Drivers' response to warnings/information provided by in-vehicle information systems

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Keywords: distraction, in-vehicle information system/s (IVIS), intelligence speed assistance/adaptation (ISA), mobile phone; nomadic device, prevalence; warning

An important note for the reader

Additional note

The Transport Agency continues to recommend that smartphones or similar devices are not used while driving. This research was conducted in controlled circumstances using a driving simulator to develop the transport sector's understanding how in-vehicle information systems, smartphone apps and other devices that promote safer driving behaviour could be used. The findings found potential for future applications that could promote safety; however such applications are not available outside of laboratory conditions at present. The research was undertaken in response to the emergence of various technologies and applications aimed at safer driving behaviours. It is intended that the research will build the sector's knowledge base and inform work that may be undertaken in this area.

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Abbreviations and acronyms

Anova	analysis of variance
AV	audio visual
CI	confidence interval
EU	European Union
ISA	intelligent speed assistance or intelligent speed adaptation
IVIS	in-vehicle information system/s
msec	millisecond
NHTSA	National Highway Traffic Safety Administration (USA)
OR	odds ratio
PDA	personal digital assistant
SD	standard deviation
SDLP	standard deviation of lane position

Contents

Executive summary

The overall purpose of the research described in this report was to provide a description of key operating principles and recommendations about drivers' use of in-vehicle information systems (IVIS), smartphone applications and nomadic devices, and their likely effects on driver performance.

The research had four main objectives:

1. To assess how drivers' reactions to road and traffic situations are affected by the potential distraction produced by different display modes associated with in-vehicle applications.
2. To measure how driving performance changes in response to the information provided by in-vehicle applications and the different display modes (eg compliance with the information presented).
3. To test how the effects of in-vehicle applications change with repeated exposure (eg habituation and desensitisation).
4. To identify the range of in-vehicle applications and information systems currently used by drivers, the prevalence and frequency of their use and drivers' attitudes towards them.

One part of the study examined the effects of an intelligent speed assistant (ISA) on driving performance in the University of Waikato driving simulator. The ISA software, displayed on a smartphone, was designed to alert the driver when they exceeded the posted speed limit. The ISA was designed according to best practice guidelines (Kroon et al 2016; NHTSA 2012) so the display used recognisable symbols consistent with traffic signs, minimised downward viewing angle for the driver, did not require glances longer than two seconds to read or operate, and system input (in the two active versions of the ISA) was facilitated by being operable with a single hand and was located within 10 to 20 cm of the driver's hand. The ISA provided two types of alert (visual only or auditory and visual) and operated in two modes (active or passive) resulting in four experimental conditions; active visual; active audio visual, passive visual and passive audio visual, plus a control group where the ISA remained off with a blank screen throughout the drive. Speed warnings consisted of the main speed rondel flashing on/off until the participant reduced their speed to within 4 km/h of the speed limit. For the audio visual conditions the warning was accompanied by a beep. In the passive conditions, the ISA display automatically updated to show the new speed limit after entering a new speed zone. In the active modes, the participants were told to select the new speed limit when they entered a new speed zone (as indicated by speed limit signs).

One hundred and twenty-three participants in total completed the simulator study. One hundred and four participants (mean age = 35.52 years; 52 male) were allocated to one of the five ISA conditions: active audio visual (n = 22), active visual (n = 22), passive audio visual (n = 21), passive visual (n = 21) or control (n = 18). Another 19 participants (mean age = 27.53 years; 8 male) completed the study wearing eye-tracking glasses in one of three conditions (active audio visual ISA (n = 6), passive audio visual ISA (n = 6) or control (n = 7). The participants drove a simulated 26.4 km section of rural road containing a combination of straight stretches and gentle horizontal and vertical curves. It took approximately 20 minutes to complete the drive at the posted speed limits. The drive consisted of two 3 km baseline sections at the beginning and end of the drive, four sections containing hazards (roadworks, busy intersection, one-lane bridge and an overtaking lane) and three speed compliance zones (no hazards and 100 km/h, 80 km/h and 60 km/h speed limits). After the drive, participants completed a short questionnaire.

The ISA resulted in good compliance; the participants' speed choices were congruent with the posted speed limits along the simulated road. This was particularly evident during the 60 km/h road segment, where the control group drove at significantly higher speeds than the groups with the ISA. No significant differences between the four versions of the ISA were observed, either in terms of speed compliance or the number of speeding alerts received from the device. The ISA did not impede participants' ability to overtake vehicles; the number of vehicles overtaken was the same for all four groups.

Across the entire simulated drive there were relatively few glances at the ISA, and although there were more glances at the device in the active version of the system, the absolute number for the entire drive was still very low (*M* = 21.0, *SD* = 4.17). The total time spent looking at the device was also very low (0.40% of the time for the active version), and the average glance duration of 190 milliseconds (ms) for this group did not approach the acknowledged upper limit for an in-vehicle device of two seconds (NHTSA 2012). Glances at the ISA device were significantly fewer and shorter than at the vehicle's speedometer, which had an overall average glance duration of 281.96 ms. An argument could be made that the active version of the ISA device reduced the amount of looking at the vehicle speedometer, but given the relatively small sample size of eye-tracking participants this was not a conclusive or reliable difference.

A survey was conducted to investigate drivers' use of IVIS applications such as navigation devices and advisory systems. The survey explored the prevalence and frequency of their use, drivers' attitudes regarding their safety, perceived negative effects on their own and others' driving, and any strategies or techniques they used to minimise these effects. A digital data collection company (Research Now) was contracted to recruit and administer the survey to drivers throughout New Zealand. The final sample (n = 1,017) consisted of a similar number of male and female (50% male) and drivers from four age groups; 16–24 years (n = 227), 25–44 years (n = 260), 45–64 years (n = 261) and 65+ years (n = 269). While the majority of respondents lived in regions with major New Zealand cities (eg Auckland, Wellington), those from smaller towns and rural communities (eg Hawke's Bay, Taranaki, Southland) also completed the questionnaire.

The most common activity drivers engaged in was listening to music, followed by listening to directions and looking at a map on a navigation system. Fewer than half of the drivers reported conversing on a hands-free phone, and fewer than a quarter reported texting/sending emails/posting on social media while driving. Only a small proportion of the sample had experience with lane departure, dangerous curve or intersection warning systems. Overall, the prevalence for each activity was similar for men and women, but varied by age, with a general decrease in engagement in each activity/behaviour with age. Interestingly for many of the activities (eg texting, talking on a hands-free phone, using a navigation device), rates were highest in the 25–44 year group. In terms of the frequency of engagement, other than listening to the car audio, respondents typically reported engaging in the activities seldom or sometimes, suggesting drivers are not engaging in other activities most of the time they are driving. The rates of navigation system and mobile phone use in the current study are similar to those reported in the EU (Jamson 2013). The small, but significant proportion of drivers using a hand-held mobile while driving reflects the findings from previous roadside observation studies (Wilson et al 2013; Ministry of Transport 2013) and clearly highlights the number of drivers who continue to use hand-held mobile phones despite legislation banning their use.

Listening to music and listening to directions were commonly rated as having no effect on driving. The use of a hand-held mobile phone for texting/emailing, using the internet and taking pictures was rated as having the greatest negative effect. The most common perceived effect of using a hand-held mobile phone was slower reactions to changing traffic, but respondents thought it would affect all aspects of driving (unintentionally altering speed, weaving, poor scanning, driving too close, not noticing pedestrians and cyclists, needing to stop suddenly, not noticing traffic signs or signals). Although a significant proportion of respondents reported having conversations on a hands-free phone, over half of these thought it would lead to decreased driving safety, most commonly slower reactions to changing traffic. The younger drivers seemed to be most aware of the negative consequences of engaging in many of the distracting activities, whereas the middle two age groups were most likely to rate hands-free phone conversations as having no impact on their driving.

Drivers used a number of strategies to minimise the detrimental effects of IVIS, the most common actions were to ask the passenger to use the device, to pull over and stop or to use it in slow moving traffic. In general, males reported the use of fewer countermeasures than women. Texting/sending emails and posting on social media were rated as having the greatest overall impact on driving safety, possibly because the activities are illegal. Drivers rated almost all of the activities or events as having a more negative impact on an average driver compared with their own driving, similar to the findings of Jamson (2013).

Focusing specifically on the use of speed warning systems (such as those used in the simulator study), almost half of the drivers sampled had access to an ISA, with around half of those (approximately a quarter of the total sample) reporting they had received speed-related warnings. Approximately half of those who had received speed related warnings reported it had no effect on their driving, while a third reported they would slow down. Participants were also asked to rate the likely safety benefits of four speed-related systems (from Warner et al 2010); 1) an information system that shows the current speed limit, 2) an advisory system that shows the current speed limit and provides visual and auditory warning when the speed limit is exceeded, 3) a supportive system that shows the current speed limit and exerts a counter-force on the accelerator at speeds over the speed limit and; 4) an intervening system that shows the current speed limit and interacts with the vehicle to prevent you exceeding the speed limit. The participants reported that each of the speed advisory systems would improve safety, reflecting the findings of Comte (2000) and Várhelyi et al (2015). Interestingly though, they would only be willing to have the information or advisory systems fitted to their car, not the supportive or intervening systems.

Overall, the results of the simulator experiment demonstrated that, if designed in accordance with best practice guidelines, safety-oriented IVIS have the potential to give drivers useful information without distracting them unduly – a net road safety benefit. We were also able to conclude there was no evidence of distraction in the drivers’ lane-keeping performance, as would be predicted if the operation of the device were increasing mental load and distracting the drivers from the steering task. Similarly, the drivers’ self-ratings of mental load only reached an average of 2.19 on the 7-point scale where a rating of 1 was ‘easy, no difficulty at all’. Further, the ISA device did not impair performance when negotiating traffic and potential hazards (eg road works, busy intersection, one lane bridge) as would have been predicted had the system distracted or overloaded the participants’ visual attention. Compliance with all versions of the ISA during the testing was good, making a significant difference to drivers’ speeds in the 60 km/h speed zone relative to the control group participants (no ISA). In a related finding, the drivers’ efficiency remained good, with no detectable interference with their ability to accomplish overtaking of slower traffic (during the overtaking lane portion of the simulation scenario). Although our participants rated the ISA they used as being useful, and ISAs as having definite safety benefits, we are not able to conclude whether drivers would continue to use and comply with the speed advisories over the longer term. It should be noted that roughly the number of drivers who report using a speed advisory system is the same as that reporting using text/email/social media while driving. This is in spite of the fact that the drivers rated the former as improving driving and the latter as impairing driving. From these results of the survey we can conclude that relatively few drivers use safety-oriented IVIS; even when they have access to the systems, 50% to 75% of drivers ‘never’ use them.

In sum, properly configured IVIS such as the ISA tested have a demonstrable safety benefit and do not produce adverse distractive effects. Use of safety-oriented warning IVIS in the driving public, however, is low and in the absence of incentives or education, is likely to remain low in spite of drivers’ belief that they do have safety benefits. In view of these conclusions we would recommend the development of guidance to drivers on what constitutes a 'good' app (easy to see position, not requiring long glances, not hand held, etc) and what constitutes bad practice in using IVIS (including legal ones such as car console displays).

Abstract

The purpose of the research was to provide an analysis of drivers' use of IVIS, smartphone applications and nomadic devices and their likely effects on driver performance. We examined the effects of a speed advisory IVIS presented on a mobile phone on the driving performance of 123 participants in the University of Waikato driving simulator. We also conducted a New Zealand-wide survey (n = 1,017) of drivers to examine the prevalence of, and frequency with which, drivers used a range of in-vehicle apps and systems. The speed advisory IVIS, designed according to best practice guidelines, improved compliance with the posted speed limits and did not impair driving performance or distract drivers. The survey found that drivers most frequently used in-vehicle audio systems and navigation devices, and a small but significant number reported using hand-held mobile phones. Although many drivers had access to a speed advisory application, only a quarter of those with access reported receiving speed-related warnings, and of these half were ignored. Given the potential safety benefits, and no detectable negative effects of a properly designed speed advisory IVIS on driving performance, the key challenge is to encourage drivers to use IVIS that improve safety.

1 Introduction

In-vehicle information systems (IVIS) refer to the range of electronic instruments and displays used by drivers for a wide variety of information and assistance during a trip. These systems include navigation and route guidance aids, speed advisory warnings and eco-driving assistance systems. Some IVIS are built into the console or dashboard of cars and trucks by the manufacturers, but as smartphones have become commonplace many IVIS have become available as 'apps' that can be run from a smartphone or other nomadic device (eg a tablet or personal digital assistance (PDA)). Sometimes the word 'system' in IVIS is replaced by the term 'service' which emphasises the aim of supporting the driver.

1.1 Benefits of IVIS

IVIS can have obvious benefits for drivers. For example, in-vehicle navigation aids can make driving in unfamiliar cities much easier and less stressful. Similarly, IVIS can provide commercial drivers and freight companies the ability to dynamically route and reroute trips for transportation of goods in cities (eg packet or food deliveries) and for innovative mobility services (eg Uber or Lyft; Pillac et al 2013). These systems have rapidly come to be considered essential because they make it possible to provide route guidance to drivers based on dynamically changing conditions and needs. In a related way, it is been argued that these apps improve fuel efficiency and decrease emissions; both through dynamic traffic rerouting and even more directly when eco-driving feedback is provided to drivers (eg Ericsson et al 2006; Jamson et al 2014).

Because excessive speed is an important contributing factor to the severity of injuries and the risk of crashes (Aarts and Van Schagen 2006; Elvik 2013), IVIS associated with speed warnings have the potential to offer significant benefits (Varhelyi 2002; Carsten 2012). This class of IVIS, sometimes referred to as intelligent speed assistance or intelligent speed adaptation (ISA) systems, provide warnings and advisories to drivers when the vehicle speed exceeds a speed limit (pre-set or contextually determined). Some ISA systems also intervene with the speed control by increasing the resistance to the accelerator pedal, limiting the rate of acceleration, or capping the maximum speed when the driver is exceeding the legal or safe limits of speed (Varhelyi 2002; Carsten 2012). Related to ISA systems are eco-driving systems that provide drivers with warnings about their speed and rate of acceleration in order to minimise fuel consumption (Barkenbus 2010; Kircher et al 2014).

Over the past 30 years, a range of analyses have demonstrated that ISA systems could decrease the number of crashes (due to the reductions in speed) and that the economic savings would outweigh the costs (Carsten and Tate 2005). In terms of their effectiveness in speed reduction, Warner and Åberg (2008) found that the speed-reducing effect of an advisory system was greatest when first introduced but decreased with continued use. The systems retained some of their effectiveness long term; even after three years the drivers sped less than before the activation of the system. However, there seems to be no carry-over effect if the system is removed (Chorlton and Connor 2012).

ISA systems have also been used to reduce the speeding of recidivist speed limit offenders. Published reports have suggested there is relatively good speed compliance with these systems, even when they allow the user to override the alerts (Van der Pas et al 2014). Another ISA application that was intended to reduce speeding at roadworks sites presented visual and visual-auditory speed advisories to subjects in a simulated drive (Whitmire et al 2011). Both of the presentation modes of the speed advisory were found to reduce speeding relative to a control condition.

1.2 Negative effects of IVIS

Undoubtedly ISA systems and other forms of IVIS offer the potential for increased safety, economy and efficiency, if drivers comply with the advisories. On the other hand, engaging in a secondary task while driving has the potential of introducing driver distraction and increasing the probability of a crash. IVIS, whether vehicle entertainment systems, smartphones, or other nomadic devices, enable drivers to engage in a wide range of activities besides those related to driving safety. Although driver distraction is often defined simply in terms of the diversion of a driver's attention from a driving activity to a competing activity (Regan et al 2011), IVIS can result in distraction either by consuming attentional resources (increasing mental workload) or by requiring drivers to divert their gaze from the road (visual demand). Thus, as with cockpit displays in aircraft, the net benefit of an IVIS is a balance between its effects on performance and its contribution to pilot or driver situation awareness. For example, an IVIS may provide useful information regarding speed and traffic and improve a driver's overall situation awareness, but if the driver is slow to notice a lead car braking when concentrating on the IVIS, then the immediate or localised effect of the system has decreased the driver's situation awareness and performance.

1.2.1 Distraction and crashes

Distraction is often cited as a key causal factor in crashes worldwide. Stutts et al (2001) estimated that in the US, between 1995 and1999, at least one in ten drivers were distracted when they had a crash (Stutts et al 2001). Closer to home, and more recently, Beanland et al (2013) analysed the contributing factors of crashes between years 2000 and 2011 using data from the Australian National Crash In-Depth Study. Half of the crashes (464/938) contained information about the contributing factors. In 340 crashes it was possible to determine if inattention was a contributing factor. For 216 of these crashes, inattention was found to be a causative factor. In 54 cases (12%) inattention was linked to diversion of attention; three were related to mobile phone use, and 14 to the use of an in-vehicle system. In comparison, 11 were related to passenger interaction, six involved external distractions and 14 were classed as internal distraction, (eg thinking of something unrelated to driving). A telephone survey conducted in Australia (McEvoy et al 2006) found that 21% of self-reported crashes involved distraction and 5% of them were attributed to interacting with an in-vehicle device, including stereos or the air conditioning system. In New Zealand, over the years 2013 to 2015 distraction (attention diverted) was a factor in 12% of all casualty crashes, 9% of fatal crashes, 9% of serious injury crashes and 12% of minor injury crashes. In 2015 alone, diverted attention was described as a contributing factor in 1,142 crashes (12% of all crashes). These crashes were associated with 31 deaths and 191 serious injuries. The social cost of these crashes, estimated to be $365 million, was 10% of the cost of all casualty crashes, or viewed another way, $1 million per day (Ministry of Transport 2016).

1.2.1.1 The effect of IVIS on crash risk and driving performance

There is only limited data regarding the role of specific types of IVIS in distraction or diverted attention crashes. The use of phones by drivers, however, is well studied and useful as a starting point. A highly cited case-crossover study by Redelmeier and Tibshirani (1997) found that drivers using a mobile phone were four times more likely to be involved in a crash with the odds ratio (OR) = 4.3, [95% CI = 3.0, 6.5] compared with drivers not using a phone. A subsequent study replicated these findings (OR = 4.1, 95% CI = 2.2, 7.7), and was also able to show there was no difference between hand-held and hands-free phones (McEvoy et al 2005).

Another approach to establishing the role of IVIS in driver distraction crashes has been the collection of videos in naturalistic driving studies. Klauer et al (2006) used data from the 100-car naturalistic study to estimate that drivers engaging in complex visual and/or manual tasks while driving have an OR = 3.10, [95% CI =1.72, 5.47] of being involved in a crash or in a near crash compared with those focusing solely on the driving task. More recently, analyses of additional data from the naturalistic driving study suggested a baseline risk of in-vehicle device distraction (including using the radio and air conditioning) of OR = 2.5, [95% CI =1.8, 3.4] for a crash compared with the baseline (Dingus et al 2016). Conversation using a hand-held mobile phone had OR = 3.6 [95% CI = 2.9, 4.5]. Dialling with a hand-held mobile phone had much larger OR = 12.2, [95% CI = 5.6, 26.4]. By way of comparison, interaction with a passenger had an OR = 1.4 [95% CI = 1.1, 1.8].

The precise number of crashes caused by distraction from IVIS is still a matter of some uncertainty, particularly because of the potential discrepancy between their prevalence and how they are actually used while driving (Young and Regan 2007). For example, setting the destination on a navigation system can be highly distracting during the drive, but if drivers enter the destination and route before they start driving, the risk of using a navigation system is greatly diminished. As mentioned earlier, there are also potentially offsetting safety advantages for an IVIS, such as ISA systems. In these cases, while there may indeed be a distractive effect on the driver, the speed reduction and redirection of attention may result in a net safety increase.

1.2.1.2 IVIS and visual load

In order to determine the net safety benefit/dis-benefit of a given type of IVIS, or any particular IVIS, a closer look at how it is used and the potential means for distraction must be considered in some detail. Analysis of the naturalistic driving video data referred to above revealed that drivers taking their eyes off the road for several seconds was common across many of these high-risk activities (Klauer et al 2006; Olson et al 2009; Dingus et al 2016) with longer off-road glances increasing the odds of a crash. Klauer et al (2006) reported that drivers' eyes were off the road on average 1.8 seconds prior to a crash, 1.3 seconds prior a near crash, and 0.9 second in baseline. Glances longer than 2 seconds had OR = 2.27 [95% CI = 1.79, 2.86] for a crash or near crash. Similarly, among truck drivers, Olson et al (2009) found that before a crash, drivers' eyes were off the road an average of 2.1 seconds; with glances longer than two seconds having an OR = 2.93 [95% CI = 2.65, 3.23] for a safety-critical event.

Laboratory research has borne out the relationship between off-road glance duration and crash risk. For example, Jamson and Merat (2005) developed a visual search task intended to emulate the visual demands of an IVIS while participants drove a simulator. In the experiment 48 participants were asked to indicate the presence or absence of a target arrow (pointing upwards) in a field of distractor arrows. The effect of the arrows search task was a significant reduction in the participants' following distances and shorter time-to-collision on a simulated car following task, even though the participants did display some compensation in the form of reduced speed.

A variant of the arrows task was used by Liang and Lee (2010) in their investigation of the effects of visual load on vehicle control and hazard detection in a driving simulator. In their task the target arrow was presented on top of the IVIS screen and drivers had to choose an arrow that matched in orientation from an array of 16 arrows. The researchers reported that this task resulted in slower visual scanning (saccades) when drivers looked at the roadway, steering neglect (failure to correct vehicle heading when it was drifting toward a lane boundary), and overcompensation (rapid and repeated steering wheel movements resulting in large swings in lateral velocity and lane position).

Tsimhoni et al (2004) used an address entry task to explore visual load effects while participants drove simulated roads of varying difficulty. Addresses could be entered either by typing on a touch screen, character-based speech recognition, or word-based speech recognition. The researchers reported that lane position variability (standard deviation of lane position (SDLP)) was 60% higher when typing an address compared with the other address entry methods. The participants rated the safety of the three methods (on a 10-point scale) where word-based speech recognition was rated as relatively safe (4.1), followed by character-based speech recognition (5.3). Keyboard entry was rated as extremely unsafe (9.2).

Wikman and Summala (2005) used a trail-making task in which the numbers 1 to 8 were randomly positioned on a display, and the participants were required to push them in sequence. After they had completed the task once, the numbers were re-positioned to new locations. In this on-road experiment 30 participants in three age groups drove an instrumented car on a trip 350 km in length with a midway break. The results indicated that older drivers (over 65 years) experienced greater visual load as indicated by longer gaze times to the in-vehicle display, a greater number of glances longer than two seconds and poorer vehicle position in their lane (lateral displacement).

The degree of visual load produced by the IVIS as a secondary task depends in part on the amount of time drivers need to look at the IVIS display, and as a consequence, away from the road. While some visual information, like flashing lights, can be readily detected peripherally, drivers typically need to look directly (ie foveate) at the screen to obtain information (and flashing lights often result in drivers reflexively foveating the lights in any case). Some degree of gaze with foveal vision is typically required for the guidance of manual actions. For example, if a driver selects something from a touchscreen, it is likely that he or she will foveate the button shortly (< 2 seconds) before the manual action (Hayhoe et al 2003; Land et al 1999). This 'gaze leads hands' effect is very robust, not because the driver does not know the location of the button, but because it is apparently and generally linked to the coordination of motor movements.

Across a range of experiments visually demanding secondary tasks have been shown to have significant and substantial effects on drivers' maintenance of lane position as measured by SDLP (Engström et al 2005; Jamson and Merat 2005; Liang and Lee 2010; Tsimhoni et al 2004). Because off-road glance duration has been identified as a safety relevant measure, it has been specified in design and assessment guidelines (Kroon et al 2016; NHTSA 2012). For example, NHTSA (2012) guidelines describe a testing procedure for in-vehicle systems where one of the criteria is that 85% of the glances off the road should be less than two seconds and the total eyes off the road time per task should not exceed 12 seconds.

1.2.1.3 IVIS and cognitive load

A second form of distraction results from demands on attention and working memory from a non-driving task. In-vehicle tasks that do not require drivers' vision, such as conversing on a hands-free phone, may still create an additional *cognitive load* which distracts drivers (Lamble et al 1999; Strayer et al 2015). Cognitive load, sometimes referred to as mental workload, is a fairly general term used to refer to the proportion of available mental resources expended on one or more tasks. The mental workload construct came about as a result of applied cognitive research associated with aircraft cockpit design, particularly as 1970's era military aircraft became so complex pilots began to turn off important systems in order to reduce their mental workload. A range of cognitive resources are limited in their capacity and mental workload typically refers collectively to these resources. Similar to the experimental research into visual load, the study of IVIS effects on cognitive load have used a range of surrogate tasks. For example, participants can be asked to keep information in working memory by performing mental arithmetic or rehearsing nonsense syllables that can be used to simulate the cognitive load associated with operating an IVIS.

Lamble et al (1999) increased drivers' cognitive load by asking 19 participants to engage in a paced auditory serial addition task. In this task participants heard a number every three seconds and were asked to mentally sum up the last numbers they heard and verbally report the tally. At the same time, the participants completed an on-road test in a car with cruise control set to maintain a speed of 80 km/h, 50 m behind a lead car, on a 30 km section of motorway in normal traffic. The participants were instructed to report whenever they detected a car ahead decelerating. The effect of the increased cognitive load was an impairment in detection ability by about 0.5 seconds in terms of brake reaction time and almost one second in terms of time to collision.

As part of their investigation of IVIS effects on simulated rural driving mentioned earlier, Jamson and Merat (2005) used an auditory continuous memory task to simulate a cognitively demanding IVIS. This task required participants to count target sounds which were presented randomly among non-target distractor sounds, and report the number of target sounds occurring during a designated interval. The level of task difficulty was manipulated by requiring participants to track up to three target sounds simultaneously. Similar to the effects of visually demanding IVIS, participants displayed some behavioural compensation by slowing their driving speed, but were unable to avoid decrements in driving performance such as poorer braking reaction times and shorter time to collision measures in the simulated vehicle following task.

In an experiment on the cognitive load associated with conversations drivers have with passengers and over hands-free mobile phones, Charlton (2009) had pairs of participants engage in conversations about any topic of their choosing while driving on a simulated road containing 'typical' hazards such as an overtaking lane, a busy intersection, roadworks and a one-lane bridge. Similar to the findings from the auditory memory task used by Jamson and Merat (2005), the cognitive load from the hands-free phone conversations resulted in longer brake reaction times, poorer anticipation of hazards and a higher rate of simulated collisions. Passenger conversations did not result in the same level of cognitive distraction, apparently because drivers and passengers paced the conversation so as not to distract from the driving task.

Overall, there have been mixed findings related to IVIS effects on drivers' speeds. Some studies found increases in mean speed (eg Recarte and Nunes 2002) and some have reported decreases in mean speed compared with free driving (eg Jamson and Merat 2005). It has been suggested that the effect depends on the degree of explicit attention drivers need to exert over their choice of speed during free driving. For example, explicit attention may be required to keep speeds under a speed limit that is perceived as too low for driving conditions that afford higher speeds (eg a wide straight road with long forward visibility). Alternatively, explicit attention and cognitive demand may also be required in cases where drivers are driving faster than is comfortable for them, for example under pressure to keep up with the pace of other traffic. When the cognitive load is increased due to demands from an IVIS or other task, drivers may not be able to continue to regulate their speeds and return to speeds, higher or lower, than are afforded by the road conditions (Engström et al 2017; Recarte and Nunes 2002). Thus, in lower speed zones the effect of cognitive load often results in an increase of speed compared with driving when undistracted (Lewis-Evans et al 2011; Recarte and Nunes 2002).

A similar effect is presumed to exist for many drivers on the road. A disinhibition of speed due to distraction, resulting in higher speeds, is especially worrisome inasmuch as the cognitive load has also been shown to delay responses to on-road hazards (Charlton 2009; Lamble et al 1999). Another finding associated with increased cognitive load has been termed the gaze concentration effect (Harbluk et al 2007; Lehtonen et al 2012; Victor et al 2005). The effect refers to the concentration of drivers' gaze on the road ahead compared with the scanning and glance patterns seen during baseline (ie low cognitive load) driving (Victor et al 2005). The increased concentration of gaze, however, does not necessarily mean better understanding or ability to react to situations on the road ahead. For example, reaction times to a lead car braking have been shown to increase while performing cognitively loading tasks even though the driver's gaze is concentrated on the lead car (Lamble et al 1999). This gaze concentration effect has been proposed to be the cause for the reduced lane-keeping variation, as scanning of the road provides visual information for steering (eg Boer et al 2016; but see He et al 2014 for alternative explanations).

Unlike the effects of visual load, the effects of cognitive load have been more difficult to quantify consistently, and for this reason neither NHTSA nor the Commission of the European Communities (2008) guidelines for IVIS have sections regulating cognitive load or mental demand produced by IVIS. Many jurisdictions have, however, limited drivers' use of mobile phones to hands-free applications, at least in part due to issues in detecting and regulating the use of hands-free applications.

1.2.1.4 The effects of repeated IVIS use

The amount of additional visual or cognitive load is a function of the difficulty of an in-vehicle task but also varies as a function of practice or experience. Some of the visual load can be due to perceptual complexity (eg it is more difficult to find something on a cluttered screen than in a screen with a few elements on it), but with practice we learn where to look and the task can become easier. Cognitive load or difficulty can increase when the driver has to keep many things in working memory ('in their mind') at the same time, or if the task requires switching between unrelated subcomponents of the tasks. Increasing the difficulty of a secondary task (where driving is the primary task) typically leads to a potentiation of difficulty and distraction (Jamson and Merat 2005). Once again, however, practice or experience may help drivers cope with cognitive demands of a secondary task (Engstrom et al 2017; Wikman et al 1998). Some drivers would claim they are so experienced at driving that engaging in a simultaneous task, such as conversing on a mobile phone does not affect their safety. Unfortunately, research does not support such claims. Time sharing between driving and any other task is bound to negatively affect driving performance. However, it is true to say that experience and training leads drivers to adapt and change their behaviour while engaging in distracting tasks (Donmez et al 2007; Shinar et al 2005; Wikman et al 1998).

Driving is mostly a self-paced task. This means that for the most part drivers have control over when they perform each subcomponent of the driving task. In addition to choosing the speeds at which they travel, they may decide to wait longer before pulling into an intersection, or wait for a longer view ahead before making a lane change. Drivers can also choose to wait before interacting with an IVIS (although visual displays and auditory alerts can draw attention and increase load simply by virtue of their presence; Kircher et al 2014). Although there is little published literature on the subject of drivers' tactical use, or pacing, of IVIS engagement, it appears that experienced drivers may be better able to cope with the additional demands posed by the presence of an IVIS.

With experience, drivers learn to adjust their visual scanning pattern to the driving situation which helps them to cope with the visual demands of driving (Chapman and Underwood 1998; Falkmer and Gregersen 2005; Räsänen and Summala 1998; Underwood 2007). Similarly, as they gain experience drivers appear to be better able to optimise a strategy for time sharing their gaze between driving and a secondary task. For example, in an on-road study with a visual secondary task, Wikman et al (1998) reported that experienced drivers were better able to distribute their looking behaviour than novice drivers; they had fewer long duration glances away from the roadway than novices, as well as fewer short, inefficient glances back to the roadway.

Simulator studies have shown that drivers do not engage in secondary tasks in situations they expect to be demanding (Metz et al 2011; Schömig et al 2011). Based on naturalistic data, Tivesten and Dozza (2014) reported that drivers adapt their glance behaviour to the situation when engaged in a phone task while driving, for example avoiding longer glances to the phone when turning, following a lead vehicle or when there was an oncoming vehicle. In addition, in a study of eco-driving displays, drivers looked at a continuous display less frequently in demanding traffic situations (Kircher et al 2014). It is also worth noting that conversations with passengers demonstrate the same effect, where in demanding situations, conversation with a passenger is suppressed, but conversation via a mobile phone is not because only the driver can see the unfolding traffic situation (Charlton 2009).

Other adaptations to the presence of IVIS may have less desirable consequences. Várhelyi et al (2015) reported that over a 53 km test route, a driver assistance system intended to warn drivers about departures from desirable speeds and lane position did lead to lower speeds on curves but also led to intersection turns at speeds that were too high. Similarly, Jamson et al (2012) argued that ISA systems could actually lead to reduced overtaking, because the drivers do not have enough space to accomplish the overtaking with lower speeds. The quality of overtaking manoeuvres was also affected; when drivers overtook (in a simulated driving environment) they spent more time in a hatched transition zone and made more sharp manoeuvres. When driving with a voluntary ISA that could be switched off by drivers, no negative effects on overtaking were observed and drivers disengaged the ISA in approximately 70% of the trials.

One criticism of the laboratory experiments used to demonstrate the distractive effects of IVIS tasks is that they typically measure performance over a short period of time using novel tasks, driving a novel vehicle in a novel environment. In the real world, it is possible that drivers learn to cope with some aspects of the distraction produced by IVIS, for example by habituating or learning to ignore the auditory alerts and visual warnings given by IVIS over time. Evidence from longer-term studies have indicated that drivers do indeed habituate to some aspects of the systems, but not all. Warner and Åberg (2008) followed test drivers who used a speed advisory system over two years. The time spent speeding decreased by 75% at the beginning of the trial, but towards the end of the study speeding had risen to 50% of baseline, suggesting the drivers showed some degree of habituation to the speed advisory system, or the drivers simply failed to comply.

Differentiating between habituation and non-compliance can be difficult; however, the latter may be more common for speed and eco-driving advisories, rather than lane departure and collision warning systems as the possible consequences of ignoring these warnings are quite different. For example, in a study of a collision warning system, increasing the false alarm rate did not lead drivers to dismiss the warning to real events (Maltz and Shinar 2004). Drivers did sometimes brake unnecessarily as a reaction to false alarms, but the consequences of such reactions are likely not as negative as the consequence of ignoring a true collision warning alert. Maltz and Shinar (2007) went on to test whether the collision warning was still effective when other distractions were present, on the grounds that driver inattention was a key contributor to rear-end collisions. The researchers reported that participants using the collision warning system performed better than without, but accuracy of the system did not lead to better performance. In fact, participants using systems that were more reliable performed worse than in the conditions where there was little reliability. The authors suggested that this finding could be interpreted as the participants becoming over-reliant on the system.

1.3 Prevalence and use of IVIS

The rapid pace of technological change and the ability of drivers to download a range of in-vehicle driver information apps on their smartphones make it difficult to estimate the prevalence of IVIS in cars, either overseas or in New Zealand. There are, however, a number of studies examining the impact of legislative changes restricting the use of nomadic devices (including mobile phones), which provide some insights into the prevalence of use. In New Zealand in 2009 the government introduced legislation banning the use of hand-held mobile phones while driving. Despite the ban, a roadside survey in 2012 in Wellington found 1.87% of drivers using hand-held phones at traffic lights and 1.34% in moving traffic (Wilson et al 2013). A larger survey of 37,000 drivers conducted across New Zealand reported similar rates; 1.3% of drivers surveyed had a phone held to their head and 2% were probably texting. Texting was more common when stationary (4.4%) than in moving vehicles (1.3%) (Ministry of Transport 2013).

A more extensive survey of nomadic device use across 27 EU states (Jamson 2013) found that personal navigation devices were reported as being the most frequently used device: 50% of the sample reported using them occasionally and 20% to 30% reported using them often. Between 20% and 30% of drivers reported using a mobile phone (hand held or hands free) occasionally or rarely. The use of portable music players and portable TV/DVD players was generally low, with 60% reporting they never used them. Annual mileage predicted use of navigation devices and mobile phones, with those driving farther reporting greater use. Age also predicted mobile phone use; middle-aged drivers (25–49 years) were more likely to report using a phone when driving compared with older drivers. In terms of illegal or high-risk behaviours, 10% to 30% of drivers reported entering destination information into a navigation device in a moving vehicle and 10% reported sending texts. Drivers rated mobile phones and TV/DVDs as being most distracting and reported that the effects of using these devices would be greater for other drivers rather than themselves. Together these studies suggest that use of various types of devices while driving is relatively common.

As noted earlier, there has been an exponential increase in the number and types of apps that are now available for use on a smart phone while driving, and an increasing number of these have been designed to improve driver safety (eg collision warning and speed advisory systems) rather than distract the driver. Given the low cost, wide accessibility and potential safety benefits of these systems, we may need to find ways to encourage drivers to use these apps on an ongoing basis and in a safe way, rather than legislate against their use.

In this context, Botzer et al (2017) conducted a field study of a collision warning smartphone application, designed to alert the driver to an imminent collision with a lead vehicle. Twenty-six drivers used the collision warning system for all their trips for between one and two weeks. The system appeared to increase driver safety as shown by improved responses to the warnings and a decrease in the number of warnings over time. Interestingly there was no evidence that drivers habituated to the warnings, in fact the opposite appeared to be the case, with drivers' responses to the warnings becoming stronger over time. The participants were provided with ongoing access to the app once the data collection was complete; however, only 16% (n = 4) of the drivers were using the app a week later, highlighting the need to either incentivise drivers to use such systems and to ensure that drivers find them acceptable.

User acceptance is also important with speed advisory and speed restriction systems such as ISA systems, which either advise the driver on the safe speed, or warn or intervene when the driver is exceeding the legal or safe limits of speed (Carsten 2012; Várhelyi 2002). Jamson (2006) found that a voluntary ISA system decreased propensity to speed (simulator and instrumented car), but the effect was mostly confined to lower speed limits. Drivers engaged ISA for approximately half of the time, and used it more on high-speed limit roads. In low-speed limit zones drivers intentionally deactivated ISA in order to speed. In the on-road trials, when driving on a low-speed rural road drivers reported a need to keep up with traffic and disengaged ISA. In addition, drivers who reported enjoying speeding were less likely to use the ISA, a finding replicated in a long-term field-study by Lai et al (2010), indicating that drivers who most needed it were least likely to use it.

Interestingly, it has been reported that although in practice drivers may find ISAs 'irritating' and turn them off, they will nonetheless rate the systems as 'useful' and enhancing safety (Várhelyi et al 2015). Comte (2000) found that ISA systems increased drivers' ratings of feeling under time pressure and frustrated, but the systems were generally rated as useful, particularly when the driver could elect when to engage the system. The main challenge is to encourage drivers to use them.

In summary, there is a growing number of IVIS and mobile phone apps available to drivers. Some are unrelated to the driving task (eg music/radio), others are designed to assist the driver (eg for navigation and route selection), or improve driver safety (eg collision warning and speed advisory systems). Regardless of the purpose, engagement in a secondary task while driving has the potential to distract the driver, increasing the probability of a crash. The purpose of the current study was to provide a description of key operating principles and recommendations about drivers' use of IVIS, smartphone applications and nomadic devices and their likely effects on driver performance. To achieve this we conducted two studies: the first examined the effects of an ISA (designed as a mobile phone app) on the driving performance of 123 participants in the University of Waikato driving simulator and addressed the following aims:

1 To assess how drivers' reactions to road and traffic situations are affected by the potential distraction produced by different display modes associated with in-vehicle applications.

2 To measure how driving performance changes in response to the information provided by in-vehicle applications and the different display modes (eg compliance with the information presented).

3 To test how the effects of in-vehicle applications change with repeated exposure (eg habituation and desensitisation).

The second study, an online questionnaire completed by 1,017 New Zealand drivers, examined the prevalence and frequency of drivers' use of IVIS and other in-vehicle apps and systems, addressing the following aim:

> *To identify the range of in-vehicle applications and information systems currently used by drivers, the prevalence and frequency of their use and drivers' attitudes towards them.*

2 The effects of an ISA on driving performance

2.1 Method

2.1.1 Participants

One hundred and forty four participants with a full New Zealand driver licence were recruited for the study via community noticeboards and electronically via university communication channels. Of these, 123 individuals completed the study (62 males, 61 females) with a mean age of 34.46 years (*SD* = 13.04, range 18–64 years) (data from the other participants was discarded due to equipment failure or simulator sickness). In terms of ethnicity, 76 participants identified as New Zealand European, 18 as Māori, 1 as Cook Island Māori, 5 as Chinese, 4 as Indian, 12 as Other (eg Japanese) and 23 as Other European (participants were able to select all that applied, hence the total exceeded 123). Participants reported having their driver licence for an average period of 16.64 years (*SD* = 13.10, range 1–49 years) and drove on average 252.20 km per week (*SD* = 678.46, range 5–7,000km). In terms of driving history, 15 participants reported being involved in a crash during the past year when they were the driver; of these 11 reported being involved in one crash, three reported being in two crashes and one person reported being in three.

When asked about their use of technology while driving, 107 participants (87%) reported using a mobile phone when driving. They were most frequently used for navigation (n = 82, 66.7%) followed by phone calls (n = 57, 46.3%), music (n = 56, 45.5%), texts (n = 32, 23%) and social media (n = 4, 3.3%). Only one participant reported having been pulled over by the police for using a mobile phone while driving. In terms of other technology, 54 (43.9%) participants had access to a manufacturer installed in-vehicle information system. The system was most commonly used for entertainment (n = 30, 24.4%), followed by monitoring fuel efficiency (n = 18, 14.6%), navigation (n = 15, 12.2%), parking assistance (n = 14, 11.4%), lane departure warnings and collision avoidance (n = 4, 3.3% for each).

Of the participants completing the study, 104 were assigned to a main simulator only group and the remaining 19 were assigned to a group whose eye movements were tracked while they completed the simulated driving task (participants in this group had to be able to drive without glasses). A comparison of the demographic characteristics between those in the simulator only group and the eye tracking group revealed the latter group were significantly younger (eye tracking mean age = 27.53 years, *SD* = 6.32 simulator only = 35.52 years, *SD* = 13.49; $F(1,111) = 5.01$, $p=.03$) and had less licensed driving experience (eye tracking mean = 9.26 years, *SD* = 6.74; simulator only = 17.99 years, *SD* = 13.54; $F(1,121) = 7.52$, $p=.007$) compared with those in the simulator only group. There were no significant differences between the groups in relation to average weekly distance driven (eye tracking mean = 175.95 km, *SD* = 170.05; simulator only 266.26 km, *SD* = 734.62; $F(1,120) = 0.28$, $p=.60$) or the proportion of males and females in each group ($X^2 = 0.05$, $p > .05$).

Table 2.1 Demographic characteristics of the participants in the simulator only group

	Active audio visual (n = 22)	Active visual (n = 22)	Passive audio visual (n = 21)	Passive visual (n = 21)	Control (n = 18)	Test of difference
Age in years (mean, *SD*)	34.09 (11.98)	35.00 (15.11)	32.38 (12.98)	42.67 (14.64)	32.08 (8.08)	$F(4, 93) = 2.11$, $p = .09$
Male (n, %)	11 (50)	11 (50)	10 (47.6)	11 (52.4)	9 (50)	$X^2 = 0.09$, $p = .9$
Years licensed driver	14.91 (12.14)	16.73 (15.14)	14.90 (12.67)	25.57 (13.91)	18.06 (11.47)	$F(4, 99) = 2.37$, $p = .06$
Km driven per week (mean, *SD*)	426.60 (1472.34)	368.64 (559.89)	135.48 (98.44)	194.29 (215.70)	176.76 (161.22)	$F(4, 98) = 0.64$, $p = .6$

Table 2.2 Demographic characteristics of the participants in the eye tracking group

	Active audio visual (n = 6)	Passive audio visual (n = 6)	Control (n = 7)	Test of difference
Age in years (mean, *SD*)	30.33 (7.10)	26.00 (5.70)	25.25 (5.74)	$F(2, 12) = 1.00$, $p > .05$
Male (n, %)	3 (50)	3 (50)	2 (28.6)	$X^2 = 3.72^a$, $p > .05$
Years licensed driver	9.17 (6.24)	6.00 (5.73)	12.14 (7.52)	$F(2,16) = 1.40$, $p > .05$
Km driven per week (mean, *SD*)	150.00 (174.24)	143.83 (181.30)	225.70 (171.65)	$F(2,16) = 0.45$, $p > .05$

[a]Fisher's exact test – cell counts less than 5

Participants in the simulator only group were pseudo randomly allocated (balanced for gender) to one of five conditions related to the display mode of the ISA; active audio visual (n = 22), active visual (n = 22), passive audio visual (n = 21), passive visual (n = 21) or control (n = 18). Those in the eye tracking group were allocated to one of three ISA conditions; active audio visual, passive audio visual or control (further details about each condition can be found in section 2.1.2.3).

The demographic details of participants in each of the experimental conditions for simulator only and eye tracking groups can be found in tables 2.1 and 2.2 respectively. As can be seen, there were no statistically significant demographic differences across the conditions for participants for the simulator only study, or the eye tracking study.

Ethical approval for the recruitment and test protocols was received from the School of Psychology Research and Ethics Committee at the University of Waikato (#17:41). Each of the participants received a $20 gift voucher for taking part.

2.1.2 Apparatus and materials

2.1.2.1 Driving simulator

Participants completed the driving task in the Applied Cognitive/Transport Research Group driving simulator consisting of a complete automobile (2010 Toyota Prius plug-in) positioned in front of three angled projection surfaces (see figure 2.1). As described in Charlton and Starkey (2016), the centre projection surface was located 2.32 m in front of the driver's eye position with two peripheral surfaces connected to the central surface at 52 degree angles. The entire projection surface was angled back away from the driver at 4.3 degrees (from the bottom to the top of the projection surface) and produced a 178.2 degree (horizontal) by 33.7 degree (vertical) forward view of the simulated roadway from the driver's position. The image projected on the central surface measured 2.6 m wide by 1.47 m high (at a resolution of 1,920 by 1,200 pixels) and each of the two peripheral images measured approximately 2.88 m by 2.15 m (at resolutions of 1,024 by 768 pixels). In addition, two colour LCDs with an active area of 12.065 cm by 7.493 cm each at a resolution of 640 by 480 pixels were mounted at the centre rear-view mirror and driver's wing mirror positions to provide views looking behind the driver's vehicle. Cameras were mounted behind the passenger seat and on the dashboard of the vehicle to record other aspects of the participants' behaviour during the experimental sessions. The projected images and vehicle model were updated at a minimum rate of 100 frames per second. The steering wheel provided tactile feedback to simulate the forces produced when steering the vehicle. Four speakers located inside the car and a sub-woofer underneath the car presented realistic engine and road noises as appropriate. The simulation software recorded the participant's speed, lane position and control actions automatically throughout the simulation scenario. For the eye tracking group, four small infra-red LEDS were placed on the outside of the car windscreen to facilitate calibration and analysis of their eye movements.

Figure 2.1 The Applied Cognitive/Transport Research Group driving simulator

2.1.2.2 Eye tracking

Tobii Pro Glasses 2 were used to monitor eye movements whilst participants completed the drive. The Tobii Pro Glasses are a wearable eye tracker (with a sample rate of 100 Hz), fitted with a high-definition scene camera (82 degree horizontal, 52 degree vertical field of view with 1,920 x 1,080 resolution at 25 frames per second), a microphone, binocular eye tracking sensors (field of view > 160 degrees horizontally, 70 degrees vertically), infra-red illuminators and accelerometer and gyroscope sensors. The glasses were connected via a HDMI cable to a pocket size recording unit which contains the batteries and stores the recorded data on a secure digital (SD) card. The eye tracker was controlled wirelessly and secured with a head strap to minimise slippage, prior to calibration. Participants were then seated in the car and completed the drive.

Gaze data were analysed with Tobii Pro Lab 1.58. Fixations were detected using IV-T algorithm with preset parameters from the Tobii Pro Lab I-VT (Attention). The fixation detection used a liberal 100 degree velocity threshold so head movements and pursuit movements were not misclassified as glances. Velocity was calculated with a 20 m window. The raw data was first run through a moving median filter with a three-sample window to reduce noise. Fixations were required to be at least 60 m long and adjacent fixations within 75 m and 0.5 degrees of visual angle were merged. The frequency and duration of the fixations to the ISA and the in-vehicle speedometer were calculated.

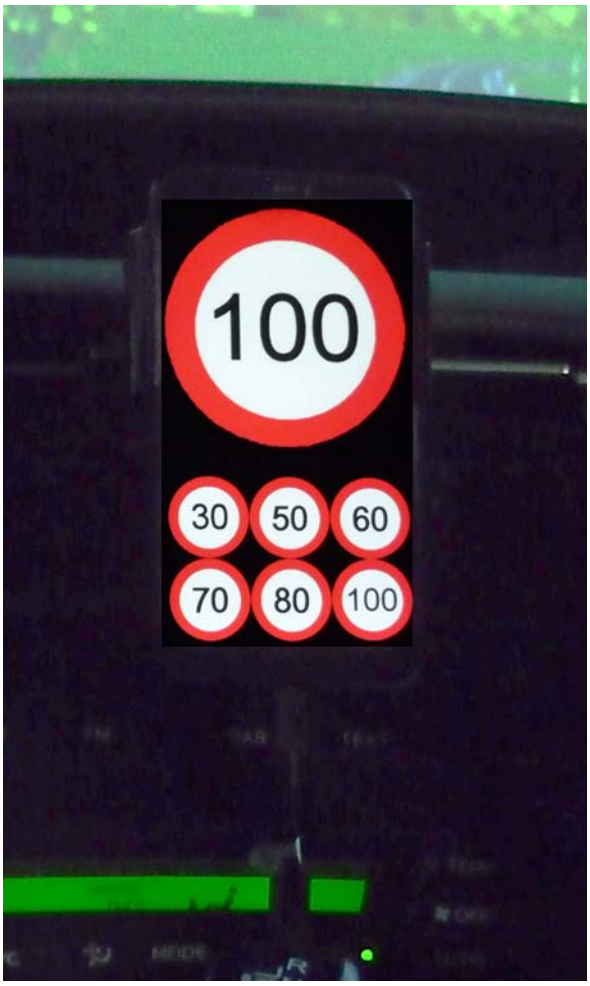
2.1.2.3 Intelligent speed assistance system

The intelligent speed assistance software (ISA) was displayed on a Microsoft Lumia 640 XL Smartphone with a display size of 2.7 inches, resolution of 1,280 x 720 and pixel density of 259 pixels per inch. The smartphone was mounted on the centre console 12 cm to the left of the steering wheel. Visually, the display was located 10.6 degrees below, and 29.3 degrees to the left of the driver's forward line of sight (figure 2.2).

The software, developed specifically for this project, was designed to alert the driver when they exceeded the posted speed limit. Start-up of the ISA was signalled by a short welcome tone when the driver reached the end of the baseline section of the road. After this the display showed a large rondel in the centre of the screen, showing the current speed limit. Smaller rondels displaying available speed warning choices (30, 50, 60, 70, 80 and 100) (matching the posted speed limits in New Zealand) were shown at the bottom of the screen (figure 2.3). The ISA was designed to provide two types of alert (visual only or auditory and visual) and operate in two modes (active or passive). This resulted in four experimental conditions; active visual; active audio visual, passive visual and passive audio visual, plus a control group where the ISA remained off with a blank screen throughout the drive.

Figure 2.2 The location of the smartphone in the car

Figure 2.3 The ISA display



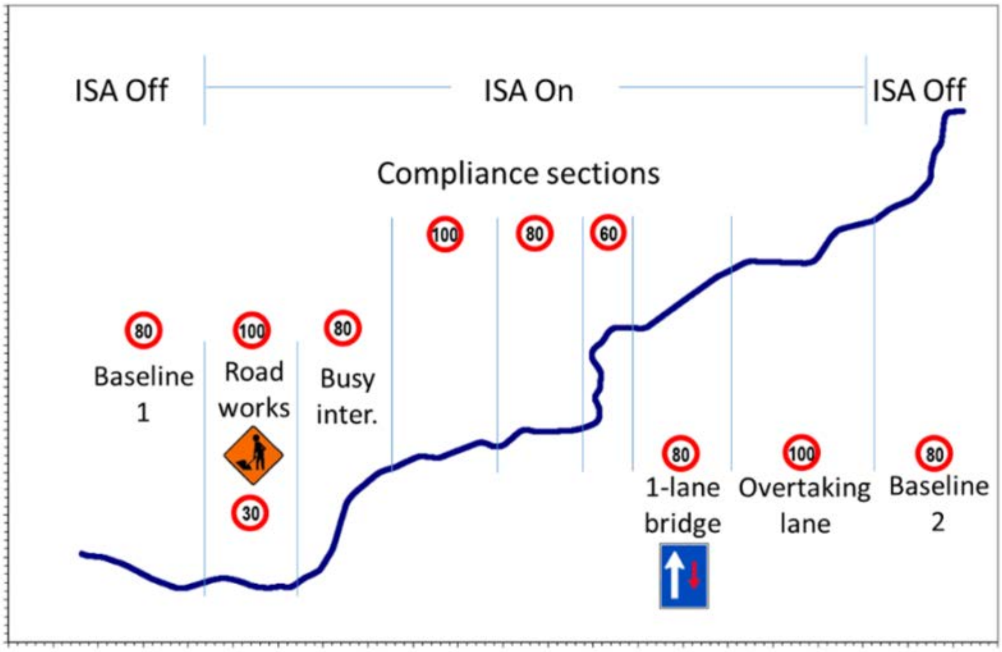
Speeding (defined as exceeding the speed limit by 4 km/h or more for at least three seconds) was accompanied by the main speed rondel flashing on/off (each state 0.5 second) until the participant reduced their speed to within 4 km/h of the speed limit. For the audio visual conditions the flashing rondel was accompanied by a beep, synchronised with the flashing, until speeding stopped.

In the passive modes (visual and audio visual), the ISA display automatically updated to show the new speed limit seven seconds after entering a new speed zone. In the active modes, the participants were told to select the new speed limit from the selection of small rondels at the bottom of the screen when they entered a new speed zone (as indicated by speed limit signs at the left and right edge of the road). Successful selection of the new speed was confirmed by a beep and the new speed was displayed in the large rondel. If the driver entered a new speed zone and failed to select a new speed, the ISA updated automatically as in the passive mode (seven seconds after entering the new speed zone). In all conditions, the ISA automatically switched off (indicated by a short 'shutting down' tone) for the final section of the drive (2.8 km from the end).

2.1.2.4 Simulation scenario

The simulation scenarios used for this study were based on a 26.4 km-long section of rural road containing a combination of straights and gentle horizontal and vertical curves (figure 2.4). The road geometry was an accurate representation of a rural two-lane state highway in New Zealand and was based on the surveyed three-dimensional road geometry of the highway. Lane widths were based on road survey data obtained from the road controlling authority, and road markings were consistent with Transport Agency guidelines. The road contained 26 intersections, and at seven of the intersections stationary cars were positioned to enter the road. It took approximately 20 minutes to complete the drive at the posted speed limits. Oncoming traffic (76 cars and trucks) was included to represent a traffic density of approximately 1,500–2,000 vehicles per day.

Figure 2.4 A map of the 26.4 km simulated road used for the simulated drive

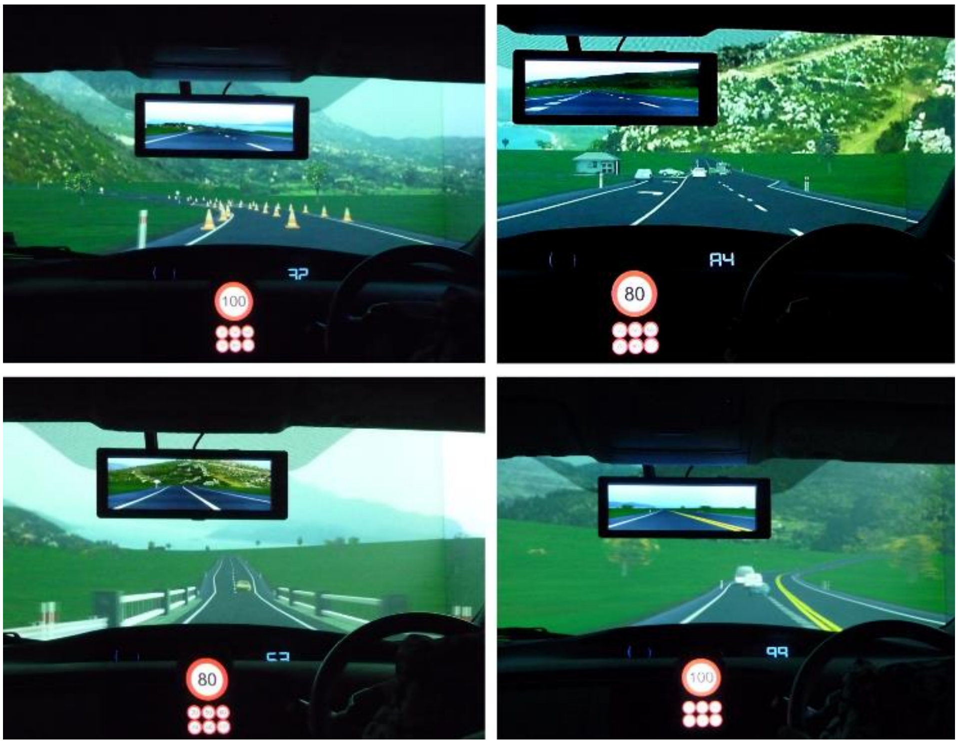


The drive consisted of two 3 km baseline sections at the beginning and end of the drive, four sections containing hazards (roadworks, busy intersection, one-lane bridge and an overtaking lane) and three speed compliance zones (no hazards and 100 km/h, 80 km/h and 60 km/h speed limits).

The road was divided into nine approximately equal sections with different posted speed limits (60 km/h, 80 km/h and 100 km/h). The first and last sections were designated as baseline conditions and were driven with the IVIS turned off. The mid-section of the drive contained three 'speed compliance zones' depicting standard New Zealand rural roads, with minimal hazards and posted speed limits of 100 km/h, 80 km/h and 60 km/h (figure 2.4).

During four of the sections the participants experienced common driving hazards: reduced speed at roadworks, a busy intersection, a single lane bridge and an overtaking lane (figure 2.5). Approaching the first hazard, drivers passed a roadworks warning sign, a temporary speed decrease sign (from 100 km/h to 30 km/h) and drove between cones over a section of gravel on the road. At the next hazard location, 2.21 km later, the driver followed two cars (in an 80 km/h zone) as they approached an intersection with an entry road at the left. Beginning 150 m before the intersection, the leading car applied the brakes, signalled a left turn and over the next five seconds moved into a left-turn lane and slowed. The car immediately ahead maintained its speed and headed through the intersection. At the intersection a stationary car on the left was waiting to pull out, and an oncoming truck moved into a right-turn bay in the centre of the road to wait to turn across traffic at the side road. The third hazard was a one-lane bridge signposted with priority for the participants' direction of travel. As the participants approached the bridge an oncoming car could be seen approaching the bridge from the other direction. The oncoming car slowed and then stopped to allow the participant to cross the bridge. For the final hazard, participants encountered a slow truck (78 km/h) being followed by a van and then a car, all travelling uphill. A sign on the left advised there was an overtaking lane 400 m ahead. At the start of the overtaking lane (1 km in length) the truck remained in the left-hand lane and the car and van overtook the truck at 84 km/h. After passing the truck, the van then moved to the left ahead of the truck and the leading car accelerated to 120 km/h. Depending on the participants' following distance, they could overtake the truck and the van (but not the car) without exceeding the speed limit.

Figure 2.5 Scenes from the simulation scenario: the roadworks (top left), busy intersection (top right), one lane bridge (bottom left) and overtaking lane (bottom right)



2.1.2.5 Post- drive questionnaire

After the drive, participants were asked to complete a study specific online questionnaire (appendix A). The first section asked them to rate the ISA system using a 5-point semantic differential scale (-2 to +2) with nine items (useful – useless, pleasant – unpleasant, bad - good, nice – annoying, effective – superfluous, irritating – likeable, assisting – worthless, undesirable – desirable, raising alertness – sleep-inducing) with items 3, 6 and 8 reverse scored (Van der Laan et al 1997). Items were coded so a higher score reflected a more positive evaluation. Two scores were calculated: a usefulness score based on the average of items 1, 3, 5, 7 and 9, and a satisfying score based on the average of items 2, 4, 6 and 8. For both subscales the scores could range from -2 to +2.

The subsequent section asked about the driver's ability to suppress potentially distracting stimuli while driving using the susceptibility to involuntary distraction subscale of the Susceptibility to Driver Distraction Questionnaire (Feng et al 2014). The subscale comprised eight items, describing events that can happen when driving (eg your phone is ringing, you are listening to music). Participants are asked to respond to the statement 'While driving, you find it distracting when...' by rating each event from 1 (strongly disagree) to 5 (strongly agree), or to indicate if it never happens. An average distractibility score was calculated for each participant (excluding 'never happen' responses), with higher scores indicating a greater susceptibility to distraction (possible range 1–5).

Participants were asked to report their current use of various devices while driving including a GPS-based navigation device, mobile phone, or a manufacturer installed information system. They were also asked to rate the likely safety benefits (from 1 definitely not safer, to 7 definitely safer) of four speed-related systems (from Warner et al 2010): 1) an information system that shows the current speed limit, 2) an advisory system that shows the current speed limit and warns the driver with a flashing light and sound if the speed limit is exceeded, 3) a supportive system that shows the current speed limit and exerts a counter-force on the accelerator at speeds over the speed limit (it is harder to push the accelerator if you are going over the speed limit) and 4) an intervening system that shows the current speed limit and interacts with the vehicle to prevent you exceeding the speed limit. After rating the likely safety benefits they were asked to indicate whether they would like each system installed in their car (from 1 definitely not, to 7 definitely). The final section asked for demographic and driving history information, including length of licensure, distance driven each week, crash history, mobile phone while driving offences, age and ethnicity.

2.1.3 Procedure

When participants arrived at the laboratory the purpose of the study was explained to them, any questions they had about the study were answered and they provided written informed consent. Participants were then seated in the car and were given standardised instructions on how to operate the driving simulator; to use the accelerator to speed up, the brake to slow down, and to gently steer to match the speed they would usually drive on these types of roads in their own car. Participants were also told that on the practice road the speed limit would be 80 km/h or 100 km/h and that the car was equipped with a speed advisory system that would remind them if they were speeding. Participants in the two visual-only groups were told that speeding would be indicated by the display flashing on the smart phone in the centre console; those in the audio visual conditions were told that speeding would be indicated by a warning sound being played from the smart phone as well as the flashing display. Participants then completed a 3 km practice drive. After this, all participants completed another practice drive to accustom themselves with the ISA. Those in the active conditions were asked to update the warning speed on the ISA when they reached a new speed limit, whereas participants in the passive conditions were told that the speed limit on the ISA would automatically change a few seconds after they entered a new speed zone.

After the second practice drive, participants were instructed to drive the simulated road just as they would in their own car, obeying the road rules and if they wanted to overtake a slow vehicle they could, if they would usually do so in their own car. The participants were also reminded to use the speed advisory (once it turned on) as they had in the practice drive and told that twice during the drive they would be asked (over the intercom) to rate the level of cognitive workload and driving difficulty they were experiencing on a scale of 1 to 7 where 1 was easy, no difficulty at all, to 7 indicating extremely difficult or unsafe (as in Charlton and Starkey 2011). During the 26.4 km drive, in the 80 km/h speed compliance zone and in the final 2.8 km baseline section, the participants were asked to verbally report how mentally demanding the last minute of driving was on the 7-point scale.

At the end of the drive, participants completed the post-drive questionnaire online (hosted on Qualtrics website), they were thanked, given a $20 gift voucher, and asked if they had any questions or comments. (Note: The procedure for the participants in the eye tracking group was identical other than the eye-tracker calibration prior to commencement of the practice drive).

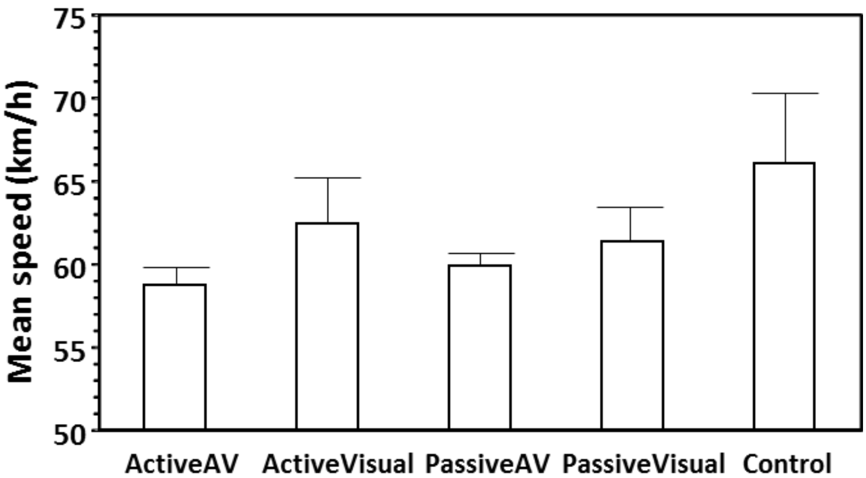
2.2 Results

2.2.1 Speed compliance

The participants' speed compliance was calculated by averaging their speeds over 110 m sections of road in which there were no intersections or significant horizontal or vertical curves. Each of these sections was drawn from the second half of the two baseline and three compliance sections (see figure 2.4).

A mixed-design analysis of variance (Anova) was used to compare the five road sections (within-subject) across the five participant groups (4 ISA conditions and control). The Anova indicated a significant difference in mean speeds across the five road sections [$F(4,396) = 763.16$, $p < .001$, $\eta_p^2 = .885$], but no overall difference in the five groups [$F(4,99) = 1.89$, $p = .118$, $\eta_p^2 = .071$], or interaction between road sections and groups [$F(16,396) = 1.47$, $p = .106$, $\eta_p^2 = .056$]. Closer inspection of the significant difference in road sections revealed that, as expected, speeds were lowest for the 60 km/h road section, but as shown in figure 2.6, not all of the participants were equally compliant in that section of road [one-way Anova $F(4,99) = 3.65$, $p = .008$, $\eta_p^2 = .128$]. Post hoc comparisons (Bonferroni adjusted) showed that participants in the control group drove significantly faster than participants in the active AV group (p = .002) and passive AV group (p = .014), but were not reliably different than the passive visual (p = .083) or active visual groups (p = .241). None of the other ISA conditions differed reliably from one another in the mean speeds observed.

Figure 2.6 Participants' average speeds in the compliance 60 (60 km/h) road section. Vertical lines indicate 95% confidence intervals

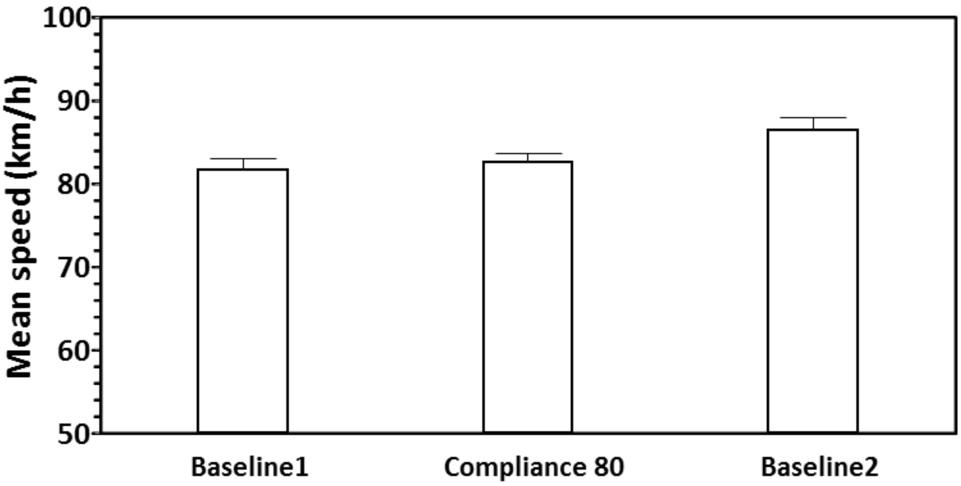


Across these five road sections there was also a reliable difference in speeds between men and women participants [$F(1,94) = 9.51$, $p = .003$, $\eta_p^2 = .092$], as men drove an average of 1.99 km/h faster than the women. There was not, however, any gender by ISA group interaction [$F(4,94) = 0.62$, $p = .647$, $\eta_p^2 = .026$]. Adding participant age to the model as a covariate did not change the outcome and did not account for a significant proportion of the variance [$F(1,87) = 0.23$, $p = .633$, $\eta_p^2 = .003$].

Over the course of the drive the participants tended to increase their speeds, particularly during the final section, baseline 2. This can best be seen by comparing the first baseline section to the middle compliance section and final baseline section, all with an 80 km/h speed limit. In this comparison, there was no significant difference between the five groups [$F(4,94) = 0.99$, $p = .415$, $\eta_p^2 = .041$], nor any significant difference by participant gender [$F(1,94) = 3.34$, $p = .071$, $\eta_p^2 = .034$], but there was a significant within-subject difference between the three road sections [$F(2,188) = 28.50$, $p < .001$, η_p^2 =

.233]. This comparison is shown in figure 2.7 and as can be seen, the source of this difference came from a 3.9 km/h elevation in mean speed during the final baseline road section [Bonferroni-adjusted *p*s < .001].

Figure 2.7 Participants' average speeds in the three 80 km/h road sections. Vertical lines indicate 95% confidence intervals



We also conducted analyses to determine if the variability of participants' speeds differed across the groups (ie were speeds compressed because they drove closer to the speed limit?). There was no significant difference between the five experimental groups (four ISA conditions and control) in their speed variability during the 110 m sections drawn from each speed section of the road (three compliance sections and two baseline sections) as indicated by a mixed-design Anova [$F(4,99) = 1.51$, $p = .207$, $\eta_p^2 = .057$]. The analysis also failed to indicate any interaction between road sections and groups [$F(16,396) = .706$, $p = .788$, $\eta_p^2 = .028$], but did show that the speed variability differed significantly across the road sections $F(4,396) = 25.60$, $p < .001$, $\eta_p^2 = .205$], with baseline1 and the 100 km/h having the lowest mean standard deviation of speeds (*M* = 0.58 and *M* = 0.75 respectively), and the highest variability associated with the 80 km/h compliance zone (*M* = 1.45). [Note: The data for these analyses is based on distance travelled and participants would travel through the 110 m speed compliance zone more quickly when travelling at higher speeds, limiting their opportunity to vary their speed].

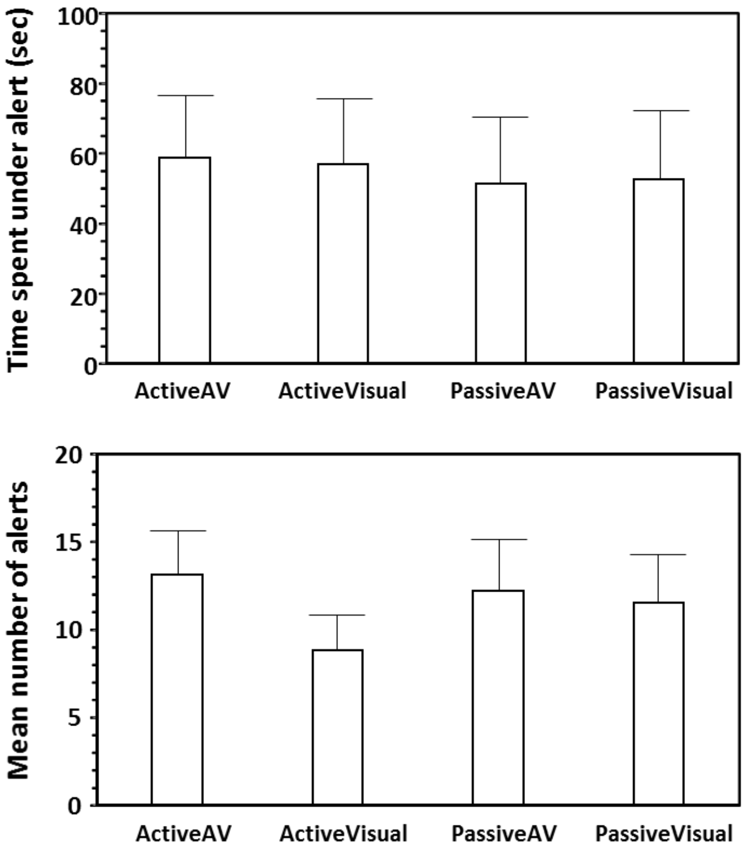
The percent of the 110 m road sections where the participants in each of the five groups exceeded the speed limit during each of the five road sections was also calculated and compared with a mixed-design Anova. This analysis did not detect any differences between the five groups [$F(4,99) = 0.51$, $p = .731$, $\eta_p^2 = .020$] or interaction between road sections and groups [$F(16,396) = 1.38$, $p = .146$, $\eta_p^2 = .053$]. The analysis did, however, indicate a difference between the five road sections [$F(4,396) = 41.35$, $p < .001$, $\eta_p^2 = .295$], with all participants exceeding the speed limit most often during baseline 1 and baseline 2 (84.42% and 94.39% of the 110 m sections respectively), and the lowest amount of speeding in the 100 km/h section (34.24%) followed by the 60 km/h zone (52.83%). Bonferroni-adjusted comparisons indicated that the two baseline sections (when the ISA was inactive) were higher than all the compliance sections except the 80 km/h zone (*p*s < .001) and that the 100 km/h and 60 km/h zones were significantly different from each other, and all other road sections (*p*s < .007).

Another way to assess the participants' compliance with the ISA was to consider the amount of time the participants spent driving with the device alerting them to excessive speed. As shown in figure 2.8, across the seven road sections when the ISA was on there was no reliable difference between the four ISA groups

[$F(3, 82) = 0.11$, $p = .952$, $\eta_p^2 = .004$]. Similarly, there were no reliable differences between the groups in the number of alerts they received from the ISA [$F(3, 82) = 1.33$, $p = .269$, $\eta_p^2 = .047$], as shown in the lower panel of figure 2.8.

Finally, although the participants showed generally good compliance with regard to the ISA system, their compliance did not significantly impede their overtaking behaviour during the eighth section of the drive. In the overtaking lane scenario, participants could overtake either one vehicle (a truck), two (the truck and a van that had just overtaken the truck), three vehicles (including a car that had overtaken the other two), or no vehicles. For each of the five groups the modal number of vehicles overtaken was one. A chi square analysis did not reveal any differences in the numbers of vehicles overtaken across the groups [$X^2(12) = 11.01$, $p = .529$], and similarly, a one-way Anova did not reveal any significant difference between the groups' mean number of vehicles overtaken [$F(4, 98) = 1.31$, $p = .273$, $\eta_p^2 = .051$].

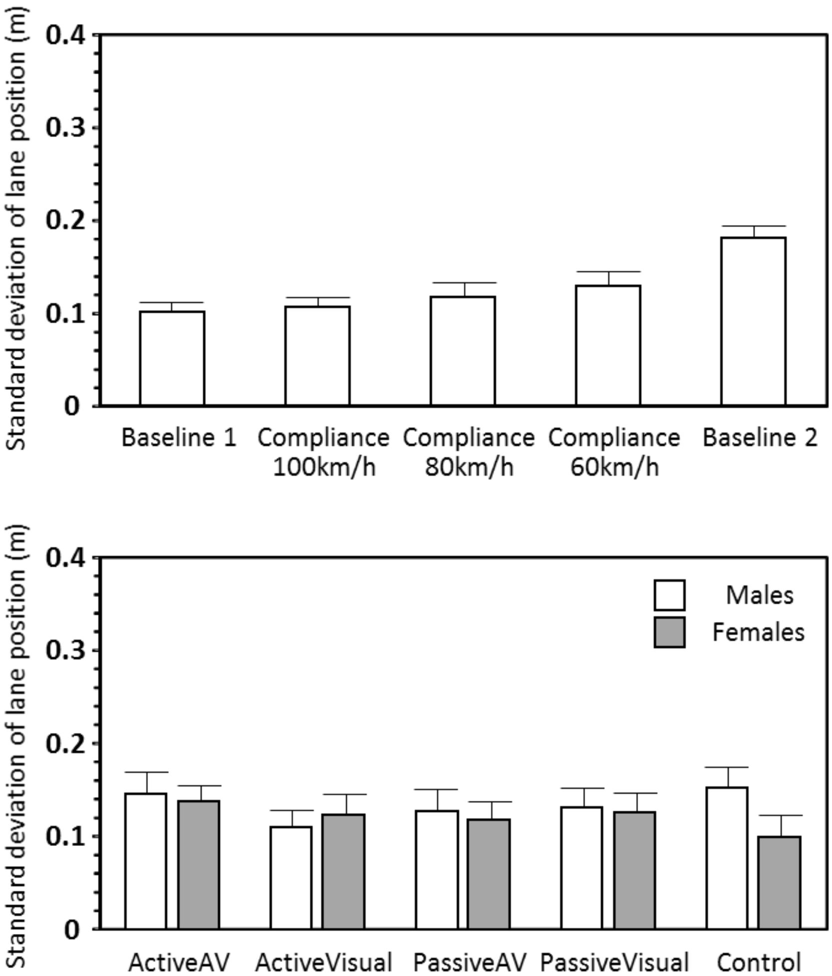
Figure 2.8 Participants' average time spend under ISA alert (top) and average number of alerts received (bottom) across the seven road sections. Vertical lines indicate 95% confidence intervals



2.2.2 Distraction

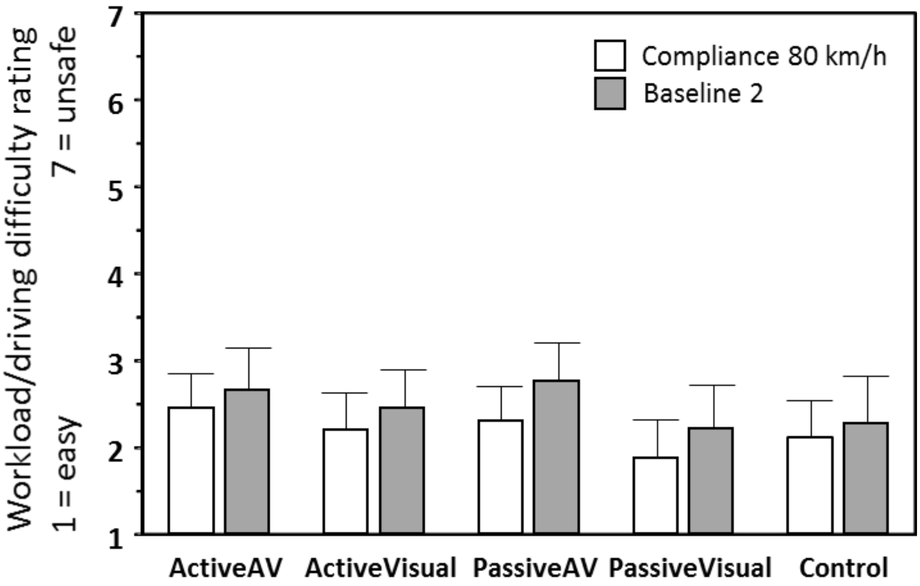
The level of distraction associated with the participants' use of the ISA was assessed in multiple ways. First, the participants' steering variability was calculated as the standard deviation of their distance from the centre of their lane over the same 110 m road sections described earlier for speed compliance. SDLP is widely considered to be an important indicator of task focus, fatigue and impairment due to distraction, alcohol and drugs (Engström et al 2005). A mixed design Anova identified a significant difference in the participants' SDLP across the five road sections [$F(4, 376) = 21.95$, $p = .952$, $\eta_p^2 = .189$]. Post hoc pairwise comparisons indicated this difference was the result of an increase in SDLP during baseline 2 ($p < .001$), as shown in the top panel of figure 2.9 (possibly due to increased levels of fatigue). The analysis did not identify any reliable difference between the five groups (four ISA groups & control group) [$F(4, 94) = 1.59$, $p = .181$, $\eta_p^2 = .064$] or difference due to participant gender [$F(1, 94) = 3.19$, $p = .077$, $\eta_p^2 = .033$], but it did reveal a small group by gender interaction [$F(4, 94) = 2.43$, $p = .053$, $\eta_p^2 = .094$]. This interaction was the result of a lower SDLP recorded for females in the control group and a higher than average SDLP recorded for the males in that group. The lower panel of figure 2.9 shows this relationship.

Figure 2.9 The participants' lane position variability (SDLP) across the three compliance and two baseline sections of road (top panel) and overall throughout the drive for the men and women participants in each of the five groups (lower panel). Vertical lines represent 95% confidence intervals



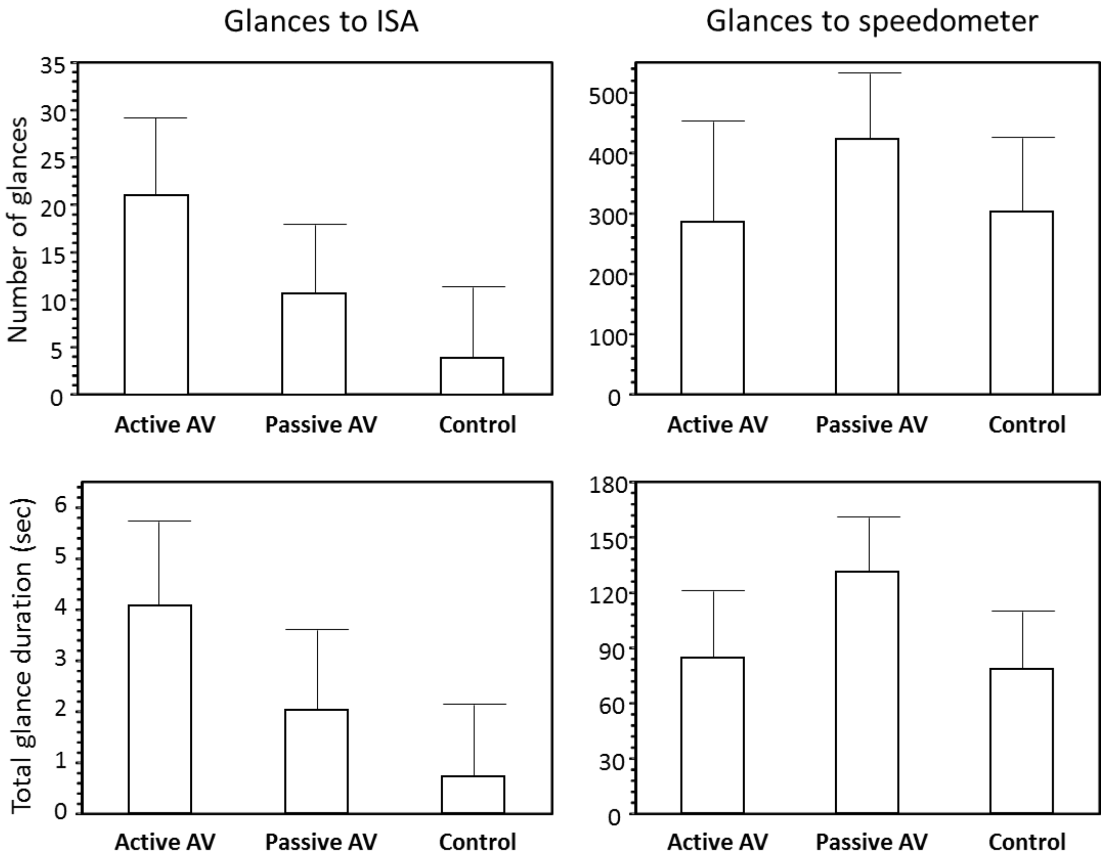
A second method of determining whether the ISA device produced additional mental load or distraction was by examining the cognitive workload/driving demand ratings collected during the 80 km/h speed compliance and baseline 2 road sections. A mixed design Anova did not reveal any difference between the five groups (four ISA groups & control group) [$F(4, 99) = 1.11$, $p = .357$, $\eta_p^2 = .043$], but did indicate a difference between the two times the workload rating was collected so the second occasion, baseline 2, was associated with slightly higher cognitive workload ratings [$F(1, 99) = 8.51$, $p = .004$, $\eta_p^2 = .079$]. The workload ratings from each road section for each of the five groups is shown in figure 2.10.

Figure 2.10 The participants' ratings of their cognitive workload or driving difficulty during the midpoint of the drive and during the final road section. Vertical lines show 95% confidence intervals



Examination of the participants' eye movements provides another means of assessing the visual load associated with the ISA device. In this case, we examined how frequently the 17 eye tracking participants looked at the ISA while driving, and for how long (the eye movement data of two participants was not usable). Figure 2.11 shows these measures (glance frequency and total gaze duration) for the ISA and, for comparison, the speedometer. As can be seen in the figure, the active group looked at the ISA more frequently and longer than the other two groups. A one-way Anova indicated the difference in the groups' mean glance frequency was significant [$F(2, 14) = 4.65$, $p = .028$, $\eta_p^2 = .399$], and the same for total glance duration [$F(2, 14) = 4.04$, $p = .041$, $\eta_p^2 = .366$]. Post hoc pairwise comparisons (Bonferroni adjusted) indicated that the active group glanced at the ISA more frequently ($p = .009$) and for longer (p = .013) than the control group but not reliably more ($p = .088$) or longer ($p = .106$) than the passive group. Differences between the groups' mean number and duration of glances at the speedometer did not meet the Bonferroni threshold, with the exception of the passive group's mean total duration of glances at the speedometer which was consistently higher than the control group ($p = .055$).

Figure 2.11 Participants' mean number of glances (top row) and mean total glance duration (bottom row) at the ISA device (left column) and speedometer (right column). Vertical lines represent 95% confidence intervals



The mean duration of individual glances at the ISA device was 155.64 msec (*SD* = 86.31), significantly shorter than the 281.95 msec (*SD* = 48.24) mean duration of participants' glances at the speedometer [$F(1, 14) = 23.77$, $p < .001$, $\eta_p^2 = .629$]. At least part of this of course was the contribution of the control group, whose glances towards their inactive ISA device averaged 122.68 msec (*SD* = 101.53). On the whole, drives glanced at the ISA rather infrequently and briefly, and for a total of 0.20% of the drive, much less than they looked at their speedometer, a total of 8.87 percent of the drive.

2.2.3 Post-drive questionnaire

After the drive, participants who used the ISA device (ie not the control group participants) were asked to provide ratings of the ISA they used (table 2.1). In general, participants rated the ISA positively (scores could range from -2 to +2) on each of the items, with the highest ratings for the likeable–irritating and useful–useless. In terms of summary scores, the usefulness ratings were higher than the satisfaction ratings. To examine participants' views on the different modes and alerts, provided by the app, further analyses with 2 (mode: active or passive) x 2 (alert: audio visual or visual only) between groups ANOVAs were conducted. Analyses revealed that participants in the passive conditions rated the device as marginally more useful than those in the active modes, $F(1, 82) = 3.63$, $p = .06$, $\eta_p^2 = .04$. There was no statistically significant interaction or main effect of alert for ratings of usefulness. In terms of satisfaction, participants in the visual only groups rated the app as more satisfying compared with those in the audio visual groups $F(1,82) = 5.39$, $p = 0.023$, $\eta_p^2 = .06$. Neither the main effect of mode nor the interaction effect was statistically significant.

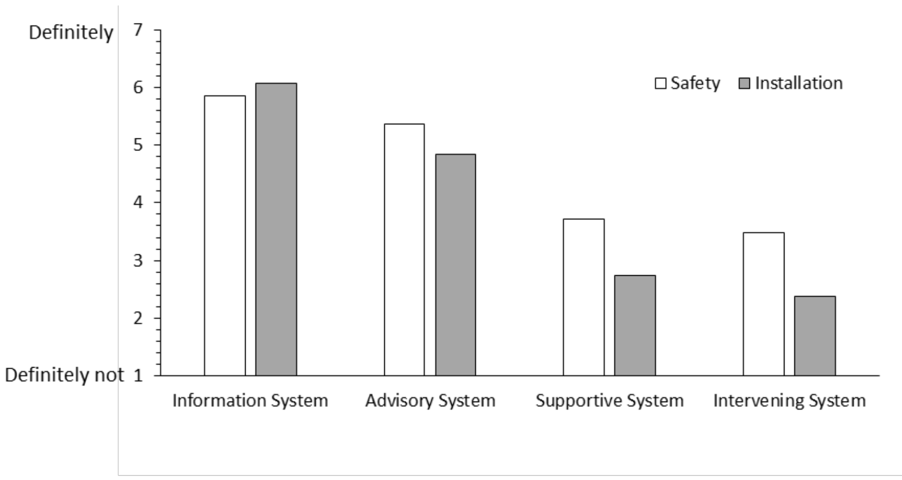
To determine if participants found the auditory alerts annoying, we carried out additional analyses on two of the items (nice–annoying and likeable–irritating). There were no statistically significant differences across the conditions for either of these items (all p's >.05), suggesting that participants did not find the auditory alerts particularly irritating.

Table 2.1 The participants' average ratings of the ISA across the four conditions. Data is presented as mean (SD) for the simulator only group. Higher scores indicate more positive ratings

Item	Active audio visual (n=22)	Active visual (n = 22)	Passive audio visual (n=21)	Passive visual (n=21)
Useful–useless	1.00 (0.82)	0.73 (1.23)	1.14 (0.91)	1.24 (0.89)
Pleasant–unpleasant	0.32 (0.89)	0.50 (0.86)	0.38 (1.28)	0.86 (1.01)
Good–bad	-0.10 (1.02)	0.41 (0.85)	-0.10 (1.34)	0.71 (1.06)
Nice–annoying	0.86 (0.89)	0.73 (1.12)	1.24 (0.89)	0.91 (1.14)
Effective–superfluous	0.61 (0.68)	1.00 (1.07)	1.14 (0.73)	1.29 (0.85)
Likeable–irritating	1.00 (0.87)	1.27 (0.83)	1.43 (0.60)	1.20 (0.75)
Assisting–worthless	0.60 (0.91)	0.68 (0.99)	1.05 (0.97)	1.19 (0.81)
Desirable–undesirable	0.09 (1.06)	0.27 (0.83)	-0.10 (1.00)	0.62 (1.02)
Raising alertness–sleep inducing	0.41 (0.73)	0.63 (1.09)	0.62 (0.86)	1.00 (1.00)
Overall: usefulness	0.87 (0.66)	0.89 (0.84)	1.20 (0.60)	1.16 (0.77)
Overall: satisfying	0.18 (0.78)	0.46 (0.75)	0.50 (0.99)	0.80 (0.93)

Participants were also asked to rate the likely safety benefits (from 1 definitely not safer to 7 definitely safer) of four speed information systems (an information system, advisory system, supportive system and intervening system) and to indicate if they would like them installed in their car (from 1 definitely not to 7 definitely). As shown in figure 2.12 participants rated the information and advisory systems as most likely to improve safety and they were generally willing to have these types of systems installed in their cars. In contrast, participants thought the supportive and intervening systems would not improve safety and they were very unlikely to have them installed in their cars.

Figure 2.12 Ratings of the safety benefits and likelihood of installation (from 1 definitely not to 7 definitely) of four speed information systems



2.3 Summary

The ISA device resulted in good compliance in that participants' speed choices were congruent with the posted speed limits along the simulated road. This was particularly evident during the 60 km/h road segment, where the control group displayed significantly higher speeds than the groups with the ISA device. No significant differences between the four versions of the ISA were observed, either in terms of speed compliance or the number of speeding alerts received from the device. The participants' speed compliance did not impair their ability to overtake vehicles, and there was no difference in the number of vehicles overtaken across the groups.

Across the entire simulated drive the number of glances at the ISA were relatively few, and although there were more glances at the device in the active version of the system, the absolute number for the entire drive was still very low (*M* = 21.0, *SD* = 4.17). The total time spent looking at the device was also very low (0.40% of the time for the active version), and the average glance duration of 190.24 msec for this group did not approach the acknowledged upper limit for in-vehicle device distraction of two seconds (NHTSA 2012). Glances at the ISA device were significantly fewer and shorter than at the vehicle speedometer, which had an overall average glance duration of 281.96 msec. An argument could be made that the active version of the ISA device reduced the amount of looking required at the vehicle speedometer, but given the relatively small sample size of eye-tracking participants this was not a conclusive or reliable difference.

In short, the visual requirements of the ISA device, even in the active mode, were not substantial and this was reflected in the participants' lane keeping performance, with SDLP levels that were equivalent across the ISA modes, and with the control group. No adverse reactions to any of the hazards were observed for any of the participants (with the exception of one participant in the active AV group who had a loss of control crash after overtaking the truck in the overtaking lane), as one might have expected if the ISA posed an increased risk due to distraction.

3 The prevalence and frequency of IVIS use

In order to identify the range of IVIS applications and information systems currently used by drivers a survey of New Zealand drivers was undertaken. The goal of the survey was to identify the types of IVIS systems commonly used by drivers in New Zealand, the prevalence and frequency of their use, drivers' attitudes regarding the safety of IVIS use, any negative effects of using them on their own driving and any strategies or techniques drivers use to minimise these effects.

3.1 Method

3.1.1 Participants

A digital data collection company (Research Now) was contracted to recruit and administer the survey to drivers throughout New Zealand. A series of mass invitations to take part in the study were sent to 22,992 Research Now panel members. Of these, 1,610 volunteered to take part, and 1,506 met the four eligibility criteria (permanent New Zealand resident, good understanding of English, over 16 years of age and had driven a car in the last month) and began the survey. Incomplete responses were removed leaving a final sample of 1,017.

Table 3.1 summarises the demographic characteristics of the sample. As can be seen in the table, similar numbers of male and female respondents were recruited across each of four age groups (16–24 years, 25–44 years, 45–64 years and 65 years and over) to ensure the findings were representative of various segments of the driving population in New Zealand. Respondents' ages ranged from 16–85 years, and the majority of respondents identified as being New Zealand European. Those in the younger age groups identified with a more diverse range of ethnic groups compared with the oldest group of respondents. While the majority of respondents lived in regions with major New Zealand cities (eg Auckland, Wellington), those from smaller towns and rural communities (eg Hawke's Bay, Taranaki, Southland) also completed the questionnaire, thus representing the views and experiences of those exposed to a wide range of New Zealand roads and road conditions.

The driving experience of the sample overall and for each of the age groups is presented in table 3.2. Most respondents held a full licence and as expected, the older groups had been licensed drivers for longer than the younger age groups. The distance driven by respondents in a typical week varied greatly, with the youngest and oldest drivers reporting driving shorter distances compared with those aged 25–44 or 45–64 years. In terms of crashes in the last 12 months, the greatest proportion of drivers involved in a crash were aged 25–44 years, closely followed by those aged 16–24 years. The fewest crashes were reported by those in the 45–64 year aged group. Those aged 25–44 were most likely to have been pulled over by the police for using a mobile phone, followed by those in the youngest age group.

Table 3.1 Demographic characteristics of the sample completing the online questionnaire

	Age group				Overall
	16–24 years (n = 227)	**25–44 years (n = 260)**	**45–64 years (n = 261)**	**65 + years (n = 269)**	**N = 1017**
Male (n, %)	111 (48.90)	127 (48.85)	131 (50.19)	139 (51.67)	508 (49.95)
Mean age (SD)	20.74 (2.70)	34.71 6.21)	55.20 (5.85)	71.45 (4.64)	45.57 (19.85)
Ethnicity (n, %)[(a)]					
New Zealand European	176 (77.53)	156 (60.00)	200 (76.63)	245 (91.08)	777 (76.40)
Māori	20 (8.81)	17 (6.54)	7 (2.68)	2 (0.74)	46 (4.52)
Pacific Island	10 (4.41)	7 (2.69)	1 (0.38)	0 (0)	18 (1.77)
Chinese	20 (8.81)	19 (7.31)	7 (2.68)	0 (0)	46 (4.52)
Indian	9 (3.96)	22 (8.46)	7 (2.68)	3 (1.11)	41 (4.00)
Other	24 (10.57	58 (22.31)	45 (17.24)	20 (7.43)	144 (14.16)
Location					
Northland	3 (1.32)	0 (0)	6 (2.30)	14 (5.20)	23 (2.26)
Auckland	75 (33.04)	113 (43.46)	53 (20.31)	50 (18.59)	291 (28.61)
Waikato	16 (7.05)	18 (6.92)	19 (7.28)	25 (9.29)	78 (7.70)
Bay of Plenty	9 (3.96)	16 (6.15)	19 (7.28)	19 (7.06)	63 (6.20)
Gisborne	0 (0)	2 (0.77)	1 (0.38)	1 0.37)	4 (0.40)
Hawkes Bay	6 (2.64)	2 (0.77)	23 (8.81)	21 (7.81)	52 (5.13)
Taranaki	6 (2.64)	4 (1.54)	8 (3.07)	4 (1.49)	22 (2.16)
Wanganui	0 (0)	4 (1.53)	10 (3.83)	7 (2.60)	21 (2.06)
Manawatu	19 (8.37)	13 (5.00)	17 (6.51)	8 (2.98)	57 (5.60)
Wairarapa	1 (0.44)	2 (0.77)	12 (4.60)	10 (3.72)	25 (2.46)
Wellington	35 (15.41)	40 (15.38)	26 (9.96)	41 (15.24)	142 (13.96)
Nelson Bays	5 (2.20)	6 (2.31)	5 (1.92)	1 (0.37)	17 (1.67)
Marlborough	1 (0.44)	0 (0)	5 (1.92)	8 (2.97)	14 (1.38)
West Coast	1 (0.44)	0 (0)	3 (1.15)	0 (0)	4 (0.40)
Canterbury	23 (10.13)	23 (8.84)	31 (11.88)	29 (10.78)	106 (10.42)
Timaru-Omaru	0 (0)	2 (0.77)	1 (0.38)	4 (1.49)	7 (0.69)
Otago	26 (11.45)	10 (3.84)	16 (11.88)	17 (10.78)	69 (6.78)
Southland	1 (0.44)	5 (1.92)	5 (1.92)	9 (3.35)	20 (1.97)
Income					
<$20,000	36 (15.86)	9 (3.46)	16 (6.13)	5 (1.86)	66 (6.48)
21–40,000	33 (14.53)	19 (7.31)	22 (8.43)	91 (33.83)	165 (16.22)
41–60,000	30 (13.22)	30 (11.54)	32 (12.26)	75 (27.88)	167 (16.42)
61–80,000	27 (11.89)	33 (12.69)	40 (15.32)	42 (15.61)	142 (13.96)
81–100,000	29 (12.78)	33 (12.69)	47 (18.01)	22 (8.17)	131 (12.88)
$100,000+	42 (18.50)	114 (43.84)	86 (32.95)	17 (6.32)	259 (15.63)
Refused	30 (13.22)	21 (8.08)	17 (6.51)	17 (6.32)	85 (8.36)

[(a)] Note that the totals may exceed 100% as respondents could select more than one ethnicity.

Table 3.2 Driving history of the sample completing the online questionnaire

	Age group				Overall
	16–24 years (n = 227)	**25–44 years (n = 260)**	**45–64 years (n = 261)**	**65 + years (n = 269)**	**N = 1017**
Licence type (n, %)					
Learners	55 (24.2)	5 (1.92)	0 (0)	0 (0)	60 (5.90)
Restricted	62 (27.31)	29 (11.15)	5 (1.92)	2 (0.74)	98 (9.64)
Full	108 (47.58)	224 (85.15)	256 (98.08)	267 (99.26)	855 (84.07)
Years licensed (mean, SD, range)	3.78 (2.61) 1–10	14.61 (7.76) 1–30	36.16 (8.76 3–50	47.51 (7.02) 2–50	26.38 (18.47) 1–50
Km driven per week (mean, SD, range)	111.08 (172.73) 0–1000	187.50 (213.65) 0–2000	245.82 (342.76) 6–3000	158.40 (151.99) 0–1000	178.20 (238.86) 0–3000
Crash in the last year (n, %, range)	31 (13.66) 1–9	37 (14.23) 1–9	12 (4.60) 1–4	21 (7.81) 1–2	101 (9.93)
Pulled over for using phone (n, %)	10 (4.4)	18 (6.9)	5 (1.9)	0	33 (3.2)

3.1.2 Procedure and questionnaire design

The study received approval (#17:25) from the School of Psychology Research and Ethics Committee at the University of Waikato. As described above, a digital data collection company, Research Now, notified their panel members by email of the opportunity to participate in the survey. The email contained a web link which potential respondents could use to access the survey. Upon activating the web link the potential respondents were provided with a short overview of the purpose of the research, followed by a request to provide consent and complete the eligibility questions. Eligible respondents were directed to the remaining questions in the survey, while ineligible respondents received a message that explained they were not eligible for the current study, and thanked them for their interest. On completion of the survey respondents were given the opportunity to provide their email address if they wanted to receive a summary of the research findings, and they were thanked for taking part.

The questionnaire was designed to investigate drivers' use of IVIS applications such as navigation devices and advisory systems (appendix B). A set of 14 behaviours and events (table 3.3) linked to the use of IVIS and related systems was developed based on existing literature (eg Jamson 2013), and supplemented by advice from the broader research team and the project steering group. We also developed a list of possible effects that the behaviour or event could produce (eg speed up or slow down unintentionally) and countermeasures that could be used by drivers to minimise these effects (eg I pull over and stop) (table 3.3).

After providing consent, and completing the eligibility questions, respondents were asked to rate how each of the 14 IVIS behaviours and events would affect an average person's driving (from -3 very impaired to +3 very improved). Following that, they were asked how frequently they personally engaged in each of the 14 IVIS behaviours (or how often each event occurred) while they were driving. The response options to this question included: not applicable, never, seldom, sometimes, often, or usually. For any response other than not applicable or never, the respondents were asked what effects this had on their driving by selecting from a list of outcomes (table 3.3), selecting as many as applied to them. The outcomes question was then followed by a question asking what, if anything, they did to minimise the effects, again by selecting as many as applied from the list of countermeasures (table 3.3). In each case, respondents had the option to provide details of ‘other’ effects the behaviour or event had on their driving and ‘other’ ways they minimised these effects. They were then asked to rate how much each behaviour or event altered their ability to drive safely, from -3 (very impaired) to +3 (very improved).

The next section of the questionnaire asked respondents about their ability to suppress reactions to potentially distracting stimuli while driving using the susceptibility to involuntary distraction subscale of the *Susceptibility to driver distraction questionnaire* (Feng et al 2014). The subscale comprised eight items, describing events that can happen when driving (eg your phone is ringing, you are listening to music). Respondents were asked to respond to the statement ‘While driving, you find it distracting when…’ by rating each event from 1 (strongly disagree) to 5 (strongly agree), or to indicate if it never happened. An average distractibility score was calculated for each respondent (excluding ‘never happen’ responses), with higher scores indicating a greater susceptibility to distraction (possible range 1–5).

Respondents were then asked whether they had ever used a speed advisory system, and if so which type (a system that informs them of the speed limit, a system that warns them if they go over the speed limit or the limit they have set manually, or one that limits the speed of their vehicle). They were also asked to rate the likely safety benefits (from 1 definitely not safer, to 7 definitely safer) of four speed-related systems (from Warner et al 2010); 1) an information system that shows the current speed limit, 2) an advisory system that shows the current speed limit and warns the driver with a flashing light and sound if the speed limit is exceeded, 3) a supportive system that shows the current speed limit and exerts a counter-force on the accelerator at speeds over the speed limit (it is harder to push the accelerator if you are going over the speed limit) and; 4) an intervening system that shows the current speed limit and interacts with the vehicle to prevent you exceeding the speed limit. After rating the likely safety benefits they were asked to indicate whether they would like each system installed in their car (from 1 definitely not, to 7 definitely). The final section of the questionnaire asked for demographic and driving history information, including length of licensure, distance driven each week, crash history, mobile phone offences, age and ethnicity.

3.1.3 Analyses

First, to provide an overall indication of IVIS prevalence, respondents’ responses to the questions about the frequency of each behaviour/event while driving were recoded to indicate whether or not the event occurred. We also calculated the total number of activities that each respondent engaged in and the frequency of engagement in each behaviour/event. All subsequent analyses focused on the drivers who reported engaging in or experiencing each event (therefore the sample sizes for each behaviour or event differ).

The next part of the analysis examined the drivers’ perceptions of the effects of engaging in the target activity. More detailed analyses (chi square) were conducted to examine the characteristics (ie age and gender) of the respondents reporting that each activity/experience had no effect on their driving. After this, we explored the techniques drivers used to minimise any negative effects of engaging in each behaviour or event, and explored the characteristics (age and gender) of the drivers who reported making no changes to their driving. To explore the overall effect of each behaviour or event on driving safety, a series of 2 x 4 Anovas were conducted to determine the influence of age and gender on the ratings. A series of repeated-measures Anovas were then conducted to compare the ratings of how much an average driver’s safety would be affected by engaging in each behaviour or event to the ratings of how much the driver’s own safety would be affected. The final section of the analyses focuses on the respondents’ ratings of the likely safety benefits and likelihood of installation of the four speed information systems.

Table 3.3 The behaviours and events, possible outcomes and countermeasures used in the online questionnaire

Behaviour or event	Outcome	Countermeasures
A conversation on a hands-free mobile phone	I slow down or speed up unintentionally	I pull over and stop
Texting/sending emails/posting on social media	My lane keeping becomes unstable (I weave in my lane)	I slow down intentionally to maintain safety
Browsing/reading social media	It impairs my ability to scan the road ahead (eg for curves, intersections)	I concentrate more on driving to ensure I stay in my lane
Use the internet via your smartphone	I drive too close to the car in front	I pay special attention so that I can monitor traffic effectively
Take pictures with your phone or camera when driving	My reaction to changing traffic situations is slower or delayed	I turn it off if it becomes distracting or annoying
Listening to music with the car audio system	Sometimes I don't notice pedestrians and cyclists	I only do this in slow moving traffic (eg in a traffic queue)
Selecting music/play lists via your smartphone	Sometimes I have to stop suddenly at intersections or crossings	I use it on a straight and clear road
Entering your destination on a navigation system/app	Sometimes I don't notice traffic signs or signals	I ask my passenger to use it instead of me
Looking at the map on a navigation system/app	None of the above	None of the above
Listening to directions from a navigation system/app	Other	Other
Using a manufacturer installed display (eg to select a radio station	None	None
Getting a warning from a lane departure warning system		
Getting a warning from a speed advisory system		
Getting a warning from a curve or dangerous intersection warning system		

3.2 Results

3.2.1 Prevalence

Figure 3.1 shows the percentage of drivers who reported carrying out each activity or experiencing the event while driving. As shown in the figure, almost all drivers (96%) listened to music with the car audio system. The next most common was listening to directions from a navigation system (64%), followed by using a manufacturer installed display (56%) and looking at a map on a navigation system (54%). Fewer than half of the respondents reported talking on a hands-free phone (47%), approximately a third (31%) entered a destination on a navigation system, and fewer than a quarter of the respondents reported sending texts, emails or using social media. Few respondents read social media (8%), used the internet via their phone when driving (15%) or experienced lane departure (10%) or curve warnings (9%). As can be seen in the figure, rates for men and women were similar for the majority of the activities/events;

however, there was a significant association between gender and reporting having received warnings from speed (X^2 (1) = 4.65, p =.031) and curve advisories (X^2 = 2.17, p = .023) with men more likely to have received warnings than women. The total number of IVIS behaviours and events reported were similar for men (M = 4.86, SD = 2.78, range = 0-14) and women (M = 4.81, SD = 0.11, range = 0-14). An independent samples t-test confirmed this difference was not statistically significant, t (1015) = 0.31, p = .76.

There was a small but statistically significant positive correlation between respondents' distractibility scores and the total number of behaviours/events they reported, r (1015) = .10, p = .001, indicating that those with higher distractibility scores engaged in a greater number of other behaviours or secondary activities while driving. There was no significant difference in the distractibility ratings between the male and female respondents (male M = 3.10, SD = 0.72; female M = 3.12, SD = 0.65; t(1015) = 0.39, p = 0.70).

Table 3.4 shows the prevalence of each IVIS behaviour or event across the four age groups. As can be seen in the table, respondents in each age group reported each event or behaviour. There were statistically significant associations between age group and the prevalence of each behaviour or event for almost all items (apart from lane departure warnings and curve/intersection warnings). Closer examination of the data revealed that the prevalence of listening to music using the in-vehicle audio, listening to directions, using the manufacturer installed display and experiencing speed advisory warnings increased with age. In contrast, selecting playlists on a phone, texting, emailing or using social media, taking pictures on a phone, using the internet on a phone, and reading social media tended to decrease with age. For the remaining behaviours (looking at a map on a navigation device, talking hands free on the phone, and entering a destination on a navigation system), prevalence was lowest in the youngest (16–24 years) and oldest age groups (> 65 years). The total activities reported by age group showed a decrease with age (16–24 years M = 5.30, SD = 2.97; 25–44 years M = 5.66, SD = 2.95; 45–64 years M = 4.61, SD = 1.98; >65 years M = 3.87, SD = 1.97). A one-way Anova confirmed this was statistically significant, [F(3, 1013) = 25.40, p <.001 η_p^2= .07]. Bonferroni corrected post-hoc tests indicated that the youngest group (16–24 years) and the 25–44 year group carried out significantly more activities compared with those over 45 years (all p's <.05. The oldest group (> 65 years) carried out significantly fewer activities compared with all other age groups (all p's <.01).

Figure 3.1 The percentage of male and female drivers reporting engaging in each activity or experiencing each event while driving

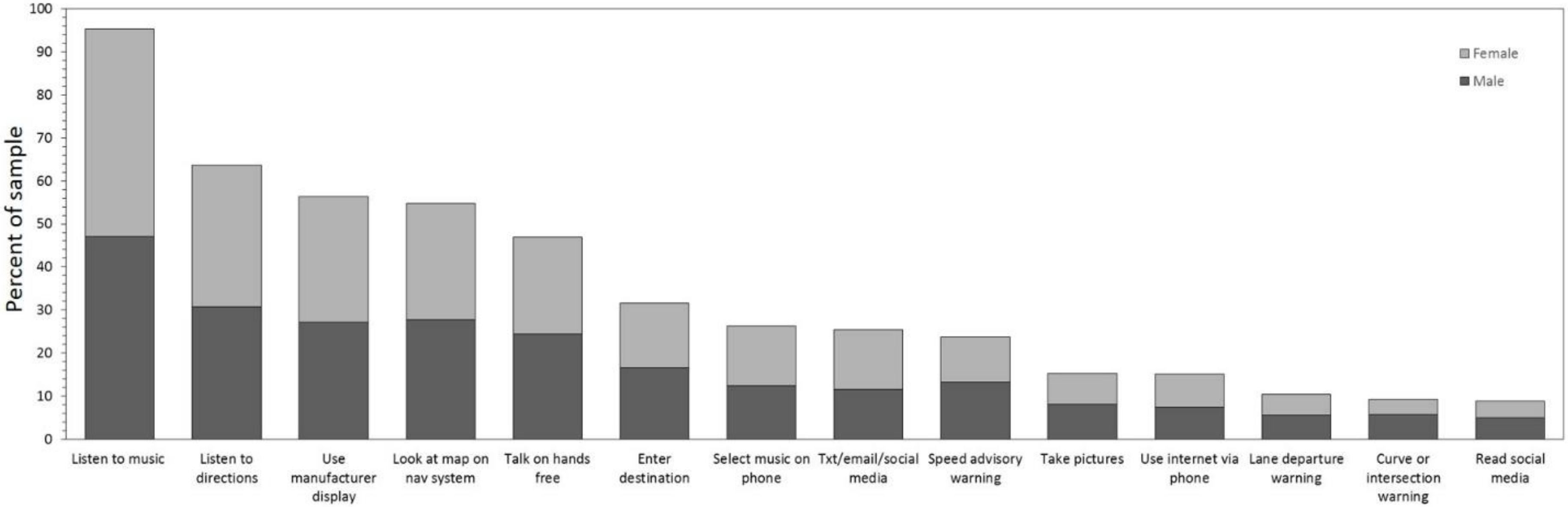


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Table 3.4 The number and percentage of the total sample engaging in each IVIS behaviour or event while driving for each age group

	16-24 years (n=227)		25-44 years (n=260)		45-64 years (n=261)		> 65 years (n=269)		Association (X^2, *df* = 3)	Total (n=1017)	
	n	%	n	%	n	%	n	%		n	%
Listen to music	208	20.5	244	24.0	258	25.4	260	25.6	16.8**	970	95.4
Listen to directions	121	11.9	171	16.8	180	17.7	176	17.3	14.6**	648	63.7
Use manufacturer display	109	10.7	136	13.4	161	15.8	167	16.4	14.7**	573	56.3
Look at map on GPS	116	11.4	174	17.1	148	14.6	120	11.8	28.4**	558	54.9
Talk on hands free	117	11.5	159	15.6	134	13.2	67	6.6	77.5**	477	46.9
Enter destination	82	8.1	115	11.3	71	7.00	54	5.3	40.2**	322	31.7
Select music on phone	122	12.0	94	9.2	35	3.4	17	1.7	178.8**	268	26.4
Text/email/social media	94	9.2	106	10.4	43	4.2	16	1.6	127.6**	259	25.5
Speed advisory warning	35	3.4	50	4.9	75	7.4	81	8.0	21.3**	241	23.7
Take pictures	53	5.2	60	5.9	22	2.2	21	2.1	44.6**	156	15.3
Use internet via phone	63	6.2	71	7.0	16	1.6	4	0.4	113.6**	154	15.4
Lane departure warning	16	1.6	28	2.8	34	3.3	28	2.8	4.7	106	10.4
Curve/intersection warning	27	2.7	23	2.3	19	1.9	26	2.6	3.1	95	9.3
Read social media	40	3.9	40	3.9	7	0.7	3	0.3	67.7**	90	8.9

** Significant association (X^2) between age and prevalence ($p < .001$).

3.2.2 Frequency of engagement in each IVIS behaviour or event

The next analyses focused on the frequency of the 14 behaviours/events for drivers who had access to the relevant device or equipment. As can be seen in table 3.5, listening to music via the in-vehicle audio system was the most common activity (carried out often or usually for 75% of respondents with an in-vehicle audio system). Listening to directions, using the manufacturer-installed display, looking at maps on a navigation system, and talking on a hands-free phone, were reported as occurring seldom, or sometimes, although interestingly fewer than 40% of drivers reported never engaging in these activities. For almost all the other IVIS activities (apart from receiving speed advisory warnings) at least 60% of the drivers reported never having engaged in the behaviour or experiencing the event even though they had the opportunity to do so (shown in the lower portion of table 3.5). For those that did engage in these IVIS activities, the majority of drivers indicated that they “seldom” did so.

The list of IVIS behaviours and events included those that are legal (eg talking on a hands-free phone), those that are illegal (eg texting), and those that are designed to improve driver safety, many of which are only available in new vehicles (eg lane departure warnings). The majority of respondents reported having access to a smart phone, and over 60% of drivers reporting talking on a hands-free phone while driving. By contrast, a much smaller proportion of drivers reported sending texts (26%), using the internet (16%) or accessing social media (9%) when driving (albeit this amount of drivers is high given their potential implications for safety). Fewer than half of the drivers in the sample reported having access to technology to improve driver safety such as speed advisory systems, lane departure warnings and curve or intersection warnings. Of those with access, over half (52%) had received speed advisory warnings (most commonly seldom or sometimes), and only a quarter had received warnings from lane departure or curve and intersection warning systems.

Table 3.5 The frequency of engagement in each IVIS behaviour or event (for those with access to the device/equipment). Data is presented as number and percentage of those with access

	Never		Seldom		Sometimes		Often		Usually		Total
	n	%	n	%	n	%	n	%	n	%	n
Listen to music	39	3.9	43	4.3	142	14.1	277	27.5	508	50.3	1009
Listen to directions	190	22.7	229	27.3	282	33.7	104	12.4	33	3.9	838
Use manufacturer display	295	34.0	194	22.4	210	24.2	82	9.4	87	10.0	868
Look at map on GPS	306	35.4	248	28.7	234	27.1	61	7.1	15	1.7	864
Talk on hands free	292	38.0	234	30.4	174	22.6	56	7.3	13	1.7	769
Enter destination	532	62.3	190	22.2	103	12.1	22	2.6	7	0.8	854
Select music on phone	667	71.3	127	13.6	97	10.4	30	3.2	14	1.5	935
Text/email/social media	735	73.9	172	17.3	65	6.5	15	1.5	7	0.7	994
Speed advisory warning	221	47.8	118	25.5	96	20.8	17	3.7	10	2.2	462
Take pictures	849	84.5	124	12.3	21	2.1	5	0.5	6	0.6	1005
Use internet via phone	791	83.7	111	11.7	32	3.4	5	0.5	6	0.6	945
Lane departure warning	332	75.8	59	13.5	31	7.1	11	2.5	5	1.1	438
Curve/intersection warning	259	73.2	48	13.6	31	8.8	10	2.8	6	1.7	354
Read social media	887	90.8	60	6.1	15	1.5	8	0.8	7	0.7	977

3.2.3 The effects of engaging in IVIS behaviours and events

Drivers who reported engaging in each behaviour (or experiencing each event) were asked to indicate how it affected their driving from a range of 10 options (see table 3.3), selecting as many options as applied to them. Initially data was pooled across all behaviours/events to provide an indication of the most frequently cited effects, and is summarised in figure 3.2. As shown in the figure, over 50% of the reported instances of various IVIS activities were judged by respondents to have no effect on their driving. The next most frequently reported effects of IVIS activities (approximately 20% of the reports) were slowed reactions to changing traffic situations, slowing down or speeding up unintentionally, and impairments in scanning the road ahead, while fewer than 10% of the effects reported were to adversely affect lane keeping, ability to notice traffic signals and signs leading to sudden stops at intersections or crossings, impaired ability to notice pedestrians and cyclists, and driving too close to the car in front. Only a small proportion of the effects reported (< 2%) were 'other' effects.

Table 3.6 provides a different look at the effects of IVIS activities by summarising the reported effects for each activity individually (for those respondents who reported engaging in each one). The majority of respondents indicated that listening to music and listening to navigation directions had no effect on their driving. A small proportion of respondents indicated that listening might slow their reaction to changing traffic situations and lead to unintentional changes in speed. 'Other' effects reported by drivers included music making them feel relaxed, more alert, distracting them, or leading to speeding; those listening to directions reported driving more slowly (a full list of comments can be found in appendix C). Activities rated as having the greatest effect on driving involved the use of a hand-held mobile phone (texting/sending emails, reading social media, using the internet and taking pictures). Slowed reaction to changing traffic was the most commonly identified effect, but respondents identified hand-held phone use as affecting driving behaviour in nearly every possible way (from the list provided). In contrast, having a conversation on a hands-free mobile was rated as having no effect by 40% of users, the remaining respondents most frequently indicated it would lead to slowed reactions to changing traffic, unintentional alterations in speed, impaired ability to scan the road ahead and failure to notice traffic signs of signals. The respondents noted that a conversation on a hands-free mobile was likely to decrease their concentration and distract them (appendix C).

Approximately a third of respondents using IVIS systems for navigation rated entering a destination and looking at a map on a navigation system or app, as having no effect on driving. The most frequently identified effects were slowed reactions to other traffic, unintentionally altering speed and poor scanning of the road ahead. In terms of other effects, respondents reported pulling over to enter details about the destination (rather than entering information while driving) and either slowing down or using spoken instructions when using a map on a navigation system or app.

Receiving warnings regarding speed, curves or lane position were reported to have no effect by approximately half of the respondents who used these types of systems. Around a third of users indicated that receiving a warning would lead them to alter their speed. 'Other' comments indicated that altering speed was intentional.

Given the possible negative consequences of driver distraction on safety, follow-up analyses were conducted to examine the characteristics (age and gender) of the drivers reporting that each behaviour or event had no effect on their driving to determine if this was related to driver experience. The proportion of drivers in each age group (table 3.7) reporting that they believed the activity had no effect was significantly different for listening to music via the car audio, the three activities relating to navigation, taking pictures and having a conversation on a hands-free phone. The proportion of those reporting no effect from listening to music, listening to directions, looking at a map and taking pictures increased with age (that is the youngest drivers were more likely to report that the behaviour or experience affected their driving). In contrast, the middle age groups had the highest proportion of users reporting no effects of a conversation on a hands-free phone (around 40%) and the lowest proportion of those rating entering a destination into a navigation system as having no effect.

We also compared the proportion of males and females rating each of the activities or experiences as having no effect. There were no significant associations between gender and ratings of no effect for all except one of the items. The proportion of men rating looking at a map on a navigation system as having no effect was significantly higher than the proportion of females providing the same rating (males 45.0%, females = 27.5%; (X^2 (1) = 18.46, p <.001).

Figure 3.2 Overall effects of engaging in the IVIS behaviours or events. Data is presented as a percentage of the total behaviours/events

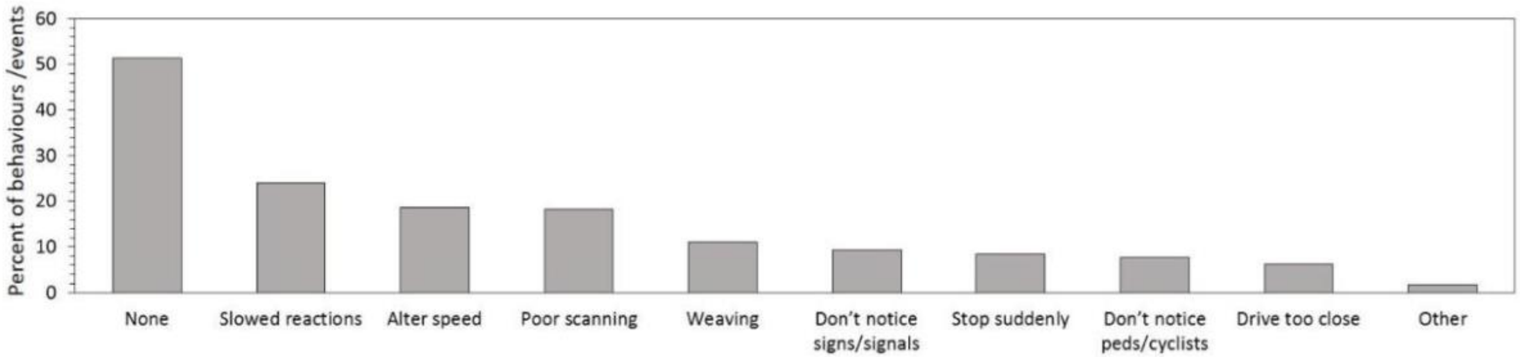


Table 3.6 The effects of engaging in each IVIS behaviour or event. Data is presented as a percentage of the total number of times the behaviour or event occurred

	Total (n)	None (%)	Slowed reaction (%)	Alter speed (%)	Poor scanning (%)	Weaving (%)	Don't notice signals (%)	Stop abruptly (%)	Don't notice peds/bikes (%)	Drive too close (%)	Other (%)
Listen to music	970	82.9	6.4	5.5	1.8	1.6	3.1	2.4	2.3	2.0	1.8
Listen to directions	648	75.8	11.7	7.4	4.8	3.4	5.4	4.3	2.9	1.7	2.0
Use manufacturer display	573	56.7	22.2	13.4	17.5	8.6	5.6	5.4	5.6	3.1	0.9
Look at map on GPS	558	36.4	34.2	20.3	27.8	12.7	11.1	9.0	8.8	6.6	1.6
Talk on hands free	477	39.0	35.8	27.3	17.0	8.6	13.4	8.6	10.3	6.3	1.5
Enter destination	322	34.2	38.2	24.8	31.4	19.9	14.0	13.7	12.4	9.6	1.6
Select music on phone	268	30.6	32.1	23.1	31.0	23.1	11.6	11.6	12.3	11.2	1.1
Text/email/social media	259	8.1	56.0	37.5	52.1	35.9	20.5	24.7	16.2	15.8	1.2
Speed advisory warning	241	56.4	5.4	29.5	4.6	2.9	3.3	3.3	2.1	3.3	5.4
Take pictures	156	17.9	34.6	29.5	42.3	23.1	19.2	17.3	16.7	14.1	1.3
Use internet via phone	154	15.6	47.4	35.1	35.1	25.3	20.1	18.2	18.8	18.8	3.2
Lane departure warning	106	54.7	16.0	22.6	12.3	11.3	4.7	6.6	7.5	5.7	0.9
Curve/intersection warning	95	47.4	8.4	32.6	10.5	6.3	4.2	7.4	8.4	5.3	4.2
Read social media	90	12.2	42.2	34.4	50.0	26.7	26.7	28.9	21.1	24.4	1.1

Table 3.7 The number and percentage of respondents in each age group engaging in each IVIS behaviour or event reporting that it had no effect on their driving

	16-24 years		25-44 years		45-64 years		> 65 years		Association (X^2, *df* = 3)	Total (n=1017)	
	n	%	n	%	n	%	n	%		n	%
Listen to music	154	74.0	192	78.7	224	86.8	234	90.0	26.60**	804	82.9
Listen to directions	83	68.6	124	72.5	136	75.6	148	84.1	11.02*	491	75.8
Use manufacturer display	56	51.4	72	52.9	93	57.8	104	62.3	4.23	325	56.7
Look at map on GPS	35	30.2	57	32.8	54	36.5	57	47.5	9.33*	203	36.4
Talk on hands free	30	25.6	69	43.4	53	39.6	34	20.7	13.97**	186	39.0
Enter destination	28	34.1	28	24.3	28	39.4	26	48.1	10.50*	110	34.2
Select music on phone	35	28.7	28	29.8	10	28.6	9	52.9	4.30	82	30.6
Text/email/social media	5	5.3	13	12.3	1	2.3	2	12.5	5.78	21	8.1
Speed advisory warning	16	45.7	25	50	46	61.3	49	60.5	3.75	136	56.4
Take pictures	5	9.4	11	18.3	3	13.6	9	42.9	11.74**	28	17.9
Use internet via phone	11	17.5	7	9.9	5	31.3	1	25.0	5.19	24	15.6
Lane departure warning	5	31.3	11	39.3	21	61.8	21	75	11.58	58	54.7
Curve/intersection warning	12	44.4	7	30.4	9	47.4	17	65.4	6.12	45	47.4
Read social media	6	15.0	4	10.0	1	14.3	0	0	0.9	11	12.2

3.2.4 Strategies to minimise the effects of IVIS use

Drivers were also asked to indicate how they mitigated any effects of the behaviours they engaged in or the events they experienced. Figure 3.3 presents the countermeasures reported across all behaviours and events. As shown in the figure, the most frequently reported countermeasures were to ask the passenger to carry out the activity (exceeding the use of no countermeasures). Other commonly reported strategies (>20%) were to slow down intentionally, concentrate more on driving to maintain lane position, pay special attention to monitor traffic effectively, and pull over and stop.

Table 3.8 presents the countermeasures associated with each activity or event. Unsurprisingly, listening to music was associated with the fewest reported countermeasures. Of those reported, the most common was to turn the music off. For activities involving a hand-held mobile, or interacting with a navigation device, the most commonly endorsed countermeasures were to ask the passenger to carry out the activity or use the device, to pull over and stop, or to use in slow traffic. Drivers indicated that they used a range of different countermeasures when having a conversation on a hands-free phone including asking their passenger to take the call, concentrating more, paying special attention to traffic and pulling over, suggesting they were aware of the possible negative effects on their driving.

Respondents also provided details of a number of other countermeasures they used (see appendix D for the complete list). For conversation on a hands-free phone, drivers indicated they would keep conversations short, by contrast, illegal use of a mobile (eg texting, social media) was conducted in slow or stopped traffic. Countermeasures to minimise the distractive effects of listening to music via the in-vehicle audio system mainly referred to lowering the volume. In terms of interacting with navigation systems, drivers reported entering the destination before they began their drive or when they were stopped. They also reported listening to directions, rather than looking at the device, and placing the device somewhere it could easily be seen. For manufacturer installed displays, drivers reported using the controls on the steering wheel, and selecting the radio station before commencing their journey.

As described in the previous section, we carried out additional descriptive analyses to examine the characteristics (age and gender) of the drivers reporting the use of no countermeasures for each IVIS behaviour or event. As shown in table 3.9, there were significant associations between age group and use of no countermeasures for listening to music, listening to directions and looking at a map on a navigation device. The middle age groups (25–44 and 45–64 years) reported proportionally less use of countermeasures when listening to music compared with the youngest and oldest age groups. Those aged 25–44 years were also less likely than the other age groups to take action to minimise the effects of listening to directions from a navigation device or when looking at a map on a navigation device.

In terms of gender differences, a greater proportion of males than females used no countermeasures when listening to music via the in-vehicle audio (males = 56.2%, females = 46.5%; [X^2 (1) = 5.66, p <.05]), when selecting a playlist on their phone (males = 16.7%, females = 7.7%, [X^2 (1) = 5.05, p <.05]) and when looking at a map on a navigation system (males = 19.5%, females = 9.4%, [X^2 (1) = 11.43, p <.01]).

Figure 3.3 Countermeasures used for all behaviours and events. Data is shown as the percentage of total number of occurrences of the behaviours and events

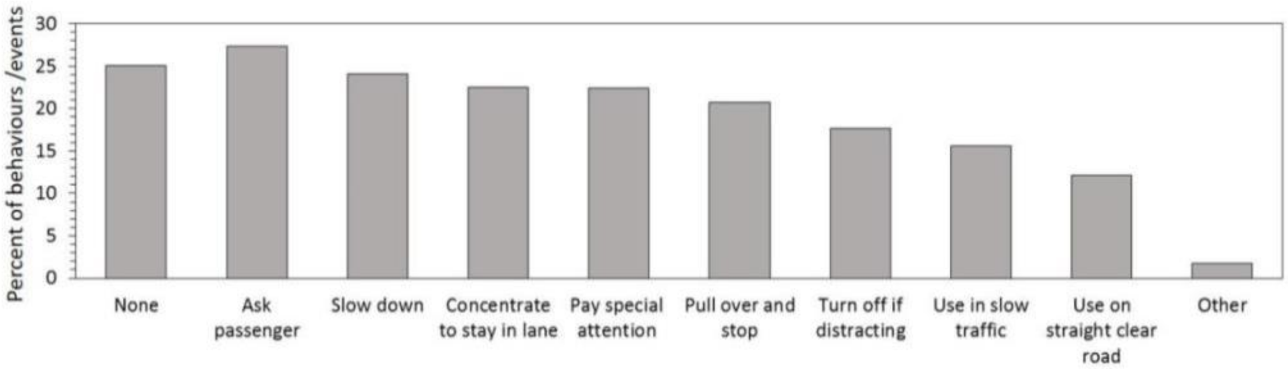


Table 3.8 Countermeasures used for each behaviour or event. Data are presented as the percentage of the total occurrences of each behaviour/event

	Total (n)	None (%)	Ask passenger (%)	Slow down (%)	Concentrate (%)	Pay attention (%)	Pull over (%)	Turn off (%)	Slow traffic (%)	Clear road (%)	Other (%)
Listen to music	970	50.3	11.8	3.8	14.8	14.0	1.4	29.2	2.6	4.4	1.5
Listen to directions	648	39.7	21.1	19.8	20.8	26.4	8.5	13.1	4.5	2.8	0.8
Use manufacturer display	573	27.9	32.5	22.9	19.7	20.9	11.7	19.4	17.8	16.8	2.3
Look at map on GPS	558	14.5	39.1	34.2	24.9	26.5	31.0	10.4	17.7	12.9	3.4
Talk on hands free	477	10.7	31.0	27.0	37.7	33.1	38.2	18.2	15.3	14.3	0.8
Enter destination	322	8.4	42.9	28.3	16.5	16.8	53.1	8.7	22.7	17.1	2.2
Select music on phone	268	11.9	45.9	27.6	22.4	17.9	20.1	16.4	26.1	19.8	1.1
Text/email/social media	259	3.9	43.2	26.3	27.8	19.7	43.6	20.5	47.1	25.9	2.7
Speed advisory warning	241	23.7	2.9	55.2	16.2	24.9	3.7	6.6	4.6	2.9	1.7
Take pictures	156	4.5	39.7	37.2	28.2	21.8	44.2	12.8	35.3	28.2	1.3
Use internet via phone	154	7.8	41.6	27.3	24.0	20.8	44.2	24.0	36.4	24.0	0.6
Lane departure warning	106	24.5	5.7	27.4	42.5	36.8	5.7	8.5	7.5	7.5	0.9
Curve/intersection warning	95	22.1	4.2	51.6	30.5	29.5	10.5	8.4	4.2	6.3	0.0
Read social media	90	5.6	28.9	24.4	18.9	26.7	32.2	32.2	41.1	22.2	2.2

Table 3.9 The number and percentage of respondents in each age group engaging in each IVIS behaviour or event reporting that they used no countermeasures

	16-24 years		25-44 years		45-64 years		> 65 years		Association (X^2, *df = 3*)	Total(n=1017)	
	n	%	n	%	n	%	n	%		n	%
Listen to music	87	41.8	148	60.7	143	55.4	110	42.3	25.80**	488	50.3
Listen to directions	49	40.5	84	49.1	73	40.6	51	29.0	14.89**	257	39.7
Use manufacturer display	34	31.2	46	33.8	46	28.6	34	20.4	7.71	160	27.9
Look at map on GPS	15	12.9	36	20.7	18	12.2	12	10.0	8.21*	81	14.5
Talk on hands free	9	7.7	20	12.6	18	13.4	4	6.0	4.31	51	10.7
Enter destination	10	12.2	8	7.0	5	7.0	4	7.4	2.09	27	8.4
Select music on phone	13	10.7	14	14.9	2	5.7	3	17.6	2.79	32	11.9
Text/email/social media	2	2.1	8	7.5	0	0	0	0	7.01	10	3.9
Speed advisory warning	5	14.3	17	34.0	18	25.0	17	21.0	4.99	57	23.7
Take pictures	3	5.7	3	5.0	1	4.5	0	0	1.19	7	4.5
Use internet via phone	4	6.3	5	7.0	3	18.8	0	0	3.25	12	7.8
Lane departure warning	5	31.3	9	32.1	5	14.7	7	0.3	3.04	26	24.5
Curve/intersection warning	3	11.1	6	26.1	5	26.3	7	26.9	2.65	21	22.1
Read social media	3	7.5	1	2.5	1	14.3	0	0	2.19	5	5.6

3.2.5 Overall ratings of impairment

Respondents were asked to rate how much they thought their own driving overall was be affected by engaging in the IVIS activities (from -3 very impaired to +3 very improved), as well as rating how much an average person's driving would be affected by each activity. A summary of the effects of each IVIS behaviour or event on the respondents' own driving safety is provided in table 3.10. As shown in the table, texting/sending emails/posting on social media were rated as producing the greatest impairment, followed by selecting music or a playlist on your phone, entering a destination and looking at a map on a navigation system. Activities or events most likely to improve safety included getting a warning from a curve or dangerous intersection warning system, a speed advisory system or a lane departure warning.

We conducted a series of 2 x 4 Anovas to determine if there were significant differences in driving safety ratings by age and gender. There were no statistically significant interactions between age and gender for any of the behaviours or events. Table 3.10 shows the ratings by age group for each item, as well as Anova statistics associated with the main effect of age. As can be seen in the table there were significant differences across the age groups for listening to music via the car audio system, using the manufacturer installed display, looking at a map on a navigation system, having a conversation on a hands-free phone, selecting a playlist on a phone and taking pictures. Bonferroni corrected post-hoc tests were used to follow up each of the significant main effects. The two oldest age groups rated listening to music as having a more negative effect on their driving safety compared with those aged 16–24 years. For using an in-vehicle display, having a conversation on a hands-free phone, selecting a playlist and taking pictures, those aged 45–64 years thought their driving was significantly more negatively affected compared with those aged 25–44 years who carried out the same activity. The 45–64 year group also rated having a conversation on a hands-free phone as having a greater negative effect on their driving safety compared with the youngest respondents (16–24 years).

There were also significant differences between men and women's ratings of the effects of listening to directions from a navigation system, using a manufacturer installed display, looking at a map on a navigation system, entering a destination on a navigation system, selecting a playlist on a phone, and texting/email/ posting on social media (table 3.11). In each case, women rated the activity as having a significantly more negative effect on their driving safety compared with men.

Table 3.10 The mean and standard deviation of the driving safety ratings by age group for the respondents engaging in each IVIS behaviour or event (ratings were from - 3 very impaired to +3 very improved)

	16–24 years (n = 227)		25–44 years (n = 260)		45–64 years (n = 261)		> 65 years (n = 269)		Anova (age)	Total (n = 1017)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD
Listen to music	0.2	0.9	0.2	1.0	0[a]	0.6	0[a]	0.6	*F*(3, 962)=5.0**	0.1	0.8
Listen to directions	0.2	1.2	0.1	1.1	-0.1	1.0	0	0.8	*F*(3, 640)=2.4	0	1.0
Use manufacturer display	-0.3	1.0	-0.3	1.0	-0.6[b]	0.9	-0.5	0.8	*F*(3, 565)=4.4**	-0.4	0.9
Look at map on GPS	-0.6	1.2	-0.6	1.2	-0.9	1.0	-0.7	1.10	*F*(3,550)=3.1*	-0.7	1.1
Talk on hands free	-0.2	1.2	-0.4	1.1	-0.7[a,b]	0.9	-0.6	0.8	*F*(3, 469)=6.1**	-0.5	1.0
Enter destination	-0.6	1.3	-0.7	1.4	-1.1	1.2	-0.7	1.2	*F*(3, 314)=2.6	-0.8	1.3
Select music on phone	-0.7	1.1	0.6	1.3	-1.3[b]	1.1	-1.3	1.4	*F*(3, 260)=4.1**	-0.8	1.2
Text/email/social media	-1.3	1.4	-1.4	1.6	-1.8	1.2	-2.1	1.0	*F*(3, 251)=2.2	-1.5	1.4
Speed advisory warning	0.6	1.5	0.8	1.2	0.7	1.3	0.7	0.9	*F*(3, 233)=0.3	0.7	1.2
Take pictures	-1.0	1.5	-0.6	1.6	-1.7[b]	1.0	-1.2	0.9	*F*(3, 148)=3.5*	-1.0	1.4
Use internet via phone	-0.9	1.4	-0.9	1.8	-1.4	1.7	-1.8	1.3	*F*(3, 146)=0.8	-0.9	1.7
Lane departure warning	0.3	1.5	0.2	1.2	0.1	1.2	0.2	0.9	*F*(3, 98)=0.1	0.2	1.2
Curve/intersection warning	0.9	1.3	0.9	1.3	0.5	1.3	0.8	0.7	*F*(3, 87)=0.5	0.8	1.2
Read social media	-0.7	1.8	-0.8	1.8	-0.7	1.9	-1.0	2.6	*F*(3, 82)=0.2	-0.8	1.8

[a] Significantly different from the 16–24 year group, [b] significantly different from the 25–44 year group ($p<.05$, Bonferroni corrected post-hoc).

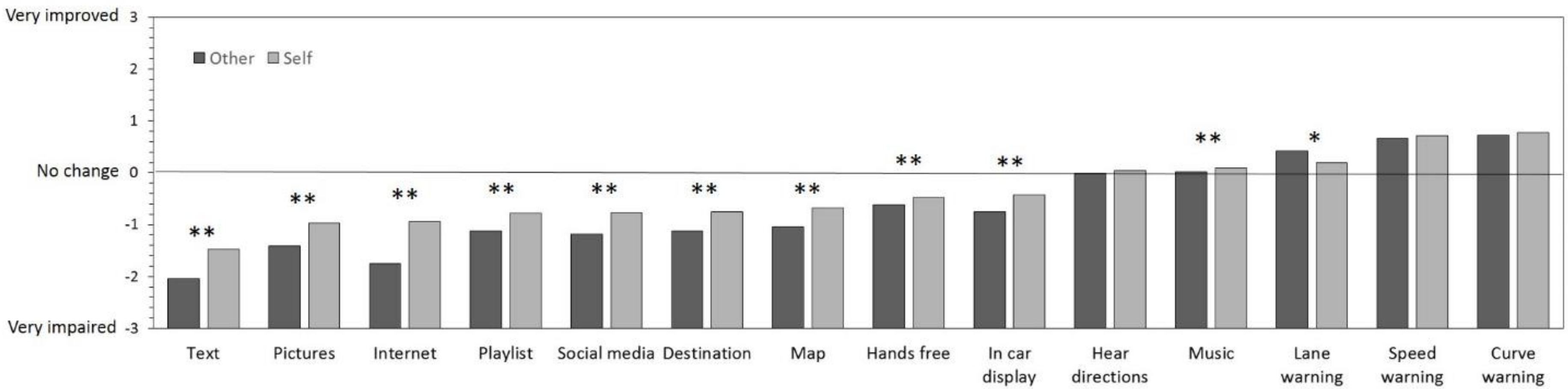
Table 3.11 The mean and standard deviation of the driving safety ratings by gender for the respondents engaging in each IVIS behaviour or event (ratings were from - 3 very impaired to +3 very improved)

	Male (n = 508)		Female (n = 509)		Anova (gender)	Total (n = 1017)	
	Mean	SD	Mean	SD		Mean	SD
Listen to music	0.1	0.9	0.1	0.7	F(1,962)=3.3	0.1	0.8
Listen to directions	0.1	1.0	-0.1	0.9	F(1,640)=5.4*	0	1.0
Use manufacturer display	-0.3	1.0	-0.5	0.7	F(1,565)=6.8**	-0.4	0.9
Look at map on GPS	-0.4	1.2	-1.0	0.9	F(1,550)=31.2**	-0.7	1.1
Talk on hands free	-0.4	1.1	-0.6	0.9	F(1,469)=2.6	-0.5	1.0
Enter destination	-0.5	1.5	-1.0	1.1	F(1,314)=7.5**	-0.8	1.3
Select music on phone	-0.5	1.4	-1.0	1.0	F(1,260)=5.9*	-0.8	1.2
Text/email/social media	-1.1	1.6	-1.8	1.2	F(1,251)=5.8*	-1.5	1.4
Speed advisory warning	0.8	1.2	0.6	1.2	F(1,233)=1.6	0.7	1.2
Take pictures	-0.8	1.7	-1.1	1.1	F(1,148)=0.2	-1.0	1.4
Use internet via phone	-0.8	1.9	-1.1	1.4	F(1,146)=0.1	-0.9	1.7
Lane departure warning	0.3	1.3	0.1	1.0	F(1,98)=0.2	0.2	1.2
Curve/intersection warning	0.9	1.3	0.5	1.0	F(1,87)=3.6	0.8	1.2
Read social media	-0.3	1.8	-1.4	1.6	F(1,82)=1.0	-0.8	1.8

The next set of analyses compared the ratings of how much an average person's driving would be affected by engaging in each IVIS behaviour or event, to the ratings of how much their own driving would be affected (from -3 very impaired to +3 very improved). This data is presented in figure 3.4. As can be seen in the figure, listening to directions, listening to music via the in-vehicle audio, receiving warnings from lane departure, speed advisory and curve/dangerous intersection systems were rated as improving driving safety overall (the mean ratings were above zero). All other behaviours and experiences were rated as producing some level of driving impairment, with texting/sending emails and posting on social media receiving the lowest ratings (ie leading to the greatest impairment). With regard to ratings of their own and others' driving safety, respondents generally rated each behaviour or experience as having a more negative effect on the average driver compared with the effects on their own driving, with only one exception. Receiving a warning from a lane departure warning system was rated as leading to a greater improvement in the driving safety of the average driver compared with themselves.

To determine if differences in the driving safety ratings between themselves and other drivers were statistically significant a series of repeated measures Anovas were undertaken (note: the sample size for each analysis differed because we only included drivers who engaged in each of the behaviours/ experiences themselves). Analyses revealed that respondents rated other drivers as significantly more impaired than themselves when texting/ emailing/posting on social media [$F(1, 258)=79.9$, $p<.001$, $\eta_p^2=.24$], taking pictures with a phone or camera [$F(1,155)=18.8$, $p<.001$, $\eta_p^2=.1$], using the internet via a smartphone ($F(1,153)=61.2$, $p<.001$, $\eta_p^2=.3$), selecting music or playlist on a phone [$F(1,321)=27.5$, $p<.001$, $\eta_p^2=.08$], browsing social media [$F(1,89)=10.0$, $p=.002$, $\eta_p^2=.1$], entering a destination [$F(1,321)=27.5$, $p<.001$, $\eta_p^2=.08$] and looking at a map on a navigation device [$F(1,557)=60.5$, $p<.001$, $\eta_p^2=0.10$], having a conversation on a hands-free phone [$F(1,476)=9.5$, $p=.002$, $\eta_p^2=.02$], using a manufacturer installed display [$F(1,572)=67.1$, $p<.001$, $\eta_p^2=.10$] and listening to music via the in-vehicle audio [$F(1,969)=9.8$, $p=.002$, $\eta_p^2=.01$]. They also rated lane departure warnings as improving driver safety to a significantly greater extent for other drivers compared with themselves [$F(1,105)=4.1$, $p=.04$. η_p^2 = .04]. There were no statistically significant differences between self and other ratings for listening to directions [$F(1,647)=1.4$, $p=.2$, $\eta_p^2<.01$], or receiving warnings from a speed advisory [$F(1,240)=0.3$, $p=.6$, $\eta_p^2<.01$] or curve and dangerous intersection warning system [$F(1,94)=0.1$, $p=.7$, η_p^2 =<.01].

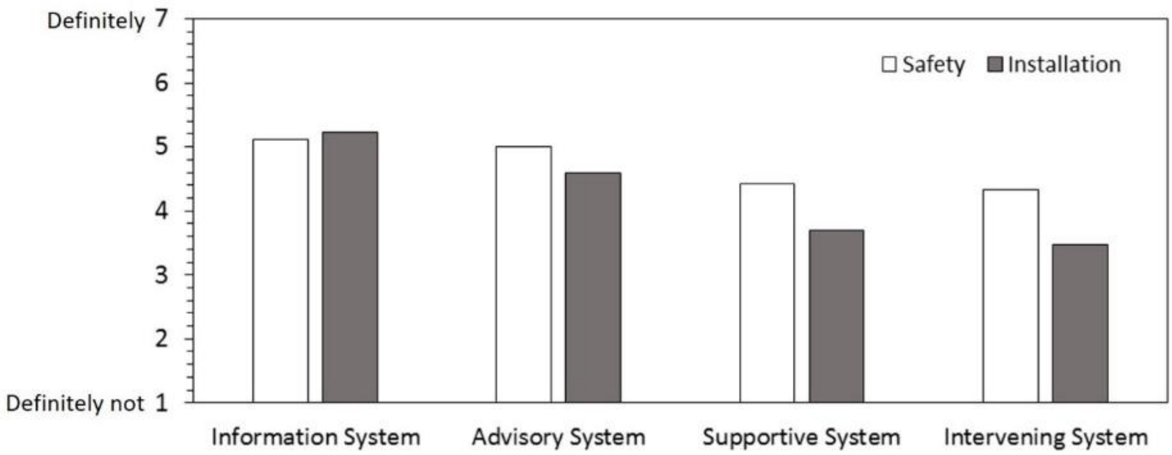
Figure 3.4 Overall ratings of the effects of each activity on driving safety for the respondents (self) and other drivers (data is presented as the mean rating for all drivers engaging in each activity) (p<.01, * p<.05 other versus self- rating)**



3.2.6 Safety benefits of speed advisory systems

As in the driving simulator study, respondents were also asked to rate the likely safety benefits (from 1 definitely not safer to 7 definitely safer) of four speed information systems (an information system, advisory system, supportive system and intervening system) and to indicate if they would like them installed in their car (from 1 definitely not to 7 definitely). As shown in figure 3.5 respondents rated the information and advisory systems as most likely to improve safety and they were generally willing to have these types of systems installed in their cars. In contrast, although the respondents thought the supportive and intervening systems would improve safety, they were unlikely to have them installed in their cars.

Figure 3.5 Ratings of the safety benefits and likelihood of installation (from 1 = definitely not, to 7 = definitely) of four speed information systems



3.3 Summary

The survey was conducted to identify the range of in-vehicle applications and information systems currently used by drivers, the prevalence and frequency of their use, the effects of their use on driving and to explore any strategies or techniques drivers use to minimise any negative consequences.

Drivers engaged or experienced all of the items listed in the online survey although the prevalence varied for each activity/event. The most common activity drivers engaged in was listening to music via the car audio system, followed by listening to directions and looking at a map on a navigation system. Fewer than half of the drivers reported having a conversation on a hands-free phone, and fewer than a quarter reported texting/sending emails/posting on social media while driving. Only a small proportion of the sample had experience with a lane departure warning system or dangerous curve and intersection warning systems. Overall, the prevalence for each activity was similar for men and women, but varied by age, with a general decrease in engagement in each activity/behaviour with age. Interestingly for many of the activities (eg texting, talking on a hands-free phone, using a navigation device), rates were highest in the 25–44 year group. In terms of the frequency of engagement, other than listening to the car audio system, respondents typically reported engaging in the activities seldom or sometimes, suggesting drivers are not engaging in other activities most of the time they are driving. The rates of navigation system and mobile phone use in the current study are similar to those reported in the EU (Jamson 2013). The small, but significant proportion of drivers using a hand-held mobile while driving reflects the findings from previous roadside observation studies (Wilson et al 2013; Ministry of Transport 2013) and clearly highlights the number of drivers who continue to use hand-held mobile phones despite legislation banning their use.

Overall, more than half of the behaviours/events were rated as having no negative effects on driving. These were most commonly listening to music and listening to directions. Those rated as most likely to have negative effects involved the use of a hand-held mobile (texting/emailing, using the internet and taking pictures). The most common consequence reported was slower reactions to changing traffic, but drivers also endorsed all of the other possible effects. Although a significant proportion of respondents reported having conversations on a hands-free phone, over half thought it would lead to decreased driving safety, most commonly slower reactions to changing traffic. The younger drivers seemed to be most aware of the negative consequences of engaging in many of the distracting activities (listening to directions, looking at a navigation system), whereas the middle two age groups were most likely to rate hands-free phone conversations as having no impact on their driving.

Drivers used a number of strategies to minimise the effects of the behaviours and events; these varied depending on the task. For those involving interaction with a device (phone or navigation system), the most common action was to ask the passenger to complete the task, to pull over and stop or to use it in slow moving traffic. In general, males reported the use of fewer countermeasures than women.

Drivers viewed texting/sending emails and posting on social media as having the greatest overall impact on driving safety, possibly because the activity is illegal. Generally males rated the activities as having less of an impact on their driving compared with the female drivers. In addition, drivers rated almost all the activities or events as having a more negative impact on an average driver compared with their own driving, similar to the findings reported by Jamson (2013).

Focusing specifically on the use of speed warning systems, almost half of the sample had access to an ISA, with around half of those (approximately one quarter of the total sample) reporting they had received speed-related warnings. After receiving a warning, around half reported it had no effect on their driving, while a third reported they would slow down. Participants completing the online survey and the driving simulator study indicated that all four speed advisory systems would improve safety, reflecting the findings of Várhelyi et al (2015). Interestingly though, they would only be willing to have the information and/or advisory systems fitted to their car, not the supportive or intervening systems. Previous research has reported similar findings (Comte 2000). Drivers were asked to rate the usefulness and their satisfaction with one of three ISAs (driver select: drivers chose to engage the system which limits their speed; mandatory system: drivers' speed could not exceed the speed limit; and variable system drivers' speed could not exceed the speed limit and their maximum speed is lowered near hazards) before and after use. The mandatory system was rated as most useful following actual use, but only the driver select system received increased 'Satisfaction' ratings after drivers had used it. The variable system, which produced the greatest control of drivers' speeds received the lowest ratings.

4 Conclusions and recommendations

The overall purpose of the present research was to provide a description of key operating principles and recommendations about drivers' use of IVIS, smartphone applications and nomadic devices and their likely effects on driver performance. To achieve this we conducted two studies: the first examined the effects of an ISA (designed as a mobile phone app) on the driving performance of 123 participants in the University of Waikato driving simulator. The second, an online questionnaire completed by 1,017 New Zealand drivers, examined the prevalence of and frequency with which drivers used a range of in-vehicle apps and systems.

The research aims of the study were to:

1 Assess how drivers' reactions to road and traffic situations are affected by the potential distraction produced by different display modes associated with in-vehicle applications.

2 Measure how driving performance changes in response to the information provide by in-vehicle applications and the different display modes (eg compliance with the information presented).

3 Test how the effects of in-vehicle applications change with repeated exposure (eg habituation and desensitisation).

4 Identify the range of in-vehicle applications and information systems currently used by drivers, the prevalence and frequency of their use and drivers' attitudes towards them.

The results of the simulator experiment demonstrated that safety-oriented IVIS, such as the ISA system tested, have the potential to give drivers useful information without distracting them unduly; a net road safety benefit to drivers. This conclusion needs to be bounded by the proviso that in order to deliver this benefit the system interface and positioning needs to enable effective operation with only short and infrequent glances. The ISA tested in the present experiment followed best practice guidelines in its development (Kroon et al 2016; NHTSA 2012) so the display used recognisable symbols consistent with traffic signs, minimised the downward viewing angle for the driver and did not require glances longer than two seconds to read or operate. The system input (in the two active versions of the ISA) was facilitated by being operable with a single hand and was located within 10 to 20 cm of the driver's hand. The testing confirmed that following these practices resulted in a device that could be operated with very short glances – average glance durations of 190.24 msec for the active groups and 159.76 msec for the passive groups. The system design also resulted in drivers glancing at the ISA relatively infrequently, an average of 21.0 glances for the entire 20-minute drive in the active conditions, and an average of 10.67 glances for the passive conditions.

We were also able to conclude there was no evidence of distraction in the drivers' lane-keeping performance as measured by SDLP, as would be predicted if the operation of the device were increasing mental load and distracting the drivers from the steering task. Similarly, the drivers' self-ratings of mental load only reached an average of 2.19 on the seven-point scale where a rating of 1 was 'easy, no difficulty at all'. Further, the ISA device did not impair performance when negotiating traffic and potential hazards (eg road works, busy intersection, one-lane bridge) as would have been predicted had the system distracted or overloaded the participants' visual attention. The participants were able to process cues from traffic and road signs in order to prioritise their driving (over the ISA device) and manage their speed and lane position across a range of safety critical situations.

Compliance with all versions of the ISA during the testing was good, making a significant difference to drivers' speeds in the 60 km/h speed zone relative to the control group participants (no ISA). In a related finding, the drivers' efficiency remained good, with no detectable interference with their ability to accomplish overtaking of slower traffic (during the overtaking lane portion of the simulation scenario). Compliance with the ISA remained good throughout the testing with no evidence of habituation or desensitisation over the course of the drive. Although our participants rated the ISA they used as being useful, and ISAs as having definite safety benefits, we are not able to conclude whether drivers would continue to use and comply with the speed advisories over the longer term. Previous research has shown that fewer than 20% of drivers continued to use a collision warning application routinely after the end of a system trial (Botzer et al 2017). There is also evidence that some drivers enjoy driving over the speed limit, and although they comply with an ISA device when present, they have a lower probability of using an ISA unless required or incentivised to do so (Lai et al 2010).

ISAs are only one of the IVIS that New Zealand drivers use, and by no means the most common; 23.7% had experienced in-vehicle speed advisory warnings (although 45.4% had access to the systems in their vehicle). The most common IVIS systems reported by our sample of New Zealand drivers were listening to the radio, using the vehicle's console display, and listening to directions or reading a navigation system map. Less often drivers reported using hands-free phones (22.6% 'sometimes' and 9% 'often' or 'usually'). None of these are safety-oriented IVIS, but they are all legal to use in New Zealand. Use of hand-held devices, illegal for drivers in New Zealand, are used much less frequently than the permitted devices and activities mentioned above. It should be noted that roughly the number of drivers who report using a speed advisory system is the same as that reporting using text/email/social media while driving. This is in spite of the fact that the drivers rated the former as improving driving and the latter as impairing driving. From these results of the survey we can conclude that relatively few drivers use safety-oriented IVIS and even when they have access to the systems 75% to 50% of drivers 'never' use them.

As with all social science studies there are a number of limitations that should be considered when interpreting the findings in this report. This includes the use of self-report data in the questionnaire and the possibility that respondents may have interpreted some of the response options differently (eg sometimes, seldom). There is also the possibility that the participants who took part in the simulator study were hypervigilant about their speed and compliance to the posted speed limits simply because they were taking part in a study and being observed. The inclusion of a control group (who drove without the ISA) helps to address this limitation. The strengths of the study include the large sample size, from a wide age range, who completed the questionnaire, and the use of driver performance and eye tracking measures in the simulator study.

In sum, properly configured IVIS such as the ISA tested have a demonstrable safety benefit and do not possess adverse distractive effects. Use of safety-oriented warning IVIS, however, is low and in the absence of incentives or education, is likely to remain low in spite of drivers' belief that they do have safety benefits. In view of these conclusions we would recommend that guidance to drivers be developed as to what constitutes a 'good' app (positioned so it is easy to see, does not require long glances, is not hand held etc) and what constitutes bad practice in using IVIS (including legal ones such as car console displays). The guidance, in the form of one or more brochures could be made generally available through automotive retailers, insurers, automobile owner groups and the Transport Agency.

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Appendix A: Post drive questionnaire (simulator)

Q1.1 Participant ID

Q1.2 Select the participant's condition

- ❍ 1. Active / audio and visual (1)
- ❍ 2. Active / visual only (2)
- ❍ 3. Passive / audio and visual (3)
- ❍ 4. Passive / visual only (4)

Q2.1 Thank you for completing the drive in the simulator. This questionnaire asks a few questions about the app you used in the simulator, the types of devices or apps you use when driving, and some demographic and driving history questions. Please indicate below your opinion of the speed advisory system you used in the simulator. My judgments of the system are..... (select a circle on every line).

useful	❍	❍	❍	❍	❍	useless
pleasant	❍	❍	❍	❍	❍	unpleasant
bad	❍	❍	❍	❍	❍	good
nice	❍	❍	❍	❍	❍	annoying
effective	❍	❍	❍	❍	❍	superfluous
irritating	❍	❍	❍	❍	❍	likeable
assisting	❍	❍	❍	❍	❍	worthless
undesirable	❍	❍	❍	❍	❍	desirable
raising alertness	❍	❍	❍	❍	❍	sleep-inducing

Q3.1 Select the option that best describes you. While driving you find it distracting when (rating from 1 strongly disagree to 5 strongly agree or 0 never happens)

	(1)	(2)	(3)	(4)	(5)	(0)
Your phone is ringing (1)	❍	❍	❍	❍	❍	❍
You receive an alert from your phone (e.g., new text message) (2)	❍	❍	❍	❍	❍	❍
You are listening to music (3)	❍	❍	❍	❍	❍	❍
You are listening to talk radio (4)	❍	❍	❍	❍	❍	❍
There are roadside advertisements (5)	❍	❍	❍	❍	❍	❍
There is a roadside accident scene (6)	❍	❍	❍	❍	❍	❍
A passenger speaks to you (7)	❍	❍	❍	❍	❍	❍
Daydreaming (8)	❍	❍	❍	❍	❍	❍

Q3.2 This section focuses on the types of devices you use when driving. How frequently do you use a GPS based navigation device (e.g., TomTom)?

- ❍ Not applicable - I don't have one (1)
- ❍ Never (2)
- ❍ Seldom (3)
- ❍ Sometimes (4)
- ❍ Often (5)
- ❍ Usually (6)

Q3.3 How frequently do you use a mobile phone (for any purpose) when driving?

- ❍ Not applicable - I don't have one (1)
- ❍ Never (2)
- ❍ Seldom (3)
- ❍ Sometimes (4)
- ❍ Often (5)
- ❍ Usually (6)

Condition: Never Is Selected. Skip To: How frequently do you use a manufactu....Condition: Not applicable - I don't ha... Is Selected. Skip To: How frequently do you use a manufactu....

Q3.4 What do you use your mobile phone for when driving? (select all that apply)

- ❑ Phone calls (1)
- ❑ Texts (2)
- ❑ Navigation (3)
- ❑ Social media (4)
- ❑ Entertainment (e.g. music) (5)
- ❑ Other (6)

Display This Question:

If What do you use your mobile phone for when driving? (select all that apply) Other Is Selected

Q3.5 What other things do you use your mobile phone for when driving?

Q3.6 How frequently do you use a manufacturer installed in car information system? (the display screen in your vehicle that allows you to control various vehicle functions)

- ❍ Not applicable - I don't have a manufacturer installed in car information system (1)
- ❍ Never (2)
- ❍ Seldom (3)
- ❍ Sometimes (4)
- ❍ Often (5)
- ❍ Usually (6)

Condition: Not applicable - I don't ha... Is Selected. Skip To: Please indicate whether you believe a....Condition: Never Is Selected. Skip To: Please indicate whether you believe a....

Q3.7 What do you use the in car information system for when driving? (select all that apply)

- ❑ Navigation (1)

- ❑ Entertainment (e.g. music or radio selection) (2)
- ❑ Monitor fuel efficiency (3)
- ❑ Collision avoidance (4)
- ❑ Parking assistance (i.e., reversing camera) (5)
- ❑ Lane departure warnings (6)
- ❑ Other (7)

Display This Question:

If What do you use the in car information system for when driving? (select all that apply) Other Is Selected

Q3.8 What other things do you use the in car information system for when driving?

Q3.9 Please indicate whether you believe any of these systems would make traffic safer if most drivers would use them, where 1 is definitely not safer and 7 is definitely safer.

1. Speed information system (shows current speed limit)
2. Advisory system (shows current speed limit and warns the driver with flashing light and sound if speed limit is exceeded)
3. Supportive system (shows current speed limit and exerts counter-force on accelerator at speeds over the speed limit (it is harder to press the accelerator if you are going over the speed limit).
4. Intervening system (shows current speed limit and interacts with the vehicle to prevent you exceeding the speed limit).

Q3.10 Please indicate whether you would like the following systems installed in your car (from 1 definitely not to 7 definitely). Please note, we do not have a specific system in mind, we just want to know if you would like to have a system with the specific functions.

1. Speed information system (shows current speed limit)
2. Advisory system (shows current speed limit and warns the driver with flashing light and sound if speed limit is exceeded)
3. Supportive system (shows current speed limit and exerts counter-force on accelerator at speeds over the speed limit (it is harder to press the accelerator if you are going over the speed limit).
4. Intervening system (shows current speed limit and interacts with the vehicle to prevent you exceeding the speed limit).

Q4.1 What type of driving licence do you hold?

- ❍ Learner's licence (1)
- ❍ Restricted licence (2)
- ❍ Full driving licence (3)
- ❍ I don't hold a current driving licence (4)
- ❍ Don' t know (5)

Display This Question:

If What type of driving licence do you hold? I don't hold a current driving licence Is Selected

Q4.2 Why do you not hold a current driving licence?

- ❍ Licence has expired (1)
- ❍ Never applied for driving licence (2)
- ❍ Licence is currently suspended (3)

- ❍ Other (4)

Q4.3 How long have you been a licenced driver? (years since you passed your learner's test)

Q4.4 How many kilometres do you usually drive each week?

Q4.5 How many crashes have you been involved in over the past year when you were the driver?

Q4.6 Have you been pulled over by the police for using a mobile phone whilst driving?

- ❍ Yes (1)
- ❍ No (2)

Display This Question:

If Have you been pulled over by the police for using a mobile phone whilst driving? Yes Is Selected

Q4.7 How many times?

Q5.1 What is your gender?

- ❍ Male (1)
- ❍ Female (2)
- ❍ Other (3)

Q5.2 How old are you?

Q5.3 Which ethnic groups do you belong to? Identify any that apply.

- ❑ New Zealand European (1)
- ❑ Other European (10)
- ❑ Maori (2)
- ❑ Samoan (3)
- ❑ Tongan (4)
- ❑ Cook Island Maori (5)
- ❑ Niuean (6)
- ❑ Chinese (7)
- ❑ Indian (8)
- ❑ Other (e.g., Japanese) (9)
- ❑ Refused to answer (11)

Q6.1 Thank you for taking part in the study, you have now reached the end of the questionnaire. If you would like to receive a summary of the findings (late 2017 / early 2018) and /or receive information about future Transport Research Group studies, please select the relevant option (s) below and provide your email address.

- ☐ I would like to receive a summary of the research findings (1)
- ☐ I would like to receive emails about future TRG research projects (2)
- ☐ No thanks (3)

Display This Question:

If Thank you for taking part in the study, you have now reached the end of the questionnaire. If you would like to receive a summary of the findings (late 2017 / early 2018) and /or receive information... No thanks Is Not Selected

Q6.2 Please provide your email address

Appendix B: Online questionnaire

Q1.1 Drivers' use of apps, navigation devices and in-vehicle information systems We are conducting research into drivers' use of phone apps, navigation devices and in-vehicle information systems. The survey is anonymous, will take about 15 minutes to complete and you can stop taking the survey at any time by closing your browser. If you have any questions about the research please contact a member of the research team: Nicola Starkey (nstarkey@waikato.ac.nz) or Samuel Charlton (samiam@waikato.ac.nz) from the University of Waikato. The research has received approval from the School of Psychology Ethics Committee at the University of Waikato and is funded by the New Zealand Transport Agency. Are you interested in taking part?

- Yes (1)
- No (2)

Condition: No Is Selected. Skip To: End of Block.

Q1.2 Are you a New Zealand resident? (Do you live permanently in NZ?)

- Yes (1)
- No (2)

Condition: No Is Selected. Skip To: End of Block.

Q1.3 Do you have a good understanding of English?

- Yes (1)
- No (2)

Condition: No Is Selected. Skip To: End of Block.

Q1.4 Are you aged 16 years or over?

- Yes (1)
- No (2)

Condition: No Is Selected. Skip To: End of Block.

Q1.5 Have you driven a car or light truck in the last month?

- Yes (1)
- No (2)

Q2.1 What is your age?

- 16-24 years (1)
- 25-44 years (2)
- 45-64 years (3)
- 65 years or over (4)

Q2.2 What is your gender?

- Male (1)
- Female (2)
- Other (3)

Q3.1 How much do you think an average person's driving would be affected if they were engaging in the following activities while driving? For each of the items, rate the extent to which it would impair or improve a typical person's driving safety.

	-3 (very impaired) (-3)	-2 (-2)	-1 (-1)	0 (no change) (0)	+1 (1)	+2 (2)	+3 (very improved) (3)
A conversation on a hands-free mobile phone							
Texting / sending emails / posting on social media							
Browsing /reading social media							
Use the internet via your smartphone							
Take pictures with your phone or camera when driving							
Listening to music with the car audio system							
Selecting music/ play lists via your smartphone							
Entering your destination on a navigation system/app							
Looking at the map on a navigation system/app							
Listening to directions from a navigation system/app							
Using a manufacturer installed display (e.g., to select a radio station)							
Getting a warning from a lane departure warning system							
Getting a warning from a speed advisory system							
Getting a warning from a curve or dangerous intersection warning system							

Q4.1 The next group of questions asks about your use of in car information systems and how they might affect your ability to drive safely. How frequently do you drive while having a conversation on a hands-free mobile phone?

- ❍ Not applicable - I don't have one (6)
- ❍ Never (1)
- ❍ Seldom (2)
- ❍ Sometimes (3)
- ❍ Often (4)
- ❍ Usually (5)

Condition: Never Is Selected. Skip To: End of Block.Condition: Not applicable - I don't ha... Is Selected. Skip To: End of Block.

Q4.2 What effect does talking on a hands-free mobile have on your driving? (select all that apply)

- ❑ I slow down or speed up unintentionally (1)
- ❑ My lane keeping becomes unstable (I weave in my lane) (2)
- ❑ It impairs my ability to scan the road ahead (e.g., for curves, intersections) (3)
- ❑ I drive too close to the car in front (4)
- ❑ My reaction to changing traffic situations is slower or delayed (5)
- ❑ Sometimes I don't notice pedestrians and cyclists (6)
- ❑ Sometimes I have to stop suddenly at intersections or crossings (7)

- ❑ Sometimes I don't notice traffic signs or signals (8)
- ❑ None of the above (9)
- ❑ Other (10)

Display This Question:

If What effect does talking on a hands-free mobile have on your driving? (select all that apply) Other Is Selected

Q4.3 Please describe what other effect it has on your driving

Q4.4 What do you do to minimise any effects of talking on a hands-free mobile? (select all that apply)

- ❑ I pull over and stop (1)
- ❑ I slow down intentionally to maintain safety (2)
- ❑ I concentrate more on driving to ensure I stay in my lane (3)
- ❑ I pay special attention so that I can monitor traffic effectively (4)
- ❑ I turn it off if it becomes distracting or annoying (5)
- ❑ I only do this in slow moving traffic (e.g. in a traffic queue) (6)
- ❑ I use it on a straight and clear road (7)
- ❑ I ask my passenger to use it instead of me (8)
- ❑ None of the above (9)
- ❑ Other (10)

Display This Question:

If What do you do to minimise any effects of talking on a hands-free mobile? (select all that apply) Other Is Selected

Q4.5 What do you do to minimise any effects?

Q4.6 Rate how much talking on a hands-free mobile when driving alters your ability to drive safely

-3 (very impaired) (-3)	-2 (-2)	-1 (-1)	0 (no change) (0)	+1 (1)	+2 (2)	+3 (very improved) (3)

The same set questions (as above) were asked for each of the following:

Q5.1 How frequently do you drive while texting or sending emails or posting on social media?

Q6.1 How frequently do you drive while browsing or reading social media?

Q7.1 How frequently do you drive while using the internet via your smartphone (manually, voice activated or hands-free)?

Q8.1 How frequently do you drive while taking pictures with your phone or camera?

Q9.1 How frequently do you drive while listening to music with the car audio system?

Q10.1 How frequently do you drive while selecting music or playlists via your smartphone?

Q11.1 How frequently do you drive while entering your destination on a navigation system or app?

Q12.1 How frequently do you drive while looking at a map on a navigation system or app?

Q13.1 How frequently do you drive while listening to directions from a navigation system or app?

Q14.1 How frequently do you drive while using a manufacturer installed display (e.g., to select a radio station)?

Q15.1 How frequently do you get a warning from a lane departure warning system when driving?

Q16.1 How frequently do you get a warning from a speed advisory system?

Q17.1 How frequently do you get a warning from a curve or dangerous intersection warning system when driving?

Q18.1 Select the option that best describes you. While driving you find it distracting when

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Never Happens (0)
Your phone is ringing (1)						
You receive an alert from your phone (e.g., new text message) (2)						
You are listening to music (3)						
You are listening to talk radio (4)						
There are roadside advertisements (5)						
There is a roadside accident scene (6)						
A passenger speaks to you (7)						
Daydreaming (8)						

Q18.2 This section focuses on speed advisory systems (apps or devices which tell you about the speed limit, warn you if you go over the speed limit, or affect the speed of the vehicle). Have you ever used a speed advisory system? (Select the option that best describes the system you have used)

- ❍ Yes, a system which just informs me of the speed limit (1)
- ❍ Yes, a system which warns me if I go over the speed limit or the limit I have manually set (2)
- ❍ Yes, a system which limits the speed of my vehicle according to the speed limit or a manually set limit (3)
- ❍ No (0)

Q18.3 Please indicate whether you believe any of these systems would make traffic safer if most drivers would use them, where 1 is definitely not safer and 7 is definitely safer.

Speed information system (shows current speed limit) (1)

Advisory system (shows current speed limit and warns driver with flashing light and sound if speed limit is exceeded) (2)

Supportive system (shows current speed limit and exerts counter-force on accelerator at speeds over the speed limit (it is harder to press the accelerator if you are going over the speed limit) (3)

Intervening system (shows current speed limit and interacts with the vehicle to prevent you exceeding the speed limit) (4)

Q18.4 Please indicate whether you would like the following systems installed in your car (from 1 definitely not to 7 definitely). Please note, we do not have a specific system in mind, we just want to know if you would like to have a system with the specific functions.

Speed information system (shows current speed limit) (1)

Advisory system (shows current speed limit and warns the driver with flashing light and sound if speed limit is exceeded) (2)

Supportive system (shows current speed limit and exerts counter-force on the accelerator at speeds over the speed limit (it is harder to press the accelerator if you are going over the speed limit) (3)

Intervening system (shows current speed limit and interacts with the vehicle to prevent you exceeding the speed limit) (4)

Q19.1 What type of driving licence do you hold?

- ❍ Learner's licence (1)
- ❍ Restricted licence (2)
- ❍ Full driving licence (3)
- ❍ I don't hold a current driving licence (4)
- ❍ Don' t know (5)

Display This Question:

If What type of driving licence do you hold? I don't hold a current driving licence Is Selected

Q19.2 Why do you not hold a current driving licence?

- ❍ Licence has expired (1)
- ❍ Never applied for driving licence (2)
- ❍ Licence is currently suspended (3)
- ❍ Other (4)

Display This Question:

If What type of driving licence do you hold? I don't hold a current driving licence Is Not Selected

Q113 How long have you been a licenced driver? (years since you passed your learner's test)

1-50

Q19.3 How many kilometres do you usually drive each week?

Q19.4 How many crashes have you been involved in over the past year when you were the driver?

Q19.5 Have you been pulled over by the police for using a mobile phone whilst driving?

- ❍ Yes (1)
- ❍ No (2)

Display This Question:

If Have you been pulled over by the police for using a mobile phone whilst driving? Yes Is Selected

Q19.6 How many times?

Q20.1 How old are you?

Age in years

Q20.2 Which ethnic groups do you belong to? Identify any that apply.

- ❑ New Zealand European (1)
- ❑ Other European (10)
- ❑ Maori (2)
- ❑ Samoan (3)
- ❑ Tongan (4)
- ❑ Cook Island Maori (5)
- ❑ Niuean (6)
- ❑ Chinese (7)
- ❑ Indian (8)
- ❑ Other (e.g., Japanese) (9)
- ❑ Refused to answer (11)

Q20.3 Where do you live in New Zealand (which province/district)?

- ❍ Northland (1)
- ❍ Auckland (2)
- ❍ Waikato (3)
- ❍ Bay of Plenty (4)
- ❍ Gisborne (5)
- ❍ Hawkes Bay (6)
- ❍ Taranaki (7)
- ❍ Wanganui (8)
- ❍ Manawatu (9)
- ❍ Wairarapa (10)
- ❍ Wellington (11)
- ❍ Nelson Bays (12)
- ❍ Marlborough (13)
- ❍ West Coast (14)
- ❍ Canterbury (15)
- ❍ Timaru-Omaru (16)
- ❍ Otago (17)
- ❍ Southland (18)

Q20.4 What is your annual household income?

- ❍ Less than $20,000 (1)
- ❍ $21,000 - $40,00 (2)
- ❍ $41,000 - $60,000 (3)
- ❍ $61,000 - $80,000 (4)
- ❍ $81,000 - $100,000 (5)
- ❍ Over $100,000 (6)
- ❍ Prefer not to say (7)

- ❍ Don't know (8)

Q21.1 The findings from the study will be available on the Transport Research Group website late 2017 / early 2018

Appendix C: 'Other' effects of each behaviour/experience on driving

Listen to music	It's a general distraction, can't hear the sounds of traffic; difficult to hear the car engine (I drive a manual); I find it harder to concentrate on directions; I feel distracted; Taking your eyes off the road while changing stations; More relaxed on the road; Relaxes me; Don't know; Helps me stay alert and awake; Depending on the music my speed creeps up; Some music makes me speed up; I get annoyed with the constant noise and that distracts me; Not consciously aware of any effect as above, but probably there is some; Calms and relaxes me; I find it annoying and feel it generally impairs my ability to concentrate on driving; Loss of concentration; Don't have it loud.
Listen to directions	It slows me down a bit so it takes me longer to reach my destination; I slow down more when I need to make a turn or slow down earlier in anticipation of an upcoming turn; No effect unless it goes off by itself; I really concentrate on my surroundings; It makes me safer because I am not looking out for my destination but only following voice prompts; I usually slow down; It can be a little off putting or intrusive at times; I drive slower; It is helpful in unfamiliar situations, however my husband operates it so I have no distraction
Use in car display	Select station before starting off; I don't know the effect it has on the quality of my driving; My selected radio station is always on; I leave it on the one radio station only so don't need to change; I slow down intentionally.
Look at map on navman	Drive slower purposely; I don't know the effect it has on the quality of my driving; I go slower or stop; I stated previously that I don't look at the navigation system or app, it is spoken aloud, so I only need to listen, not look at an app or nav system. I set it before I drive and turn it off once I get there; I slow down, pull over or stop and check map; I slow down intentionally; I pull to over to the side of the road; I don't use it very often as I'm not usually the driver on out of town journeys; My phone has a very clear voice description so I tend to listen to directions and if I need to look I'll stop driving.
Talk on hands free	I sometimes switch into auto-pilot. This basically means I'm still paying attention to everything around me, but I end up driving the same route that I usually would, given the roads that I'm driving on. So, if I was meant to be turning a different direction for some reason, I wouldn't; Concentration and awareness decrease; Miss an exit; Get distracted; Need to concentrate and focus more on driving; Somewhat distracted so not fully concentrating on the road.
Enter destination	I don't know the effect it has on the quality of my driving; I enter the info before I drive so no affect at all never do it while driving that's just stupid; I usually stop to enter it; I pull over and enter destination or enter before I leave my driveway.
Select music on phone	Use car radio not phone for music
Txt/email/social media	Take eyes off the road but only do it when in stationary traffic; Don't know the effects and feel guilty; Pull over to side of road.
Speed advisory warning	Jolt; It helps me to check my speed and lower it accordingly; I slow down to the speed limit; I slow down a bit; I slow down; Take my foot off the accelerator!; It slows me down intentionally; I slow down; Tells me to buck my ideas up; I do not speed, very careful to watch speed limits; I slow down!; Good effect - if I am going to fast I slow down; Stops me from going over the speed limit driving on the motorway I get the warning from my device.
Take pictures	Don't know; Only if it is to record an incident.
Use internet via phone	Don't know effect; I drool uncontrollably and my tongue protrudes (just kidding); I pull over if it impairs my driving ability, otherwise only initiated at very slow speed and without any traffic around.
Lane departure warning	It assists as a backup in case were to miss a vehicle in blind spot
Curve/intersection warning	When I'm on long route; It reminds me to slow down before a sharp corner; I try to drive defensively at all times.
Read social media	I only have text facility for emergencies whilst driving;

Appendix D: ‘Other’ countermeasures reported by the participants.

Listen to music	I don't play the volume too loudly; Turn the volume down; Use the controls on steering wheel to change radio channel; Ensure the volume is not too loud to impair hearing other noises outside the vehicle; I make sure I know I am in control when listening to music on audio system- gives me a break from talking with myself as I drive alone a lot; May turn down the radio if it gets distracting; Select suitable mood enhancing driving music; Turn it down if it is distracting; I rarely listen to music or radio in vehicle anyway, so I can be sure to maximise concentration on driving; Usually I only have it as background music; Set things up before I start the journey; Keep the volume low; don’t have it loud; Only listen to classical music, which is soothing, keep volume low and only turn on when stationary.
Listen to directions	Just listening doesn't affect my driving; I plan routes in advance so I do not normally need to use navigation; Stick to windscreen so can listen and look at same time.
Use in car display	I try not to look away from the road; Use control on steering wheel; Use controls on steering wheel; Only change station when stationary and steering wheel has volume control so do not have to look away anyway; I very seldom change radio station; Set it before starting out; Usually listen to same station; I set before starting journey and stick with my choice; I use pre-programmed radio stations, the controls are on the steering wheel, and everything shows on the heads up display on the windscreen; I know where the control is and action without looking; I do not select radio stations whilst the car is mobile; I set the station before I start driving.
Look at map on navman	I listen to the app instead of looking at it; I listen to the voice instructions first and may have a quick glimpse of the map to get a sense of awareness of where I am and what turnoffs I need to make so that I can minimise diversion of my eyes from the road; Have my phone in an easy to view place on my dashboard so I can still see the road; Only quickly glance at the map; Try not to use it while moving; I very rarely use it but if a quick look can't give the info I want then I pull over; Keep glances short and rely on voice feedback; Place it in a position where I can view it without taking my eyes and attention from the road; Would only do if there is no traffic in sight on a normally deserted road; My vehicle has a heads up display that shows on the windscreen; Use it stuck to the front windscreen to avoid looking down at it; I have the app on hands free so the directions are spoken and I can continue to keep my eyes on the road rather than look down at the app; Only do a quick glance; I only ever glance at the cars installed gps never on a phone or a tablet or hand-held device; Have it on the audio that gives me directions instead.; I have a system that speaks the directions out loud so I don't look at the app or navi system.; If on a motorway keep going until I recognise a landmark / street exit sign; I have preselected my route; Set the device for my destination before leaving and listen to the voice prompts.
Talk on hands free	Use for simple fast tasks; Keep conversation short; Stop conversation if need to concentrate (eg at intersection); Only use in emergency – for incoming call make it short and reply at later stage when stationary.
Enter destination	I plug in the destination before I leave/begin to drive; I turn on mic instead of typing into navigation app; Put in destination when stationary; Enter destination before leaving on journey; I will set my GPS beforehand; I use voice to select destination; My satnav system won't allow me to enter an address or even a previous destination from the list, while moving. I have to be stationary e.g. in a queue.
Select music on phone	I try to do it quickly; I have a preloaded playlist, I simply play it.
Txt/email/social media	Do it at red traffic lights; Use at stoplight; I have an old school clicky phone and I can actually text without looking at my phone - I only need to look when I select the recipient but not when I'm typing the message. This is why I 'occasionally' text however I am trying to do it less as I know it's illegal and could potentially be unsafe (one hand off the steering wheel for one thing which could make it hard to act really fast in an emergency); I stop; Try not to do it at all; Check in stopped

	traffic; Text while stopped at read lights.
Speed advisory warning	I drive within the speed limit and the conditions; Keep looking at speedo; I reduce speed to the speed limit; I check my speed.
Take pictures	I do it quickly, don't check the quality of the shots, and then put my phone away; I take the photo without looking at the camera at all. Just hold it up in the general direction and click.
Use internet via phone	NA
Lane departure warning	I don't change lanes.
Curve/intersection warning	NA
Read social media	Only at red lights; Look when stopped at red lights.