Transport Research Laboratory

The Effect Of Text Messaging On Driver Behaviour

A Simulator Study

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PPR 367

PUBLISHED PROJECT REPORT

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by N. Reed & R. Robbins (TRL)

Prepared for:	**Project Record:**	**Texting Whilst Driving**
	Client:	**RAC Foundation (Elizabeth Dainton)**

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Executive summary

The detrimental effects of mobile phone use on driver performance have been widely studied (e.g. Brown & Poulton, 1961; Burns, Parkes, Burton, Smith & Burch, 2002; Parkes, Luke, Burns & Lansdown, 2007). However, there is a significant gap in the research literature, namely the effects of text messaging on driving. In 2008, The RAC Foundation asked 2002 members of the social networking website Facebook (www.facebook.com), to self report on whether they text whilst driving and 45% admitted doing so. In response to this, the RAC Foundation commissioned TRL to investigate the relative driver impairment caused by texting whilst driving.

The aim of the study was to assess the impact of text messaging on driver performance, and the attitudes and beliefs that surrounded the activity in the 17-25 age category. Reaction times, car following ability, lane control, and driver speed were used as measures of driver performance and driver attitudes were assessed using personality questionnaires. The TRL driving simulator was used to conduct the research. Seventeen participants between the ages of 17-24 were recruited for the study (8 male; 9 female). All participants described themselves as regular users of text messaging and used phones with standard key pads (i.e. alphanumeric key pads. Other phone types were excluded). It was hypothesised that when writing/reading text messages, drivers would display increased reaction times, poorer car following ability, poorer lateral lane control, and reduced speed. It was also hypothesised that reductions in drivers' performance will be greater when writing a text message than when reading a text message.

Participants first completed a familiarisation drive, which consisted of a ten minute motorway drive in which the participant was required to follow a lead vehicle at a safe distance designated with chevrons. This was followed by two identical test drives. In one of the drives, participants were required to complete text messaging tasks following verbal instructions (read a received message; compose and send a message to a contact; ignore an incoming message). In the other drive, participants completed the same route without any distractions. Questionnaires were completed before and after the simulator drives. Participants were also timed completing a comparable set of text messages to those used in the simulator drive to investigate how much longer it takes to text when driving.

Results demonstrated that participants' driving behaviour was impaired by concurrent text message tasks. Writing text messages created a significantly greater impairment than reading text messages. Behaviour in response to the arrival of an ignored text message was unaffected. Reaction times to (task-unrelated) trigger stimuli tended to be higher when reading or writing a message. The slowest average reaction time was observed for drivers responding to the visual reaction time task whilst trying to compose a text message where reaction times increased from 1.2 to 1.6 seconds. Furthermore, participants were significantly more likely to fail to respond to the reaction time stimuli if engaged in concurrent text messaging whilst text completion times when driving were nearly three times longer than when composing similar messages undistracted. The failure to detect hazards, increased response times to hazards, and exposure time to that risk have clear implications for safety. At motorway speeds (as were present in the visual RT task), a driver would travel more than one mile whilst completing the text message and the increase in mean reaction time would result in an increased stopping distance of 12.5m (approximately three car lengths). This could easily make the difference between causing and avoiding an accident or between a fatal and non-fatal collision.

It was observed that drivers tended to reduce their speed in the texting conditions. It is suggested that drivers were aware that their driving was impaired to some degree whilst engaged in text messaging tasks and chose to reduce their speed in order to mitigate accident risk. The most conspicuous change in performance was the large increases in variability of lane position resulting in many more lane departures when texting. It was further identified that the impairment caused by texting was far more significant for

female rather than male drivers. The survey by the RAC Foundation (2008) found that male drivers were more likely to text and drive. It is concluded that, although male drivers may show a reduced impairment when texting and driving, the increased probability that male drivers will engage in this behaviour suggests that the overall impairment across the sexes may be more equal.

It was observed that participants, when texting, were less able to maintain a constant distance behind a lead vehicle and showed increased variability in lateral lane position when following that vehicle. In real world traffic situations, it is suggested that poorer control of vehicle speed, lateral position, and increased reaction times in this situation would increase the likelihood of collision dramatically.

As hypothesised, reading text messages had a less detrimental effect on performance than writing messages but a detrimental effect nevertheless. Ignored text messages appeared to have a negligible effect on performance. This pattern of results is consistent with a lower relative task demand of reading a text message compared to writing a message where, in addition to viewing the phone display screen, the driver must consider the text to be written and interact with the phone to compose the message.

The questionnaire results indicated that participants were confused about the legality of texting whilst driving. A majority of participants felt that use of a phone for texting whilst handheld or in a cradle should be illegal. Participants reported feeling impaired in their driving when texting recognising that they had poorer lane positioning, chose to drive more slowly, and kept larger safety margins. They also recognised that writing/sending a message was more of a distraction than reading an incoming message.

Results in the study were compared to three earlier TRL studies that used a similar methodology (Burns, Parkes, Burton, Smith & Burch, 2002; Sexton, Tunbridge, Brook-Carter, Jackson, Wright, Stark, & Englehart, 2000; Sexton, Tunbridge, Board, Jackson, Wright, Stark, & Englehart, 2002. Reaction time impairment caused by texting whilst driving was apparently greater than that caused by alcohol consumption to the legal limit for driving, cannabis, and handsfree conversations but less detrimental than using a mobile phone for handheld conversations. Participants tended to drive more slowly when texting whilst driving than when conversing on a mobile phone but the speed reduction was less than observed when drivers were under the influence of cannabis. This suggests participants feel that they have to compensate for a greater perceived behavioural impairment caused by texting whilst driving than that caused by talking whilst driving but less when experiencing the combined physiological and psychological effect of cannabis. Burns et al. found that there were no significant differences in lateral lane control in the handheld or handsfree conversation conditions. Driving whilst at the legal limit of alcohol consumption did result in significantly less steady lane keeping than any of the other conditions in the study. Sexton et al. (2000) found that drivers displayed an increase of around 35% in lateral position variability with high does of cannabis whilst Sexton et al. (2002) found an approximate 14% increase in SDLP for the cannabis and cannabis + alcohol conditions. This study found that reading messages resulted in a 12.7% increase in lateral position variability whilst that for writing a message increased by 91.4%. It was further observed that the read and write message tasks were also accompanied by a significantly greater number of lane departures.

It is concluded that the combination of increased mental workload required to write a text message, the control impairment caused by the physical act of holding the phone, and the visual impairment caused by continually shifting visual orientation between the phone display and the road ahead resulted in significantly impaired ability to maintain safe road position. Participants' reduction in speed indicated their awareness of the impairment caused by texting whilst driving. However, this attempt to mitigate risk cannot fully compensate for their deterioration in performance when attempting to text and drive.

Abstract

RAC Foundation (2008) reported the results of a survey of 2,000+ users of Facebook, showing that 45% of UK drivers engage in texting whilst driving. The RAC Foundation commissioned TRL to study the impairment caused by texting whilst driving using TRL's driving simulator.

Seventeen drivers (aged 17-24 years) took part in the study. Drivers completed one drive as normal (undistracted) and one drive in which they completed text messaging tasks. Participants were impaired in their performance when reading and writing text messages, particularly reaction time and ability to maintain lateral vehicle control. Reaction times were around 35% slower when writing a text message. Earlier studies at TRL showed that alcohol consumption to the legal limit caused a 12% reaction time increase; cannabis slowed reaction times by 21%. When texting, drivers slowed significantly, indicating that they recognised the impairment, attempting to mitigate risk by reducing speed. However, greater lateral variability in lane position and drifting into adjacent lanes when texting are not mitigated by speed reduction and would lead to potential conflict with other traffic.

Female drivers showed greater variability in lateral lane position when texting than male drivers. However, female participants tended to show greater speed reductions indicating that they may have had greater awareness that their driving was impaired.

This study highlighted that when texting, a driver may present a greater accident risk than when at the legal limit for alcohol consumption or when under the influence of cannabis, reinforcing that drivers should refrain from this dangerous activity.

1 Introduction

With the emergence of new technologies such as mobile phones, entertainment systems, in-vehicle information systems (IVIS), etc, the number of distractions to which drivers are potentially exposed continues to increase. One of the most popular devices used whilst driving is the mobile phone. Over the last decade mobile phones have transitioned from a luxury enjoyed by the few, to a must-have item enjoyed by a large proportion of the world's population (there are 3.3 billion mobile phone subscriptions worldwide as of Q4 2007 (The GSM Association, 2007)). There is a clear need to account for the consequences of mobile phone use on driver performance and behaviour, and a great deal of research has been conducted into this subject.

Even though the detrimental effects of mobile phone use on driver performance have been widely studied (Brown & Poulton, 1961; Burns, Parkes, Burton, Smith & Burch, 2002; Strayer, Drews & Crouch, 2006; Horberry, Anderson, Regan, Triggs & Brown, 2006; Parkes, Luke, Burns & Lansdown, 2007; Just, Keller & Cynkar, 2008), there is a significant gap in the research literature, namely the effects of SMS (Short Message Service) messaging (texting). To date most research has focused on verbal communication at best, or at worst conflated text messaging with verbal communication under vague labels such as 'mobile phone use'.

Generally, research has failed to recognise that mobile phones are multi-function devices, and have focused on their primary function, verbal communication. Indeed, whether verbal communication is still clearly their primary function, especially amongst young users, is not certain (over 7 billion text messages are sent each day throughout the world (The GSM Association, 2007)). Despite texting being so popular, its effects on performance are underrepresented in the research literature. This lack of research is of concern as a significant number of drivers admit to texting whilst driving (RAC Foundation, 2008; McEvoy, Stevenson & Woodward, 2006; Gras, Cunill, Sullman, Planes, Aymerich & Font-Mayolas, 2007; Thulin & Gustafsson, 2004).

In 2008, The RAC Foundation asked 2002 members of the social networking website Facebook (www.facebook.com), to self report on whether they text whilst driving. Alarmingly, 45% admitted doing so. They separated those who text into several categories: 21% read and send message regardless of traffic flows ("multi-tasking multimedia maestros"), 19% use their phones when stuck in a jam ("opportunistic optimisers"), and 5% read texts whilst driving but would not respond ("casual observers"). Research in other countries has also discovered significant amounts of texting whilst driving (though much less than in the RAC Foundation survey). According to the McEvoy et al. (2006), 12.4% of Australian drivers admit to having texted whilst driving. Furthermore, they identify young drivers (18-30) as being significantly more likely to text whilst driving than older drivers. In similar research, Gras et al. (2006), found that amongst Spanish drivers, 19.1% admitted texting on highways and 22.5% on rural roads at least once a month. A survey of Swedish drivers found on average they sent one text message per month, with drivers between 18 and 24 sending three (Thulin & Gustafsson, 2004), suggesting that younger drivers are much more likely to text whilst driving than older drivers.

Note, while we may recognise it is important to separate texting from verbal communication as the two tasks are very different, it is also appropriate to break down texting into sending a text message and retrieving a text message, as these tasks differ in some important characteristics (namely the greater complexity and duration of the key presses required for sending a text). This distinction is addressed in this study.

Kircher, Vogel, Bolling, Nillson, Patten, Malmstrom, & Ceci, (2004) studied the effects of receiving a text message on the performance of a small sample (ten) of experienced drivers and found it significantly increased reaction times in a peripheral detection task and generally reduced driver speed. From this we can infer that sending a message would be even more detrimental to performance than receiving a message, however, as

Kircher *et al*. did not examine the impact of sending messages, this assumption can not be supported by their findings.

An attempt to measure the performance effects of retrieving and sending text messages on young drivers was completed by Hosking, Young and Regan (2006) at Monash University. They measured the effect of texting on young driver performance using the advanced driving simulator located at Monash University Accident Research Centre (MUARC). Twenty young adults (18-21) completed two drives which contained eight "critical events" (e.g. avoiding a pedestrian, changing lane in accordance with traffic signs, etc). During the drive participants were required to send and retrieve text messages. Several measures of driving performance were found to be impaired during the texting whilst driving condition. When texting, participants:

- spent 40% time looking away from the road environment compared to 10% when undistracted
- were less consistent at maintaining appropriate positioning of their vehicle in their lane (70% more variability in lateral lane positioning and 28% more lane excursions).
- frequently failed to see signs instructing them to change lane (140% more incorrect lane changes)

Participants were asked to complete a questionnaire post trial in which participants self-rated any change in performance associated with driving whilst texting. These results showed an awareness of a decline in performance, with 19/20 participants rating their performance as worse when retrieving a message, and a full 20/20 participants rating their performance as worse when sending a message.

Further support for drivers' general awareness of the dangers of texting whilst driving were also found by Ginsburg, Winston, Senserrick, Garcia-España, Kinsman, Quistberg, Ross and Elliot (2008), who asked 5665 teenagers in the USA to rate various dangers associated with driving. Texting whilst driving was rated as the second most likely situation to make "a lot of difference" in driving safety. A modified and shortened list of the risks used by Ginsburg, et al. was presented to participants in this trial.

Another key difference between using a mobile phone for verbal communication and texting is that while adults generally share a similarly advanced degree of verbal skill, the degree of experience/skill with texting can vary considerably between individuals. It would seem reasonable to assume that while the performance impairments caused by verbal communication are likely to be normally distributed, the performance impairments of texting are likely to be skewed with older drivers showing greater reductions in performance due to lack of experience with texting and diminished manual dexterity.

No research has been found to describe any performance differences resulting from experience of texting, however, Chisholm, Caird and Lockhart (2007) examined a related technology; the use of MP3 players whilst driving. This places similar demands on drivers as texting whilst driving; both require a sequence of key inputs and are likely to divert drivers' vision away from the road environment and towards the device. Chisholm et al, required 19 participants to operate an MP3 player whilst driving a simulator and subjected them to a number of "critical events". Their results demonstrated that participants' performance slowed responses to driving hazards while interacting with the MP3 player declined somewhat, but a decrement still remained relative to the baseline condition. This suggests that a driver's risk of collisions whilst texting may decrease as their experience/skill with texting increases.

Whilst research may have established that younger drivers are more likely to text, this greater exposure to risks may be off-set (to a degree) by greater familiarity with texting and increased confidence in their own abilities. While drivers are prone to overestimate their own abilities, there is evidence that confidence is linked to driving performance. Lesch and Hancock (2004) found that higher confidence amongst male drivers predicted increased driving performance. In contrast, higher confidence amongst female drivers predicted lower driving performance. The reduction in performance amongst women was accounted for by confidence rising with age; older women tended to be more confident despite having slower reactions. However, confidence was a more accurate predictor of performance amongst men regardless of age; when older male drivers reported more confidence in their ability they did indeed exhibit superior performance regardless of their age.

In order to determine whether confidence is predictive of performance when texting whilst driving, this study required participants to complete a series of questions designed to measure their confidence in their ability to text whilst driving and their general sense of Self-efficacy (as measured by the IPIP NEO subscale). By comparing these outputs to measures of experience with driving, and with general texting, the relationship between confidence in general or confidence with texting and performance was investigated.

Further behavioural or attitudinal factors were explored. The RAC Foundation's survey of texting whilst driving (2008) described several personality archetypes that engage in this behaviour. Analysis of these archetypes suggested that by examining participants Immoderation, Liberalism and Self-efficacy (as measured by the IPIP NEO subscales), we would have a description of their ability to resist using their phone to text whilst driving, their degree of attachment to society's rules and values, and how confident they were regarding their own abilities in general. The predictive effects of these three factors on texting whilst driving behaviour was investigated.

This study investigated two aspects of texting whilst driving using a high fidelity car simulator:

- Driving performance. Quantitative measurements of driving performance were recorded from participants as they drive a high fidelity car simulator when engaged in a variety of text message tasks. This was to measure empirically the changes in performance consequent from this behaviour. It was hypothesised that:
    - When writing/reading text messages, drivers would display:
        - Increased reaction times
        - Poorer car following ability
        - Poorer lateral lane control
        - Reduced speed
    - Reductions in drivers' performance would be greater when writing a text message than when reading a text message.
- Subjective performance measures. Drivers reported how well they believe that they drove in the simulator scenarios when engaged in text message tasks and when undistracted. It was hypothesised that:
    - Drivers shall report greater difficulty writing than reading text messages

2 Method

2.1 Participants

Participants were recruited from the TRL participant database to take part in the study. The aim was to recruit sixteen participants (eight male; eight female) aged between 18 and 25 years. Participants were selected if they described themselves as regular users of text messaging to ensure that any performance effects seen are due to distraction from the texting task and not due to drivers being unfamiliar with text messaging itself.

To ensure familiarity with phone operation, participants were required to use their own mobile phones for the study. Participants had to use a phone that had a standard alphanumeric keypad to ensure consistency in the task demand of message composition. Participants whose personal phones had e.g. touch-screens; QWERTY keyboards for the composition of text messages were excluded.

On arrival at TRL participants informed the trials manager of their mobile phone number, the phone network that they use, and the phone make and model number (if known). Participants were also asked to add four new contacts to their phone (all with the same contact number) in order that they may send messages to these contacts over the course of the drive.

Participants involved in the study were paid £35 as compensation for their time and expenses incurred because of their participation.

2.2 Study design

In addition to their familiarisation drive, participants completed two test drives whilst at TRL. A Texting drive in which they were required to perform a number of different text messaging tasks (read; write; ignore) and a Control drive in which the participant drove along the same route as the Texting drive but without having to perform the additional texting tasks. To counterbalance any learning effect caused by completing the same driving task twice, the order in which participants completed the Control and Texting drives was alternated between participants.

2.3 Equipment

The TRL Driving Simulator (CarSim) consists of a medium sized family hatchback (Honda Civic) surrounded by four 3 × 4 metre projection screens giving 210º front vision and 60º rear vision, enabling the normal use of the vehicle's driving and wing mirrors. The road images are generated by four PCs running SCANeR II software (manufactured by Oktal) and are projected onto the screens by four Digital Light Processing (DLP) projectors at a resolution of 1280 × 1024 pixels (giving a screen resolution of approx 13 pixels per inch). Images are refreshed at a rate of 60Hz (every 16.7msec) whilst data is sampled at a rate of 20Hz (every 50msec). Electric motors supply motion with 3 degrees of freedom (heave, pitch and roll) whilst engine noise, external road noise, and the sounds of passing traffic are provided by a stereo sound system. Two studies demonstrate the validity of the TRL simulator (Duncan, 1995; Sexton, 1997) and it can be assumed that the current simulator system is at least as accurate as that used in the Duncan and Sexton studies. Further details are provided in Appendix A.

An HP iPAQ 500 Series Voice Messenger mobile phone on the Vodafone network was used by TRL to send /receive the text messages for the study (participants used their own mobile phone/network provider).

2.4 Familiarisation

Participants were required to complete a familiarisation drive prior to completing any of the test drives in order to be comfortable with controlling the simulator vehicle and driving in the virtual environment. This familiarisation drive was in a benign motorway environment and lasted approximately ten minutes. It included a car following task in which participants were required to drive at a safe and constant distance behind a lead vehicle. During this task, white chevrons were included on the motorway (as used on some sections of UK motorways) helping the participant to judge a safe distance to the lead vehicle.

Figure 2.1 Car-following route with motorway chevrons

2.5 Participant instructions

Participants were given specific instructions before driving relating to the simulator task. These are shown in the following text box:

<u>Participant instructions</u>

Beside the car:

Please adjust the seat position and secure the safety belt. The car controls work in the same manner as any normal car and it operates with a manual gearbox.

You need to make sure the car is in neutral when you start it and it needs plenty of revs, otherwise it has a tendency to stall.

It is important that you drive as you would normally. We don't want you to drive as if you are on a driving test nor as if the simulation is a computer game. We are not here to judge your driving, so please do not feel anxious.

A red bar like the one you can see on the screen now will appear at some point during your drive. There is also a buzzing noise that will sound at some point during the drive. When you hear the buzzing noise, or see the red bar please press the clutch pedal as quickly as you possibly can. .You will hear the buzzing sound about 20 seconds into this drive as a practice to help you recognise it.

The drive will start on the motorway with normal traffic. After some while, the motorway will end and you will reach a series of bends. You should try to keep to 40 mph through this section and the simulator will assess your ability to keep to the centre of your lane through the bends.

After the series of bends, you will drive on the motorway again. After a period of time you will see a vehicle in front of you. Please pull up behind this vehicle and follow it, doing your best to keep at a safe and constant distance behind it. A voice instruction will let you know when the car following task has finished.

There will be voice instructions to remind you about these tasks.

Text drive only

During this drive you will be asked to send and receive text messages, please only read text messages when you are asked to. Please text as you normally would i.e. using short words and predictive text.

From the control room:

Start: Please start the engine using the ignition key and proceed, driving as you would normally

2.6 Questionnaires

Over the course of their involvement in the study, participants completed a questionnaire covering a range of items:

- Demographic information
- Participant experience of simulator sickness over the course of the trial
- Questions about the received text messages (to confirm that participants read the text)
- Participants' self assessment of performance in the simulator drives
- Participants' self assessment of the effect of texting on their driving performance
- Participants' assessment of relative risk in a range of risky scenarios
- Participants' perception of the legality of reading/writing text messages whilst driving
- Participants' reported mobile phone usage

The questionnaire included the Driver Behaviour Questionnaire (DBQ; Reason, Manstead, Stradling, Baxter, & Campbell, 1990). The DBQ gives a relative score in three dimensions of driving behaviour: Violations, Errors, and Lapses. The correlations between scores on these dimensions and the driving behaviour measures recorded in the simulator were measured.

Extracts of the International Personality Item Pool (IPIP; Goldberg, Johnson, Eber, Hogan, Ashton, Cloninger & Gough, 2006) were also used in an attempt to describe the differences between personality types and their frequency of texting: in effect, why participants choose to text. Three facets were chosen; these are shown in Table 2.1.

Table 2.1 IPIP facets used and their hypothesised relation to texting whilst driving

IPIP facet	Supposed relation to texting whilst driving
Self-efficacy	An individual's confidence in their ability to drive and text
Openness to values	An individual's tendency to follow the rules (in this case, of the road)
Impulsiveness	An individual's ability to resist temptation to text

2.7 Route design

The simulator route driven by participants consisted of four sections with smooth naturalistic transitions between each section.

Table 2.2 The road sections used for the simulator trial

Section	Description	Length	Configuration
1	Motorway 1	28.1km	3 lane motorway plus hard shoulder in each direction. Light traffic present
2	Two loops	7.3km	Each loop is a two-lane 'figure 8' with a long left turn and long right turn separated by a short straight
3	Car following	13.0km	3 lane motorway plus hard shoulder in each direction. One vehicle present that the participant is required to follow at a steady distance
4	Motorway 2	11.6km	3 lane motorway plus hard shoulder in each direction. Light traffic present
	Total	60.0km	

In the loops section, participants were instructed to attempt to stay in the centre of their lane and to drive at 40mph[1].

In the car following section, participants were instructed to follow the lead vehicle at safe and steady distance (as they would have experienced in the familiarisation drive). The lead vehicle continuously varied its speed sinusoidally between 70km/h (43.8mph) and 110km/h (68.8mph) over a period of 20 seconds.

[1] In previous studies at TRL that have used a similar route design, participants were required to drive through the loops section at 60mph. However, in pilot trials, it was found that combining the text messaging tasks with safe route navigation at this speed was too difficult. Consequently, a lower speed was chosen to reduce the risk that participants would lose control of the vehicle, which would have negative implications both for the participant's experience of the trial and data collection.

2.7.1 Reaction time events

Over the course of both the Texting and Control drive, participants were required to respond to trigger stimuli on four occasions. The response was to depress the clutch pedal as quickly as possible. Clutch depression is measured from 0 (foot off clutch) to 1 (clutch fully depressed). The threshold for clutch activation was 0.1 (10% clutch depression). If clutch depression was greater than 10% at the time of the reaction time trigger, the event would have been ignored but this did not occur in any of the trials. If participants failed to respond within 10 seconds, this was treated as a missed event.

In three of the reaction events, the trigger stimulus was a short auditory tone (60dB; 0.45 seconds duration; 333Hz). The fourth reaction time trigger event was the presentation of a red bar stimulus above the carriageway and ahead of the driven vehicle across all motorway lanes. This is shown in Figure 2.2.

Figure 2.2 The trigger stimulus for the visual reaction time event

The reaction time tasks were triggered through the drive at times when the participant was likely to be engaged in a texting task in the Texting drive. The reaction time triggers were in exactly the same place for the Control drive.

2.7.2 Texting tasks

Through the course of the drive participants were required to perform a succession of different text messaging tasks.

2.7.2.1 *Writing text messages*

Participants had to write five text messages in the drive. All required an approximately similar number of characters with some possibilities to apply SMS language if desired. The instructions as to what to write and the message recipient were delivered as automated verbal messages in the simulation. As shown in section 2.5, participants were instructed to compose the text in their own usual style. This included using predictive text and applying SMS language. The first message was included as practice to ensure participants were comfortable what was required of them.

Table 2.3 shows the text messages that participants were required to compose.

Table 2.3 Text messages composed by participants whilst driving

Message	Recipient	Section	Message	Characters
Practice	Adam	1	"I am driving a great car simulator"	34
1	Adam	1	"Happy birthday Have fun at the party"	36
2	Brian	2	"Nice to see you at the cafe yesterday"	37
3	Claire	3	"Dont worry Have a nice time in Paris"	36
4	Dawn	4	"Sorry about your ankle Get well soon"	36

2.7.2.2 *Reading text messages*

Participants were sent two text messages over the course of their drive. Before receiving messages, participants were informed by an automated voice instruction that they were about to receive a message and that they would need to read the message in order to be able to answer the questionnaire at the end of the drive. Table 2.4 shows the messages that participants received.

Table 2.4 Text messages received by participants whilst driving

Message	**Section**	**Message**
1	1	"Edward has forgotten his BOWTIE for the wedding"
2	2	"Fiona won the SILVER medal in the 100m sprint"

2.7.2.3 *Ignored text message*

In addition to writing and reading text messages, participants were also sent a text message without any forewarning. As shown in section 2.5, participants were informed only to read messages that they had been instructed to read. So this event represented the distraction caused a message that participants knew they had received but were unable to read. The message is shown in Table 2.1.

Table 2.5 Text message to be ignored by participants whilst driving

Message	**Section**	**Message**
1	3	"Text message from TRL – please ignore"

2.7.2.4 Control messages

To compare the difficulty of texting whilst driving against composing text messages with no other distractions, participants were timed composing some comparable text messages. These were as follows:

Table 2.6 Timed text messages composed by participants without distraction

Recipient	Message	Characters
Adam	"Best of luck for your driving test today"	40
Brian	"Well done Looking forward to the wedding"	40
Claire	"Please can you bring red wine tonight"	37
Dawn	"Where did you get those new trousers"	36

2.7.3 Overall design

Figure 2.3 shows how the various texting tasks and reaction time events were initiated over the course of the drive. Note that the Control drive was the same as the Texting drive with the exception that participant was not required to interact with their phone.

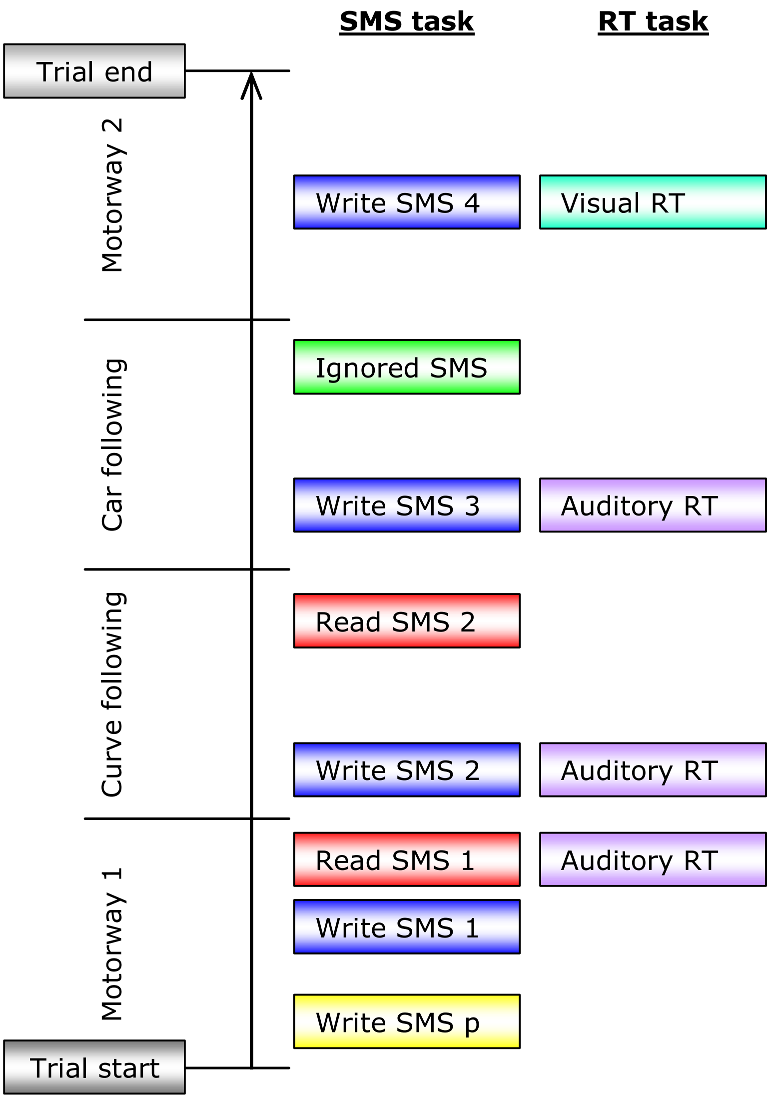

Figure 2.3 Overall design of Texting drive

2.8 Trial procedure

The trial proceeded as shown in Table 2.7.

Table 2.7 Trial procedure

Time from start	Activity	Duration
0	Welcome and introduction	5
5	Simulator: Baseline drive	10
15	Drive 1 (Texting or Control)	40
55	Control messages	40
95	Drive 2 (Control or Texting)	40
135	Questionnaire	30
165	Depart	

2.9 Recorded simulator data

The simulator recorded the following data about participants' simulator driving at 20Hz through each drive.

Table 2.8 Data recorded by the simulator at 20Hz

Data	Notes
Time	Time elapsed since the start of the trial
X position of interactive vehicle	The X position of the interactive vehicle within the map of the simulated environment.
Y position of interactive vehicle	The Y position of the interactive vehicle within the map of the simulated environment.
Z position of interactive vehicle	The Z position of the interactive vehicle within the map of the simulated environment.
Speed	Current speed of the interactive vehicle
Distance through trial	Distance travelled by participant relative to the start of the virtual road
Lateral distance from centre of road	The distance of the centre of the interactive vehicle from the centre of the road
Headway	The distance headway between the interactive vehicle and the back of any vehicle ahead.
Time Headway	The time headway between the interactive vehicle and the back of any vehicle ahead.
Accelerator pedal	Current proportion of accelerator pedal depression.
Brake pedal	Current proportion of brake pedal depression.
Clutch pedal	Current proportion of clutch pedal depression.
Steering wheel	Current angle of steering wheel rotation

2.10 Calculation

Manipulation of the simulator data was conducted using Microsoft Excel 2002. Statistical analyses were conducted using SPSS 14.0. In statistical tests, p values of less than 0.05 were taken to be significant. Where shown, error bars indicate the 95% confidence interval on the mean.

3 Results

3.1 Participants

Seventeen participants (selected from the TRL participant database) took part in the study. This consisted of nine females and eight males. As it was expected that young drivers are more likely to be habitual text message users, the age range of participants identified for this study was chosen in light of this, with all participants aged between 17 and 24 (M = 20.4, SD = 1.84). Only participants who described themselves as regular users of text messaging were selected. Furthermore, it was required that all participants owned a mobile phone with a standard alphanumeric keypad. The phone makes and network providers used by participants are described in Appendix B.

3.2 Reaction time (RT) tasks

In the simulator drives, participants were required to respond to three auditory tones and one red bar visual stimulus by pressing the clutch as quickly as possible.

- Auditory RT task 1 coincided with Read text message 1 in section 1
- Auditory RT task 2 coincided with Write text message 2 in section 2
- Auditory RT task 3 coincided with Write text message 3 in section 3
- Visual RT task coincided with Write text message 4 in section 4

3.2.1 Response rate

In each of the Control and Testing drives there should have been 68 responses (17 participants × 4 RT events per drive). Participants failed to respond on 6/68 occasions in the Control drive. Participants failed to respond on 14/68 occasions in the Texting drive. These proportions near significance in a chi-square comparison ($\chi^2(1) = 3.752$; $p = 0.053$) suggesting that the texting tasks interfered with participants' ability to respond to the reaction time tasks.

3.2.2 Reaction times

In the reaction time tasks where participants successfully responded to the stimulus, Figure 3.1 shows the mean reaction time to each of the stimuli. Note that Auditory 1 was triggered during a read text message task whilst the other RT tasks were triggered during a write text message task.

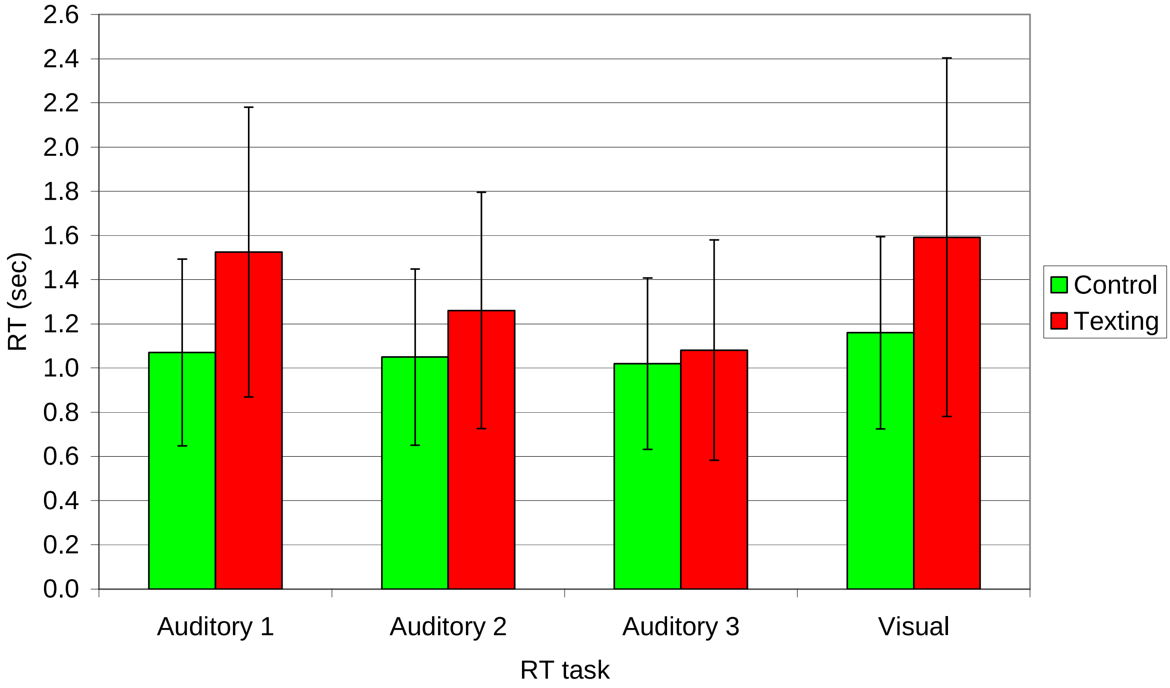

Figure 3.1 Mean reaction times to each of the RT tasks

Figure 3.1 shows that in each of the RT tasks, the mean RT was greater in the Texting drive than in the Control drive. Paired sample t-test comparisons show that this difference was significant in each case apart from Auditory 3 (Auditory 1: $t(13) = -5.689$, $p < 0.001$; Auditory 2: $t(13) = -2.904$; $p = 0.012$; Auditory 3: $t(12) = -0.654$; $p = 0.526$; Visual: $t(12) = -2.442$; $p = 0.031$).

3.3 Analyses by section

In previous similar studies conducted by TRL (e.g. Burns, Parkes, Burton, Smith & Burch, 2002; Parkes, Luke, Burns & Lansdown 2007), comparisons between control and distracted conditions have been conducted over complete sections of the drive; for example, comparing performance through the entire loop sections. This is less appropriate for this study since the texting tasks are not being performed continuously through each section.

Some basic analyses were performed to compare behaviours in sections and for each complete drive to investigate whether the texting drives may have had significant and/or long lasting effects on behaviour.

3.3.1 Speed

Figure 3.2 shows the maximum observed speed across participants over the course of the trial.

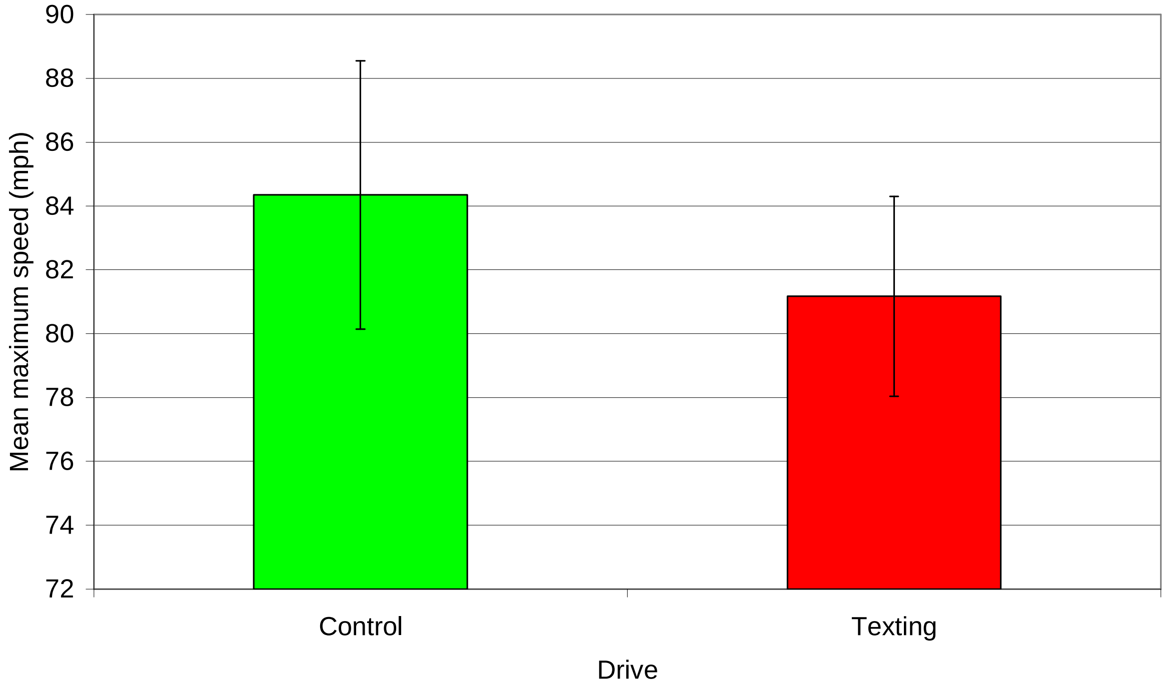

Figure 3.2 The mean of Maximum speed values observed across participants in each drive

The maximum speed observed across participants was significantly lower in the Texting drive ($t(16) = 2.297$; $p = 0.035$). A similar pattern is seen for the maximum speed observed in section 1 (Control: 82.4mph vs. Texting: 78.9mph; $t(16) = 2.206$; $p = 0.042$).

Figure 3.3 shows the mean speed observed within section 3 (Car following) of the drive. Note that due to the requirements of the car following task within section 3, there was much less variability in the observed speeds.

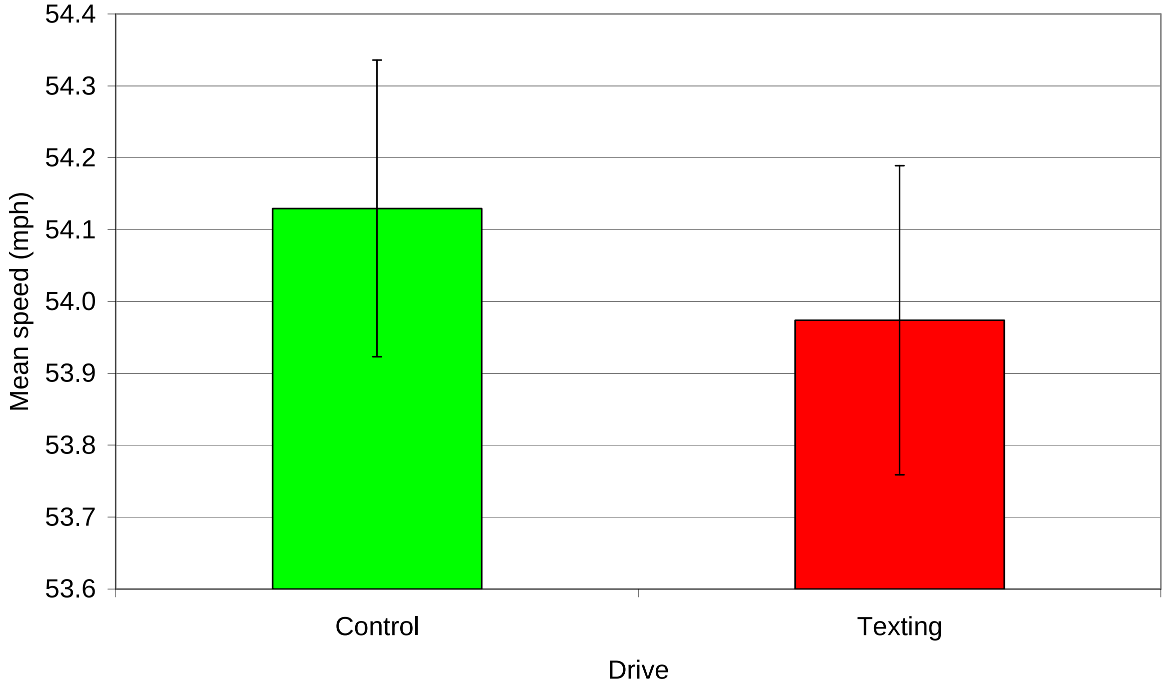

Figure 3.3 The mean speed values observed across participants in Section 3 of each drive

Again, significantly lower speeds are observed in the Texting condition (Control: 54.13mph vs. Texting: 53.97mph; $t(16) = 2.216$; $p = 0.042$).

The overall pattern of results regarding speed is indicative that participants felt less comfortable when driving and having to complete the texting tasks and chose to reduce their speed in order to manage their perceived level of risk to a subjectively acceptable level.

3.3.2 Variation in lane position

Variability in lane position is a commonly used measure of driving performance and is usually measured as the standard deviation of lane position (SDLP). Additional task demands and/or sub-optimal driver physical state are reflected in increased swerving behaviour (e.g. Brookhuis, de Vries & de Waard, 1991; Burns et al., 2002). SDLP was available for measurement in this trial since position across the road was measured in metres throughout the recorded drives. Figure 3.4 shows SDLP within section 3.

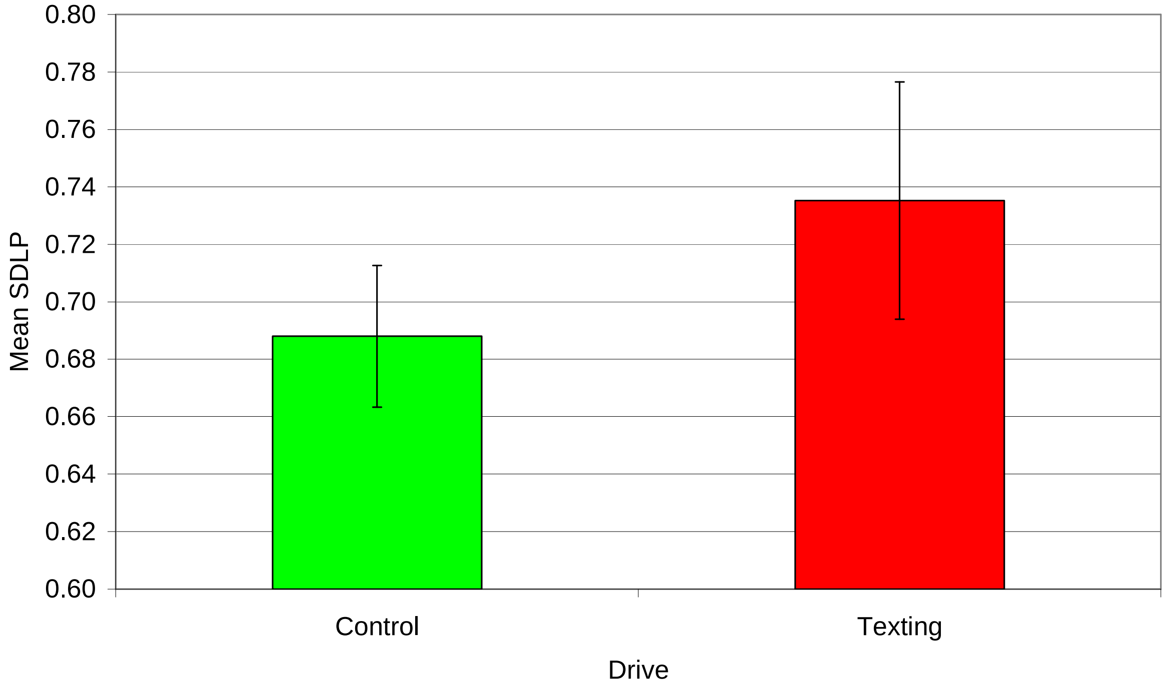

Figure 3.4 Mean SDLP across participants observed in section 3.

The difference shown in Figure 3.4 indicates significantly greater variability in lane position when texting ($t(16) = -2.175$; $p = 0.045$). Note that this in spite of participants' significant reduction in speed within section 3. The comparison of overall SDLP within section 2 (Loops) also nears significance ($t(16) = -2.077$; $p = 0.054$).

3.4 Analyses by texting episode

An intuitively more appealing approach was to examine the periods during which the participant was engaged in a texting task and to compare behaviour in the identical section of the Control drive. This analysis region was determined in two ways. For the write text message tasks, the start point was taken as the position of the driven vehicle at the end of the voice instruction relating to that message. The endpoint was taken as the position of the driven vehicle when the participant sent the composed message. For the read and ignore text message tasks, the start point was taken as the position of the driven vehicle when the text message arrived at their phone. There was no easily discernible endpoint to use for these tasks so the position of the vehicle 60 seconds after the start point demarcated the analysis region. By comparing behaviour in the analysis region when texting to the equivalent analysis region in the control drive, a more precise evaluation of the direct impairment caused by the texting task may be obtained.

There are two key assumptions in this approach. Firstly, that the distraction caused by the texting task is immediate (whether that means they begin writing the message directly after the end of the voice instruction, that they try to read the message immediately after it arrives, or they are distracted by the arrival of a message that they must ignore). Secondly, that the impairment caused by the text message task is confined to the analysis region. This is by no means certain. Redelmeier & Tibshirani (1997) found that accident risk increased significantly not only during a mobile phone conversation but also in the following minutes. Consequently, defining such endpoints to the analysis means that some driving impairment may not be accounted for in the analysis.

For each text message task, four key measures were taken:

- Mean speed
- Standard deviation of speed
- SDLP
- Maximum observed speed

For Sections 2 (Loops) and 3 (Car following), some additional measures were taken based on the additional task demands in these sections.

3.4.1 Section 1 (Motorway 1)

After the initial (practice) write text message task, there were two analysed text message tasks within section 1; a write message task (Write 1) and a read message task (Read 1). The Read 1 task was associated with an auditory RT event.

3.4.1.1 Read 1

Comparisons of behaviour in Read 1 revealed very few differences in the measures taken. The only comparison that neared significance was that between the maximum speed observed within the Read 1 analysis region (Control: 77.1mph vs. Texting: 73.1mph; $t(16) = 2.216$; $p = 0.042$). This fits with the observation that overall speeds were lower in Section 1.

3.4.1.2 Write 1

As with Read 1, the measures taken did not reveal large differences in behaviour in the Write 1 task. None of the paired comparison t-tests neared significance ($p > 0.15$ in each case).

3.4.2 Section 2 (Loops)

In Section 2, participants completed two repeats of a figure-eight with variable radius loops. Within the first loop, participants were required to complete a write message task (Write 2) and a read message task (Read 2).

3.4.2.1 Write 2

The key difference between the Control and Texting drives was the increase in SDLP when composing the message as illustrated by Figure 3.5. The paired comparisons t-test produced a highly significant result ($t(14) = -3.137$; $p = 0.00728$). Other comparisons failed to reach significance ($p > 0.14$ in each case).

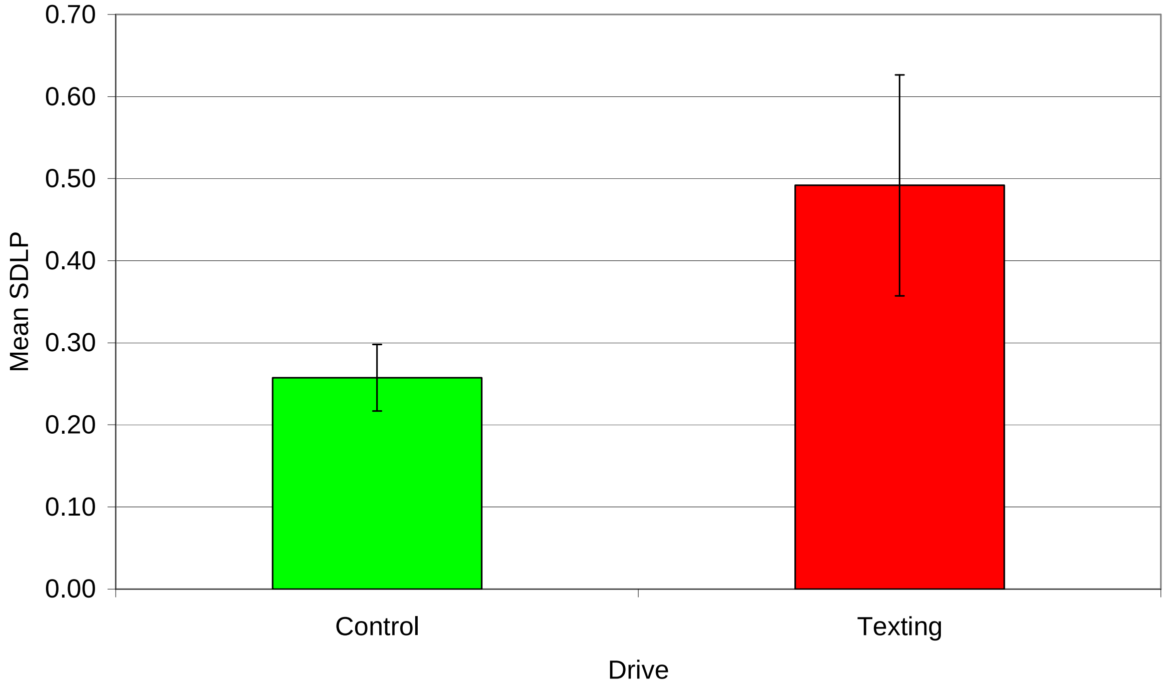

Figure 3.5 Mean SDLP in the Write 2 task relative to that observed in the Control drive

This big difference in lateral position variability warranted further investigation. The number of occasions in which an edge of the driven vehicle departed from the driven lane was counted for each participant. Figure 3.6 shows the frequency count of lane departures for all participants in the Write 2 task compared to the Control drive.

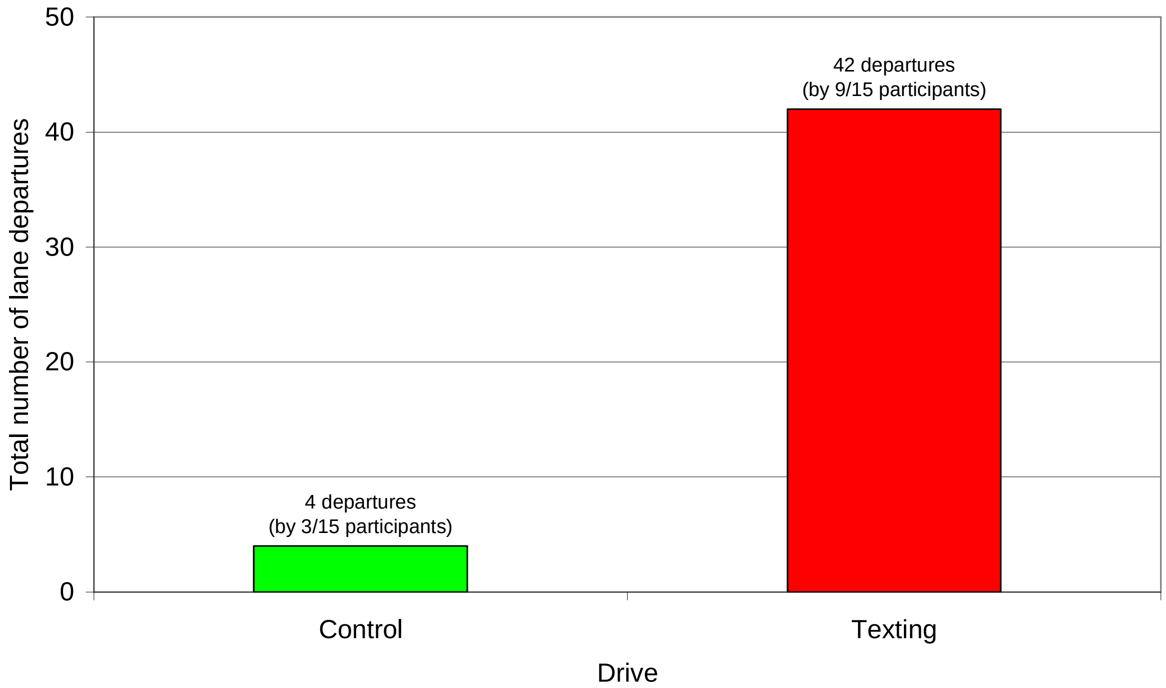

Figure 3.6 Total number of lane departures observed in the Write 2 task compared to those in the Control drive

Figure 3.5 gives a clear demonstration of the impairment to vehicle control caused by attempting to compose a text message whilst driving through a series of bends. More lane departures are observed by more participants when engaged in the text messaging task.

3.4.2.2 Read 2

As with Write 2, the clearest difference between the Control and Texting drives was in SDLP with the texting task causing SDLP to increase. However, the paired comparison t-test of SDLP failed to reach significance for this task (t(16) = -1.681; p = 0.112). All other tests failed to reach significance. As before, however, the total number of lane departures was calculated for the Read 2 task and is shown in Figure 3.7.

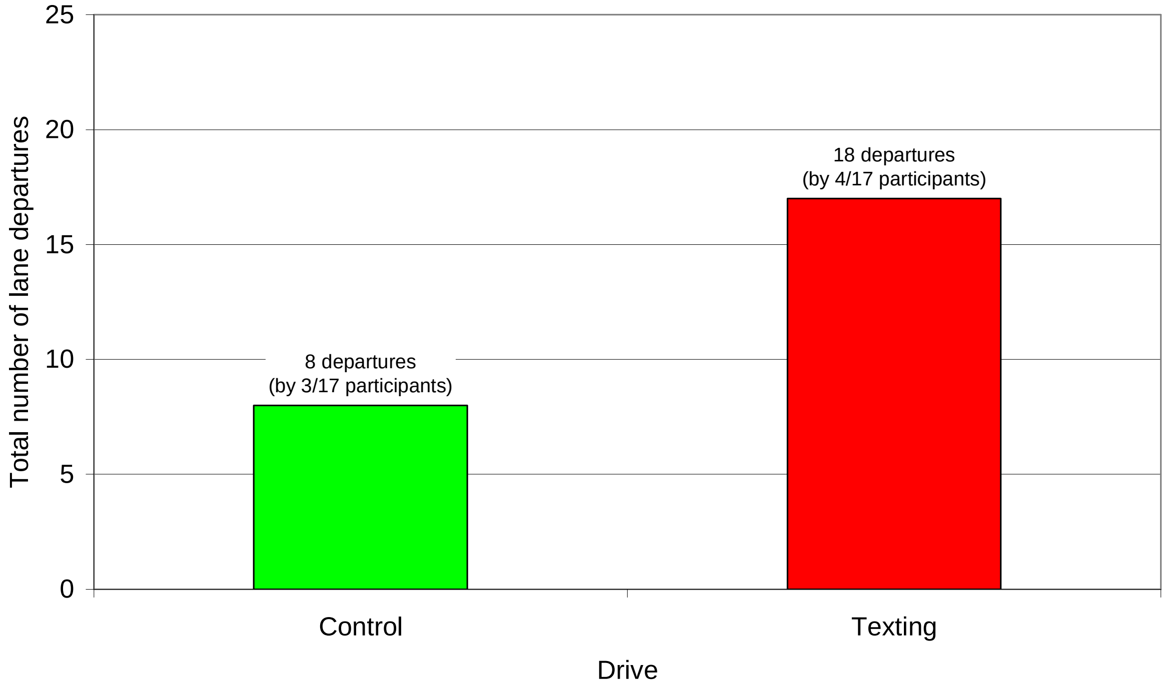

Figure 3.7 Total number of lane departures observed in the Read 2 task compared to those in the Control drive

Again, it can be seen that lane departures are more frequent and made by more participants when they were completing the read text task, although the differences are less clear cut than in the Write 2 comparison.

3.4.3 Section 3 (Car following)

In Section 3, participants were required to follow a lead vehicle at a subjectively safe, constant distance whilst the lead vehicle varied its speed sinusoidally. Whilst engaged in the car-following task, participants were required to write a text message (Write 3) and to ignore an unexpected incoming message (Ignore).

3.4.3.1 Write 3

Paired-comparisons t-tests across all the main measures reached (or neared) significance in the Write 3 task. When texting, mean speed was lower (t(16) = 2.213; p = 0.0418), maximum speed was lower (t(16) = 4.067; p < 0.001), speed variability was lower (t(16) = 3.974; p = 0.00109), and SDLP was higher (t(16) = -2.06; p = 0.0555).

Figure 3.8 shows the differences in mean and maximum speed for the Write 3 task.

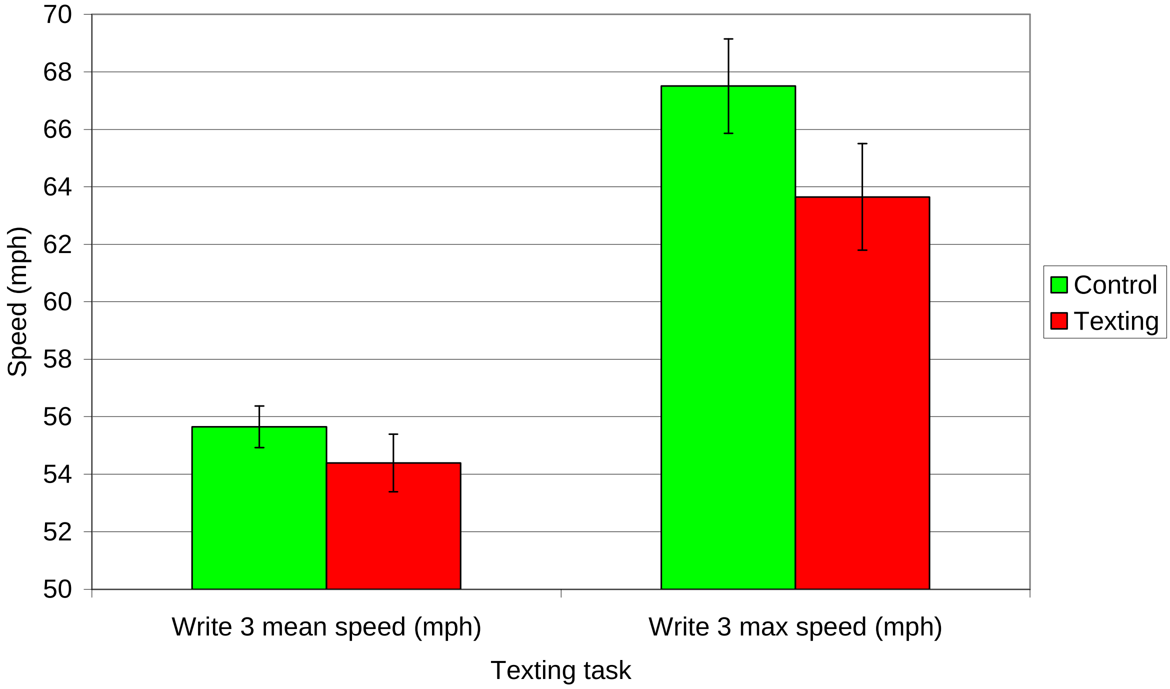

Figure 3.8 Mean speed and Maximum speed observed in the Write 3 task relative to that observed in the Control drive

It may seem counterintuitive that participants should reduce speed variability when composing the text message in the Write 3 task. However, remember that the task in Section 3 was to remain at a constant distance behind a lead vehicle that varied its speed. Therefore, the participant *should* vary their speed in order to maintain this constant distance. That reduced variability is observed when texting is indicative of performance *impairment* in the car following task. This can be investigated by examining the time headway relative to the lead vehicle during the texting task. Figure 3.9 shows the mean, standard deviation, and minimum time headways observed for the Write 3 task in the Texting and Control drives.

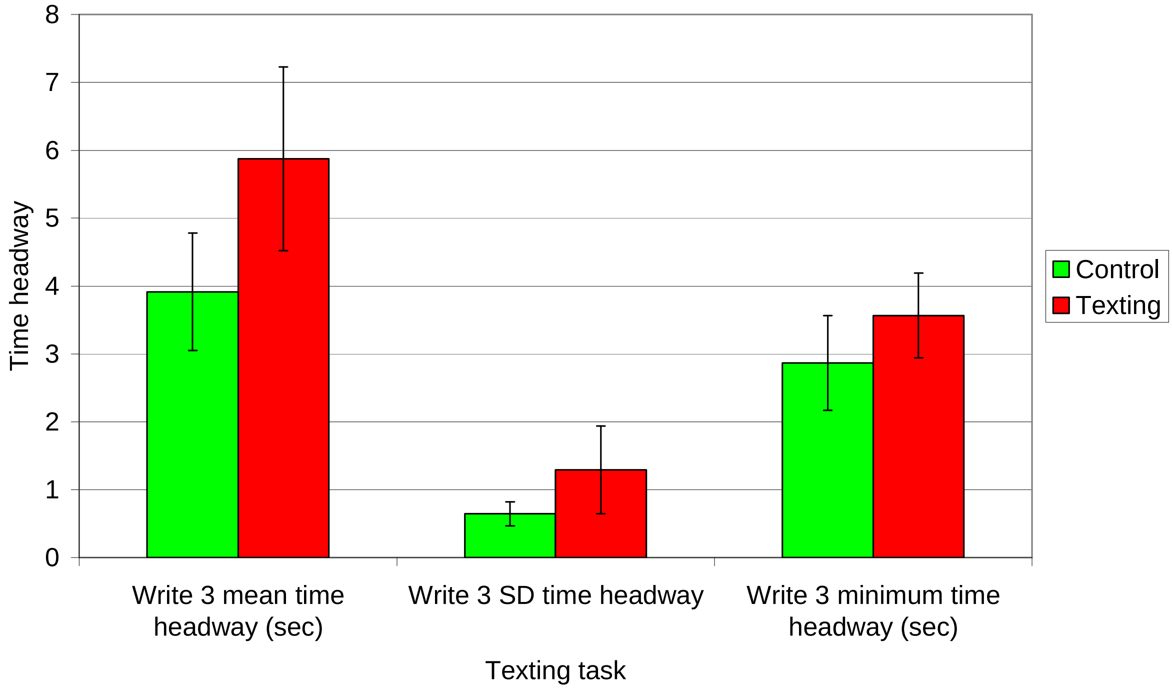

Figure 3.9 Mean, Standard Deviation of, and Minimum time headway relative to the lead vehicle for the Write 3 task during the car following section relative to that observed in the Control drive

It can be seen that participants maintained higher mean and minimum time headways to the lead vehicle in the Texting drive. This may have been a risk mitigation tactic in the awareness that they had poorer control of their vehicle. However, time headway variability is much lower in the Control drive due to participants maintaining a better constant distance behind the lead vehicle. Paired comparison t-tests are significant (or near significant) for all three time headway comparisons (Mean time headway: $t(16) = -4.344$; $p < 0.001$. SD time headway: $t(16) = -2.043$; p. = 0.0579. Minimum time headway: $t(14) = -3.346$; $p = 0.00480$).

As stated above, the comparison of SDLP across drives neared significance. This is shown in Figure 3.10.

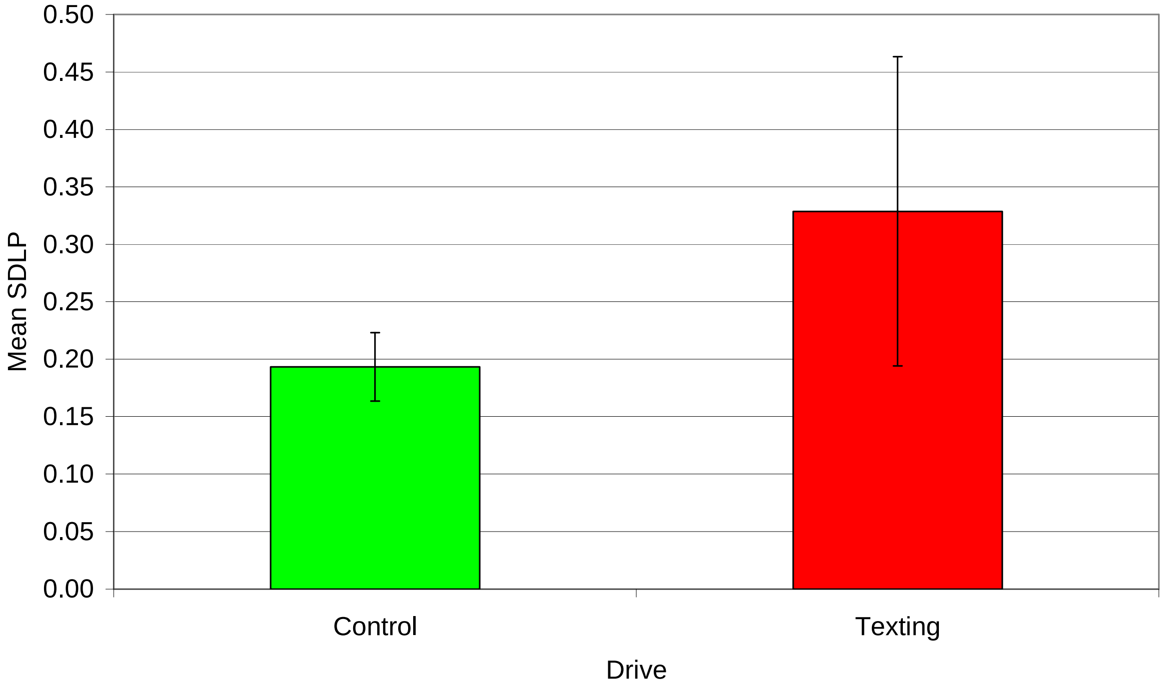

Figure 3.10 Mean SDLP in the Write 3 task relative to that observed in the Control drive

Figure 3.10 demonstrates that although participants may be able to manage their risk of collision with a vehicle in front by increasing headway distances, they are unable to compensate for the impairment in lateral control. As with Write 2, the variation in lane position may have lead to an increase in the number of lane departures observed in the Write 3 task. The frequency count is shown in Figure 3.11.

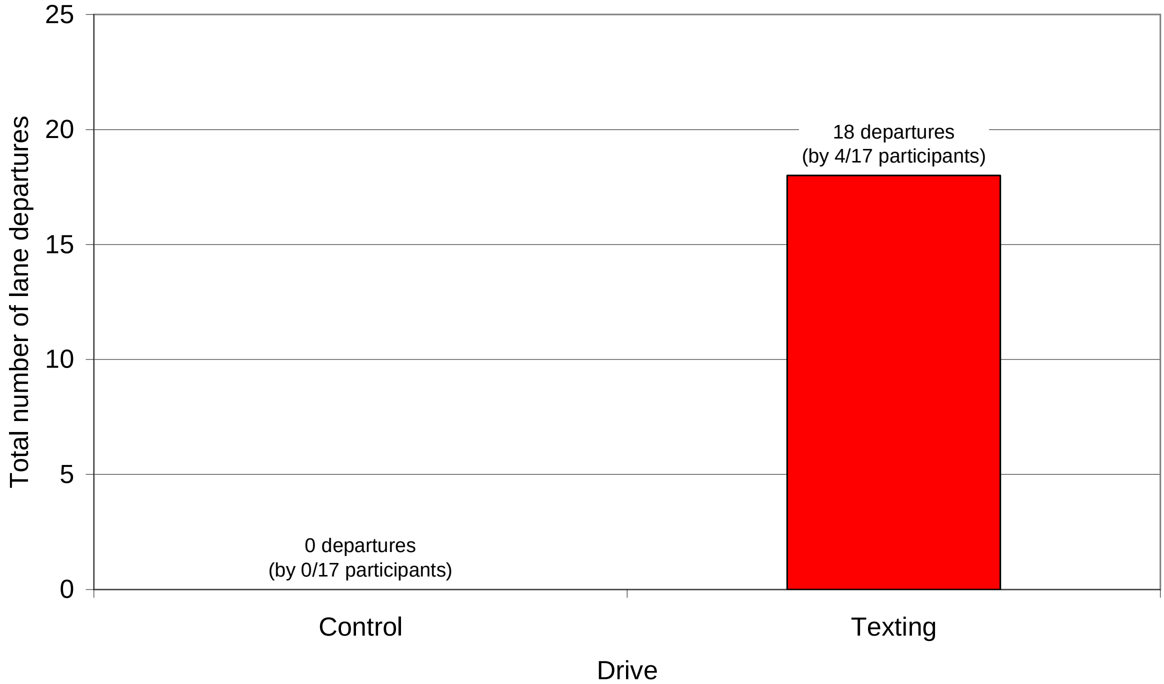

Figure 3.11 Total number of lane departures observed in the Write 3 task compared to those in the Control drive

As with the Write 2 task, Figure 3.11 shows a stark contrast between the Texting and Control drives. The increase in SDLP observed in the Texting condition led to occasions when the edge of the driven vehicle drifted into the adjacent lane in a task where the participant was required to remain behind a lead vehicle travelling in one lane only.

3.4.3.2 Ignored

The ignored message did not appear to cause any changes in participants' measured driving behaviour. The observed mean values for the four key measures were relatively close and paired samples t-tests did not near significance for any comparison ($p > 0.23$ in each case).

3.4.4 Section 4 (Motorway 2)

In Section 4, participants returned to the standard 3-lane motorway environment with moderate traffic levels. Within section 4, participants were required to write a text message (Write 4) and the visual RT stimulus was displayed concurrently.

3.4.4.1 Write 4

In the Write 4 task, only one key measure reached significance in the paired comparisons t-tests; that comparing mean speed between the Texting and Control drive ($t(15) = 3.073$; $p = 0.00773$). Once again, participants chose to adopt a significantly lower speed when texting (Control: 73.1mph; Texting 681.mph). The comparisons of maximum speed (lower in Texting drive) and speed variability (higher in Texting drive) also neared significance ($p = 0.0619$; $p = 0.099$ respectively.

3.4.5 Texting completion times

The time taken to complete composition of each text message was recorded. The mean times taken for each message are shown in Figure 3.12.

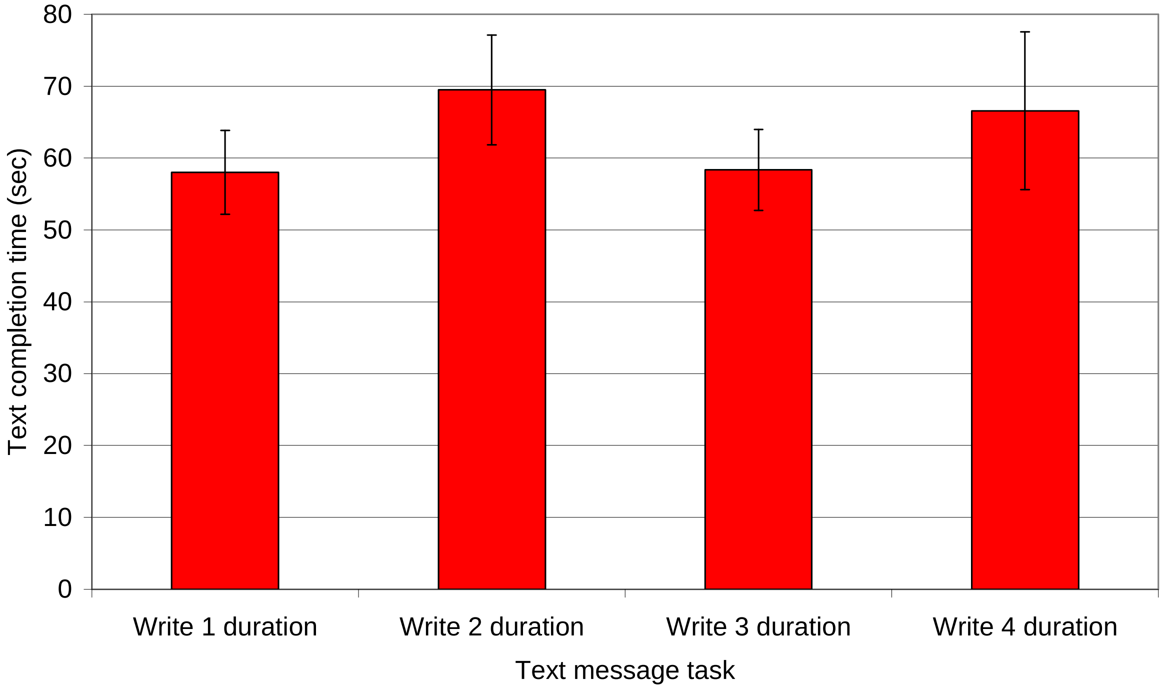

Figure 3.12 Text completion times when driving

Repeated measures t-tests between each message revealed that Write 1 was completed significantly more quickly than Write 2 ($t(14) = -5.199$; $p < 0.001$) and than Write 4 ($t(15) = -2.275$; $p = 0.038$). Write 3 was completed significantly more quickly than Write 2 ($t(14) = 3.496$; $p = 0.004$). The increased task difficulty in the loops section is likely to account for the increase in completion time for Write 2. The mean completion time overall was 63.7 seconds.

3.5 Gender differences

Approximately equal numbers of male and female participants were recruited for the study, providing an opportunity to investigate the relative affect of the text messaging tasks on male and female drivers by repeated measures ANOVA tests on the recorded simulator measures across the factor of gender. Significant interaction results are described below.

- SDLP in Write 2 ($F(1, 13) = 5.774$; $p = 0.032$)
- Mean speed in Write 3 ($F(1, 15) = 4.920$; $p = 0.042$)

Plots for the interactions are shown in figure

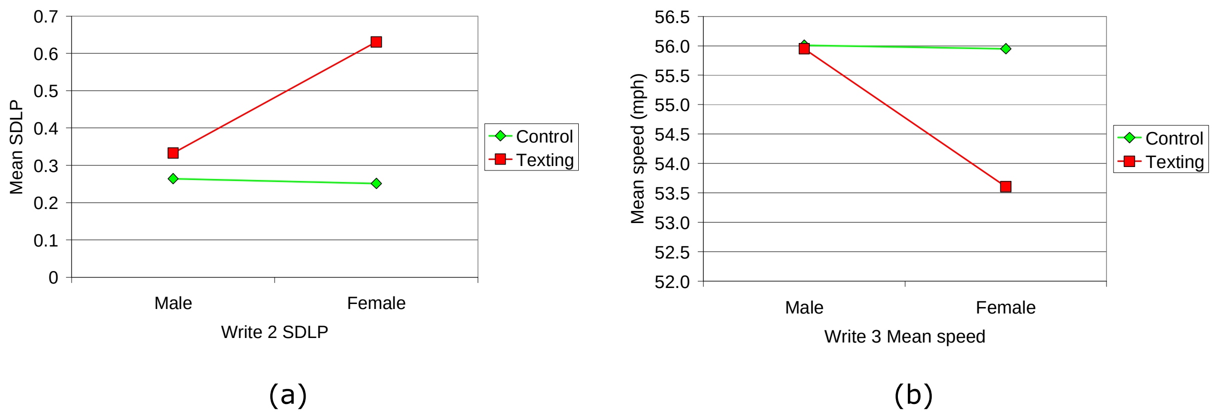

Figure 3.13 Plots of the interaction between gender and (a) SDLP in Write 2 and (b) Mean speed in Write 3

Male participants appear to show less impairment in SDLP when texting in the loops section. Female drivers appeared to be more aware of the impairment as they showed greater reductions in speed in the Texting drive. By contrast, male drivers showed a negligible reduction in speed. Note that similar ANOVA tests on text completion times showed that there was no significant differences between male and female participants in the time taken to complete the text messages composed whilst driving ($p > 0.5$) or those composed in controlled conditions ($p > 0.3$).

This reduction in SDLP impairment in Write 2 for male drivers resulted in fewer lane departures. Of the 42 lane departures observed in Write 2 in the Texting drive, 39 were by the female drivers. In the Write 2 analysis region of the Control drive both males and females made three lane departures. A chi-square test comparing the frequency of lane departures by male and female drivers for the Write 3 analysis region in the Control and Texting drives reveals that this difference is significant ($\chi^2(1) = 8.816$; $p = 0.003$). Furthermore, all eighteen observed lane departures in the Write 3 analysis region were by female drivers. However, when the frequency count of the 17 lane departures observed when reading text messages in the Read 2 analysis region is examined, the distribution is more even (7 male; 10 female).

3.6 Error rate

The messages sent by participants within the Texting drive were recorded for analysis. There was variation in the style of composition (use of SMS language, punctuation, capitalisation, spelling) but, given the dual task demand, accuracy was remarkably high. Two participants failed to complete messages (one participant missed one of the four test messages, the other missed two of the four test messages). Of the remaining 65 messages, only two had significant errors that might compromise understanding by the recipient:

- Participant 10
    - *"Niåe to se u at the cafe y'day"*
        - Should be "Nice to see you at the café yesterday"
    - *"Sorry abovt ur ankle get well soon."*
        - Should be "Sorry about your ankle. Get well soon"
- Participant 17
    - *"Sorry about youre ankle gdu well soon"*
        - Should be "Sorry about your ankle. Get well soon"

A table of the text of all composed messages is shown in Appendix B.

3.7 Patterns of mobile phone use

As a part of the post-trial questionnaires, participants were required to describe their habitual patterns of mobile phone use. These questions were asked to ensure that all participants were of a similar level of experience/familiarity with mobile phones, and texting in particular.

3.7.1 Familiarity with mobile phones and text messaging

Participants reported owning a mobile phone for a mean duration of 7.5 years (range = 5-12, SD = 2.06). This duration of ownership suggests that participants were familiar with the normal operation of mobile phones for making calls and sending text messages.

The frequency with which participants used their mobile phones for verbal communication and text messaging was obtained. As can be seen in Figure 3.14, the frequency of verbal communication was evenly spread between the first four categories, with no participants reporting using their phone more then 30 times a week. In contrast, reported use of text messaging was heavily skewed towards the "21 to 30" category, with 11 out of 17 participants selecting this category. This suggests texting is very popular amongst our participants and their exposure to incidents of text messaging (either composing or receiving) while driving is likely to be significantly higher than their exposure to incidents of verbal communication. Therefore, texting whilst driving might be the greatest source of risk associated with mobile phone use whilst driving.

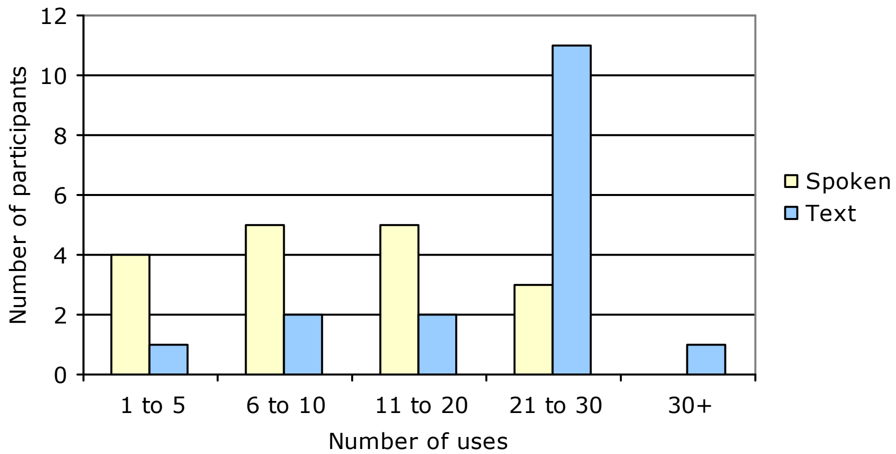

Figure 3.14 Weekly use of mobile phone for spoken conversations and text messaging.

A range of makes and models of mobile phones were used by the participants: 8 Nokia, 4 Samsung, 4 Sony Ericcson, 1 Sagem. Furthermore, 8 of the participants used predictive texting and 9 did not. Participants were also asked to rate how easy they felt their phone was to operate. As can be seen in Figure 3.15, participants mostly rated their phones as easy to used (M = 76.01, SD = 29.70). Note the presence of an outlier was identified in the data. One participant rated their phone as much more difficult to use than the others (specifically, its ease of use was rated as 10 out of 100). This may be because the participant genuinely finds their phone difficult to use, or perhaps the participant might have misread the scale leading to a reversed score.

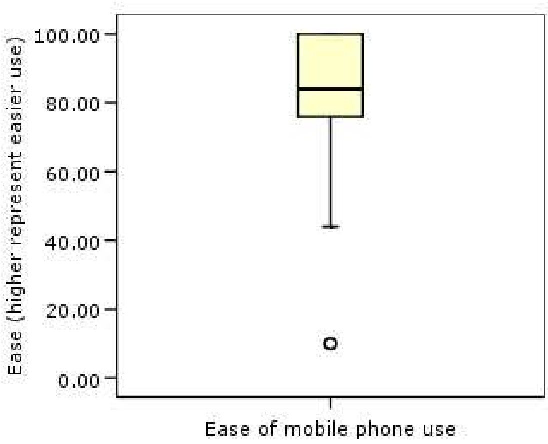

Figure 3.15 Participants' ratings of ease of use of their mobile phones

3.7.2 Storage and method of use of mobile phones whilst driving

Several questions regarding how participants store their mobile phone when driving. Specifically, participants were asked:

- If they bring their phones with them when driving
- If they leave their phones switched on when driving
- If they leave them on silent
- If they use a phone cradle
- If they use their phone 'hands-free'

For three of the questions all of the participants chose the same answer. All seventeen participants reported: taking their mobile phones while them "always" when driving, "always" leaving their phones switched on when driving, and none of the participants reported using a cradle for their mobile phone. These results indicate that all of the participants may be at risk of non-compliance with the law, as it is illegal to use a mobile phone when in a car if you are required to touch your phone to do so (unless it is in a cradle).

There was more variation in the participant's tendency to leave their phones on silent and whether they used their phones 'hands-free'. In Figure 3.16, we can see that only three participants always switch their phone on silent when driving. In contrast, a combined number of 13 participants reported "sometimes", "occasionally" or "never" doing so. This suggests that the majority participants may be aware of their phone receiving an incoming call or message while they drive (and are exposing themselves to the temptation of answering it).

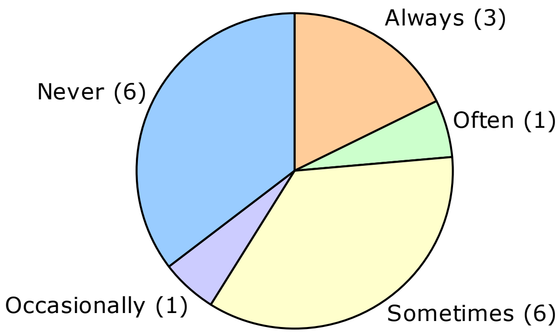

Figure 3.16 Frequency with which participants leave their mobile phones on silent

In Figure 3.17, we can see that only two participants report using their phone hands-free, with another three reporting using it "sometimes". Twelve participants reported not using their mobile hands-free at all.

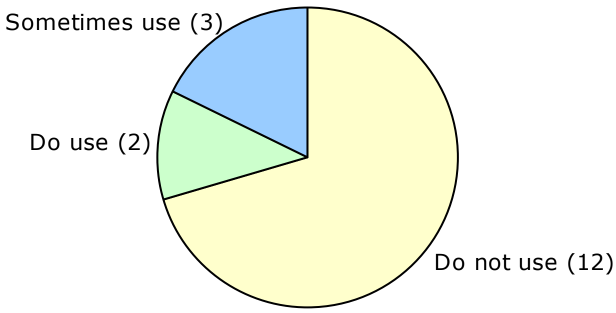

Figure 3.17 Frequency with which participants use their mobile phones 'hands-free'

Together these results show that the majority of participants are likely to leave their phones switched on and in non-silent mode when they drive. They also do not use a cradle for their phones, nor do the majority of them use their phones 'hands-free'.

3.7.3 Baseline texting completion time

Before the trial, participants were required to complete four baseline texting tasks to measure their speed of texting when undistracted. Fifteen of the participants completed these baseline texts and a box plot was produced from these results (see Figure 3.18). As can be seen in Figure 3.18, the mean time per text was 22.66 seconds (Min = 10.75; Max = 42.75; SD = 8.51). The degree of variation in texting speed was within acceptable bounds, indicating participants were reasonably similar in their texting speed.

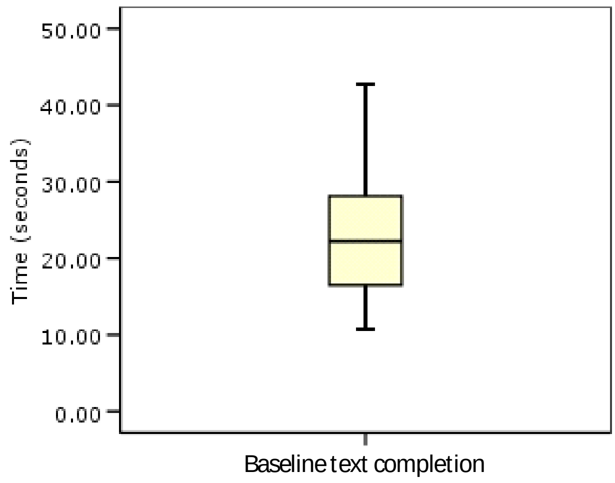

Figure 3.18 Distribution of participants' mean baseline texting completion times

3.7.4 Comparison of text completion time when driving vs. baseline

Figure 3.19 shows the difference between the time taken to complete text messages when driving in comparison to the time taken to complete similar text messages in the undistracted, baseline condition.

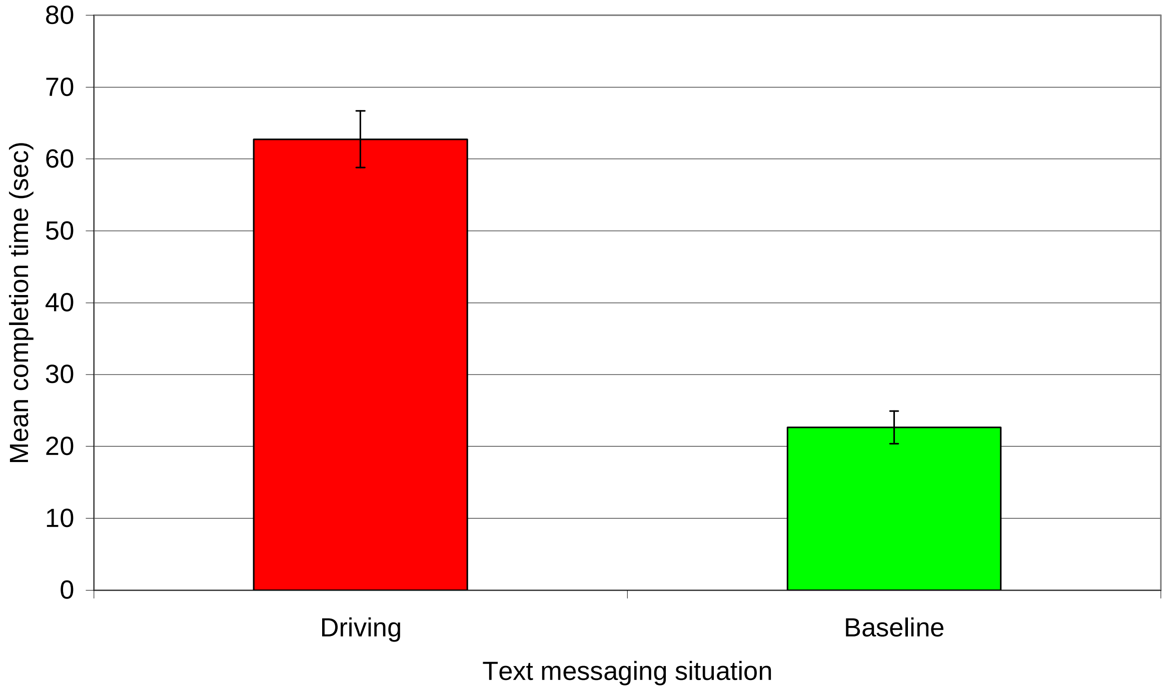

Figure 3.19 Text completion times when driving compared to the baseline condition

Figure 3.19 shows that the text messages took considerably longer to complete when driving. This is unsurprising given that attention must be split between texting and driving in the dual task condition. The difference between the average completion times is highly significant in a t-test ($t(123) = 16.84$, $p < 0.001$).

3.8 Perceptions of the legality of mobile phone use while driving

Participants' beliefs about the legality of texting whilst driving were garnered after the trials. The questions were split into two sections: participants understanding of the laws as they now stand, and their beliefs about whether these behaviours should be illegal. In both sections participants were asked four questions (to which they could answer "legal", "illegal" or "not sure"):

- Is it *currently* legal [or *should it be* legal] to use your phone whilst driving to…
  - …send a text message if it is in a cradle?
  - …read a text message if it is in a cradle?
  - …send a text message if you are using it handheld?
  - …read a text message if you are using it handheld?

In Figure 3.20, we can see a series of pie charts describing that the majority of participants believe it is illegal to text whilst driving in all circumstances. The first two pie charts in Figure 3.20 demonstrate participants' view of the legality of sending and reading a text when the phone is in a cradle. Eleven participants thought it was illegal to send a text message whilst driving and nine thought it was illegal to read a message. These participants were incorrect. Only two correctly responded that it was legal to send a text message as long as the phone is in a cradle, and four participants responded that it is legal to read a message. In fact, current legislation does not explicitly prohibit texting whilst driving provided the phone is secured in a cradle. However the UK Highway Code (2007) does state that:

"You MUST exercise proper control of your vehicle at all times. You MUST NOT use a hand-held mobile phone, or similar device, when driving or when supervising a learner driver, except to call 999 or 112 in a genuine emergency when it is unsafe or impractical to stop. Never use a hand-held microphone when driving. Using hands free equipment is also likely to distract your attention from the road. It is far safer not to use any telephone while you are driving - find a safe place to stop first."
(Laws RTA 1988 sects 2 & 3 & CUR regs 104 & 110; Highway Code, The Stationery Office, 2007)

The third and fourth pie charts show participants' responses in relation to texting using a handheld phone. We can see that the response pattern was almost identical to the first two questions. Specifically, this time eleven participants thought that it was illegal to text using a handheld phone to send a message, and nine thought it was illegal to read a text. However, this time, they were correct.

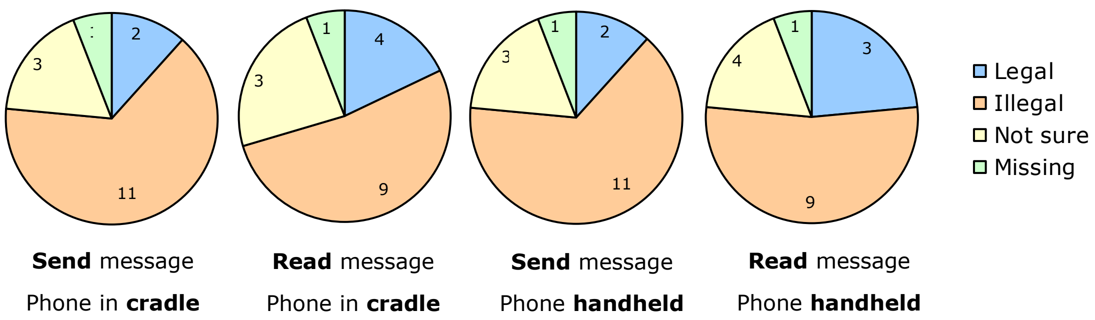

Figure 3.20 Participants' understanding of the current legality of mobile phone use

After asking participants for their beliefs about the current state of the law they were asked whether they thought the same four activities should be illegal (or not). In Figure 3.21, a series of pie charts describes their responses, and from them we can see a broad consensual trend towards the attitude that sending a message should be illegal, regardless of whether the phone is in a cradle or handheld (only one participant felt it should be legal in either circumstance). Furthermore, there was a good deal of agreement that reading a text message should be illegal. However, a few participants felt reading messages was acceptable (Four for when the phone is in a cradle and three for when it is handheld).

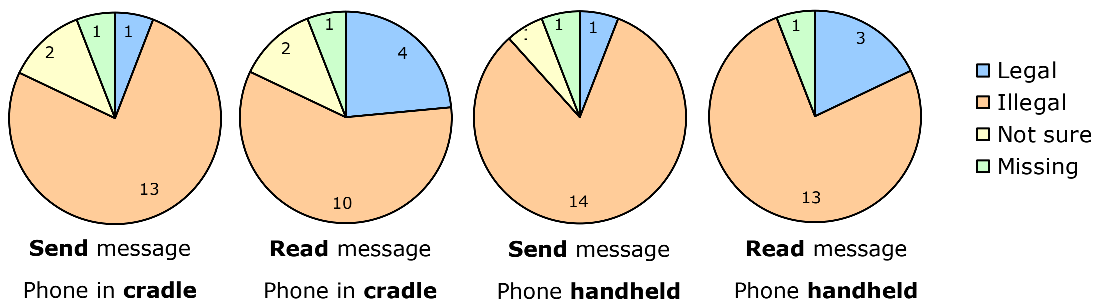

Figure 3.21 Participants' beliefs about whether various behaviours should be legal

3.9 Perceptions of the relative risks of driving behaviours

Participants were asked to judge the degree of risk presented by a variety of driving behaviours (14 in total). The scale stretched from "Less dangerous" (0%) to "More dangerous" (100%). The results of this section of the questionnaire can be seen in Table 3.1. Participants reported alcohol, racing and fatigue to be three greatest risks out of the fourteen presented (rated at 92.9%, 87.4% and 86.2% respectively). The risk ratings of writing or reading a text message were almost identical at 79.0% and 78.9% respectively. This ranked them as the sixth and seventh highest risks. This was only 0.1% lower than the fifth highest risk, speaking on a handheld mobile phone.

Table 3.1 A ranked list of the mean risk ratings assigned to driving behaviours

Rank	Driving Behaviour	Percentage rating of risk
1	When a driver has been drinking (regardless of amount)	92.9
2	When a driver is racing others	87.4
3	When a driver is tired	86.2
4	Other drivers on the road are acting unsafely	81.6
5	When a driver is talking on their mobile phone (handheld)	79.1
6	**When a driver is writing a text message**	**79.0**
7	**When a driver is reading a text message**	**78.9**
8	When a driver is angry enough to have road rage	77.2
9	When a driver is speeding	71.8
10	When a driver is in a hurry	71.4
11	When a driver is selecting music while driving	67.7
12	When a driver is inexperienced	65.4
13	When a driver is talking on their mobile phone (handsfree)	61.6
14	When passengers are in the car	49.2

3.10 Subjective effects of Texting on performance

3.10.1 Recall of text messages received when driving

During the texting trial, participants were sent two messages and were prompted in the questionnaire to recall key facts contained within the messages after completing the drive. Due to technical difficulties, three participants did not receive either text message and one participant only received one of the messages. As can be seen in Table 3.2, out of the text messages which were received (14 for the first text and 13 for the second), virtually all were recalled correctly (only one participant failed to recall the second question correctly). The dual-task of reading a text message and driving did not seem to affect recall of the text messages.

Table 3.2 Post-trial message recall performance

	Message 1		Message 2	
	Frequency	**Percent**	**Frequency**	**Percent**
Correct	14	100%	12	92.3%
Incorrect	0	0%	1	7.70%
Missing	3		4	
Total	17		17	

3.10.2 Driving performance in the Texting and Control drives

After completion of both simulator drives, participants were asked to rate their performance in a number of key measures. Questions asked were:

1. Compared to how you normally drive, how well do you think you drove in the first motorway section?
2. How easy or difficult was it to drive at 60mph and stay in the centre of the lane during the **curve following section**?
3. Compared to how you normally drive on curved roads, how well do you think you drove during the **curve following tasks**?
4. Compared to how you normally drive when following other vehicles, how well do you think you drove in the **car following section**?
5. How easy or difficult was it to maintain a constant distance during the **car following**?
6. How easy or difficult was it to respond to any tones you might have heard?
7. How easy or difficult was it to respond to the red bar stimulus which you might have observed?
8. Compared to how you normally drive, how well do you think you drove overall?

Participants selected a percentage score, with high scores indicating superior performance. Range, mean and standard deviations were calculated for all questions and are displayed in Table 3.3.

Table 3.3 Descriptive statistics for participants' perceptions of their performance in the Texting and Control drives (* Ratings represent percentages where high values correspond to superior driving performance).

Question		Texting	Control
1. Compared to how you normally drive, how well do you think you drove in the first motorway section?	Minimum	2	0
	Maximum	81	86
	Mean	**55.76**	**55.00**
	SD	22.13	23.25
2. How easy or difficult was it to drive at 60mph and stay in the centre of the lane during the **curve following section**?	Minimum	0	16
	Maximum	67	73
	Mean	**31.12**	**51.24**
	SD	19.86	20.17
3. Compared to how you normally drive on curved roads, how well do you think you drove during the **curve following tasks**?	Minimum	0	11
	Maximum	60	82
	Mean	**24.47**	**42.88**
	SD	18.14	23.66
4. Compared to how you normally drive when following other vehicles, how well do you think you drove in the **car following section**?	Minimum	0	10
	Maximum	70	86
	Mean	**45.00**	**46.12**
	SD	18.84	23.89
5. How easy or difficult was it to maintain a constant distance during the **car following**?	Minimum	0	10
	Maximum	65	74
	Mean	**33.29**	**34.41**
	SD	20.26	17.90
6. How easy or difficult was it to respond to any tones you might have heard?	Minimum	4	14
	Maximum	82	100
	Mean	**44.82**	**65.59**
	SD	25.73	23.25
7. How easy or difficult was it to respond to the red bar stimulus which you might have observed?	Minimum	0	36
	Maximum	79	99
	Mean	**41.67**	**66.12**
	SD	23.57	17.20
8. Compared to how you normally drive, how well do you think you drove overall?	Minimum	1	16
	Maximum	60	76
	Mean	**34.94**	**54.94**
	SD	15.03	18.01

Paired-samples t-tests were performed on the data, comparing participant's perception of each measure of performance in the texting whilst driving trial and the control trial, the results of which are displayed in Table 3.4.

Table 3.4 Differences in participants' perceptions of their performance in the Texting and Control drives (paired samples t-tests)

Question	Mean	SD	t	df	Sig. (2-tailed)
1. Compared to how you normally drive, how well do you think you drove in the first motorway section?	0.76	32.17	0.10	16	0.92
2. How easy or difficult was it to drive at 40mph and stay in the centre of the lane during the **curve following section**?	-20.12	27.77	-2.99	16	**0.01**
3. Compared to how you normally drive on curved roads, how well do you think you drove during the **curve following tasks**?	-18.41	27.86	-2.72	16	**0.01**
4. Compared to how you normally drive when following other vehicles, how well do you think you drove in the **car following section**?	-1.12	25.00	-0.18	16	0.86
5. How easy or difficult was it to maintain a constant distance during the **car following**?	-1.12	15.71	-0.29	16	0.77
6. How easy or difficult was it to respond to any tones you might have heard?	-20.76	26.43	-3.24	16	**0.01**
7. How easy or difficult was it to respond to the red bar stimulus which you might have observed?	-22.67	25.75	-3.41	16	**<0.01**
8. Compared to how you normally drive, how well do you think you drove overall?	-20.00	20.30	-4.06	16	**<0.01**

As can be seen in Table 3.4, several significant differences were identified. Participants rated their performance as significantly worse in the Texting drive for:

- Maintenance of lane position and speed in the curve following section.
- Responding to the RT tasks
- Overall performance

This suggests participants felt their ability to control their vehicles lateral lane position was affected in the Texting drive ($t(16) = -2.99$, $p < 0.01$). However, just as revealing they did not feel it affected their ability to maintain a constant distance to the vehicle in front ($t(16) = -0.029$; p =0 .86). Finally, participants reported that responding to the RT stimuli was more difficult in the trial (Auditory: $t(16) = -3.24$, $p < 0.01$; Visual; $t(16) = -3.41$, $p < 0.001$).

3.10.3 Differences in performance when sending or receiving a text message

Participants were asked how they felt a variety of driving behaviours were affected by either sending or receiving a text message whilst driving. Specifically, their impressions of the relative difficulty of sending or receiving a text message across a range of performance aspects.

3.10.3.1 Concentration required and keeping in lane

In the first section, two questions asked participants how much concentration was required when sending or receiving a text message ("virtually no concentration" to "complete concentration") and how difficult they found it to stay in a lane when sending or receiving a text message ("maintained normal positioning" to "struggled to maintain normal lane positioning"). The results of the questions can be seen at the top of Table 3.5.

Table 3.5 Differences in participants' perceptions of performance impairment when sending or receiving a text message.

		N	Min.	Max.	Mean	SD
Concentration	Sending	17	10	86	**59.94**	22.32
(High scores represent increased concentration)	Receiving	16	16	80	**41.50**	17.12
Keeping in lane	Sending	17	12	100	**70.58**	21.94
(High scores represent struggling to maintain lane position)	Receiving	16	7	94	**54.25**	19.10
Speed	Sending	15	4	81	**39.53**	21.16
(High scores represent driving faster)	Receiving	16	10	54	**38.56**	12.77
Distance	Sending	17	7	78	**36.24**	18.57
(High scores represent leaving less space to the car in front)	Receiving	15	12	94	**44.20**	18.58
Awareness of hazards	Sending	17	41	100	**70.41**	15.07
(High scores represent being less aware)	Receiving	16	44	86	**62.50**	10.99
General driving performance	Sending	17	48	100	**76.11**	13.23
(High scores represent worse driving performance)	Receiving	16	45	84	**63.37**	12.76

From these we can see that participants thought more concentration is required and keeping in lane is more difficult when sending a message. Paired comparisons t-tests were performed and the results confirmed that both these differences were significant ($t(15) = 2.50$; $p = 0.02$ for concentration and $t(15) = 4.68$, $p < 0.001$ for Keeping in lane). Figure 3.22 was displays these results.

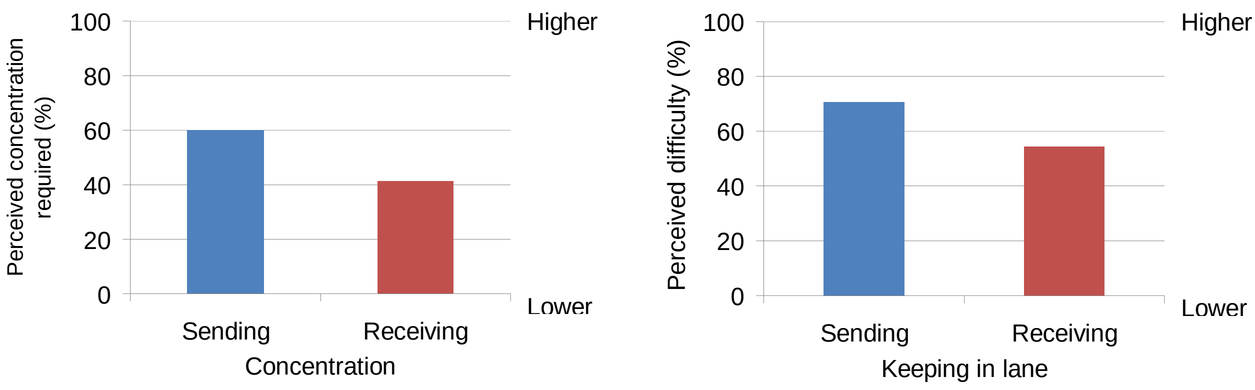

Figure 3.22 Participants' mean ratings of performance effects of sending or receiving a text message on Concentration and Keeping in lane

3.10.3.2 Speed selection, distance to vehicle in front, awareness of road hazards and general driving performance

The four questions in the second section of the questionnaire asked participants to rate their performance when sending or receiving a text message. However, the scales allowed participants to report if aspects of their driving were affected positively, negatively, or were unaffected by sending or receiving a text message. Therefore, the bi-directional nature of these questions provides us with the answers to two questions: firstly, does sending impact performance more than receiving (or *vice versa*) and, compared to normal driving, how does performance change when sending or receiving a text message?

The mean, range and SD of each question are listed in Table 3.5. From this table we can see that there were differences in the participant's perceived level of performance across the various behaviours, both between sending and receiving and in comparison with normal driving behaviour (which is represented by a value of 50). Figure 3.23 illustrates these differences.

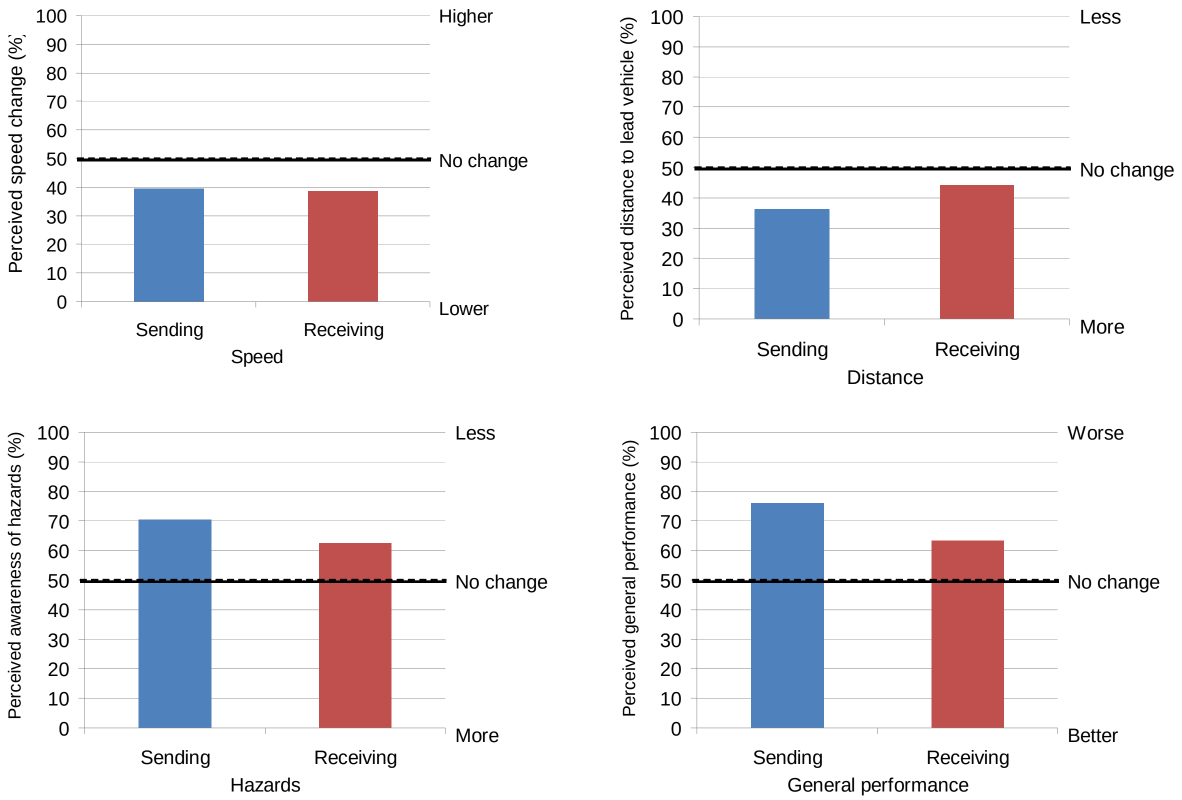

Figure 3.23 Participants' mean ratings of performance effects of sending or receiving a text message on Speed, Distance, Hazard awareness and General performance

Initial inspection revealed that there was virtually no difference in participants' subjective appraisal of speed choice when sending or receiving a text message. However, both figures appeared to be substantially lower than the 'no change' level of 50%. Independent samples t-tests were computed for sending and for receiving, to compare to the 'no change' level. The comparison for Receiving was significant ($t(15) = -3.58$, $p < 0.001$) whilst the result for Sending neared significance ($t(14) = -1.92$; $p = 0.08$). This demonstrates that participants reported selecting driving more slowly than normal when receiving a text messaging.

Figure 3.23 seems to display a larger difference in the ratings of distance to the vehicle in front. The figure shows that participants reported leaving more distance when Sending than Receiving a message. However, the comparison only neared significance ($t(14) = -1.78$; $p = 0.10$). Although both results are below the 'no change' value, independent samples t-tests demonstrated that a significant result was only achieved for Sending a message ($t(16) = -3.06$; $p < 0.01$). This suggests that participants did leave more distance to the vehicle in front than they usually would when sending a text message.

Drivers reported being less aware of hazards when Sending than when Reading a message and a paired-samples t-text confirmed this as a significant difference ($t(15) = 3.28$; $p < 0.01$). To determine if these differences were significantly different from the 'no change' level, independent samples t-tests were computed for both sending and receiving, both of which were significant at the 0.001 level (Sending: $t(16) = 5.58$; $p < 0.001$, Receiving: $t(15) = 4.55$; $p < 0.001$). Therefore, participants were less aware of hazards when both sending and receiving a text message, and their awareness was worse when sending.

Finally, participants also rated their general performance. As with the hazard awareness results, both sending and receiving lead to worse general performance than normal (Sending: $t(16) = 5.58$; $p < 0.001$; Receiving: $t(15) = 4.55$; $p < 0.001$). Additionally, Sending produced a greater reduction in general performance than Receiving, confirmed by a paired-samples t-test ($t(15) = 3.08$, $p < 0.01$).

3.11 Personality tests

Participants completed extracts of the IPIP relating to three personality measures: Self-efficacy; Openness to values; and Impulsiveness. They also completed the DBQ (Reason et al., 1990). Unfortunately, the correlations between overall scores on the questionnaires and both the driving behaviour measures and the other questionnaire measures failed to reveal any significant results. This is perhaps unsurprising since it was relatively ambitious to try to find significant results using personality tools with such a small sample.

4 Discussion

This study sought to identify the impairment to driving behaviour caused by concurrent participation in a range of text message tasks. It followed from research findings by the RAC Foundation (RAC Foundation, 2008) that significant numbers of young drivers reported writing and reading text messages whilst driving. Young male and female drivers were recruited to participate in the study. They were required to drive a high fidelity driving simulator through the same test scenario twice. This enabled a potentially dangerous task to be completed repeatably and in complete safety. In one instance, participants completed a number of text message tasks and in the other, they drove undistracted.

The results demonstrated that participants' driving behaviour was impaired by concurrent text message tasks. Writing text messages created a significantly greater impairment than reading text messages. Behaviour in response to the arrival of an ignored text message was unaffected.

Reaction times to (task-unrelated) trigger stimuli tended to be higher when reading or writing a message. This corresponds with the results reported in Burns et al. (2002) who showed that drivers' reaction times were significantly higher with concurrent mobile phone conversations (using either handheld or handsfree phone). The slowest average reaction time was observed for drivers responding to the visual reaction time task whilst trying to compose a text message where reaction times increased from 1.2 to 1.6 seconds. Furthermore, participants were significantly more likely to fail to respond to the reaction time stimuli if engaged in concurrent text messaging. The failure to detect hazards and increased response times to hazards has clear implications for safety. At motorway speeds (as were present in the visual RT task), the increase in mean reaction time would result in an increased stopping distance of 12.5m (approximately three car lengths). This could easily make the difference between causing and avoiding an accident or between a fatal and non-fatal collision. The average completion time for these rather simple messages was over one minute (nearly three times longer than when undistracted). On a motorway, a car driver may have travelled more than one mile with impairment.

It was observed that drivers tended to reduce their speed in the texting conditions. This corresponds with the results of Kircher et al. (2004) who found that participants tended to reduce their speed when receiving text messages. Wilde (1982, 1988, 1994) described this phenomenon as 'risk homeostasis' whereby in response to a change in the road-vehicle-user system, behaviour changes to maintain a target level of risk per unit time. Whilst there is some debate about the exact processes involved (see Grayson, 1996), the evidence from the questionnaire supports the theory that drivers were aware that their driving was impaired to some degree whilst engaged in text messaging tasks and chose to reduce their speed in order to mitigate accident risk.

The most conspicuous change in performance was that observed when texting in the loops section. The overall pattern revealed large increases in variability of lane position resulting in many more lane departures when texting. The Department for Transport STATS19 figures for 2006 reveal that 15% of all accidents and 35% of fatal accidents were due to loss of control, highlighting the risk that drivers face when their driving is impaired due to concurrent texting. It was further identified that the impairment caused by texting was far more significant for female than male drivers. It is possible that this reflects classic sex differences in motor skills requiring accurate targeting and finger dexterity (see Kimura, 1999). The survey by the RAC Foundation (2008) found that male drivers constituted the majority of the "Multi-tasking multimedia maestros" who were more likely to text and drive. Consequently, although male drivers may show a reduced impairment when texting and driving, the increased probability that male drivers will engage in this behaviour suggests that the overall impairment across the sexes may be more evenly spread. The results found in this study are based on a small sample of drivers and it would interesting to study this phenomenon further.

It was observed that participants, when texting, were less able to maintain a constant distance behind a lead vehicle and showed increased variability in lateral lane position when following that vehicle. This has significant implications for a driver's ability to control a vehicle in normal traffic flows. In the simulated situation, the lead vehicle varied its speed in a relatively benign manner so collision risk was insubstantial. The lack of any other traffic in that part of the task meant that participants could afford to leave large safety margins whilst texting. However, in a normal, real world traffic situation, vehicles following the driven vehicle would create pressure for a texting driver to maintain progress relative to vehicles ahead, which in turn may decelerate more rapidly than was experienced in the simulator scenario. Poorer control of vehicle speed, lateral position, and increased reaction times in this situation dramatically increase the likelihood of collision.

As hypothesised, reading text messages had a less detrimental effect on performance but a detrimental effect nevertheless. Reaction times were slower and lane position was more variable than under control conditions. There was also an indication that drivers reduced speed when reading messages, suggesting that they recognised the impairment to driving ability caused by trying to read the text message and drive. This pattern of results is consistent with a lower relative task demand of reading a text message compared to writing a message where, in addition to viewing the phone display screen, the driver has increased cognitive load when considering message composition and increased physical load due to greater interaction with the phone keypad.

No changes in behaviour were observed when drivers were required to ignore a text message that they received whilst driving. This suggests that, if drivers can resist the temptation to read a received message, there is little harm in a driver leaving their phone switched on. Indeed, text messaging can be a very useful technique for communication with a driver, provided the driver chooses to stop in a safe place when they decide to read/write a message.

The questionnaire results indicated that participants were familiar with the operation of their phones and tended to leave them active when driving, typically not in a suitable cradle. There was some confusion about the legality of texting whilst driving. The majority of participants correctly reported that use of a phone for texting whilst handheld is illegal. However, a majority of participants also incorrectly reported that use of a phone for texting whilst in a cradle is illegal. Furthermore, a majority of participants felt that use of a phone for texting whilst in a cradle should be illegal. This study did not investigate the effect of texting on driving performance when the phone was in a cradle. However, the observation that participants brought the phone as near as possible to their eye-line when driving to read/write messages suggests that separation of the driver from the phone display (by locating it in a cradle) would impair driving performance by at least as much a that observed here.

The subjective assessments of performance suggest that participants had insight into the observed impairment caused by the various text messaging tasks in the simulator drive. Participants recognised that, when engaged in a text messaging task, they had poorer lane positioning, chose to drive more slowly, and kept larger safety margins. They also recognised that writing/sending a message was more of a distraction than reading an incoming message. Participants tended to rate texting tasks as subjectively more dangerous than many other in-car activities. The personality tests that were implemented did not reveal any significant results; probably due to the lack of statistical power.

4.1 Comparison with previous distraction studies

Earlier studies at TRL have used a similar methodology to that applied in the current study to:

- benchmark the relative performance impairment of mobile phone conversations against that caused by alcohol consumption to the legal limit (Burns et al. 2002)
- Investigate the influence of cannabis on driving (Sexton, Tunbridge, Brook-Carter, Jackson, Wright, Stark, & Englehart, 2000)
- Investigate the influence of cannabis and alcohol on driving (Sexton, Tunbridge, Board, Jackson, Wright, Stark, & Englehart, 2002).

This allows comparisons of the relative impairment caused by texting whilst driving to be made.

4.1.1 Reaction times

All three previous studies used reaction time tasks to assess relative impairment. The trigger stimuli and response mechanisms were slightly different to those used in the current study but bear comparison. Burns et al. found that reaction times were significantly higher in each of the three test conditions than in the control condition (12.4% higher when at the legal alcohol limit; 26.5% higher whilst talking on a handsfree phone; 45.9% higher whilst talking on a handheld phone). Sexton et al. (2000) found reaction times were 21% higher when drivers were under the influence of cannabis. In the current study, there was a mean increase in reaction time of 34.7% to the visual stimulus making it apparently worse than alcohol, cannabis, and handsfree conversations but less detrimental than using a mobile phone for handheld conversations.

4.1.2 Speed

In the current study, it was observed that participants drove more slowly in the Texting drive. Direct comparisons with Burns et al. 2002, Sexton et al, 2000, and Sexton et al. 2002 are not simple because their studies were investigating long lasting performance impairments. The texting episodes in this study were short (typically around 60 seconds) so the duration over which speed could fall to a lower level was reduced. However in Write 1, mean speeds were 5.7% lower and in Write 4, mean speeds were 6.9% lower (note these were in sections of the drive where speed was unconstrained by traffic or route configuration). In Burns et al., it was found that participants drove around 2.2% slower when using their phone handsfree and 4.8% slower when using their phone handheld (participants drove slightly faster when at the legal limit of alcohol). This suggests participants feel that they have to compensate for a greater perceived behavioural impairment caused by texting whilst driving than that caused by talking whilst driving.

In the studies of cannabis, greater speed reductions were observed when drivers were under the influence of the drug (7.7% reduction in speed in Sexton et al. 2000; 9.1% reduction in speed in Sexton et al. 2002). This suggests that the combined physiological and psychological effect of cannabis caused a greater perceived behavioural impairment than texting whilst driving.

4.1.3 SDLP

Variation in lateral lane position in is a common measure of driving performance and was used in each of the three previous studies to assess relative impairment. In each, a similar set of loops was used and lane keeping ability was assessed in the impaired and control conditions. In comparing, results from the current study, it is worth noting that measures of SDLP in each texting episode are likely to be higher than in the previous studies since the texting episodes are shorter. This may have had a significant effect on the percentage differences observed.

Burns et al. found that there were no significant differences in SDLP in the handheld or handsfree conversation conditions. Driving whilst at the legal limit of alcohol consumption did result in significantly less steady lane keeping than any of the other conditions in the study.

Sexton et al. (2000) found that drivers displayed an increase of around 35% in SDLP with high does of cannabis whilst Sexton et al. (2002) found an approximate 14% increase in SDLP for the cannabis and cannabis + alcohol conditions.

In the current study, the Read 2 and Write 2 tasks were in presented in the loops section. Each showed an increase in SDLP, significantly so in the Write 2 task (Read 2: SDLP increased by 12.7%; Write 2: SDLP increased by 91.4%). Increases in SDLP for Read 2 and Write 2 were also accompanied a significantly greater number of lane departures in each task.

It would appear that the combination of increased mental workload required to write a text message, the control impairment caused by the physical act of holding the phone, and the visual impairment caused by continually shifting visual orientation between the phone display and the road ahead resulted in significantly impaired ability to maintain safe road position, particularly when driving through the loops section. Participants' reduction in speed indicated their awareness of the impairment caused by texting whilst driving. However, this attempt to mitigate risk cannot fully compensate for the deterioration in performance when attempting to text and drive.

Acknowledgements

The work described in this report was carried out in the Human Factors and Simulation group of the Transport Research Laboratory. The authors are grateful to Andrew Parkes who carried out the technical review and auditing of this report.

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Appendix A The TRL Driving Simulator Centre

A.1 TRL Driving Simulator

TRL has successfully operated a driving simulator for more than 15 years and in that time the simulator has seen a number of different incarnations to keep pace with improvements in vehicle, projection, computing, and simulation technologies and as such is one of the most advanced simulators in the UK. The latest iteration uses a Honda Civic family hatchback (see Figure A.1). Its engine and major mechanical systems have been replaced by a sophisticated electric motion system that drives rams attached to the axles underneath each wheel. These impart limited motion in three axes (heave, pitch, and roll) and provide the driver with an impression of the acceleration forces and vibrations that would be experienced when driving a real vehicle. This significantly enhances the realism with which drivers approach the driving task and reduces the incidence of simulator sickness (a condition with symptoms similar to those of motion sickness) among participants. All control interfaces have a realistic feel and the manual gearbox can be used in the normal manner (automatic gears can be simulated).

Figure A.1 TRL driving simulator, CarSim

Surrounding the simulator vehicle are large display screens onto which are projected the graphic images that represent the external visual environment to the driver. The level of environmental detail includes photo-realistic images of buildings, vehicles, signing, and markings, with terrain accurate to the camber and texture of the road surface. We have also recently added the capability to simulate night-time driving scenarios. The driving environment is projected at a resolution of 1280×1024 onto three forward screens to give the driver a 210º horizontal forward field of view. The presence of the two flat side screens adjacent to the driver gives a very strong impression of other vehicles travelling alongside of the vehicle. A rear screen provides a 60º rearward field of view, thus enabling normal use of all mirrors.

Surveillance video cameras are mounted in the car and participants can be recorded during their drive. There is also an intercom facility for communication between the vehicle and the control room. An in-car colour LCD display can also be used to give instructions or provide other task-related information.

Figure A.2 TRL CarSim: Control Room

More than one hundred autonomous traffic vehicles can be programmed to participate in the simulation. TRL has a library of different vehicle types to choose from including cars, trucks, buses, emergency vehicles, bicycles, and pedestrians. Each obeys specific driving rules to behave in a normal manner with respect to other traffic vehicles. However, these can be overridden causing them to perform specific manoeuvres e.g. emergency stop, sudden lane change etc. The autonomous vehicles also have dynamic properties of their own – they appear to pitch realistically under acceleration and braking, and vehicle graphics include body tilt and roll under braking, acceleration and turning; speed dependent rotating wheels and fully working brake, indicator, fog, and head lights. These provide additional cues to the driver and greatly enhance the realism of a scene. To generate scenarios with a heavy traffic load (> 1700 vehicles per lane per hour) we can generate a vehicle 'swarm'. The swarm function allows us to define a region around the driver where vehicles will be placed and controlled. A vehicle moving out of the visible range of the driver is replaced by a new vehicle positioned to maintain the desired traffic density. This gives the impression of very high volume of traffic while maintaining the performance of the simulator.

A stereo sound system with speakers inside and outside the vehicle generates realistic engine, road, and traffic sounds to complete the representation of the driving environment. The software used to implement the simulation is called SCANeR II and was created by OKTAL to provide a flexible and powerful simulation with a highly advanced traffic model. It is employed by more than twenty research institutes across the globe and TRL leads the user group with access to OKTAL expertise for trial set-up and integration, if required.

The dynamics of the vehicle are modelled using a validated vehicle model that is used for product development by Renault. The model interprets the driver's control inputs, relates them to the current vehicle status and computes a prediction of how a real vehicle would behave in the given circumstances. The system then responds to present to the driver its optimal representation of how this behaviour would be perceived through the visual, sound, and motion sub-systems. The vehicle dynamics are updated at 100Hz whilst the visuals are refreshed at 60Hz so that the driver perceives a seemingly continuous driving experience. Data is then recorded relating to all control inputs made by the driver, including steering, pedals, gear, indicators; vehicle parameters such as speed, RPM; and parameters to assess behaviour in relation to other vehicles such as distance and time headways. The data recording rate is fully controllable dependent upon the trial demands, up to a rate of 100Hz.

The simulator also includes a full integrated SmartEye eye–tracking system for the analysis of driver visual behaviour. This system, in addition to being able to report the driver's gaze direction, is integrated with the 3D environment presented in the simulation, such that the eye-tracker can report in the simulator data the specific element on which the participant is fixating – a specific road sign, traffic light, the road ahead, or interior items such as the instrument panel or infotainment system. This dramatically improves the accuracy and efficiency of post-trial data analysis.

Participants for trials are recruited from a dedicated database of over 1000 members of the public. This comprises drivers from a wide range of ages and backgrounds, all of whom are familiar to TRL such that participants from particular demographic bands or driving experience/ability ratings can be selected to suit the trial requirements. The simulator facilities include a medical room for taking any physiological measures and trials management staff are trained in Good Clinical Practice. There is an interview room for questionnaire completion and debriefing and an information room for conducting computer based test or training tasks. Data management procedures are well established and compliant with the Data Protection Act 1998 to ensure security, confidentiality, and integrity of all records.

Appendix B Phone makes and network providers

Error! Reference source not found. shows the count of makes of participants' mobile phone used in the study and network providers used by each participant.

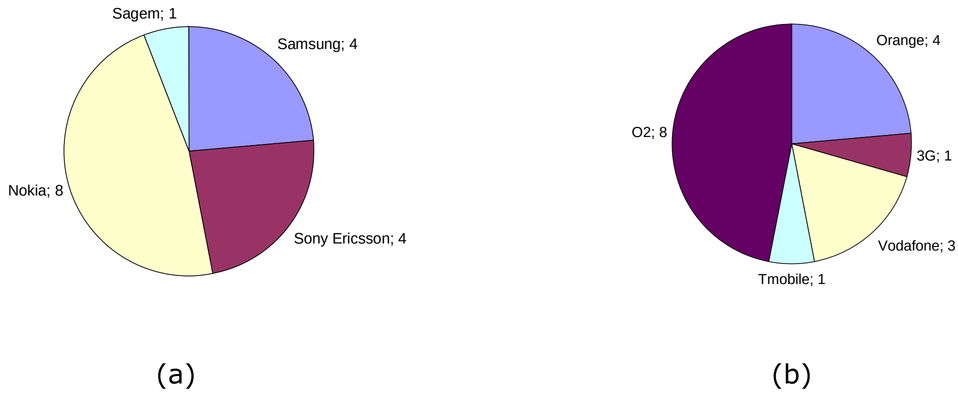

Figure B.4.1 Count of (a) mobile phone makes and (b) network providers used in the study

Given the relatively small sample size the distribution of mobile phone makes does match the UK market share of each manufacturer reasonably well (August 2008: Nokia 43%; Sony Ericsson 25%; Samsung 21% (Mobile Today, 2008)). One notable absence from the study was the manufacturer, Motorola, although that company is experiencing a fall in market share currently. The distribution of network providers among participants is less consistent with UK market share. In the UK, phone users are spread approximately equal across the 'big four' (Q1 2008: Vodafone 26.6%; O2 26.4%; T-mobile 24.5%; Orange 22.6% (Telecoms Market Research, 2008)). The skewed distribution amongst participants may be due to differences in signal strength in the local area or may simply be a function of the small sample size.

Eight participants reported using predictive text for message composition (four male; four female). Nine participants did not use predictive text (five female; four male).

Appendix C Messages sent in Texting drive

Table C.1 shows the text messages composed by each participant in the Texting drive.

Table C.1 Text messages composed by each participant in their Texting drive

Participant number	Write practice	Write 1	Write 2	Write 3	Write 4
1	I am drin a gr8 car simulator.	Happy birthday hav fun at the party	Nice 2cu at the cafe yesterday	Dont worry have a nice time in paris	Sorry bout ur ankle get well soon
2	I am driving a great car simulator.	Happy bday.have fun at the party		Dont worry, have a nice time in paris	Sorry about your ankle.get well soon
3	I am driving a great car simulator	Happy bday have fun at the party	Nice to see u at the cafe yesterday	Dont worry have a nice time in paris	Sorry about your ankle get well room
4	i am driving a great car simulator	happy birthday have fun at the party!	nice to see u at the cafe yesterday	dont worry have a nice time in paris	sorry about ure ankle get well soon
5	Im driving a great car simulator	Happy birthday have fun at the party	Nice to see u at the cafe yesterday	Dont worry, have a nice time in paris	Sorry bout ur ankle, get well soon
6	I am driving a great car simulator	Happy bday have fun at the party	Nice 2 c u at the cafe yesterday	Dont worry, have a nice time in paris	Sorry bout ur ankle get well soon
7	I am driving a great car simulator!	Happy birthday,have fun at the party!	Nice c see u at the cafe yesterday!	Dnt worry have a nice time in paris	Sorry about ur ankle, get well soon!
8	I am driving a great car simulator	Happy bday. Hav fun at the party	Nice to c u at the cafe yesterday	Dnt worry hav a nice time in paris	Sorry about ur ankle get well soon
9	I am driving a great car sim.	Happy birthday. Have fun at the party.	Nice to see u at the cafe yesterday.	Don't worry. Have a nice time in paris.	Sorry about your ankle. Get well soon.
10	I am driűing a great car simulator.	Happy birthday have fun at the party.	Niåe to se u at the cafe y'day	Doot worry have a gd time in paris	Sorry abovt ur ankle get well soon.
11	I am driving a great car simulator	Happy birthday, have fun at the party.	Nice to see you at the cafe yesterday	Don't worry, have a nice time in paris!	Sorry about your ankle, get well soon
12	I am driving a great car simulator	Happy birthday hav fun at the party	Nice 2 c u at the cafe yesterday	Dont worry have a nice time in paris	Sorry about ur ankle get well soon
13	I'm driving a great car simulator	Happy birthday, have fun at the party	Nice to see you at the cafe yesterday	Don't worry have a nice time in paris	Sorry about your ankle, get well soon
14		Happy birthday have fun at the party	Nice to c u at the cafe yesterday		
15	I an driving a great car simulator	Happy birthday have fun at the party	Nice to see you at the cafe yesterday	Don't worry have a nice time in paris	Sorry about your ankle, get well soon
16	I am driving a great car simulator	Happy birthday, have fun at the party	Nice to see you at the cafe yesterday	Don't worry have a nice time in paris	Sorry about your ankle. Get well soon
17	I am driving a great car simulator	Happy birthday have fun at the party	Nice to cu at the cafe yesterday	Dont worry have a nice time in paris	Sorry about youre ankle gdu well soon