's quite loud aye? Is that the phone?' Driver 'Pardon?' Conv 'Is that the phone beeping?' Driv 'We're at a one way bridge'. Conv 'This trip's gonna last about five hours'.
Hazard 4 Road works	Pair 6M. Driv 'it's um (pause) it's something'. Conv 'no kidding'. Driv 'I'm trying to concentrate people, I'm trying to concentrate, jeez what do you think this is'. Conv 'I'm sorry. Are you through the hazard yet?' Driver 'Yeah'. Pair 20F: Driv '200 metres till road works [pause] ooh how exciting'. Conv: '"Haha hit the workers. Ha-ha you know you want to'. Driv '30kms? I hate it when it says 30kms!' Conv 'Try driving all the way out from Feilding, where they had road works on every [pause] every 20 or 30 minutes'.
Hazard 5 Land slip	Pair 8F. Conv 'Yeah until I was sixteen'. Driv 'Sixteen!' Conv 'Yeah (pause) then we moved down to Hamilton'. Driver 'Oh that would have been cool. Ok (pause) what's this hazard? A slip'. Conv 'Man it's hard to just keep talking'. Pair15M. Driv 'I think New Zealand, the New Zealand accent is the best English accent. But yep. Oh What! Oh no! Oooh'. Conv 'Are you alright?' Driv: 'Yep, there are a lot of – tell Sam there are a lot of hazards, they did well making the hazards'.

3.3 Discussion

The alerting cellphone was associated with driving performance nearly as good as that of the no-conversation controls from the previous experiment. The drivers' deceleration responses were faster, earlier and further away than those of the Cellphone group. The discourse produced during the cellphone alerts contained more frequent pauses, more often referred to the driving situation and had shorter utterances than the Cellphone group. Given the explicit alerting function of the cellphone beeps, it was perhaps not surprising to find that this condition produced the highest hazard recall accuracy as well. The low number of crashes observed in this experiment suggests that the alerting cellphone was at least as effective as passengers at helping drivers prepare for, and respond to, road hazards. More testing would be required to investigate the technical feasibility of an alerting cellphone, particularly as regards radio frequencies, signal strength and placement. Clearly, not all road hazards would be possible or suitable for such warnings, but the approach might be of some use at locations where stationary hazards might normally be unexpected or have limited visibility to drivers, such as temporary road works sites.

When asked to write down what they thought of the alerting cellphone, the participants' comments were almost universally positive. Some of those reactions included:

> Driver 3F. The beeping cellphone was very good at its job. I became distracted from the conversation the second I heard the first beep and started concentrating on what was ahead.
>
> Driver 4F. I found that having the warning beeps were beneficial in keeping my driving safe and my concentration on the road.
>
> Driver 6M. I certainly reacted verbally to the tones when they came on and found myself searching the road more.
>
> Driver 15M. I personally found the cellphone beeps helpful, as they alerted me to the fact that I was approaching a section of road that would require more than the baseline attention to navigate safely.
>
> Driver 17F. I found the hazard warning signals made me focus my attention on my driving and my driving environment by making me feel slightly apprehensive about what was coming up further down the road.
>
> Driver 20 F. I did appreciate the warning tones as they drew my attention to a possible hazard approaching which possibly meant I was better able to react when the hazard appeared.
>
> Driver 26F. When the tones sounded I noticed our conversation slowed, stopped and sometimes changed our conversation directly to talking about the upcoming hazard.

In sum, the alerting cellphone presents an appealing technological possibility for overcoming many of the unsafe effects associated with drivers conversing on cellphones.

4. General discussion

Driving while talking on a cellphone is different from driving while talking to a passenger. Drivers conversing on cellphones are less likely to initiate a deceleration response as they approach a hazard. When cellphone drivers do decelerate, they decelerate later and closer to the hazard and they are more likely to crash. In the present study, many of these cellphone drivers failed to prepare for hazards, often didn't react when they had close calls or minor collisions, and they had no recollection of the hazard afterwards. One can infer that these drivers never detected the hazards unless they had a significant collision. This finding is consistent with recent reports in the literature that drivers are typically unaware of how poor their driving has become as a result of conversing on cellphones (Horrey et al 2008). Because drivers' attention is directed towards the conversation, rather than their driving, they neither detect nor recall performance decrements or close calls.

The practical implication of the findings obtained for drivers' conversing with passengers is clear; the idea that drivers' use of cellphones need not be restricted simply because of the impracticality of restricting equally hazardous conversations with passengers is not a viable argument. Drivers' cellphone and passenger conversations are different and have different effects on driving performance. One reason for the safety differences between drivers conversing on cellphones and passenger conversations may lie in the content and form of the discourse in these two cases. Passengers were more likely to pause and make shorter utterances (conversation suppression) and were more likely to say something about the current driving situation (SA utterances) as compared to cellphone conversors.

Which of these two conversational aspects is important for avoiding the negative consequences of drivers' cellphone use? The remote passengers displayed some of the topic shifts but very few of the pauses, with the result that their driving partners displayed nearly the same level of disruption as drivers conversing with a conversor who was blind to the drivers' situation. Several aspects of this finding are important to consider: 1) seeing the drivers' situation can result in more utterances about the situation; 2) seeing what the driver sees doesn't necessarily produce conversation suppression (being physically present in the car may be required); and 3) conversation suppression appears to be somewhat more important than situation-relevant utterances for safe driving. These findings suggest that conversation suppression can indeed allow the driver to allocate more attention to the primary driving task when they need to. The conversation interference ratings were reliably lower for drivers talking to passengers, but the driving difficulty ratings were too variable to show clear differences between the conditions. The better driving performance seen in the passenger condition could also be interpreted as resulting from some other factors such as lower workload due to better intelligibility or even more caution resulting from the driver's concern about the welfare of their passenger. The performance of the drivers conversing on the alerting cellphone was nearly as good as the control drivers in the second experiment, suggesting that decreased workload due to better speech intelligibility was not the reason for the advantage enjoyed by passenger conversations. Similarly, concern for the passengers was probably not a significant factor moderating driver behaviour inasmuch as the passenger condition did not produce slower speeds or faster reaction times than the control condition and alerting cellphone condition (when drivers were alone).

The role of conversation suppression appears to be a key factor in avoiding the negative effects associated with drivers conversing on cellphones. The alerting cellphone simulation was able to produce a level of conversation suppression similar to that found with passengers and thus promises a technological solution to a vexing problem associated with public resistance to restrictions on the use of cellphones in cars. The feasibility of this solution, however, would require considerably more investigation in order to judge its ultimate usefulness. Additional research could also productively explore the relative contributions of speech intelligibility and speech rate on driver workload to determine whether attention and workload are the important constituents of the advantage of passenger conversations over cellphone conversations. Finally, an argument can be made that cellphone conversations are more distracting than other in-car activities because they are continuous and externally paced. In contrast, operation of radios and CD changers can be stopped and started, drivers can actively manage their level of distraction, similar to the way passengers manage their distraction by pausing. Drivers can not, however, manage their cellphone conversations in the same way. Participants in a conversation have an expectation of continuous discourse, with no interruptions, that places cognitive demands on drivers that other distractions do not (McKnight and McKnight 1993). Although an alerting cellphone may provide one suggested method of relieving some of this continuous demand when necessary, more research examining other methods of presenting alerting information to drivers regardles of their cellphone use (eg via in-car navigation aids such as GPS) would be required before any one solution is pursued. Further, future research exploring and comparing the self-paced and externally paced aspects of other in-car distractions of various durations would be very useful.

The artificiality of laboratory procedures generally, and simulations specifically, must be taken into account when generalising the results from such procedures to real-life situations. In the present case, the unfamiliar car and visual resolution may have contributed to poorer performance than we would obtain in an actual car on the highway. Although the hazards included in the simulation scenario were all plausible, their concentration in a short section of road was unlikely. Certainly the number of crashes observed in the present experiments would be extremely disappointing and tragic were they to occur in real life. This does, however, speak to one advantage of simulation, the possibility of even a low rate of crashes would make replication of this sort of experiment on the highway unethical and impractical. Further there is an emerging consensus that relative validity (ie the equal generalisability of the conditions being compared in a simulated environment) may be more important than absolute validity (eg the veridical correspondence between driver speeds and reaction times obtained in simulation and on real roads) (Godley et al 2002; Törnros 1998). The number of laboratories using simulation has increased dramatically in recent years, perhaps reflecting this understanding (Bella 2008). In the specific case of research into driving and cellphone use, a recent meta analysis failed to detect any significant differences in on-road and simulator research (Caird et al 2008).

At the outset of this research we posed the question of whether driving while conversing with passengers was safer than conversing over a cellphone; and, if so, was it because of passengers' conversation suppression or their ability to alert drivers to hazards ahead? The present research has shown that passenger conversations are indeed safer than cellphone conversations, and that what passengers don't say to drivers may be more important than what they do say.

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