DRIVER PERFORMANCE WHILE USING A CELLULAR TELEPHONE INTERFACE TO A TRAVELER INFORMATION SYSTEM

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EXECUTIVE SUMMARY

The growing availability of in-vehicle technology to acquire and communicate information has proven to be advantageous for motorists. Mobile telephones allow motorists to maintain critical communication between personal and business contacts. Along with the advantages of in-vehicle information dissemination, the communication technologies and their user interfaces may have created a potentially unsafe environment for motorists.

Several studies during the past decade have analyzed the effects of using mobile telephones while driving. Results from these studies have indicated that the use of cell phones while driving, whether dialing, answering, or conducting mobile telephone calls, may add a significant increment of risk to the driving task. Studies have found that making a call during a trip may more than triple the risk of a crash.

Because of the indications that mobile phones increase crash risk, some jurisdictions have banned the use of hand-held mobile phones. Currently, 45 nations restrict the use of mobile phones while driving. In the United States, New York, New Jersey, and the District of Columbia have similar laws. These regulations have primarily targeted hand-held telephone instruments while allowing the use of hands-free mobile phones from vehicles, apparently on the assumption that limiting manual handling creates a lower risk level.

Recent studies, however, have reported that hands-free cell phones have at least as great a risk factor as hand-held phones. It appears that the increased driving risk associated with cell phone use may be attributed primarily to cognitive and attentional factors rather than manual manipulation of the instrument.

Recently many states have implemented a "Dial 511" traveler information system. This system allows motorists to conveniently obtain advanced information on road conditions, adverse weather, traffic incidents, and construction along their planned route by dialing 511 on their telephones. Providers of the 511 system have emphasized that drivers should obtain this information prior to departure or park their cars safely on the route to make the call. Many drivers, however, access the system to updated their travel information while they are driving. No studies to date have examined the safety of using mobile telephones to acquire such travel information.

The study referred to in this document analyzed driving performance and situation awareness while subjects accessed the Montana Department of Transportation's 511 traveler information system via a cellular telephone. Data were collected using the Western Transportation Institute's Driving Simulation Laboratory. Thirty-six subjects were recruited for the study. Subjects drove a series of four 6.5 minute scenarios. Two of the scenarios had cultural features, traffic control devices, and ambient traffic typical of an urban environment while the other two scenarios had features typical of a rural driving environment. For testing, the subjects were divided into three groups of 12: Group 1 used a hands-free cellular phone; Group 2 used a hand-held cellular phone; and Group 3, the control group, did not use a cell phone. The two cell phone groups were asked to acquire road and weather information for a particular segment of Interstate 90 using Montana's 511 traveler information system employing voice commands to navigate the system menus. In a post-testing questionnaire, subjects were asked about the road and weather information they received from the 511 system.

The dependent variables relating to driver performance were analyzed. These include velocity, root-mean-square values of lane position, steering, acceleration, braking, lateral and longitudinal acceleration, number of collisions, and maintenance of speed limit. After the completion of each scenario subjects were asked questions related to their awareness of objects which appeared in the visual scenes. At the end of the testing session, subjects completed a usability survey on the 511 traveler information system.

Performance on the primary tasks of driving (e.g., lane and speed maintenance) was found to be unaffected by interacting with the cell phone. Yet the tasks that require more prompt response times (e.g., avoiding collisions during unexpected conflicts) were degraded by the use of a cell phone, regardless of the type of instrument used.

It appeared that drivers were less aware of their surroundings when interacting with the 511 traveler information system while using a cellular phone and driving. Drivers who communicated with 511 performed more poorly in recalling target objects in the environment than did their counterparts without communication tasks. This reduction in situation awareness could largely explain the increased braking responses and higher number of collisions.

It should be noted that the task of acquiring information using the 511-traveler information system via a cellular phone differs from that of conversing and interacting on a cellular phone. The 511 task was not a free conversation. During the task, subjects did not engage in conversation. Subjects used voice commands to acquire the road and weather conditions for the selected segment of highway from the automated computer system.

Despite these differences, results from this study were strikingly similar to findings from other studies of cell phone conversations while driving. Interaction with the 511 travel information system appears to have the same performance effects and risks as a free-form cell phone conversation.

INTRODUCTION

The burgeoning availability of information and communication devices for use in vehicles has become a double-edged sword with both significant benefits and significant costs. Mobile telephones allow motorists to maintain social contacts, conduct and coordinate business, make restaurant and theatre reservations, and even track their stock portfolios. Traveler information such as lodging availability and driving directions can be sought from within the vehicle.

Recently motorists have begun using mobile telephones to connect to a state's "511" traveler information system in order to obtain advanced information on road conditions, adverse weather, serious traffic incidents, and construction along the planned route. The national "511" system is heavily used by drivers, especially during inclement weather, to plan and replan their trips. Few studies have explored the usability of the 511 user interface, especially in the context of a mobile phone user who has the added workload of driving a vehicle. It should be noted that 511 providers do not recommend the use of the information system by drivers of moving vehicles. It is universally recommended that drivers make their 511 call before they begin their trips or pull to the side of the road and stop before dialing.

Anecdotal reports of vehicle accidents caused by drivers who were dialing, answering, or conducting mobile telephone calls suggest that the distractions and added workload of cellular phone use may add a significant increment of risk. Several studies during the past decade seem to verify this hypothesis. In a recent survey by Thulin and Gustafsson (2004), drivers admitted to missing exits, failing to see traffic signals, losing control of their speed, and experiencing near-crashes while using their mobile phones. None of the drivers reported an actual accident but it was estimated that 10-20 Swedish fatalities per year result from the use of mobile phones while driving.

In a widely cited earlier study, Redelmeier and Tibshirani (1997) examined the telephone billing records of approximately 700 drivers who had experienced property damage crashes. They found that drivers who were using their phones within 10 minutes before the accident had a risk factor approximately 4 times that of non-phone users. The investigators subsequently reported that, due to a number of limitations on their original experimental design, these numbers are probably underestimates of the actual risk (Redelmeier and Tibshirani, 2001). Green (2000) summarized studies of crash frequency and cell phone use and concluded that making a single call during a trip approximately triples the crash risk. The crash risk escalates with each additional call made during the trip.

To combat this increased crash risk, some jurisdictions have banned the use of hand-held mobile phones while driving. Currently, 45 nations have placed restrictions on cell phone use while driving. In the United States, New York, New Jersey, and the District of Columbia have banned the use of hand-held phones while driving. Other states have placed conditional restrictions on cell phone use while driving (e.g. by younger drivers).

Jurisdictions that have regulated the use of mobile phones from vehicles usually allow the use of hands-free interfaces. The assumption made is that limiting the manual handling of the device, lowers the associated risk factor. The Redelmeier et al. (1997) study reported, however, that hands-free cell phones have a greater risk factor (5.9) than hand-held phones (3.9) although this difference was not statistically significant. This counterintuitive finding could be a result of hands-free phone users making more, longer, or more cognitively demanding calls than those using hand-held instruments. In a survey of Swedish drivers, Thulin and Gustafsson (2004) found that hands-free phone users did report 20% more phone use from their vehicles. Redelmeier et al. (1997) concluded that the increased driving risk associated with cell phone use could be attributed primarily to attentional factors rather than manual manipulation of the device.

A number of laboratory studies have explored the effects of mobile phone use on the performance of perceptual and cognitive tasks related to driving. Using a dual task laboratory paradigm involving pursuit tracking and reaction time to test the impact of mobile phone conversations, Strayer and Johnston (2001) found that both subtasks were degraded during phone conversations. The greatest performance decrements were seen when the subjects engaged in conversations requiring cognitive activity and generation of speech responses. Boase, Hannigan and Porter (1988) also used a dual task paradigm in which subjects played a computer game while conducting a hands-free telephone conversation. Performance on the computer game was significantly degraded by the telephone dialogues although less so during more cognitively challenging conversations.

Patton, Kircher, Ostlund and Nilsson (2004) evaluated the effects of memory and cognitive tasks mediated by mobile telephones on professional drivers in instrumented vehicles on a rural highway. The complexity of the cognitive tasks (digit memory versus mental arithmetic) during simulated conversations had a much greater impact on driving performance than did the type of cellular phone (handheld or hands-free) utilized.

Primary driving tasks such as simple lane and speed maintenance are not significantly impacted by a communication task (Horrey and Wickens, 2004a). For experienced drivers, these tasks represent automated psychomotor responses requiring little cognitive activity. Horrey and Wickens (2004b) postulated that the primary driving tasks involve different attentional resources (ambient visual channels) than do responses to unexpected events (focal visual channels).

Communication tasks may interfere more with processing in the focal channels and differentially degrade performance on tasks using those channels.

Haigney and Westerman (2001) examined many of the earlier studies, both epidemiological and experimental, and reported flaws in the methodology and interpretation that would bias the results. For ethical reasons, methodology, and ecological validity, they concluded that research in a high fidelity driving simulator that measures key dimensions of driver performance is the best approach to addressing the research issues of mobile telephone hazards. The research environment in a driving simulator, however, is not a perfect reproduction of the real-world driving task. Even with the best simulation systems, the visual elements are a degraded representation, motion and haptic cues are imperfect, and scenarios are limited. Perhaps most important is the fact that the simulator may promote riskier driving behaviors and decisions because the costs of a collision are trivial compared to actual roadway driving. Although, after comparing the results of 16 studies using either simulation or field data collection, Horrey and Wickens (2004a) concluded that comparable results are obtained from research in either of the two environments.

Few studies have examined exactly how phone conversations impact driving behavior and performance. Several studies have found that cell phone conversations cause a withdrawal of attention from the visual scene leading to inattention blindness (Rensink, Oregan, & Clark, 1997; Simons & Chabris, 1999) and a reduced useful field of view (Atchley and Dressel, 2004). The practical impacts of such deficits in visual attention include reduced situation awareness, especially outside the areas of central vision, and a slower reaction time to hazards encroaching from the sides of the vehicle.

A study conducted by Briem & Hedman (1995) found that simple conversations do not affect a person's ability to maintain road position. Other studies found that working memory tasks (Alm & Nilsson, 1995; Briem & Hedman, 1995), mental arithmetic tasks (McKnight & McKnight, 1993), and reasoning tasks (Brown, Tickner, & Simmonds, 1969) interrupt simulated driving performance. Additional studies have indicated that the greatest performance decrements occur when drivers are engaged in conversations requiring cognitive activity and generation of speech responses. A more recent study by Strayer, Drews, Crouch, & Johnston (2005) found that drivers engaged in cell phone conversations had significantly slower response times to urgent events than they would normally. The conclusion was drawn that drivers engaged in free cell phone conversations became less aware of their surrounding environment. Furthermore, distracting effects of cell phone conversations persisted despite the type of cell phone device used (hand-held or hands-free).

It should be noted that the task of acquiring information using the 511-traveler information system via a cellular phone differs from that of conversing and interacting on a cellular phone. The 511 task was not a free conversation. During the task, subjects did not engage in conversation. Subjects used voice commands to acquire the road and weather conditions for the selected segment of highway from the automated computer system. Interactions with the computer can be largely user-paced.

Some studies have investigated the social pressure to maintain the pace of cell phone conversations and the corresponding influences on driving performance. The pressure to maintain conversations may be higher when conducting a cell phone conversation as opposed to conversing with passengers. Passengers may be more aware of changes in driving demands than those engaged in a cell phone conversation from a remote location (Parkes, 1991). It could be hypothesized that giving drivers more control over the pace of conversation might assist their driving. Due to the fact that "511” is not conversation based, impacts on driver performance might be reduced as users may pace their interactions with the system.

If we assume timesharing of the primary and secondary task, then how do we design in-vehicle information systems that multi-task effectively to reduce driver distraction? One possible solution is to think of the secondary-task as being continuously interrupted by the primary task of driving. Gellatly & Kleiss (2000) found that drivers shift their attention between the primary task of driving to secondary in-vehicle tasks in bursts of 1 to 3s. It should be noted the assumption of timesharing found in the aforementioned studies conflicts with the findings of Horrey and Wickens (2004a). Horrey and Wickens (2004a) stated that the primary task of driving is not significantly impacted by a communication task. Some research has shown that the ability to resume the primary task after being interrupted by the secondary task is the key to task management. In the case of “511”, perhaps having response times that are adequate to ensure that drivers are not forced to maintain a certain pace might assist in the driving task. A recent study by Monk, Davis, & Trafton (2004) found the timing of interruptions has a significant effect on task resumption times The study found that the most costly time to interrupt the task performance was in the middle of the task. Clearly driving is a continuous task, but such driving maneuvers as turning, changing lanes, braking, etc. are not continuous and occur at specific points in time. An ideal case would include having the secondary task, such as “511”, be completely user paced or know when best to interrupt or prompt users for inputs . Recent research has begun to investigate such systems in terms of workload management while handling interruptions more effectively (Piechulla, Mayser, Gehrke, & Konig, 2003; Verwey, 2000).

METHODOLOGY

Subjects

The subjects were 36 licensed drivers between the ages of 18 and 63 years (mean age = 31) who were recruited by announcements on the university campus and in the surrounding community. All subjects were users of cellular telephones. Subjects were compensated for their participation in the research and received a bonus for completing the testing without experiencing a crash. Potential subjects completed a screening questionnaire to identify and disqualify those who had medical conditions or histories that might indicate increased levels of risk (e.g., headaches and motion sickness) in the simulation environment. All 36 subjects who began testing completed the study although four reported some symptoms of motion discomfort.

Laboratory Equipment

Simulator. Data were collected using the Western Transportation Institute's Driving Simulation Laboratory. This laboratory is a 36 square meter light and sound controlled room containing a DriveSafety 500C simulator running HyperDrive ™ Simulation Authoring Suite software and Vection™ simulation software version 1.9.8. The simulator is comprised of a partial 1996 Saturn SL sedan cab with fully functional controls, five rear projection plasma displays arranged in a semicircle around the front of the cab providing a 150-degree field of view and on-screen rear-view mirrors, four audio speakers, vibration generator, a simulator programmer/operator station, and seven associated computers to generate the scenarios, visual and auditory environment, and collect data.

The simulator provides physics-based vehicle dynamics. The graphics systems render realistic driving scenarios including geometrically correct urban and rural roadways, traffic control devices, cultural features, ambient traffic, pedestrians, animals and other features. Realistic auditory effects of traffic, engine noise, and wind noise are generated by the 3-D audio system.

Figure 1. The DriveSafety 500C Vection Driving Simulator

Telephone. The telephone was a standard Motorola V120 handheld cell phone. A Plantronics headphone with a single ear cup and boom microphone was used for hands-free operation.

Procedures.

Simulator induced discomfort (SID), including nausea, headaches, and dizziness, can be a significant issue during driving simulation research and it frequently results in attrition of subjects. Prior to testing sessions, subjects completed screening questionnaires primarily directed at their potential susceptibility to SID. Subjects were then acclimated to the driving simulator by completing a series of six three to five minute training scenarios in the simulator, each lasting between three and five minutes. Training began with relatively gentle drives designed to minimize SID. As subjects proceeded through the training, the scenarios became longer, more challenging, and more visually complex. Subjects were then trained and given practice using the Montana Department of Transportation's 511 highway information line including the voice understanding system. At the completion of training, subjects completed a follow-up questionnaire on any SID symptoms they might have experienced.

The testing session was conducted one or two days after the training session. For testing, subjects were divided into three groups of 12 each; Hand Held Phone, Hands Free Phone, and Control. The groups were equalized in terms of gender and mean age. Subjects drove a series of four 6.5 minute scenarios. Two of the scenarios had cultural features, traffic control devices, and ambient traffic typical of an urban environment while the other two had features typical of a rural driving environment. The order of scenario presentation was randomized among subjects within the groups.

All subjects using the 511 system were given the following instructions prior to testing:

> Your task is to drive for about six minutes along the road obeying all traffic signs and signals. You should drive at the posted speed limit and drive as you normally would. If there is a vehicle in front of you, maintain a safe following distance of about two seconds**.** Avoid collisions with other vehicles or objects. As you drive, we'll ask you to gather road and weather related conditions using Montana’s 511- phone generated traveler information system. For this trip we ask you to get road condition information for Interstate 90 from Butte, MT to Bozeman, MT. At the start of the drive you will accelerate up to the posted speed limit and will wait for me to prompt you to dial 511 with the provided cell phone. When I prompt you to begin dialing you will pick up the cell phone and dial 5-1-1. From that point, you will follow the voice generated prompts from the 511 system using voice-recognition commands. Do not use button commands. Using voice commands you will gather road and weather related conditions for Interstate 90 from Butte, MT to Bozeman, MT and from Billings, MT to Big Timber, MT. If you become frustrated with the system’s voice recognition, or if, for example, the system is not responding to your commands, try speaking louder, more clearly, or reposition the phone. If none of these techniques are successful use the button commands to complete the task. At the completion of this task, please hang-up the phone, Let me know when you have ended the call and continue driving until I tell you to stop. There will be a 4-minute break between each testing scenario. You will get out of the car and answer a memory test of objects seen.

Control group subjects were given similar instructions which omitted references to the phone task.After each scenario subjects were given a situation awareness questionnaire in which they were asked a series of ten questions regarding objects they remembered seeing while driving. The number of incorrect responses were recorded and used for data analysis. At the end of the test session, subjects completed a questionnaire related to their experience with simulator discomfort (if any) and a usability survey on the 511-traveler information system. The survey and the responses to the usability survey can be found in Appendix A.

RESULTS AND DISCUSSION

Dependent Variables

All subjects made all turns as instructed and properly stopped at all signaled intersections, i.e. no red-light running. Several errors were made in using the 511-traveler information system, primarily due to the system's voice understanding limitations. The number of errors was not recorded due to the lack of an interface that would enable the experimenter to hear the interactions between the subject and the 511-system. To address this inadequacy, at the end of the session, subjects were asked to report and describe any errors made. Ninety-four percent reported making errors due to the voice understanding software.

The dependent variables relating to driver performance were analyzed. These include velocity, headway distance, headway time, root-mean-square values of lane position, steering, acceleration, braking, lateral and longitudinal acceleration, number of collisions, and maintenance of speed limit. *Velocity* was the speed of the subject vehicle (in miles/second). *Headway distance* was the distance in meters from the subject's front bumper to the rear bumper of the vehicle ahead. *Headway time* was the time in seconds to the vehicle ahead. This value was calculated using the headway distance and the subject vehicle velocity. *Lane position* was the lane offset (in meters) within the current lane. The position of the subject in the right lane indicated a positive value. A position in the left lane indicated a negative value. *Steering data* included the steering input in degrees with clockwise being positive. *Acceleration* and *braking* measured the normalized accelerator and braking input value (0.0-1.0), respectively. A value greater than 0.0 indicated the brake or accelerator was being applied. An accelerator or brake input value of 1.0 indicated the maximum amount of pressure to the pedal was being applied. *Lateral and longitudinal acceleration* measured the lateral and longitudinal component for the acceleration of the subject vehicle, respectively. *Collisions* was a count of how many objects the subject collided with while driving. *Maintenance of the speed limit* included the subject's velocity minus the posted speed limit at that frame. The root-mean-square (RMS) value for lane position, steering, acceleration, braking, lateral and longitudinal acceleration were used in the analysis given by the following equation:

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_N^2}{N}}$$

Where x=the variable value, N=number of observations

Data collection for the cell-phone groups began when the experimenter pushed the external remote control button that corresponded to digital inputs. A digital input of 01 (Button A) began the call and a digital input of 10 (Button B) indicated the end of the call. Data analysis for the cell phone groups included the data between the digital inputs 01 and 10, for the control group. Data analysis included the average start (43 seconds into the scenario) and end time of the cell phone (5 min into the scenario). The average time on the phone was around 4:30 minutes. Data acquisition and management was analyzed using SAS 9.00. MiniTAB 14.1 was used for statistical analysis. Data was filtered for the headway time and headway distance with time between 0 and 10 seconds and 0 and 100 meters, respectively. This was done to eliminate extraneous data due to irrelevant dynamic calculations.

At the end of each driving scenario subjects were asked ten questions about what they remembered seeing in the scenario (e.g. Did you see an ambulance?). The number of incorrect responses was recorded. The questions were used to assess the subjects' awareness of the driving environment.

Two types of analyses were conducted: driver performance measurement and driver distraction analysis. For the driving performance data, excluding the number of *collisions*, mean differences on each dependent variable as a function of the experimental condition was conducted using a 3 (Task Condition: Control, Hands free Cell Phone, Hand-held Cell Phone) x 4 (Environment: Rural 1, Rural 2, Urban 1, Urban 2) analysis of variance (ANOVA). In assessing situation awareness and the number of collisions, the Kruskal-Wallis one-way analysis of variance by ranks (Sheskin, 1997) was performed on the number of incorrect responses and the number of collisions. In each environment subjects completed two tests in that environment i.e. two rural and two urban scenarios. The ANOVA was completed separately for each driving environment: aggregation was not conducted as all scenarios were different..

No significant interactions were found between task condition and driving environment. Braking RMS and number of collisions showed significant main effects of task condition. There were not any significant main effects for velocity, headway distance and time, lane position, steering, acceleration, lateral and longitudinal acceleration, and maintenance of speed limit. In the evaluation of situation awareness, marginally significant main effects were found among the task conditions.

Driving Performance

Only those variables that showed statistical significance are discussed below. Velocity, one of the primary driving performance variables, showed no indication of statistical significance based on task condition or driving environment. Results are shown in Figure 2 below.

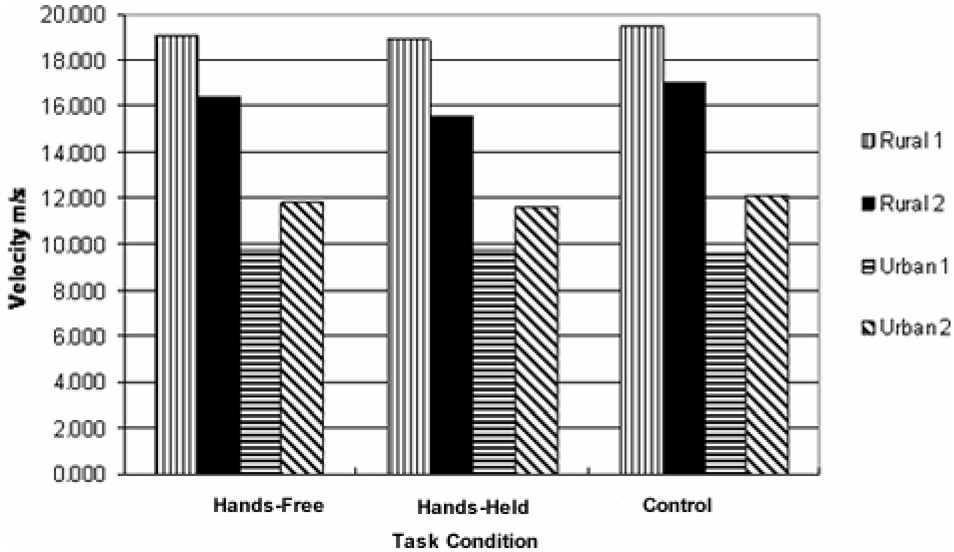

Figure 2. Mean velocity (m/s) across groups and driving environments

The braking input values were measured from zero to one, where a value greater than 0 indicated the brake pedal was being applied. For the braking RMS, a measure of braking activity, significant main effects were found for task condition, $F(2, 33) = 4.74$, $p < .05$, $MSE = 0.001$. The mean braking RMS for the hand-held cell phone condition ($M = 0.1196$) was significantly higher ($p < .05$) than for the control condition ($M = 0.0991$). Results are shown in Figure 3 below.

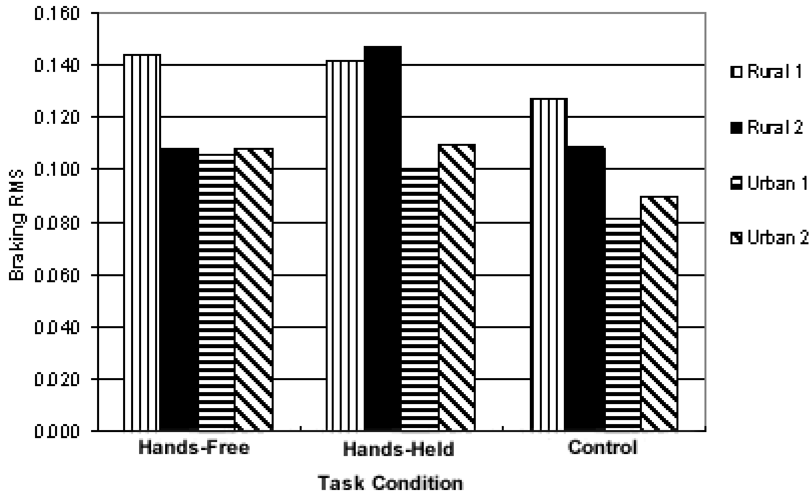

Figure 3. Braking RMS across groups and driving environments

For the number of collisions, significant differences were found among task conditions, $F(2,33) = 10.69$, $p<.05$, $MSE = 0.224$. The number of collisions for the hand-held cell phone condition ($M = 4.75$) and the hands-free condition ($M = 3.75$) was significantly higher, $X^2 = 7.123$, $p <.05$ than for the control condition ($M = 1.25$), as shown in Figure 4.

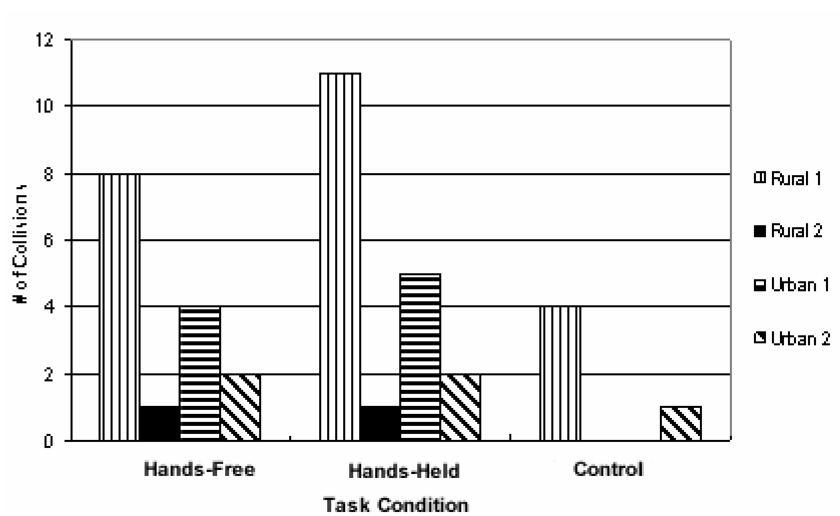

Figure 4. Number of collisions across groups and driving environments

Situation Awareness

The number of incorrect responses had marginally significant effects among task condition, $X^2 = 2.15$, $p < .10$. The mean number of incorrect responses for the hand-held condition (M = 16.5) and the hands free condition (M = 16.25) was marginally higher ($p < .10$) than the for the control condition (M = 13.75), as shown in Figure 5.

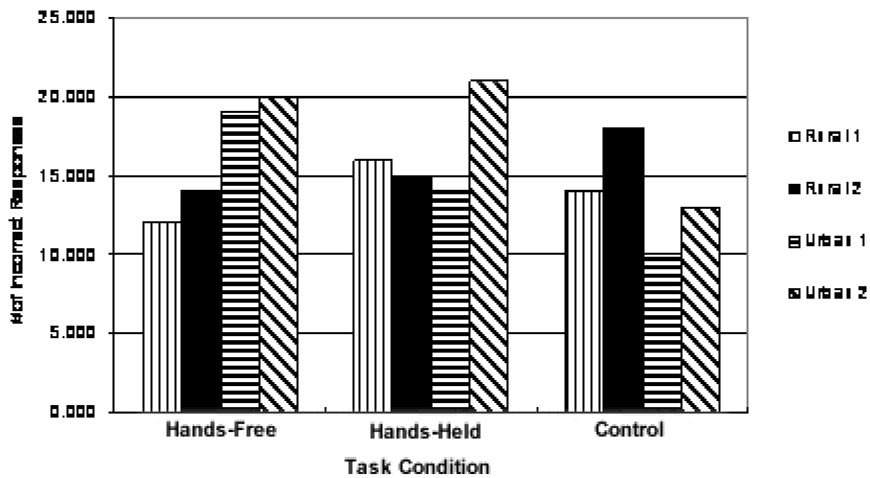

Figure 5. Number of incorrect responses across groups and driving environments

Discussion

In summary, the mean braking RMS for the hand-held cell phone condition was significantly higher ($p < .05$) than for the control condition. The number of collisions for the hand-held cell phone condition and the hands-free condition was significantly higher ($p <.05$) than for the control condition. The mean number of incorrect responses for the hand-held condition and the hands free condition was marginally higher ($p = .10$) than for the control condition. The driving performance data found that those measures relative to the primary task of driving were not affected by whether the person was using a cell phone. Driving events that required urgent attention were influenced by using the cell phone, despite the type of device used (hand-held or hands-free). Hand-held cell phone users were found to have a higher number of collisions, more braking responses, and greater distraction than those drivers who used hands-free systems or did not use a cell phone.

CONCLUSIONS AND IMPLICATIONS

The task of acquiring information using the 511-traveler information system via a cellular phone is different than that of conversing and interacting on a cellular phone. Past literature has shown that the greatest performance decrements occur when drivers are engaged in conversations requiring cognitive activity and generation of speech responses. The 511 task was not a free conversation. During the task, subjects did not engage in conversation. Subjects used voice commands to acquire the road and weather conditions for the selected segment of highway from the automated computer system.

Despite these differences, results from this study were strikingly similar to findings from other studies of cell phone conversations while driving. Interaction with the 511 travel information system appears to have the same performance effects and risks as a free-form cell phone conversation. Research using a broad range of methodologies including accident epidemiology, field studies, and simulation studies has indicated that cell phone use increases accident risk by a factor of 3 to 4. Our results using the 511 interaction task duplicated those numbers.

Furthermore, few studies have found the anticipated safety benefit of a hands-free telephone interface over a hand-held interface. This study agreed. We found, at most, a marginal safety benefit for the hands-free interface.

Shinar, et al. (2004) noted that most laboratory and simulator studies of cell phone driver distraction have used communication tasks with limited ecological validity such as speech shadowing, mental arithmetic, or conversations about contrived topics. The communication task represented by a 511 interaction is probably as similar to a free conversation as many of these other experimental tasks.

The primary task of driving (lane and speed maintenance) was found to be unaffected by interacting with the cell phone. Yet the tasks that require more prompt response times (e.g., avoiding collisions during unexpected conflicts) were degraded by the use of a cell phone, regardless of the device type. This finding is typical of driving simulation and test track research (Horrey and Wickens, 2004a) and is consistent with the multiple resource model of attention (Horrey and Wickens, 2004b).

It appeared that drivers were less aware of their surroundings when interacting with the 511 traveler information system while using a cellular phone and driving. Our drivers who communicated with 511 performed more poorly in recalling target objects in the environment than their counterparts without communication tasks. This finding is consistent with other studies reporting a decrement in visual attention and shrinkage of the field of view by phone users (e.g. Atchley and Dressel, 2004).

Recommendations

- The risk factor for using a cell phone to interact with the Montana DOT's 511 system, as presently configured, is approximately the same as the risk associated with conducting a free conversation on the phone while driving. MDT and other 511 providers should continue to emphasize that users should "dial before they drive" or safely pull off of the road in order to make their call.
- At most, a marginal benefit was found for the use of hands-free phones. This is consistent with the bulk of research which has found that the risk of cell phone use while

driving is related to the cognitive aspects of communication rather than manual manipulation of the instrument. Restrictions on cell phone use that allow unrestricted use of hands-free devices are ill-considered.

- Most users reported having problems using the voice-recognition software due to the software's inability to properly recognize voice commands and sensitivity to external noise, i.e. breathing and/or vehicle noise. Near-term recommendations for improving the effectiveness of the 511-system include providing a voice understanding software that better comprehends voice commands with less sensitivity to external sounds.

- A potential near-term solution to increasing the usability of the 511-system and decreasing driver workload requirements would be system allowed for a paced approach with more time between voice-commands. This approach has the potential to reduce driver workload by minimizing paced responses. Long-term design solutions would include a system that understood the driving environment and driver workload at specific points in time and would permit the driver to respond at a pace proportional to the workload.

APPENDIX

Appendix A. Usability Questionnaire

Mean Responses to 511-System Usability Questionnaire			
1. I think I would like to use this system frequently.	2.9	Strongly Disagree	1
2. I found the system unnecessarily complex.	2.5	Disagree	2
3. I thought the system was easy to use.	3.3	Neutral	3
4. I think that I would need further help to be able to use this system.	1.5	Agree	4
5. I found the this system was easy to navigate, i.e. the functions flowed logically.	4.0	Strongly Agree	5
6. I thought there was too much inconsistency in this system.	2.4		
7. I would imagine that most people would learn to use this system very quickly.	3.6		
8. I found the system very cumbersome to use.	2.7		
9. I felt very confident using the system.	3.3		
10. I need to learn a lot of things before I could get going with this system.	1.5		
11. Education Level 3=college	3.4		
12. Prior 511-Experience 1=no experience	1.4		
13. Prefer Voice or Button Commands 2=button	1.6		
14. Problems with voice-recognition 1=yes	1.1		
15. Discomfort Level 1=no discomfort	1.5		

Based on user feedback and comments, most agreed that the system was easy to navigate, was not unnecessarily complex, and found that they could learn to use the system very quickly. Most users had no previous experience with 511 and had some form of college education. Users were neutral in whether they would use this system frequently, whether it was easy to use, whether it was cumbersome, and whether they felt confident using the system. Most users reported having problems using the voice-recognition software and preferred using button commands. The preference for button commands and the fact that users did not have strong feelings about the ease-of-use of the system might be due to the inadequacy of the voice understanding software. Common user complaints regarding the voice understanding software included:

- the system did not recognize voice commands,
- the system had particular difficulty with subjects who spoke accented English,
- the phone had to be positioned closer to the mouth for the system to understand voice commands,
- the system was sensitive to breathing and external noise, i.e. vehicle noise.

Recommendations for improving the effectiveness of the 511-system include providing a more robust voice-recognition software that better understands voice commands with less sensitivity to external sounds.

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