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The effects of text messaging on young novice driver performance

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The current project aimed to evaluate, using the advanced driving simulator located at the Monash University Accident Research Centre, the effects of text (SMS) messaging on the driving performance of young novice drivers. Twenty participants drove on a simulated roadway which contained a number of events, including a pedestrian emerging from behind parked cars, traffic lights, cars turning right in front of the driver, a car following episode and a lane change task. The results revealed that retrieving and, in particular, sending text messages had a detrimental effect on a number of safety critical driving measures. When text messaging, drivers' ability to maintain their lateral position on the road and to detect and respond appropriately to traffic signs was significantly reduced. In addition, drivers spent up to 400 percent more time with their eyes off the road when text messaging, than when not text messaging. While there was some evidence that drivers attempted to compensate for being distracted by increasing their following distance when following a lead vehicle, drivers did not reduce their speed while distracted. Failure to do so in the real world could increase their risk of being involved in a crash as it increases the stopping distance required to avoid a collision. The practical implications of these findings are discussed.

Introduction

Approximately one quarter of vehicle crashes are estimated to result from the driver being inattentive or distracted (Stutts, Reinfurt, Staplin, & Rodgman, 2001). As more wireless communication, entertainment and driver assistance systems enter the vehicle market, the incidence of distraction-related crashes can be expected to escalate (Regan, 2004). The dangers of using mobile phones while driving have been debated in the literature for some time and a growing body of research has generally found that talking on a mobile phone degrades driving performance significantly (Goodman et al, 1997; Young, regan & Hammer, 2003). However, surprisingly little experimental research has been conducted on the potentially distracting effects of using a mobile phone to send or receive text messages while driving.

The popularity of mobile or portable devices, particularly mobile phones, has escalated in recent years, with approximately 80 percent of Australians currently owning a mobile phone (Allen Consulting Group, 2004). As more in-vehicle and portable devices proliferate the market, there has been growing concern regarding the safety implications of using such devices while driving. Several studies have sought to determine how many drivers use mobile phones, particularly hand-held phones, while driving. An Australian study observed drivers use of hand-held mobile phones on major roads in the city of Melbourne, where it is illegal to use a hand-held phone while driving (Taylor, Bennett, Carter & Garewell, 2003). They found that two percent of drivers were using a hand-held mobile phone, and that these drivers were predominantly younger males. Research conducted in the United States and United Kingdom has found similar rates of hand-held mobile phone use among drivers (Johal, Napier, Britt-Compton & Marshall, 2005; McCartt, Braver & Geary, 2003). In terms of the prevalence of text messaging while driving, an Australian study conducted by Telstra, found that 30 percent of people surveyed had, in the past, sent text messages while driving and that one in six drivers regularly send text messages while driving (Telstra, 2003). Given evidence of such a high prevalence of text messaging while driving, it is critical that research concentrates on examining the impact on driving performance of sending and retrieving text messages. This is particularly important as the physical, visual and cognitive distraction associated with text messaging while driving is likely to be greater than that associated with simply talking on a hand-held phone. To date however, only a handful of studies have examined the perceived and real effects of text messaging on driving.

A Direct Line MORI survey of 2,000 drivers in the United Kingdom revealed that drivers considered sending a text message to be the most distracting activity to perform while driving (above reading a map, using a hand-held or hands-free phone, or changing a tape) (MORI, 2001, cited in Direct Line Motor Insurance, 2002). A small-scale simulator study has also been conducted in Sweden by Kircher and colleagues (2004) to examine the effects of *receiving* text messages on driving behaviour. Ten participants drove along a simulated roadway, where they periodically received text messages, which they were required to retrieve and respond to verbally. They found that braking reaction times in response to a motorcycle hazard were significantly slower when the drivers were retrieving a text message than when they were not. The drivers also reported that they felt their speed had reduced while they were retrieving the text messages. No other effects of text messaging on driving performance were found. However, it is important to note that this study had some methodological shortcomings, including a very small sample size, which reduced its statistical power and render its results somewhat unreliable. The study also focused only on relatively experienced drivers (mean age: 28 years), and only on the effects of *receiving* text messages, rather than both receiving *and* sending them.

The current project aimed to evaluate, using the advanced driving simulator located at the Monash University Accident Research Centre (MUARC), the effects of text (SMS) messaging on the driving performance of young novice drivers. Importantly, this study aimed to extend the findings of previous research by examining the effects on driving performance of both retrieving *and* sending text messages while driving. The study also focused on the effects of text messaging on young novice drivers aged 18 to 21 years, given that drivers in this category are more likely than other drivers to use a mobile phone while driving (Lam, 2002) and appear to be more vulnerable to the effects of distraction because of their relative inexperience behind the wheel.

Given the scarcity of research on text messaging, it is difficult to formulate hypotheses regarding the precise effects of sending and retrieving text messages on driving performance. However, on the basis of findings of previous research that has examined the effects on driving of dialing and conversing on mobile phones, it is possible to derive some tentative hypotheses regarding the effects of text messaging on driving performance. First, it is predicted that mean speed will decrease (as a self-regulatory or compensatory response to the distraction) and speed variability will increase when text messaging. It is also expected that lane position and following distance variability and the number of lane excursions will increase while text messaging. Finally, it is expected that drivers will fail, or take longer, to detect potentially hazardous events and traffic signals.

Method

Participants

Twenty participants aged between 18 and 21 years (M = 19.1, SD = 1.2) with six months or less of experience driving on a Probationary driver's license took part in the study. The 12 male and eight female participants had an average of 3.8 months driving experience and drove an average of six hours per week. All were experienced at reading and sending text messages on Nokia™ mobile phones in non-driving environments (with some experienced in driving environments) and were familiar with using predictive text messaging functions. Participants were undergraduate students at Monash University and were paid a stipend of $20 for their time.

Apparatus

The simulator experiment was carried out in Monash University Accident Research Centre's Advanced Driving Simulator. Scenarios were generated by a Silicon Graphics Onyx computer and projected by four BarcoGraphics 808 High Performance Graphic Projectors onto a display screen that subtended a visual angle of 180° horizontally and 40° vertically. The scenarios were displayed with a refresh rate of 30Hz and a resolution of 1280 x 768 (front panel) and 640 x 480 (front side panels). A Crystal River Engineering Audio Reality Accoustetron II audio system produced accurate localised sound such as engine and road noises and sound from other vehicles. Drivers viewed the scenarios from within a 2003 Holden VX Calais sedan that was positioned on a motion platform that displaced the vehicle according to the virtual dynamics of the car and environment. Data were collected from the control pedals, steering wheel and gearshift and synchronised with the timing of the scenarios.

The experimenter conducted the study from a separate control room located beside the simulator room that provided two-way communication between the experimenter and the participant, as well as a video monitor for visual monitoring of the participant. A second monitor displayed the scenarios driven through by participants in real-time to the experimenter. Participants' head and eye movements were tracked using Facelab™ head and eye tracking hardware and software. Text messages were read and sent on a Nokia™ 6210 mobile phone that had eight text messages pre-loaded in the Inbox.

Simulated Driving Scenarios

The simulated driving scenario consisted of an 8km section of mainly straight dual-lane road in an urban environment. Throughout the driving scenario, seven critical events occurred in the following order.

1. A traffic light signal changed from green to red (after an intermediate amber signal) when the driver's vehicle (Own-Cab) was 81.7m from the signalized cross intersection.
2. A test vehicle under computer control entered the same lane as the Own-Cab (in front of it) in the same direction of travel and maintained a 33.3m headway between it and the Own-Cab for 10 seconds. The test vehicle then traveled at a constant speed for 42.2 seconds, and then either increased its speed or exited the road by turning right.
3. A pedestrian under computer control began walking from behind two cars (parked on the left-hand side of the road) to the center of the road on a collision path with the Own-Cab when the Own-Cab was 80.2m from the pedestrian.

4. A second test vehicle entered the same lane as the Own-Cab (in front of it) in the same direction of travel and maintained a 50.0m headway between it and the Own-Cab for 10 seconds. The test vehicle then traveled at a constant speed for 36.5 seconds, and then either increased its speed or exited the road by turning right.
5. A Lane Change Task was included which consisted of a 3100m section of straight road with three lanes of travel in each direction. Throughout this segment of road, 18 signs were placed approximately 150m apart to signal to drivers which lane they should change to and travel in. Due to the length of the lane change task, two text message episodes were included within this task; one in the first half of the task and the other in the second half.
6. A third test vehicle at a cross-intersection initiated a right turn across the path of the Own-Cab when the Own-Cab had right of way and was 84m in front of the test vehicle.
7. A fourth test vehicle entered the same lane as the Own-Cab (in front of it) in the same direction of travel and maintained a 29.17m headway between it and the Own-Cab for 10 seconds. The test vehicle then traveled at a constant speed for 45.4 seconds, and exited the road by turning right.

The driving scenarios also contained two additional features that were designed to reduce participants' expectancies for the test events described in items three and six above. Firstly, two sets of two cars parked on the left side of the road were placed intermittently in the drive. These sets of parked cars did not have a pedestrian stepping out from behind them. Secondly, two cars stopped and waited to turn right at a signalized cross intersection and gave way to the Own-Cab (rather the turning across its path), which had a green traffic signal. Traffic signs indicated the speed limit for each section of road, and varied from 50-80km/h. The timing of participants' text messaging was under computer control by a simulated standard Nokia™ text message "beep" that signaled the receiving and reading of text messages, and a "reply now" simulated voice message that signaled the replying and sending of text messages.

Questionnaires

During the experiment, participants were asked to complete a pre-drive demographics questionnaire, a post-drive questionnaire and a subjective workload inventory. The pre-drive demographics questionnaire was designed to collect information regarding the participants' demographic characteristics (e.g., age, education level), driving experience, travel patterns, history of crashes and driving infringements, and their use of hands-free and hand-held mobile phones while driving. The post-drive questionnaire collected information regarding the participants' perceptions of whether, and how, sending and retrieving the text messages while driving affected particular aspects of their driving performance (e.g., speed maintenance, following behaviour, lane keeping performance, detection of hazards).

The NASA RTLX subjective workload inventory, developed by Byers, Bittner & Hill (1989) from the original NASA TLX (Hart & Staveland, 1988), was administered to participants after the experiment was completed to record their subjective mental workload while retrieving and sending text messages. The scale consists of six different workload aspects: mental demand, physical demand, time pressure, performance, effort, and frustration level. Each statement asked the participant to rate the difficulty of the driving task while text messaging on the six aspects by marking a visual analogue scale ranging from Low (0) to High (100).

Procedure

Participants were provided with a plain language statement describing the experiment and asked to sign a Monash University Ethics Committee consent form. Participants first completed the pre-drive questionnaire. Participants then completed a five minute practice drive in the driving simulator so that participants could adapt to the dynamics of the simulator environment.

After the practice drive, participants were instructed to drive as they normally would, and as closely as possible to the signed speed limit. Participants then completed the experimental drive twice. For one of the drives, participants were required to read and reply to text messages on the first (traffic light), third (pedestrian), fourth (second car following event) and sixth (second half of lane change task) events in the drive. Hence, the second, fifth, seventh and eighth events in this drive served as control events in which the participants were not text messaging. On the other drive, participants were required to read and reply to text messages on the second (first car following event), fifth (first half of lane change task), seventh (right turning car) and eighth (third car following event) events in the drive. The first, third, fourth and sixth events in this drive served as control events. The order in which participants were exposed to the two drives was counterbalanced across participants in order to control for practice effects. After the participants completed the two test drives, they completed the post-drive questionnaire and the NASA RTLX.

Design and Driving Performance Measures

A repeated measures design was used in the study. Two levels of distraction were examined: non distraction (i.e., no text messaging; control) and distraction (i.e., text messaging; treatment). Driving performance measures were recorded in both distraction and non distraction conditions at the time period corresponding to retrieving test messages and sending text messages. Mean speed and the standard deviation of speed for the retrieving and sending text periods for both the distraction and non-distraction conditions were recorded. In addition, spot speeds at the pedestrian and right-turning car events were obtained for the distraction and non-distraction conditions. The standard deviation of lane position and number of lane excursions were also recorded for the retrieving text, sending text and non-distraction conditions. Mean and minimum time headway and headway variability during the car following tasks were also recorded. Drivers' traffic light violations, and reactions to potential hazards, such as parked cars, pedestrians and turning cars were noted and drivers' performance on the lane change task (e.g., number of missed signs, number of correct lane changes made) were recorded. Finally, the proportion of total driving time drivers spent with their eyes off the road (e.g., looking inside the car) was recorded for the distraction and non-distraction conditions.

Results

Driving Performance Results

For the purpose of analysing and reporting the driving performance results, the text message episodes were analysed separately for the time periods corresponding to the retrieving and sending of text messages. Retrieving was defined as opening the text message and reading it and sending was defined as writing the text message and sending it. Data were analysed using mixed model 2 X 2 repeated measures Analyses of Variance (ANOVAs). The first factor was driver distraction with two levels: text messaging and non text messaging. The second factor was the order of the drives that the participants completed with two levels: Order 1 (Drive 1 completed first) and Order 2 (Drive 2 completed first). For all of the ANOVAs reported in this section, there were no significant main effects of Order, nor were there any interactions between Order and Distraction. For the purpose of brevity, only the significant main effects of Distraction are reported here.

Effects of Text Messaging Events on Overall Driving Performance

For this section of the report, driving performance data has been collapsed across all driving events for the time periods corresponding to retrieving and sending text messages.

Total Eye Movement Analyses

The data for the proportions of time spent not looking at the road for text messaging and non-text messaging conditions for each of the eight driving events are shown in Figure 1.

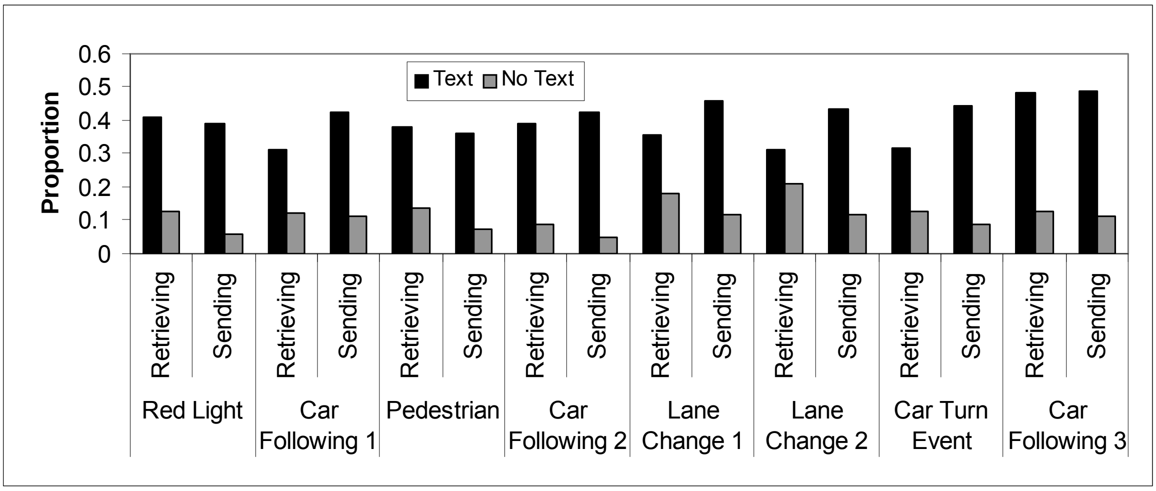

Figure 1. Proportion of time spent not looking at road environment for text messaging and non-text messaging conditions as a function of each driving event.

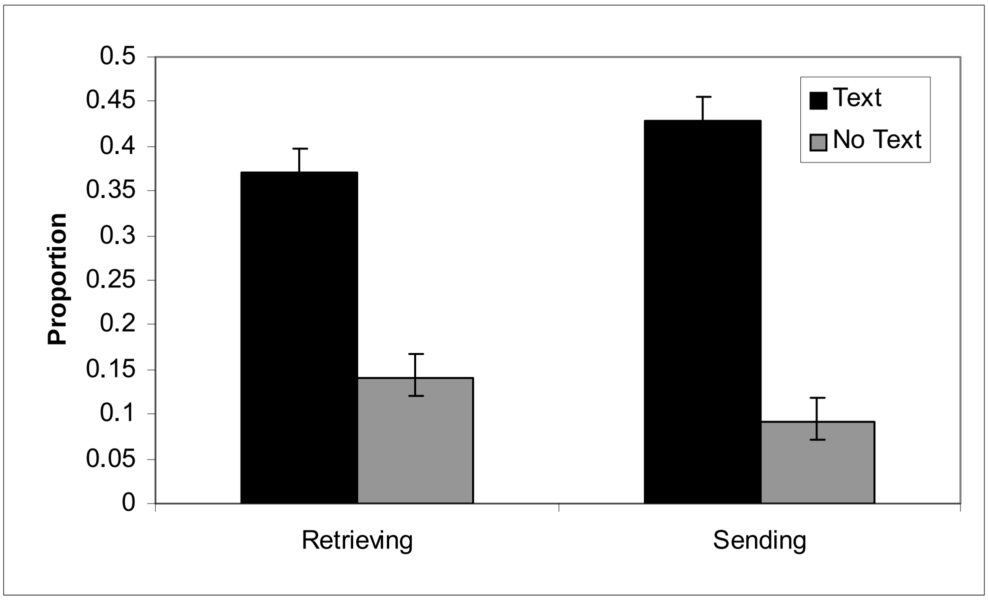

Figure 2. Mean proportion of time spent not looking at road environment for all events as a function of text messaging and non-text messaging conditions for retrieving and sending sections of drives.

For each driving event, the proportion of time spent not looking at the road in both the retrieving and sending text messaging conditions (≈ 40%) was consistently higher than for non-text messaging conditions (≈ 10%). Two-way ANOVAs were performed on the mean proportion of time spent not looking at the road data collapsed across all driving events for both retrieving and sending time periods (see Figure 2). The ANOVAs found that the proportion of time not looking at the road was significantly larger for text messaging than non-text messaging conditions for both retrieving messages $F(1,18) = 114.87$, $p<.001$, and sending messages $F(1,18) = 219.54$, $p< .001$.

Total Speed Analyses

Speed measurements were recorded at a rate of 30 Hz throughout the length of each drive. Two-way ANOVAs on mean speed and mean standard deviations of speed collapsed across all eight driving events (i.e., total mean and SD) found that were no significant differences between text and non-text messaging conditions for both retrieving and sending time periods.

Total Lateral Position Analyses

For the total lateral lane position analyses, data was collapsed across all events except for lane changing. Two-way ANOVAs on mean lateral position, and mean standard deviation of lateral position, found no significant differences between text messaging and non-text messaging conditions for both retrieving and sending time periods.

Total Lane Excursions Analysis

The total number of lane excursions data was averaged over all events except for lane changing. The total number of lane excursions for the retrieving and sending time periods for text messaging and non-text messaging conditions is shown in Figure 3. A chi-squared analysis revealed that the total number of lane excursions was significantly greater in the text messaging conditions than in the non-text messaging conditions for both the retrieving $\chi^2(1, n = 20) = 4.36$, $p<.05$, and sending $\chi^2(1, n = 20) = 17.67$, $p<.001$, time periods.

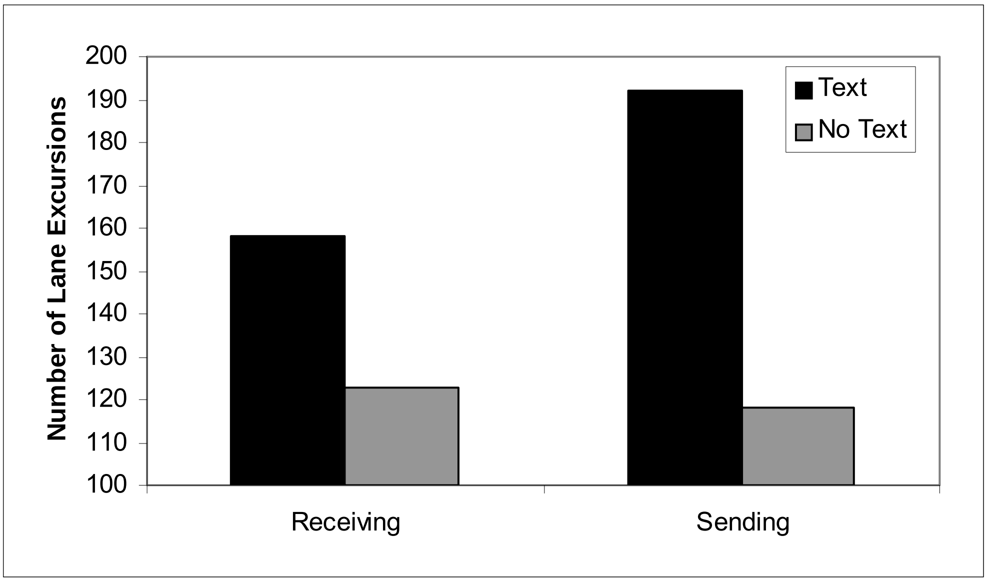

Figure 3. Total number of lane excursions for retrieving and sending time periods for all events (excluding lane changing event) as a function of text messaging and non-text messaging conditions.

Effects of Text Messaging for Separate Driving Events

Red Light Intersection Event

For the traffic light driving event, the ANOVAs found that mean standard deviations of lateral position for sending time periods were significantly greater for text messaging than non-text messaging conditions $F(1,18) = 8.18$, $p<.05$ (see Figure 4). However, there was no significant difference between text messaging and non-text messaging conditions for the receiving time period. The ANOVAs also found that there were no significant differences between text messaging and non-text messaging conditions for mean speed, mean standard deviation of speed, and mean lateral position for both retrieving and sending time periods.

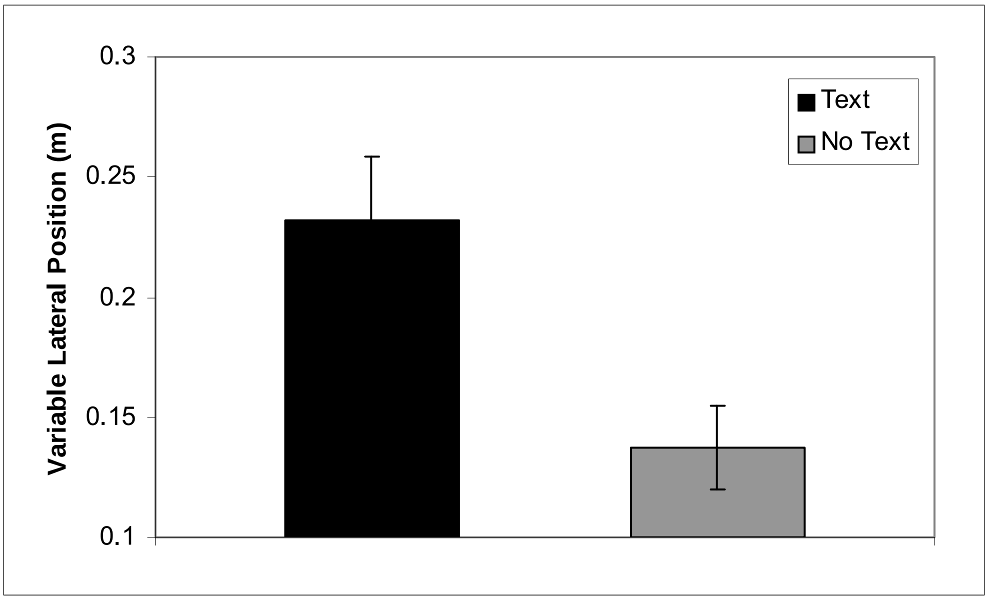

Figure 4. Mean proportion of standard deviation of lateral lane position for red-light intersection event as a function of text-messaging and non-text messaging conditions in sending time period.

Pedestrian Event

For the pedestrian event, the ANOVAs found that mean standard deviations of lateral position for sending time periods were significantly greater for text messaging than non-text messaging conditions $F(1,18) = 6.75$, $p<.05$ (see Figure 5). There was no significant difference between text messaging and non-text messaging conditions for the receiving time period. There were also no significant differences between text messaging and non-text messaging conditions for mean speed, mean standard deviation of speed, and mean lateral position for both retrieving and sending time periods. Additional analyses of the mean distance from the pedestrian to the Own-Cab when the Own-Cab was perpendicular to the pedestrian, and mean speeds at the point of passing the pedestrian found no significant differences between text messaging and non-text messaging conditions.

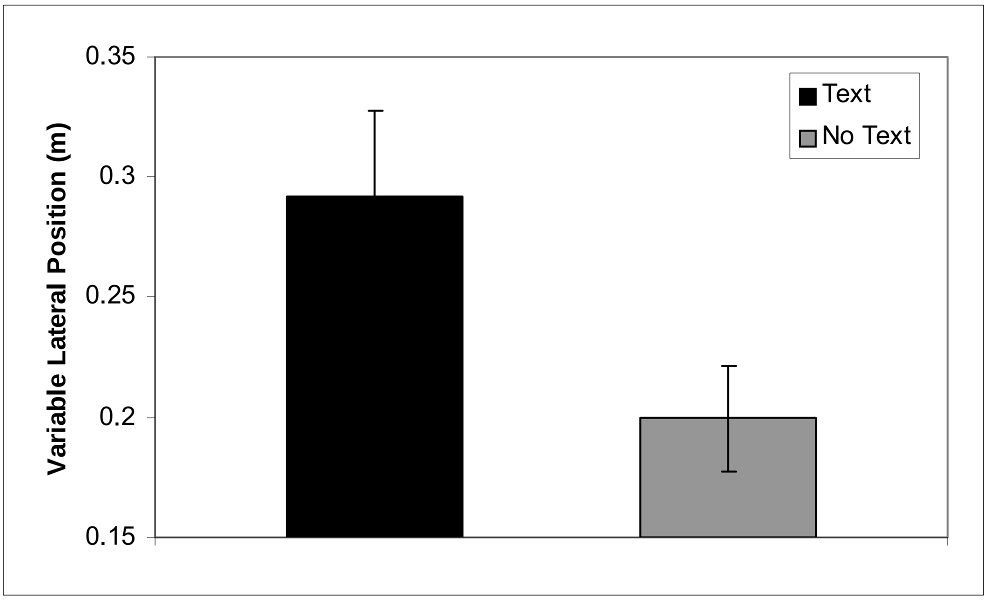

Figure 5. Mean standard deviation of lateral lane position for sending section of drive for pedestrian event as a function of text messaging and non-text messaging conditions.

Vehicle Turning Right Event
ANOVAs of driving performance data in the vehicle turning right event found no significant differences between text messaging and non-text messaging conditions for mean speed, mean standard deviation of speed, mean lateral position, and mean standard deviation of lateral position. An additional ANOVA was performed on the mean longitudinal distance from the Own-Cab to the right turning vehicle from the time that the vehicle was in the center of the lane that the Own-Cab was traveling, and found no significant differences between the text messaging and non-text messaging conditions.

Car Following Event
For the first car following event, none of the driving performance measures were found to be significantly different between the text messaging and non-text messaging conditions for either the receiving and sending time periods. However, for the second car following event, an ANOVA of the mean standard deviation of lateral lane position found a significant difference between text messaging and non-text messaging conditions for the sending time period $F(1,18) = 4.83$, $p<.05$, but not in the receiving time period. As can be seen in Figure 6, the mean standard deviation of lane position for the sending time period was larger in the text messaging condition. ANOVAs for mean speed, mean standard deviation of speed, and mean lateral lane position found no significant differences between text messaging and non-text messaging conditions.

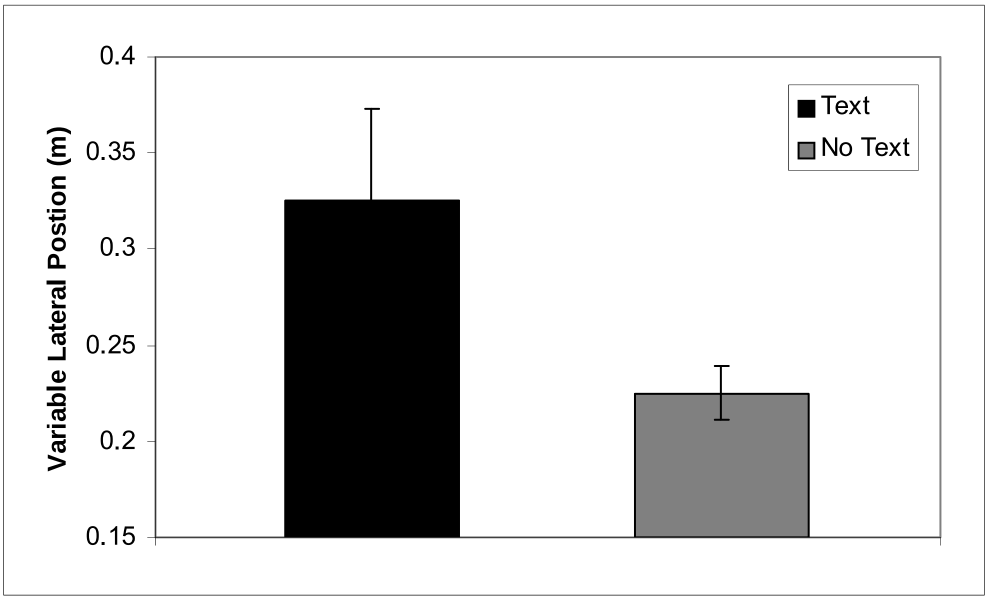

Figure 6. Mean standard deviation of lateral lane position for sending section of car following event as a function of text messaging and non-text messaging conditions.

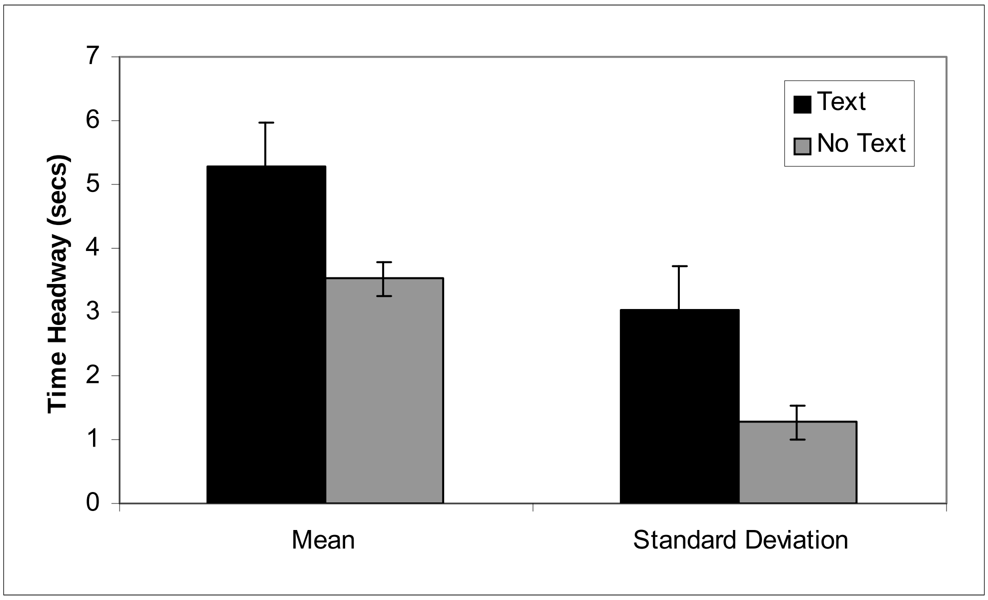

Figure 7. Mean time headway and standard deviation of time headway (in seconds) for receiving time period of car following event as a function of text messaging and non-text messaging conditions.

For the car following event, additional analyses were performed on the mean time headway, mean standard deviation of time headway, and minimum time headway (in seconds) between the Own-Cab and the lead vehicle. For the receiving time periods, separate AVOVAs found a significant difference between text messaging and non-text messaging conditions in mean time headway $F(1,18) = 9.40$, $p<.01$, and mean standard deviation of time headway $F(1,18) = 9.40$, $p<.01$. As can be seen in Figure 7, mean time headway and mean standard deviation time headway was significantly larger for the text messaging condition for the receiving time periods.

For the sending time periods, ANOVAs found significant differences between text messaging and non-text messaging conditions for mean time headway $F(1,18) = 9.63$, $p<.01$, mean standard deviation of time headway $F(1,18) = 9.63$, $p<.01$, and mean minimum time headway $F(1,18) = 6.22$, $p<.05$. As can be seen in figure 8, mean time headway, standard deviation of time headway, and minimum time headway was larger in text messaging conditions. Due to technical problems, the third following event yielded an incomplete set of data which were not analysed.

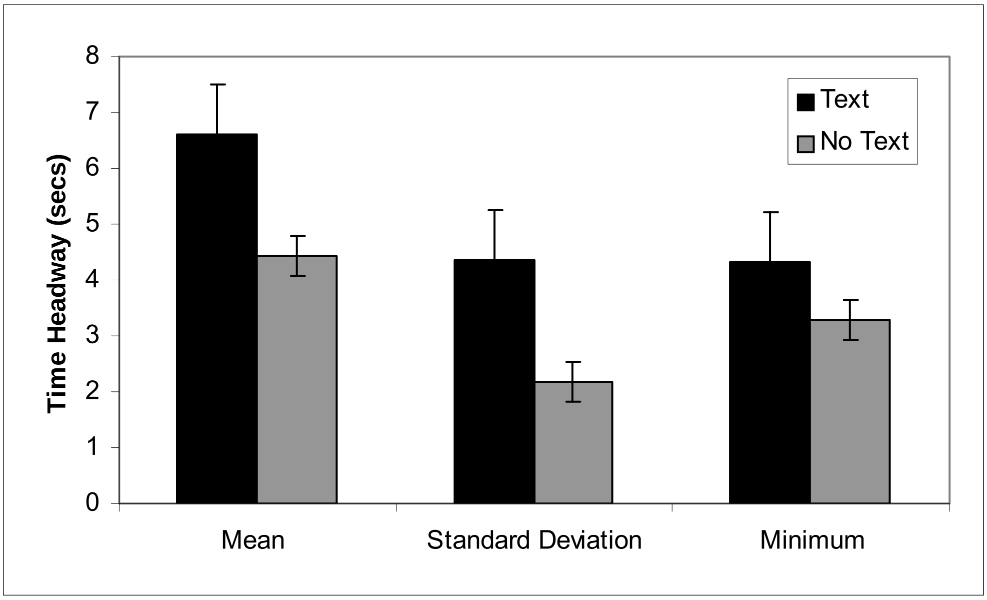

Figure 8. Mean, standard deviation, and minimum time headway (in seconds) for sending section of car following event as a function of text messaging and non-text messaging conditions.

Lane Changing Event

For the lane changing event, lateral lane position data were not analysed as constant changes in lane position were required in order to successfully complete this task. ANOVAs on mean speed and mean standard deviation of speed did not find any significant differences between text messaging and non-text messaging conditions for either the retrieving or sending time periods.

An additional chi-squared analysis was performed on the number of times that participants did not successfully enter the correct lane from the time a lane change sign was visible to 150m past the sign for the text messaging and non-text messaging conditions. When analysed separately for the retrieving and sending time periods there were no significant differences in correct lane choice for the two text messaging conditions. However, a chi-squared analysis of the combined receiving and sending time periods revealed significant differences between text messaging and non-text messaging conditions $\chi^2(1, n = 20) = 5.76$, $p<.05$. As can be seen in Figure 9, a larger number of participants did not enter the correct lane in the text messaging condition.

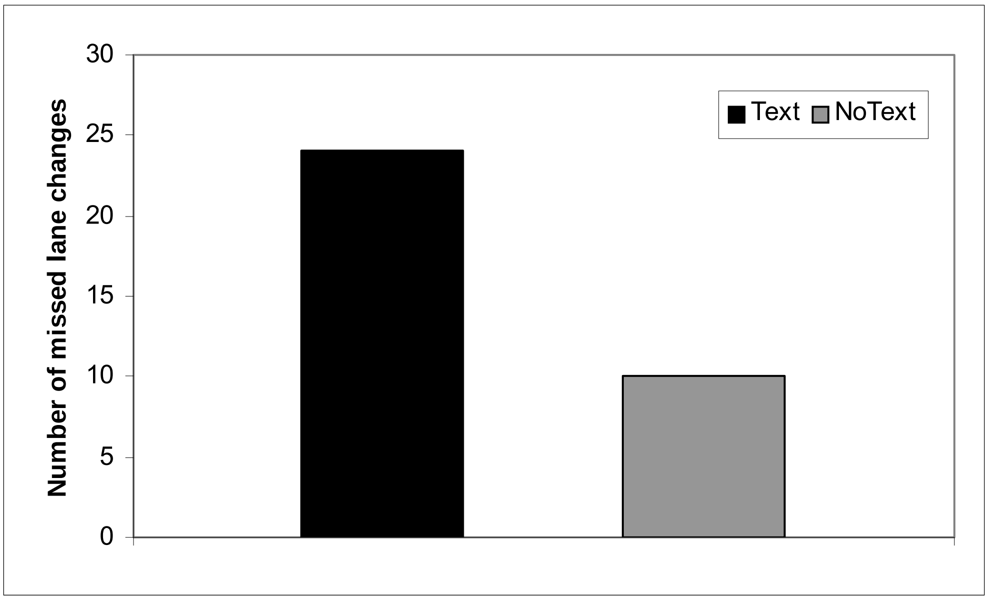

Figure 9. Total number of missed lane changes for lane changing events collapsed across retrieving and sending sections as a function of text messaging and non-text messaging conditions.

Subjective Results

Participants completed a questionnaire prior-to and after driving in the simulator. The pre-drive questionnaire was designed to collect demographic information (age, gender, license type), information about the participants' driving patterns, driving violations and crash history, and use of mobile phones while driving.

The post-drive questionnaire was designed to obtain information regarding the participants' perceptions of whether and how sending and retrieving text messages affected particular aspects of their driving performance (e.g., speed maintenance, following behaviour, lane keeping performance, detection of hazards).

Mobile Phone Use While Driving

Participants were asked if they ever talk on a hand-held or hands-free phone while driving and, if so, approximately how many times a week they do this. Seven of the 20 participants reported that they talk on a hand-held mobile phone while driving and that they do this on average five times per week (range: 1-30 times per week). Six of the 20 participants indicated that they talk on a hands-free mobile phone while driving and that they do this about three times per week on average (range: 1-7 times). Participants were also asked whether they ever read and/or send text messages while driving and, if so, approximately how many times per week they read or send messages. Nine of the 20 participants claimed that they *read* text messages while driving and that they read an average of four text messages per week (range: 1-10 times). Six of the 20 participants started that they send text messages while driving. These participants indicated that they send an average of two text messages per week (range: 15 times).

Concentration when Retrieving and Sending Text Messages

After completing the test drives, participants were asked which task - retrieving or sending the text messages – they devoted most attention to whilst driving. When the text message arrived, 17 of the 20 participants reported that they concentrated most on retrieving the message, while the other three indicated that they concentrated mostly on driving. When sending a text message, 14 of the 20 drivers indicated that they concentrated most on writing and sending the message, while the remaining six said that they concentrated most on driving.

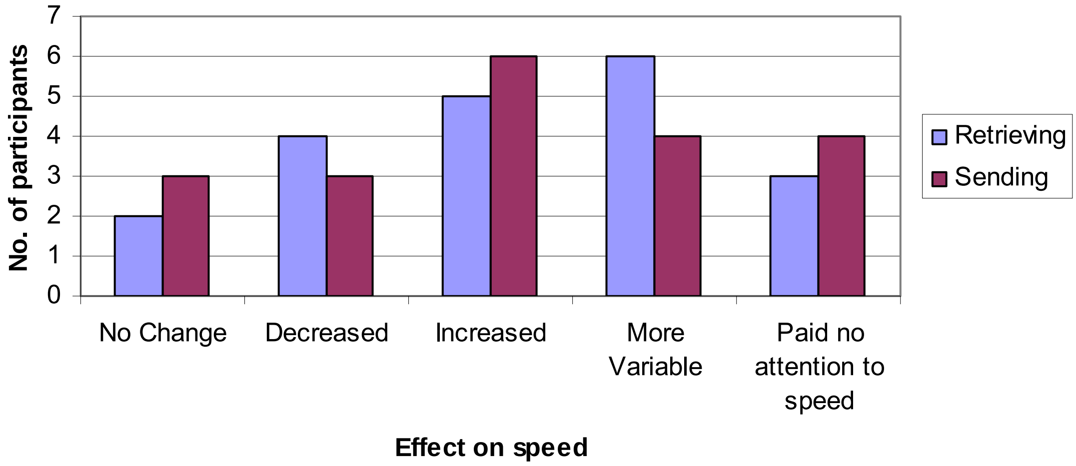

Figure 10. Reported effect on speed of retrieving and sending text messages.

Effects of Text Messaging on Speed

Participants were asked whether they believed that sending and retrieving the text messages affected their speed and, if so, how. Of the 20 participants, 18 indicated that *retrieving* text messages affected their speed, while 17 participants claimed that *sending* the text messages affected their speed. Figure 10 displays the number of drivers that reported that their speed was affected by text messaging. The responses were mixed across participants, with some reporting that it decreased their speed, some that it increased their speed and others that it made their speed more variable. A number of participants responded that they did not pay any attention to their speed while text messaging and, thus, were not aware how their speed was affected by this task.

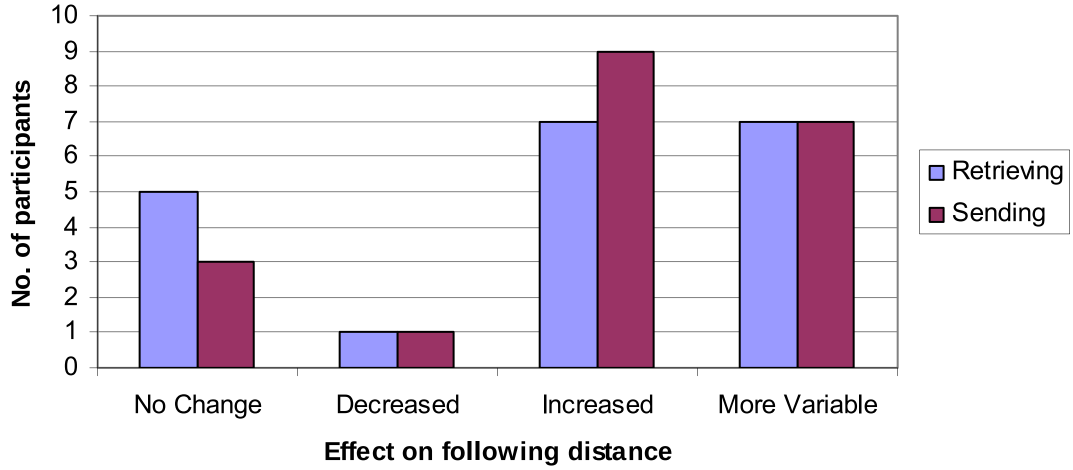

Figure 11. Reported effect on following distance of retrieving and sending text messages.

Effects of Text Messaging on Following Behaviour

Participants were also asked to report whether sending and retrieving the text messages affected their following distance during the car following tasks and, if so, how. Of the 20 participants, 15 indicated that *retrieving* text messages affected their following behaviour, while 17 participants reported that *sending* the text messages affected their following behaviour. Figure 11 displays the reported changes in following behaviour as a result of text messaging. As shown, only one participant indicated that retrieving and sending the text messages reduced their following distance from the lead car. The majority of participants reported that text messaging increased their following distance or made it more variable.

Effects of Text Messaging on Lane Keeping Ability
Participants answered questions regarding whether they believed that sending and retrieving the text messages affected their lane keeping ability and, if so, how. Thirteen of the 20 participants indicated that *retrieving* text messages affected their ability to maintain their lane position, while 16 participants reported that *sending* the text messages affected their lane keeping ability. Of the participants who indicated that their lane keeping ability was affected, all stated that retrieving and sending the text messages increased the variability of lateral position and resulted in them swerving and deviating from their lane of travel.

Effects of Text Messaging on Hazard Detection and Response
Participants also answered questions regarding whether they believed that sending and retrieving the text messages affected their ability to detect and respond to hazards present in the driving scenarios (e.g., pedestrian and turning car) and, if so, how. Seventeen of the 20 participants indicated that *retrieving* text messages affected their ability to detect and respond to hazards, while 19 participants claimed that *sending* the text messages affected their hazard detection and response. Of the participants who indicated that their hazard detection and response times were affected, all stated that retrieving and sending the text messages made it more difficult to detect hazards and increased their response times to the hazards if they did detect them.

Overall Driving Performance
Participants were asked whether they believed that their overall driving performance was better, worse or no different from their normal driving when retrieving and sending text messages. Of the 20 participants, 19 indicated that their driving was worse than normal when retrieving the text messages, while one driver indicated that their driving was no different from normal. All 20 participants reported that their driving was worse than normal when sending the text messages.

Subjective Mental Workload
Scores on the six subscales of the NASA-RTLX were averaged to obtain an overall measure of subjective workload while retrieving and sending text messages. Subjective mental workload is measured on a scale ranging from low (0) to high (100). The mean subjective mental workload score given by participants was 61.1, suggesting that participants found the text messaging task moderately high in mental workload.

Discussion

The current project aimed to evaluate, using the advanced driving simulator located at the Monash University Accident Research Centre, the effects of text (SMS) messaging on the driving performance of young novice drivers. This study is, to the knowledge of the authors, the first to examine the effects on driving performance of both retrieving and sending text messages while driving. Previous research, conducted in Sweden, only examined the effects of retrieving text messages on driving performance. The present study also focused on young inexperienced drivers aged 18 to 21 years, given that this group is more likely than other driving groups to use a mobile phone while driving (Lam, 2002) and is, as a result of inexperience, more likely than more experienced drivers to be vulnerable to the effects of distraction.

It was difficult to formulate hypotheses regarding the precise effects of sending and retrieving text messages on driving performance measures given the scarcity of research in this area. However, it was possible based on the findings of previous research that has examined the effects on driving of dialing and conversing on mobile phones to draw some tentative hypotheses regarding the effects of text messaging. First, it was predicted that mean speed would decrease and speed variability would increase when text messaging whilst driving. It was also expected that lane position and following distance variability and the number of lane excursions would increase while text messaging. Finally, it was expected that drivers would fail, or take longer, to detect potentially hazardous events and traffic signals.

In contrast to the prediction that mean speed would decrease and speed variability would increase when retrieving and sending text messages, no significant differences in mean or standard deviation of speed were found across the retrieving text, sending text and non-text conditions. A simulator study by Kircher and colleagues (2004) also found no significant effect of reading text messages on driving speed. However, several on-road and simulator studies have found that drivers tend to decrease their mean speed when dialing or talking on a mobile phone in an attempt to reduce workload and moderate their exposure to risk (Alm & Nilsson, 1990; Burns, Parkes, Burton, Smith & Burch, 2002; Haigney, Taylor & Westerman, 2000; Horberry, Anderson, Regan & Triggs, in press Rakauskas, Gugerty & Ward, 2004). Many of these studies have also found that speed variability tends to increase when the driver is using a mobile phone. The speed findings from the current study suggest that the drivers were not attempting to compensate for being distracted by the mobile phone task by reducing their speed. This behaviour has road safety implications, as drivers who do not reduce their speed when distracted will have less time and capacity to avoid a collision should a hazard arise. Alternatively, this finding could be the result of the instructions given to participants during the experiment; they were told to drive as closely as possible to the posted speed limit.

As predicted, time headway variability increased by 138 and 101 percent when retrieving and sending text messages, respectively, from baseline (non-text) levels. Mean time headway also increased by 50 percent when both retrieving and sending text messages and minimum time headway increased by 32 percent from baseline levels, but only when sending text messages. These findings were revealed, however, for the second car following event only. No significant differences in following distance were found across the distraction conditions for the first and third following events, which was possibly due to unfamiliarity with the requirements of the task in the first event, and missing data due to technical problems that arose in the third event.

While drivers did not appear to compensate for the distracting effects of text messaging by decreasing their speed, the finding that drivers increased their mean and minimum time headway indicates that drivers did attempt to compensate for being distracted by increasing their following distance from the vehicle ahead. This finding is consistent with the results of previous research, which found that drivers tended to increase their following distance when using a mobile phone or an in-car email system (Jamson, Westerman, Hockey & Carsten, 2004; Strayer & Drews, 2004; Strayer, Drews & Johnston, 2003). The variability of time headway did increase when text messaging, suggesting that while drivers did attempt to increase their safety margin by increasing following distance, they were not able to maintain a constant following distance from the vehicle ahead while text messaging.

Substantial differences in the amount of time spent with eyes off the road were found between the text and non-text conditions. More specifically, the amount of time participants spent with their eyes off the road (e.g., looking inside the vehicle) increased by approximately 400 percent from baseline levels when were retrieving and sending messages. Participants spent approximately 10 percent of time with their eyes off the road when not text messaging, but this percentage increased to around 40 percent when participants were both retrieving and sending text messages. This percentage equated to drivers spending about 12 seconds of each 30 second text messaging episode with their eyes off the road. At present, the frequency and duration of glances away from the road has not been analysed (this data will be examined and reported in the full project report), thus it is difficult to draw conclusions regarding the precise implications of this finding for road safety. Clearly, however, drivers spending such a high proportion of driving time with their eyes diverted away from the road while text messaging is likely to significantly enhance crash risk, as drivers will be spending less time safely navigating through traffic and scanning for hazards. Indeed, previous research has shown that eyes off road time is highly positively correlated with number of lane excursions and number of hazards not detected (Curry, Greenberg & Blanco, 2002; Haigney & Westerman, 2001).

Contrary to expectation, when lateral position was examined for the entire set of text message episodes, no significant differences in mean lateral position or lateral position variability were revealed. However, a number of differences in the standard deviation of lateral position across the text and non-text conditions were revealed for a number of events. Specifically, the standard deviation of lateral position increased while drivers were sending, but not reading, text messages during the pedestrian event (by 46 percent), the red traffic light event (by 70 percent) and the second car following event (by 45 percent). Numerous other studies have also revealed that a driver’s ability to maintain their lateral position is adversely affected by dialling and talking on a mobile phone or entering destination details into a route navigation system (Dingus et al., 1995; Green, Hoekstra & Williams, 1993; Reed & Green, 1999; Tijerina, Parmer & Goodman, 1998). The fact that the drivers’ ability to maintain their lateral position was only adversely affected when sending text messages and not when reading messages suggests that the structural interference associated with physically manipulating the phone’s keys may have also caused drivers to unconsciously move the steering wheel as well. This structural interference is less evident when retrieving messages, as drivers are not manipulating the phone’s key to the same degree as when sending. Furthermore, it could be argued that writing and sending the text messages was more cognitively demanding than reading the messages because it required the drivers to generate a response and check that this response was both the correct answer and that it was spelt correctly in order for the predictive text function to recognise the word.

In line with the lateral position findings, the results also revealed that, across all text messaging episodes, the drivers made a greater number of lane excursions (28 and 63 percent more) when retrieving and sending text messages, respectively, than when not text messaging. The finding that drivers are unable to maintain lane position and are more likely to veer out of their lane while text messaging has obvious implications for the safety of not only drivers, but also for all other road users, as drivers could veer into on-coming traffic or onto the footpath, colliding with pedestrians or cyclists.

During the drives, participants were required to complete the lane change task, which is designed to assess drivers’ ability to detect and respond to signs indicating the correct lane of travel, and maintain the ideal lane change course, when performing a secondary task. No significant differences in mean speed or speed variability were revealed across the text and no-text conditions during the lane change task. However, when retrieving and sending text messages, the number of incorrect lane changes made increased by 140 percent, suggesting that drivers either failed to detect the signs and did not change lanes, or that they misread the signs and changed into the incorrect lane. This finding is in line with a number of other studies which have found that drivers are more likely to miss traffic signs, or not process the information provided on the sign, when distracted (Strayer, Cooper & Drews, 2004; Strayer & Johnston, 2001). These failures to attend to the visual environment can have a significant impact on safety if drivers fail to detect important traffic signals such as stop signs or signs indicating a blocked lane ahead.

During the test drives, participants encountered a number of potential hazards, including a pedestrian stepping onto the road from behind a parked car, a traffic light turning red suddenly and an on-coming car unexpectedly turning right in front of the simulator car. It was predicted that drivers would be more likely to fail to detect these potential hazards, or take longer to respond to those hazards they did detect when retrieving and sending text messages. Whilst there is no evidence in the driving data to suggest that drivers failed to detect some of the hazards present in the driving scenarios, drivers did report in the post-drive questionnaire that they had difficulty detecting the hazardous events in the drives while text messaging. The fact that there were no significant differences in speeds on approach to, or when passing, the hazardous events between the text and no-text conditions suggests that drivers did not reduce their speeds in either condition in response to the hazards. This may simply reflect their inexperience; that is, they may simply not have seen the need, even when undistracted, to taken precautionary action in the vicinity of potential hazards. It is possible that, with a more experienced group of drivers, text messaging may have affected responses to potential hazards.

As discussed above, it was revealed that, when sending a text message, drivers' lateral position deviation increased significantly during the pedestrian and traffic light event. No difference in lateral position, however, was revealed for the right turning car event. This failure to find a difference across distraction conditions may be due to the fact that there was missing data on this event for some drivers and, thus, not enough power to detect differences. Alternatively, it could be due to the nature of the event. In order to avoid a collision with the turning vehicle, which would have meant that participants could not complete the remainder of the drive, it was necessary to design the event so that drivers came close to, but did not ever collide with, the car if they did not make any corrective response (e.g., brake or swerve). It is possible that the participants may have realised that no corrective manoeuvre was necessary to avoid a collision and, hence, they did not alter their lateral position.

Comparing the participants' questionnaire responses regarding the perceived effects of text messaging on their driving with the actual driving data revealed that drivers are not always aware of how distraction affects their driving performance. In particular, the majority of participants reported that text messaging affected their speed, either by increasing or decreasing it or by making it more variable. The driving data, however, revealed that the participants' speed did not differ significantly across the text and no-text conditions. In addition, although the drivers reported that they believed their ability to detect hazards was reduced when text messaging, the driving data did not support this belief. Nonetheless, the driving data did support the participants' perceptions that text messaging increased their average following distance and the variability of following distance and lateral position. While there was some evidence that drivers were not always aware of exactly how their driving performance is affected by text messaging, if anything, the drivers tended to overestimate the negative impact of distraction on their driving. Whether these perceptions translate into drivers being less willing to retrieve and send text messages while driving in the real-world, however, is unclear and should be the focus of further research.

The results of the current study provide evidence that retrieving and, in particular, sending text messages has a detrimental effect on a number of safety critical driving measures, such as the ability to maintain lateral position, detect hazards, and to detect and respond appropriately to traffic signs. Also, when text messaging, drivers spent up to 400 percent more time with their eyes off the road than they did when not text messaging. Moreover, while their was some evidence that drivers attempted to compensate for being distracted by increasing their following distance, drivers did not reduce their speed while distracted, which could have an enormous impact on crash risk because it increases the stopping distance required to avoid a collision. The driving data results become even more concerning when the drivers' use of hand-held phones are considered. The results of the questionnaires revealed that a large proportion of the participants use hand-held phones while driving to talk and to retrieve and send text messages despite this being illegal in Australia. Combined, these results suggest that mobile phone safety education and advertising campaigns need to be targeted heavily towards young drivers to address the issue of the high number of young drivers using these current-generation devices while driving. More stringent mobile phone enforcement should also be considered in an effort to deter drivers, and young drivers in particular, from using hand-held phones while driving.

As with any preliminary research, this study did have a number of limitations. First, no significant differences in time headway across distraction conditions were found for the first car following event. This is thought to result from the drivers being unfamiliar with the requirements of the following task, even though they received instructions about the task. In hindsight, a practice car following task should have been included in the practice drive to avoid this problem. Second, one concern that has been raised about previous distraction research is that, in many studies, the effects of in-vehicle devices on driving performance are only examined over a limited number of trials or drives. Participants are not given the opportunity to interact with the device over a number of trials and, therefore, any learning effects, whereby drivers learn to effectively time-share the non-driving and driving tasks, are not assessed. A recent study by Shinar and colleagues (2005) examined whether repeated experience conversing on a mobile phone led to a learning effect. They found that over the course of five sessions, the negative effects of the phone task on driving performance diminished such that, on several of the driving measures, there was no difference between performance in the distraction and no-distraction conditions. Due to time and budgetary constraints, the current study did not examine the effects of text messaging on driving performance over a number of trials. However, we did attempt to control for this learning effect by only using participants who were familiar with how to send and retrieve text messages, specifically on a Nokia mobile phone.

Third, Shinar and colleagues (2005) have also raised the issue that in many distraction studies the secondary tasks are experimenter-paced (e.g., the experimenter controls when drivers engage in the secondary task) rather than driver-paced, which is not typical of how tasks are carried out in real-world driving (e.g., drivers can decide whether or not engage in the task). In order to control the timing of the text messages so that they were presented at exactly the same points in the drive for each driver, the text message episodes in the current task were also experimenter-based. Participants were required to retrieve the text messages when they heard the simulated message beep and start replying when they heard the "reply now" signal, whereas in the real-world drivers can choose whether or not to retrieve and respond to text messages received while driving. There was some flexibility in the task, however, in that drivers could take as much time as they needed to reply to the text messages.

A final comment concerns the use of simulators in research. While the driving simulator allows a safe environment for testing the effects of secondary tasks on driving performance that cannot be replicated in the real world, it does have a number of limitations that researchers need to be mindful of. First, data collected from a driving simulator includes the effects of learning to use the simulator and in-vehicle devices and may also include the effects of being monitored by the experimenter. Second, one of the most problematic aspects of driving simulator research that has major implications for driver distraction research is the effect of the simulator on drivers' priorities in relation to the primary driving task and the secondary task of interacting with in-vehicle devices. Drivers' behaviour and the relative amount of cognitive resources they devote to these tasks while in the simulator may differ significantly from their behaviour on actual roads because there are no serious consequences resulting from driving errors made in the simulator (Goodman et al., 1997). Previous research has shown, however, that people behave in the high fidelity MUARC simulator in much the same way as they do in the real world.

Based on the results of the current study, a number of areas for further research can be defined. First, the effect of text messaging on the driving performance of drivers from a range of age groups and driving experience levels should be examined to determine if any differences exist across these groups. More detailed information regarding how frequently drivers from different driver groups engage in text messaging while driving, what factors motivate or encourage drivers to willingly engage in this activity, and under what conditions they usually engage in them is also needed. Research is also needed to establish the conditions under which text messaging may be particularly detrimental to driving performance (e.g., heavy traffic, poor weather, emotional message content). Finally, research should establish whether and how practice over a number of trials using driver-paced tasks could minimise the interference associated with retrieving and sending text messages.

Conclusions

The results of the current study provide evidence that retrieving and, in particular, sending text messages has a detrimental effect on a number of safety-critical driving measures. In particular, when text messaging, drivers' ability to maintain lateral position and to detect and respond appropriately to traffic signs is negatively affected. In addition, when text messaging, drivers spent up to 400 percent more time with their eyes off the road than they did when not text messaging. Moreover, while there was some evidence that drivers attempted to compensate for being distracted by increasing their following distance, drivers did not reduce their speed while distracted, which could increase their risk of being involved in a crash because it increases the stopping distance required to avoid a collision. Despite these degradations in driving performance and legislation banning the use of hand-held phones while driving, a large proportion of the drivers examined reported that they regularly use hand-held phones while driving for talking and text messaging. These findings highlight the need for mobile phone safety campaigns to target the young driver population in particular, in order to minimise the use of these devices among this population.

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PRESENTATION SLIDES

The Effects of Text Messaging On the Driving Performance of Young Novice Drivers

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International Conference on Driver Distraction, Sydney, 2-3 June 2005

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Overview

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- Acknowledgements
- Background
- Method
- Results
- Discussion
- Conclusions
- Next Steps

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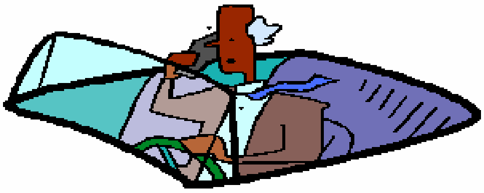

Background

- Approximately 80% of Australians own a mobile phone.
- 2% of drivers observed using a hand-held phone in Melbourne (Taylor et al., 2003)
- Survey found that one in six drivers admit to regularly sending text messages while driving (Telstra, 2003).
- But….
- Very little research has examined the effects on driving performance of text messaging.

Previous Research

- Survey of 2000 UK drivers found that text messaging viewed as most distracting activity a driver can perform.
- Swedish simulator study found that retrieving and reading text messages reduced reaction times to hazards and increased driver workload (Kircher et al., 2004).
- However, Swedish study only examined effects of receiving text messages, used experienced drivers and sample size was small (n = 10).

Study Aims

- Aimed to evaluate, using an advanced driving simulator, the effects of text messaging on the driving performance of young novice drivers.
- Examined effects of both retrieving and sending text messages.
- Focused on young novice drivers aged 18 to 21 years who had held drivers licence for 6 months or less.

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Method

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- Participants
  - 20 drivers aged 18 to 21 yrs (mean age: 19.1 yrs).
  - All had held their driver's licence for 6 months or less.
  - All were familiar with how to send text messages on a Nokia mobile phone.
- Materials
  - Advanced Driving Simulator located at MUARC
  - FaceLab eye tracking equipment
  - Nokia 6210 mobile phone

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Method

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- Drives
  - 2 identical test drives containing:
    - 3 car following tasks
    - Pedestrian and other traffic hazards
    - Lane Change Task
    - 4 text message episodes per drive
- Instructions
  - Drive as close as possible to speed limit
  - Stay in right hand lane unless indicated to do otherwise
  - Obey road rules

Method

- Procedure
  - 5 minute practice drive
  - Completed test drive twice
  - On one drive text messages were received at events 1,3,4 and 6.
  - On other drive text messages were received at events 2,5,7 and 8.
  - Above two event orders were designed to minimise practice effects
  - Order of drives counterbalanced across participants

Driving Scene Footage

Questionnaire – subjective results

Pre Drive Questionnaire revealed

- Seven of the 20 participants said they talk on a hand held mobile - 5 times per week
- Nine of the 20 participants said they read text messages – four times per week
- Six of the 20 participants said they send text messages – two per week

Post Drive Questionnaire

- Participant's subjective mental load was assessed by the NASA-RTLX scoring system
- Participants rated the task 61/100 on the scale – moderately high mental workload.

…19 out of the 20 participants believed their driving performance was worse when receiving messages.

…all participants believed their driving performance was worse when sending text messages.

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Results

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Definitions: Retrieving – retrieving message and reading it,
Sending – writing message and sending

- Driving Speeds
  - No significant differences in mean, maximum & standard deviation of speed across all driving events
- 3 Car Following Events
  - Average gap between driver and lead vehicle was 50% larger when text messaging
  - The average gap between driver and lead vehicle was 138% more variable when text messaging.
  - Minimum gap between the driver and the lead vehicle was 32% larger when text messaging.

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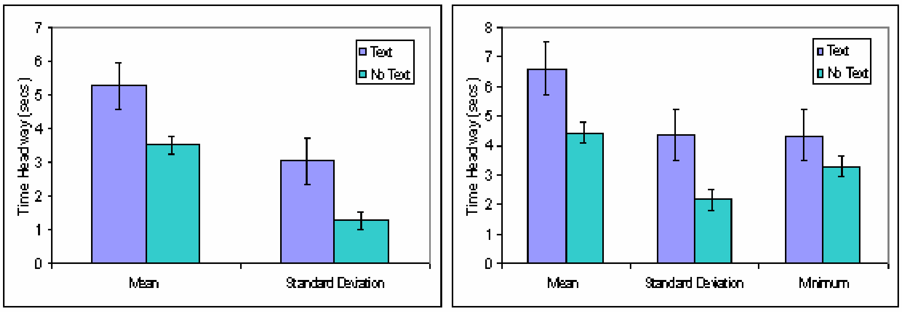
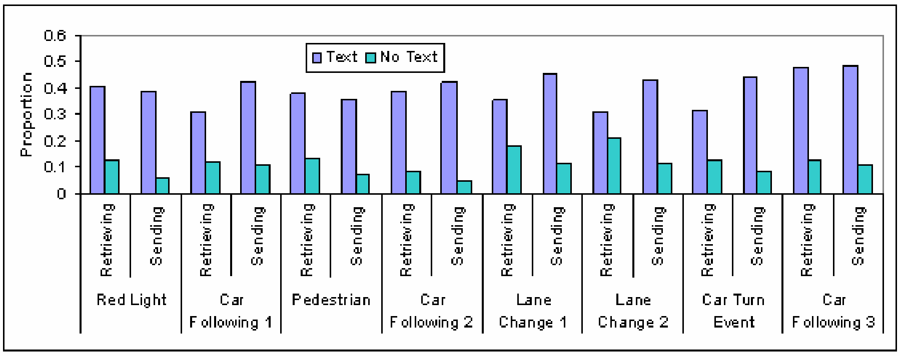
Mean & SD Time Headway



Results – Eyes off Road Time

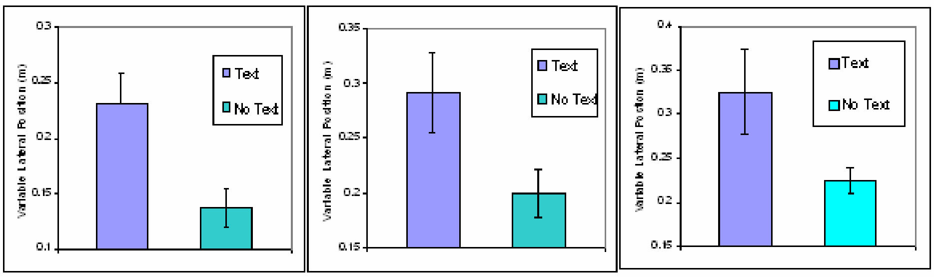
- **The amount of time drivers spent with their eyes off the road increased by up to 400% when retrieving and sending text messages.**



Driving Events

Results – Lane Keeping Ability

- Lateral position deviation increased by up to 70% when sending texts during the traffic light, pedestrian and 2nd car following events.



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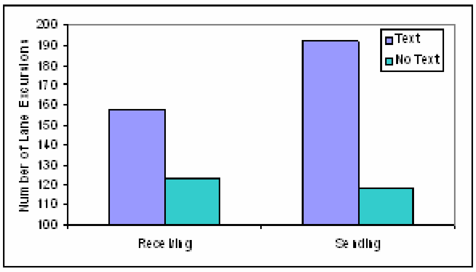
Results – Lane Excursion & Changes

- Drivers made 28% and 63% more lane excursions when retrieving and sending texts, respectively.

- Number of incorrect lanes changes made increased by 140% when retrieving and sending texts.



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Discussion

- Drivers did not attempt to compensate for being distracted by reducing speed – may be a result of instructions.

- But, they did compensate by increasing their following distance.

- Drivers spent a greater amount of time with their eyes off the road when text messaging.

Discussion

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- Drivers' lane keeping ability and ability to detect traffic signs and hazards reduced when text messaging.
- Sending text messages appeared to be more distracting than reading texts – generating a response is more cognitively and physically demanding.

Conclusions

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- Retrieving and, in particular, sending text messages has a detrimental effect on driving performance.
- Text messaging affected drivers' lane keeping ability, ability to detect signs and hazards and increases the amount of time spent not looking at the road.
- Drivers did attempt to compensate for this degradation in driving performance by increasing following distance, but not by reducing speed.
- These degradations are likely to greatly increase crash risk.

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Next Steps

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- Further research to determine how frequently drivers are engaging in texting while driving.
- Further research to understand the effect of text messaging on the driving performance of other age groups.
- Determine what countermeasures will deter this risky driver behaviour.