UNDERSTANDING IN-CAR DRIVER DISTRACTION: ENGAGEMENT WITH TECHNOLOGY WHILE DRIVING

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Thesis submitted to the University of Nottingham

for the degree of Doctor of Philosophy

December 2016

ABSTRACT

Most drivers are aware of the distracting effects and possible dangers of using their mobile phones while driving. Many studies have investigated this effect and although not all have found large changes in driver performance, all have concluded that nothing good can come from this behaviour. Without adding to the wealth of studies in this area, this PhD aimed to discover what kinds of attitudes drivers have towards these technologies, how these drivers behave in a 'natural' situation and how these drivers can be persuaded to cease using these technologies while driving.

The first study was a large questionnaire aimed at measuring theory of planned behaviour constructs from drivers towards five in-car technologies; hand-held mobile phone use, hands-free mobile phone use, text messaging, MP3 player use and satellite navigation use. These identified that attitudes in particular are important predictors of intentions and behaviour. Regression models explained 38-76% of the variance in past behaviour for the five technologies showing that the theory of planned behaviour is a useful tool in understanding these kinds of behaviour.

Studies 2 and 2.5 aimed to discover whether in-car technology could have a positive effect on driver performance with the use of a 'risk monitor'. These results indicated that heart rate could be influenced in a simulator by instilling a sense of risk. Although no differences in driving variables were found, participants' heart rates increased as accident risk increased, importantly showing that feelings of risk arousal can be induced in a simulated environment.

Studies 3 and 4 used a novel design in which participants were given the choice to interact with an MP3 player and skip music that they personally did not like. Study 3 found that participants spent a significant amount of time looking away from the road when interacting with the device. However, no differences in lane deviations or speed deviation were found. Study 4 was then conducted to increase sample size and increase variability by introducing a second speed limit. Results showed that participants had a tendency to miss this speed limit due to interactions with the device. Main effects were found for standard deviation of speed, with the easy skip condition showing more variability than the control condition, possibly reflecting compensatory behaviours due to technology use. Eye data also showed the effects of technology use where glance durations were significantly longer while skipping compared to controls and were significantly longer during hard compared to easy tasks.

Study 5 aimed to combine the risk monitor studies with the MP3 studies and create an environment where participants were free to interact with the device if they wished, but were also given some information on their risk of accident to take into account. Drivers on low risk roads interacted with the device more often than on high risk roads and spent more time listening to unpleasant music when the risk tone was present. In terms of driving measures, participants reached higher speeds when the tone was not present, while mean speeds showed a tendency to be lower when the tone was present.

Study 6 was an intervention study which, informed by the results of study 1, created an intervention based on changing drivers attitudes towards technology use while driving. After the intervention was given, drivers

completed a similar study to the MP3 experiments. This meant that not only could attitudes be measured at different time points, but actual behaviour relating to technology use could be measured. Theory of planned behaviour interventions are often criticised as they tend to measure behaviour by questionnaire rather than tangible measures of behaviour and so this was an advantage to this study. However, the intervention showed no significant effect on attitudes or MP3 music skipping behaviour. However, a significant correlation was found between the number of times a participant skipped and measures of driving violations.

The challenge for future work will be to determine how attitudes can be changed towards technology use and whether further experiments may observe 'natural' behaviour in relation to different types of technology.

ACKNOWLEDGEMENTS

Firstly I'd like to thank my supervisors Dr Peter Chapman and Dr Gary Burnett, for their enthusiasm, motivation and knowledge. Another large thank you to my funders, the Economic and Social Research Council and Transport Scotland. Thank you also to Dr Editha van Loon who has gone out of her way to help me, I couldn't be more grateful. Esther also, for being a brilliant intern and for having a great many friends willing to drive in a simulator.

Thank you to my mother, who single handedly got me where I am today and who always had confidence in my abilities when I did not. My brother and sister who continue to be an extra set of parents, always there when others weren't. The Duddles', for giving me a home and for always knowing how to celebrate when there's nothing to celebrate.

And my Jonny, an endless source of love and support. Thank you for managing to put a smile on my face when times were tough.

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SUMMARY

Driving is considered to be a complex task requiring manual operation and higher cognitive functions. The comprehension of this task becomes more difficult when distractions are added. Therefore, the thesis will review the relevant literature firstly with regards to driving in a general sense and then review more specific research appropriate to the studies conducted. This is necessary as a range of methods were used which require their own appraisal.

The general introduction will discuss theories of driving, what happens when drivers are distracted and how simulators are used in driving research. This serves to give a basic understanding of why driving research is conducted and why simulators are often chosen to examine the effects of otherwise dangerous distractions.

Chapter two will go on to discuss the theory of planned behaviour and how it is important to discover the motivating factors behind technology use while driving. Studies using this framework to gain knowledge on mobile phone use in particular are discussed to form a basis for the theory of planned behaviour questionnaires presented as study one.

Chapter three introduces the idea of a risk monitor to aid driver performance. This monitor gives drivers' information about their risk of accident on simulated roads and so literature on in-vehicle warning systems is included. There is always the potential however, for the risk monitor to be distracting to the driver, or that the driver will become accustomed to its effect. Therefore studies on behavioural adaptation are presented.

Chapter four describes three simulator tasks using an MP3 player. These studies use participant rated unpleasant music as a way to provoke participants into interacting with the device i.e. skipping bad music. Studies on engaging with MP3 players are taken into account as well as the separate effects that music can have on driving performance.

Finally, chapter five describes the various techniques researchers have used to change the behaviour of problem drivers and will continue to evaluate the theory of planned behaviour; this time regarding its effectiveness as the basis of an intervention.

CHAPTER ONE – INTRODUCTION TO DRIVER DISTRACTION RESEARCH AND THE USE OF DRIVING SIMULATORS

Getting from one location to another is often the main goal of a driver, however there are many goals that a person may want to achieve while driving. Young drivers tend to drive for leisure with friends, whilst older drivers have family and work commitments (Hatakka et al, 2002). We might assume that safety and abiding by the law are at the top of a drivers' priority list, however, enjoying the drive is still important to many. In this case, listening to music, avoiding traffic and time efficiency are paramount. In some cases, drivers speed to gain more pleasure from driving (Vogel & Rothengatter, 1984). Realising that people will engage in other activities while driving has led us to explore what drivers will do when we recreate the conditions of the real world. Of course, some of these behaviours increase a drivers' risk of accident and so there is a need to investigate what is safe and what becomes a significant distraction.

Driver Distraction

To discuss driver distraction, a definition of distraction is needed. A framework for understanding driver distraction was put forward by Strayer, Watson and Drews (2011). According to them, distraction in vehicle comes from three sources; visual distraction (the driver takes their eyes off the road to attend to another person or device), manual distraction (the driver takes their

hands off the wheel to interact with a device) and cognitive distraction (safe handling of the vehicle is compromised when enough attention is taken away from the driving task). Definitions of distraction often incorporate the idea that the attention that is supposed to be focussed on the driving task is, at least a proportion, somewhere else (Patten et al, 2004; Sheridan, 2004). Young, Lee and Regan (2008) reviewed 14 definitions of distraction from the literature and make an important distinction between driver distraction and driver inattention. Inattention occurs when the driver fails to attend to the driving task. Distraction is when attention to the driving task is reduced due to a competing activity or device e.g. tiredness (inattention) versus texting while driving (distraction). This distraction may come from inside or outside the vehicle (Horberry et al, 2006). Distraction will be discussed in terms of theories of attention and models relating to distraction, what happens when a driver is distracted and what technological devices are most likely to cause distraction.

Theories of Driving

It is an unfortunate turn of events that not only are younger drivers are more likely to be involved in an accident (Massie, Campbell & Williams, 1995; Ryan, Legge & Rosman, 1998; Lourens, Vissers & Jessurun, 1999), but these younger drivers are also the ones most likely to use technology while driving (Young & Lenne, 2010; White, Eiser & Harris, 2004). Young driver models therefore endeavour to identify the predictors of accident involvement in order to better understand and perhaps prevent young driver accidents.

Young Driver Model

Gregerson and Bjurulf (1996) proposed a model of accident involvement for young drivers (Fig 1.1). A key aspect of the model is driver learning, which is split into 'teaching', 'training' and 'experience'. Training is important here as many drivers would admit that their goal was to obtain a driving licence, rather than become a fantastic driver. It is assumed that training gives a basic knowledge of driving, while experience makes a capable driver. This part of the model is based on finding that drivers with higher mileage have less accidents per mile and that novice drivers at any age are more likely to be involved in an accident (although very young drivers are at a higher risk). Skills which come from training and experience improve things like risk awareness and risk evaluation and in turn modify the motivations and intentions of the driver. Another part of the model takes into account social aspects of life and individual differences. Subjective norms (discussed fully in chapter two - Theory of Planned Behaviour: Ajzen, 1985) describe the way in which young drivers may be influenced by others in the way that they drive. Previous research lead Gregersen and Bjurulf to include this section as young people often drive with passengers and are involved in thrill seeking behaviour. Motivations are described here as being controlled by reinforcement, for example, if a driver uses his mobile phone while driving and isn't seen by the police, isn't involved in an accident and manages to complete his phone call successfully, then he will conclude that this behaviour is something that is acceptable. A behaviour which is pleasurable will act as positive reinforcement if there are no unpleasant consequences. Behavioural

adaptation theories are touched on here which will be discussed in chapter three.

This model describes the factors which contribute to how a driver behaves and ultimately, their accident involvement. Beginning right at the learning stage, authors have outlined how education at this early point can have a large impact on final driver behaviour. Although this model has been developed for young drivers, accident statistics have found that driver experience contributes more to accident involvement than age and is ultimately a useful tool in understanding why a driver may partake in risky behaviour.

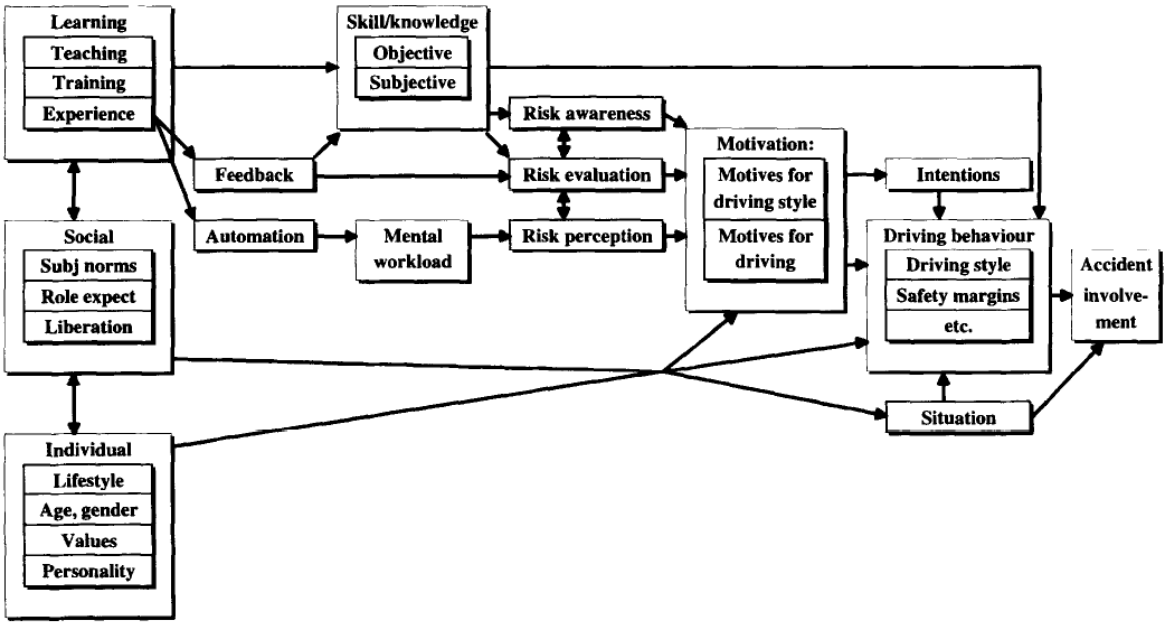


Figure. 1.1. Model of young drivers' accident involvement (Gregersen & Bjurulf, 1996).

Risk utility and risk propensity

Jonah (1986) proposed that young drivers are at a higher risk of being involved in an accident involving a casualty than older drivers and that the reason for this is largely down to younger drivers having a greater propensity for risk. Jonah (1986) describes the phenomenon of 'risk behaviour syndrome' as drivers who already perform one risky behaviour will perform other risky behaviours. For example, non-seat belt wearing drivers are prone to driving with small headways (Evans, Wasielewski & von Buseck, 1982), non-seat belt wearing drivers are also more likely to be smokers, drug takers and drink drivers (Oleckno & Blacconiere, 1990). The danger is that drivers who already take risks in normal driving e.g. not wearing a seat belt, driving too close to the car in front etc. may also choose to use technology while driving. Coupled with their already risky driving style, this could have obvious consequences.

Risk utility references the benefits and value of risk taking, in that some risks may pay off, for example, speeding may prevent being late (Jonah, 1986). The risk itself is appealing to some who view taking risks as exciting as a form of sensation seeking (Fernandes, Job & Hatfield, 2007).

Risk propensity (Hatfield & Fernandes, 2008) describes a positive attitude to risk. Drivers with high risk propensity are more likely to engage in risky driver behaviour, particularly young drivers. According to Hatfield and Fernandes (2008), drivers may regard perceived risk as costly or beneficial; demonstrating that safety is not always a top priority. The biggest goal for most drivers is to remain as safe as possible. However, drivers may have multiple goals which invariably compete, for example a driver who wants to

comply with speed limits but who is in a hurry (Dogan, Steg & Delhomme, 2011). However, not all drivers who partake in some risky behaviours will also perform other risky driving behaviours. Fernandes, Job and Hatfield (2007) conducted a student survey aimed at investigating whether the factors underlying risk taking in driving were the same for all risky driving behaviours. Results found various different predictors for risky driving e.g. speeding was predicted by 'authority rebellion' while competitive driving was predicted by 'hyper-competitiveness'. Authority rebellion was measured by the Authoritarianism-Rebellion Scale (Kohn, 1972), first used to measure political attitudes. Here it has been utilised to measure liberal tendencies and attitudes towards authority. Hyper-competitiveness describes individuals who show an incredible desire to compete and win. Winning to these individuals is necessary to preserve or increase self-worth (Ryckman, Hammer, Kaczor & Gold, 1990). This is important to investigate as drivers with these traits may be more likely to break the law, in reference to their rebellious tendencies towards authority and they may be more likely to disregard safety in order to 'outdo' other drivers.

A framework for understanding risk propensity in driving behaviour has been composed by Hatfield and Fernandes (2009). Figure 1.2 shows how a driver's feelings on perceived risk, risk aversion and risk propensity may interact to result in a risky driving behaviour. Driver error is included here to show how a young driver's inexperience may also contribute to risky behaviour. In another questionnaire based study, general risk propensity was associated with higher incidences of drink-driving in older males, while

speeding and drink-driving were associated with excitement for younger males. A further study found thrill seeking to be significantly associated with not wearing seat-belts but found no relationship for speeding or drink driving (Hatfield, Fernandes & Job, 2014). This model builds on the previous in that it takes into account how a driver willing to partake in one questionable behaviour is also more likely to partake in another.

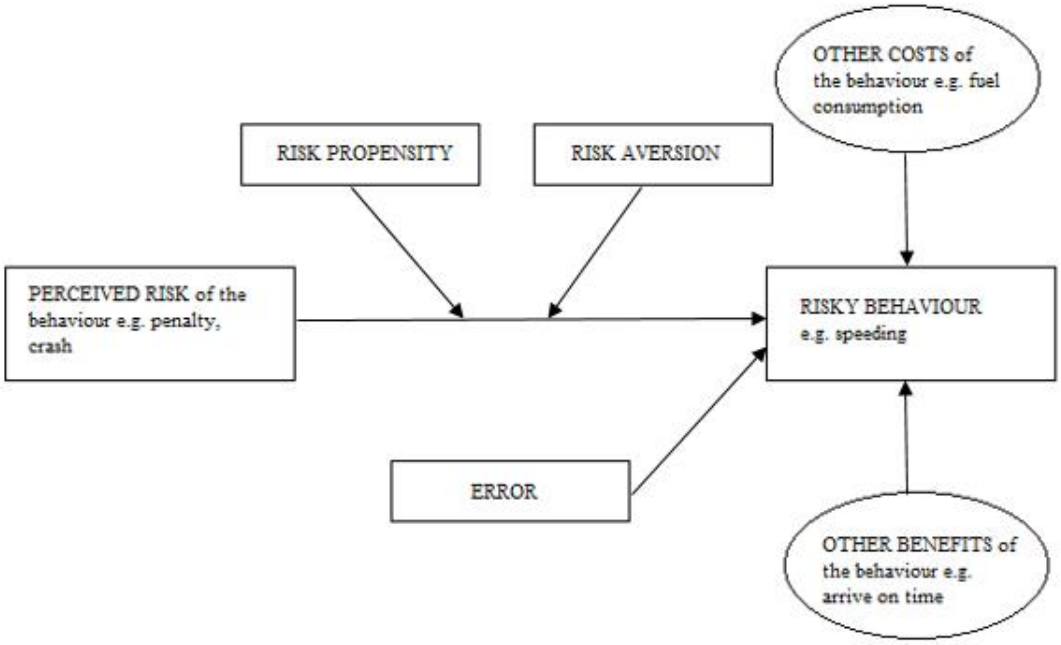


*Figure 1.2***.** The role of risk propensity in risky driving behaviour (Hatfield & Fernandes, 2009).

Crossmodal Attention

The models above have given an indication of the factors which can influence and predict risky driving behaviour. Discussed now are cognitive explanations of what happens when a driver is distracted while driving and which combinations of distractions can be most dangerous.

Previous research, such as Multiple Resource Theory (Wickens, 1984, 2002), hypothesised that people have separate resources for sensory channels which are limited in capacity. According to this model, task performance is decreased when two or more tasks exploit the same resource, which worsens as tasks become more difficult (Wickens, 1984). The reverse should also be true, in that multiple tasks that do not use the same resource should not suffer. The idea of independent resources for each sense has since been challenged with evidence supporting the idea of cross-modal connections (Spence & Driver, 1997a). As a result, crossmodal interfaces have been developed in order to relay information across modalities, for example, a satellite navigation system gives auditory and visual information (Sarter, 2007).

If drivers have separate resources for auditory and visual information, then they should have little or no problem in conversing with a passenger or mobile phone while attending to the road. In fact, many studies have found the opposite, with drivers experiencing visual tunnelling (Reimer, 2009; Reimer et al, 2012; Gaspar et al, 2016), slower response times to hazards (Horberry et al, 2006; Gaspar et al, 2014), impaired ability to monitor speed and situational awareness (Heenan, Herdman, Brown & Robert, 2014). Drivers then show compensatory behaviours for the increase in workload by increasing headway and lowering speed (Saifuzzaman et al, 2015). Therefore, research is discussed in terms of crossmodal attention. Studies focussing particularly on dual-tasks have found cross-modal links between visual, auditory, touch and spatial modalities (Eimer, Van Velzen & Driver, 2002; Spence & Driver, 1997b; Spence & Read, 2003). These studies are particularly interesting in the

field of driver distraction as they suggest that the manual holding of a mobile phone is not the reason for decreased driver performance (Strayer & Johnston, 2001), but rather it is the conversations themselves which distract visual attention away from the road. Hands-free drivers in fact show increases in reaction times to drivers braking in front and have impaired recall of billboards at the roadside (Strayer, Drews & Johnston, 2003). Gherri and Eimer (2011) suggest that 'active listening' is the reason for this apparent distraction of visual attention.

Dividing attention across modalities is desirable to many, as we save time by multitasking. However, spatial attention in particular has been shown to have crossmodal links with auditory and visual attention with speech tasks in simulated driving. Participants (n = 8) in a simulator experiment were given a speech shadowing task where speech presented through speakers either came from a speaker directly in front of the driver or from the left of the driver (Spence & Read, 2003). The shadowing task was performed once while driving and once while stationary, with half of the task words coming from one speaker and half from the other. Drivers repeated more words successfully when they were stationary (no driving) compared to driving. Shadowing task performance was significantly better when words were aired from the front speaker compared to the side speaker and this difference was larger in the driving task, prompting authors to conclude that auditory information is better attended to when a concurrent visual task is presented from the same spatial location. However, no differences in driver performance were found between single and dual task conditions.

A further experiment required participants to drive in a simulator whilst listening to true and false statements (Bergen et al, 2013). A motor condition was included as previous research indicates that motor language such as instructions on how to open a jar can actually interfere with real motor control. A visual condition included statements on relevant visual content within the simulated drive such as the colour of signs on the road. A final 'abstract' condition included statements about geographical information. Participants were required to state whether the statements they heard were true or false. A fourth, control condition was included whereby participants were instructed to say the word 'true' or 'false' at similar intervals. Brake response time was measured. A separate experiment was conducted in the same manner, however, participants were required to repeat the statements as well as remarking on their veracity. No differences were found between these experimental groups and so results were accumulated (n = 93). Brake response times were slower in the experimental conditions compared to the control condition, which suggests that language interferes with proper driving and supports the idea of a domain-general approach of interference. Following distance was greater in the visual condition compared to abstract and controls, while motor condition was greater than the abstract and controls. This suggests that motor and in particular visual language interferes with driving to a greater extent than abstract language. As predicted by authors, visual language disturbs successful driving when the language is visually relevant to the task. Differences were found between conditions in terms of following distance but not for braking reaction times. The reason for this, authors

suggest, is that following distance requires planning in addition to visual and motor control. Therefore, these processes used for planning must also be engaged in visual and motor language. However, an alternative explanation is that the driver is displaying compensatory behaviour by maintaining a greater distance between the car in front to compensate for the higher workload.

Basic Distraction Findings

What happens when drivers are distracted?

Theories and models describe what kinds of drivers are more susceptible to distraction and the mechanisms underlying distraction. Drivers can be distracted many times in one journey, by children, pets, mobile phones, amongst numerous other things. In reality, these distractions do not always equal an accident, so what happens when drivers are distracted?

Investigating what happens when a driver is distracted is vitally important considering just the driving task itself can occasionally require more mental resources than the driver has to offer (Hurts, Angell & Perez, 2011). Therefore, any distraction to the driver can result in near-misses, or accidents, injuring themselves or others. A recent study on teenage drivers found up to 76% of actual rear-end collisions were due to distracted behaviour (Carney, Harland & McGehee, 2016) and after analysing in-vehicle video footage from four hundred 16-19 year olds, authors found mobile phone use to be the most prevalent distraction involved in an accident (18%). This was closely followed by the driver's attention being elsewhere outside the vehicle (17.2%) and paying attention to a passenger (16%).

One study found those using a mobile phone (regardless of whether the phone was hands-free) were four times more likely to crash if a mobile phone was used up to 10 minutes before crashing (McEvoy, Stevenson & Woodward, 2007). Results also found drivers carrying two or more passengers were twice as likely to crash and attend hospital than those carrying no passengers, suggesting a distraction element for both types. However, this study only assessed the likelihood of crashes when a mobile phone was in use when the crash was serious enough that the driver had to attend hospital. This presents an information bias, as other crashes brought about by mobile phone distraction are not major enough to involve hospital trips. However, a Finnish study found 13.7% of survey respondents reported 'close call situations' due to a mobile phone (Korpinen & Paakonen, 2012). Participants in this study based responses on whether the mobile phone 'had a partial effect' on the close call. Without knowing the type of conversation being had at the time, or the handset type (hands-free, hand-held) it is difficult to attribute the cause to that of added cognitive load due to a taxing conversation (Drews & Strayer, 2009) or whether manual manipulation of the phone conflicted with vehicle transmission type (Haigney & Westerman, 2001). 'Close call situations' were not defined in this study and it appears that respondents were left to speculate about the meaning of a close call when answering the survey. However the famous 100 car naturalistic study, which filmed drivers in their own vehicles, defined near-crashes as situations in which an immediate evasive manoeuvre was required to avoid an accident (Neale et al, 2002; Dingus et al, 2006).

Many drivers are aware of the dangers of distraction and so modify their behaviour as a result. A positive aspect of a survey conducted by Young and Lenne (2010) was that an extra section was included with the intention of assessing the compensatory behaviours which respondents engaged in. Results found 94% of participants reported owning a mobile phone, with 59% of these admitting to using the phone while driving. 27.8% of older drivers confessed to using a mobile phone while driving compared to almost 70% of 26-55 year olds and 70% of 18-25 year olds. As discussed earlier, this use of technology while driving is particularly dangerous in the younger age group as these drivers do not have the experience to be able to adequately cope with extra demands. 84% of drivers acknowledged that they drive less safely when involved in a distracting activity, which was consistent across age groups and 80% believed that they are slower to respond to events when engaging in a distracting behaviour. Not surprisingly, almost 80% of drivers compensate for their behaviour by slowing down, or pulling over to the side of the road (67.8%). Drivers reported to taking into account road situations which would prevent them from engaging in a distracting activity, with the most common being bad weather (91.7%). 17.8% of drivers stated that they had been in a crash in the last two years and, of these, 10% of the crashes were due to self-reported distraction, although the distraction involved did not involve mobile phone use.

Consistent with the survey findings, many driving simulator studies have found that changes in speed are often indicators that a driver is distracted. Drivers tend to slow down when distracted which authors tend to interpret as

compensating for increase in workload (Haigney, Taylor & Westerman, 2000; Törnros & Bolling, 2005; Törnros & Bolling, 2006). Cognitive tasks in particular lead drivers to tunnel their vision and have less variation in gaze patterns due to increases in workload (Reimer, 2009; Reimer et al, 2012; Gaspar et al, 2016).

In-car technology & driver performance

Drivers can be distracted by a range of technologies and the resulting diversion of attention can manifest in different ways i.e. the cognitive demands of a hands-free mobile phone conversation compared to the manual demands of satellite navigation use. The presence of multiple in-car distractions is an essential subject to investigate as the demands required by these distractions have been shown to impair driver performance (Lansdown, Brook-Carter & Kersloot, 2004). It is for these reasons why technology based distractions must be investigated with the goal of ultimately discouraging the behaviour. Researchers have focussed mainly on three areas of distraction (visual, physical and cognitive distraction) to explain how attention is diverted or allocated incorrectly (Young & Salmon, 2012). Each of the technological devices discussed may distract the driver in one or all three of these areas.

Mobile phones.

Mobile phones, satellite navigation devices and portable music players have become increasingly popular in the past ten years (Strayer, Drews & Crouch, 2006). For this reason, driver safety while using these devices has

become a major concern, particularly the use of mobile phones (Young & Regan, 2007). Lansdown (2012) conducted a large scale survey in which respondents rated various in-car behaviours for how distracting they were. The highest rated distracting behaviours were writing a text message, reading a text message and using a hand-held mobile phone. Around half of drivers admitted to performing these behaviours while driving. 'Add on media devices' (such as an MP3 player) were rated as moderately distracting, with 13% of respondents claiming to use them daily while driving. Studies on music and drivers' use of MP3 players will be discussed in chapter three.

Using a hand-held mobile phone while driving is predominantly illegal in many parts of the world, including the UK (Road Vehicles [Construction and Use], 2003). Nevertheless, it is estimated that 21% of UK drivers have used their mobile phone while driving at least once in the past month (Naumann & Dellinger, 2013). 1.6% of English and Scottish drivers have been observed using a mobile phone while driving, rising to 2.3% when stationary (Department for Transport, 2015). This statistic is open to variation with other studies estimating between 27-70% of drivers using mobile phones depending on age (Young & Lenne, 2010). It is estimated that distractions were implicated in 3% of accidents involving a casualty in Great Britain during 2015 (STATS19, 2016). However, there is much difficulty in attributing specific distractions to accidents as drivers can be less than forthcoming about the cause of their accident to police. However, simulator studies have enabled researchers to directly record the effects of mobile conversations on driving performance. Strayer and Drews (2004) compared 18-25 year olds (n = 20) to

65-74 year olds (n = 20) in two counterbalanced conditions in which they drove in a high-fidelity driving simulator while talking on a hands-free phone and again in a non-distracted condition. Participants were required to follow a simulated car and brake and accelerate behind the car. The simulator was able to record data relating to speed and braking distances. These showed, perhaps not surprisingly that a hands-free conversation negatively affected driving performance and this negative affect was equal for all ages. It has demonstrated that even while participating in a legal behaviour (hands-free mobile phone use while driving) the performance of the driver can be directly affected. As highlighted, conversation alone impaired performance, which is also important when considering passenger conversations, although studies examining the impacts of conversations are limited by the genuineness of these conversations.

An added danger comes when drivers choose to use texting functions while driving. An interesting dynamic has been presented in regards to text messaging through touchscreen and physical keyboard mobile phones (Crandall & Chaparro, 2012). Using a lane change task on a low fidelity simulator, participants (n = 23) were required to text four letter words, presented on a nearby laptop, using a mobile phone which had both touch screen and physical keyboard capability. A signal was given as to when the participant should change lanes and this movement was compared to 'ideal' lane change behaviour in both touch screen and physical text conditions. Touch screen texting was found to result in greater mean deviations from the ideal lane change path than physical texting and no texting. Participants also

experienced higher self-reported workload in the touch screen texting condition, resulting in the conclusion that the lack of physical feedback from the touch screen contributes to higher cognitive demand and therefore, a greater amount of driving error. Although a low fidelity simulator was used, low and high fidelity simulators seem to reach the same conclusions when conducting mobile phone research (Drews & Strayer, 2009). A study using a higher fidelity simulator found braking response and lateral lane position to be greater while texting compared to a control condition (Drews et al, 2009). This highlights how technology shift can create a more difficult task for drivers who choose to perform these behaviours.

Other Devices

A relatively new driver aid is the satellite navigation system. Much like mobile phones, these have progressed to touch screen interfaces on dedicated devices, apps on mobile phones and built in car-systems. Satellite navigation systems are a welcome alternative to map reading as they allow the driver to reach their destination in quicker times whilst minimising the time the eyes are not on the road compared to map reading (Lee & Cheng, 2008). However, these systems still require visual and/or auditory attention. One study required professional drivers to navigate a familiar area in a real car and then follow a satellite navigation system in the same area, using a different route, all while completing a peripheral detection task (Harms & Patten, 2003). Performance measures specific to driving were similar for both satellite navigation use and driving from memory. However, reaction times on the

PDT were slower when following the visual directions of the navigation device, suggesting that satellite navigation interrupts important visual scanning. Studies involving satellite navigation systems are rare as navigation systems specific to simulated environments are difficult to create.

However, another study compared the effects of portable satellite navigation use to a smartphone application used for navigation (Google maps) (Dopart et al, 2013). Participants were required to enter two addresses into the device in each condition. No differences in lane position were found and eye data were very similar for both devices, although glance time was higher for the portable device. No participant was able to complete the device tasks in the 12 seconds glance time the NHTSA recommends. The National Highway Traffic Administration (NHTSA) of America suggest that any secondary task should not require the driver to look away from the road for more than two seconds at a time and these glances should not exceed twelve seconds (NHTSA, 2012). Although no large differences were found, the authors did recommend that devices be mounted as these require significantly less eye time off road than hand-held devices.

Multiple in-car distractions.

The use of in-car technology is of particular concern with newer drivers as their spare attentional resources may be low compared to more experienced drivers and so have less resources to 'spend' on other activities while driving (Lee, 2007). Multiple distractions are of concern as drivers have access to a range of devices which have the potential to impair driving performance.

Dewing, Johnson and Stackhouse (1995) assessed the driving performance of drivers in a simulator (n = 40) while performing three secondary tasks, either alone, in pairs or all at once. The three tasks consisted of a conversation task through an intercom, reading an electronic map and searching for an object inside a container. This experiment was problematic in that performing the three tasks truly simultaneously was impossible, however, these tasks were chosen in respect to high ecological validity. Ecological validity in this case reflects how participants may find themselves doing similar tasks in their own vehicles on real roads and so these tasks can be generalised more to real life settings. Limited differences in performance were found between the tasks and control condition, however, it was clear that the map task impaired driving performance in terms of speed maintenance and response time. This demonstrates that secondary tasks have their own individual effect and the impact on driving performance differs for different tasks.

This experiment inspired another simulator study. (Lansdown, Brook-Carter & Kersloot, 2004) demonstrated the negative effects on simulated driving performance using visual tasks (n = 23). The experiment included four tasks; the first task required participants to identify whether a number displayed to the left of the driver, on a screen, were odd or even by pressing a button located on the steering wheel. The second task involved the same stimuli as the first, with the difference being that the numbers appeared at sporadic, random intervals. The third task involved the same number stimuli as the first two tasks, however, letters were added and the participant was required to press a corresponding key as to whether the letter was a consonant

or vowel. The experiment also involved a control task where participants drove in the simulator without the tasks as distractions. The NASA TLX questionnaire provided a measure of workload after each condition. This questionnaire is comprised of six subscales which measure one of six facets of workload; mental demand (how mentally taxing the task was), temporal demand (how rushed the task felt), physical demand (how physically demanding the task was), performance (how successful the task was), effort (how much effort was required to complete the task) and frustration (how frustrating the task was). This questionnaire is widely used throughout the driving literature to evaluate tasks during experiments. Not surprisingly, the lowest measure of mental workload was seen in the control condition and the highest mental load was seen in the task involving both letters and numbers. The addition of tasks while driving also decreased the average distance between the driver and the car in front and also increased the average brake pressure. Speed data showed that participants had maintained significantly slower speeds while involved in a secondary task, suggesting that this was a compensatory behaviour to reduce the negative effects of the second task.

Simulation

Simulators in Psychological Research

The majority of studies discussed were only possible due to the driving simulators involved. These simulators have allowed scientists to investigate dangerous situations in complete safety. Simulators are widely used in many areas of psychology such as aviation (Salas, Bowers & Rhodenizer, 1998),

navigation (Janzen et al, 2001), memory (Brooks, 1999) and driving research (Bella, 2008). One of the major issues with virtual reality in simulators is the lack of ecological validity. However, some research has suggested that participants do not differ largely in real world compared to simulator data (Caird et al, 2008). In spite of this argument, it is clear that the emergence of simulators in research has allowed the academic community to explore in detail, the types of behaviours and situations which would be unsafe in reality.

The use of simulators in research has dramatically changed some fields of psychology, particularly the psychology of driving behaviour (Wade Allen, Rosenthal & Cook, 2011). Not only has research benefited from this technology, the safety of training in aviation, military and medicine allows new trainees to gain practical and safe experience (Salas, Bowers & Rhodenizer, 1998; Dunn & Murphy, 2008).

The simulators described range from low to high fidelity, which essentially describes how realistic the simulator is (Aliner et al, 2006). A distinction has been made between fidelity in engineering terms and fidelity in psychological terms. Engineering fidelity is the extent to which the simulator imitates the physical qualities of the real task, whereas psychological fidelity is the extent to which the simulator replicates the skills and tasks that are found in the real task (Maran & Glovin, 2003). Low fidelity simulators are often simply computer screens with a manual input system such as a keyboard or joystick for control (Prince et al, 2007). High fidelity simulators such as those in driving or aviation research will be set in a full or partial car or cockpit and may have the capacity to move on a motion base (Hallvig et al, 2013;

Subramanyam, 2013). A point to note here is that a high fidelity simulator in 2004 may not be described as such today. It may only be described as high fidelity relative to the year in which the study was published.

Safety is key for many researchers and so to have the facility to train or experiment safely, in what would have been, in reality quite dangerous, is very appealing, particularly in the fields of aviation and medicine (Salas, Bowers & Rhodenizer, 1998; Dunn & Murphy, 2008). Regardless of the field of study, simulators can be expensive to acquire and run, however, they are becoming increasingly more economical (Lenné, Groeger & Triggs, 2011). When considering that a simulator can be used repeatedly for the same task, it may be more cost effective than the real-life equivalent (Maran & Glovin, 2003).

The advantage of using a simulated environment in a memory or navigation experiment is that every participant is on an equal footing in terms of never having experienced the environment before. It also offers greater freedom in that the virtual world is stored on computer whereas a real-world version of the maze would require a large physical space (Weniger & Irle, 2008). In addition, any slight changes can be made to the virtual environment relatively easily compared to a large physical space such as this.

Whatever the purpose of research, the use of simulators has a major drawback of simulator sickness. Participants may drop out due to nausea and confusion (Mourant & Thattacherry, 2000) and this may create a bias in that those without simulator sickness symptoms may be fundamentally different and respond differently to the experiment, training or therapy than those who drop out. For example, females and older participants are thought to be more

prone to simulator sickness and this could have implications for results (Brooks et al. 2010; Mourant & Thattacherry, 2000). However, one study has shown that this can be overcome by introducing participants to the simulator before the experiment is to begin. After an initial 10 minute long drive, designed to familiarise the participant with the simulator, participants who returned two days later to complete the driving task experienced significantly less simulator sickness symptoms (measured by the Revised Simulator Sickness Questionnaire, RSSQ) than those who completed the driving task after the familiarisation exercise (Domeyer, Cassavaugh & Backs, 2013). The field of view is also thought to be important in the occurrence of simulator sickness with one study estimating 140^{o} as the critical value (Lin et al, 2002). This may be important for the higher fidelity simulators, which often have a full 360^{o} field of view (Kaptein, Theeuwes & van der Horst, 1996).

Use of simulators in driver behaviour research.

Perhaps one of the most popular uses for simulators is in the area of driver behaviour. Driving simulators have become advanced enough to test many variables in the interest of safety, such as speeding (Boyle & Lee, 2010), distraction (Garrison & Williams, 2013), age (Bunce et al, 2012), fatigue (Hallvig et al, 2013), alcohol (Helland et al, 2013), and cognitive syndromes such as dementia (Brown & Ott, 2004). Extraneous variables can be controlled such as traffic density, weather and hazards in the simulator, allowing for the experiment to be properly controlled and under direct control which would not be possible on a real road (Summala, Nieminen & Punto, 1996). Because of

this, one of the major advantages to simulator research is the ability to directly manipulate variables and determine a cause and effect relationship.

Driving simulators are valuable to research as they often include eye trackers. Eye trackers present us with the differences seen in the range of visual fixations in different situations. Driving studies have proved the necessity for the use of eye trackers in that visual tasks utilise the same resources as the driving task itself (Jamson & Merat, 2005). Therefore, of particular interest is the impact of distraction and for how long a distraction such as a mobile phone may take a driver's eyes off the road. Victor, Harbluk and Engstrom (2005) analysed eye movements from participants who drove in a simulator while concurrently completing a visual task. Results showed that as the visual task became more difficult, eye fixations tended toward the visual task screen and toward the centre of the road. This is important when considering in-vehicle technologies such as satellite navigation systems that could elicit similar eye fixation patterns and may reduce peripheral detection and increase risk of an accident. Research has also used eye-tracking equipment as an exploratory measure to investigate typical eye movements of drivers. Eye positions while driving have been found to fixate on the 'future position' of the car in order to make steering easier, especially when navigating bends in the road (Wann & Swapp, 2001).

Briggs, Hole and Land (2011) aimed to find whether emotionally charged mobile phone conversations could affect a simulated driving task. Half of participants were spider-phobic and the other half non-phobic (measured using the Spider Phobia Questionnaire (SPQ). All participants (n =

23) drove in a simulator once, undistracted and again while having a conversation about spiders while wearing a head-mounted video eye tracker. Unsurprisingly, a significant difference was found in driving errors between the undistracted control condition and the distracted condition. No significant differences were found in the number of eye fixations and phobic status. However, differences were found in terms of horizontal and vertical fixations, where the non-phobic participants made significantly more horizontal and vertical fixations than those with a spider phobia. This is explained as 'visual tunnelling'. This eye tracking data was used to explain this visual tunnelling in terms of cognitive world load, where a higher demand in this workload due to the emotional conversation, decreased the amount of visual scanning. However, only 30 seconds of eye tracking footage was analysed for each participant in each condition and so may leave out clues about the nature of the scanning further into the conversation. This demonstrates that a high fidelity simulator does not always result in rich data.

Ecological validity.

However, ecological validity remains an issue and perhaps the most obvious drawback to the use of simulators in research is that the simulator cannot truly represent the real environment. Nevertheless, without the use of these simulators, vital safety research would not be possible. For example, using hand-held mobile phones while driving is illegal in many parts of the world, including the UK (Road Vehicles [Construction and Use], 2003). Therefore, it would be unethical to request a participant to use a hand-held

mobile phone while in a natural environment. Even the most naturalistic experiments in this area must make some concessions in terms of validity by using test tracks (Ishida & Matsuura, 2001). Particularly with dangerous illegal behaviours such as driving under the influence of alcohol, the driving simulator is particularly useful in examining effects without the danger or ethical considerations of an on road study.

The use of a high fidelity simulator is desirable for researchers as the loss of ecological validity can be partially recovered depending on how realistic the simulated experience is. However, with the cost of acquiring and maintaining such a simulator being so high, it is sometimes more prudent to use a simulator of lower fidelity. Although high and low fidelity simulators in mobile phone and driving research have generally arrived at the same conclusions (Caird et al, 2008; Drews & Strayer, 2009), a higher fidelity simulator may have created a more realistic setting while also collecting additional performance data. In addition, a particular problem for participants in driving simulators is the perception of speed. It is thought that speed can be estimated correctly in high fidelity simulators with a wide field of view while, in lower fidelity simulators, speed estimations can be inaccurate (Kemeny & Panerai, 2003). Simulators have also been found to inflate the effects of variables such as fatigue (Hallvig et al, 2013). Regardless, the data collected may be a concern in its own right, as the type of data recorded and the type of task or scenario included in the experiments vary wildly and so generalisation becomes an issue (Green, 2005).

Touched on earlier, an important factor in simulator research is to consider a simulator practice for the participant before they start the experiment. In driving research, this has been found to be hugely important. Sahami and Sayed (2013) stress the importance of adaptation to the simulator as no practice or not enough practice may result in distraction from the main task at hand due to added workload brought on by the task of being in the simulator itself. Other authors have added to this notion by suggesting that a practice or adaptation period should be set for each road type that the participant will encounter on the experimental task with a measure of adaptation taken to ensure the participant is fully accustomed to the simulator (Ronen & Yair, 2013).

The ability to analyse dangerous situations in a safe environment is a major benefit to simulators. Then again, realism is a problem that may only improve as technology advances. Currently, reaction times in a simulator are estimated to be around 13% slower than those when participants are driving real cars (Riener & Kepler, 2010) and so experiencing a real sense of danger or urgency may be the key to gaining a realistic simulated experience (Ranney, 2011). However, little or no differences in terms of driving performance data have been found between on-road and simulator studies (Caird et al, 2008) which suggests that the use of simulators, particularly in driving research are necessary for answering questions which cannot be answered ethically on road. Even so, when a true environment is on hand, it would be difficult to justify the use of a simulator over and above the real environment.

Conclusions

By examining the attitudes and beliefs behind technology use while driving, it is hoped that the following studies will advance and expand current knowledge into technologies which have not been investigated previously. Specific emphasis will be placed on conducting simulator studies which give a high amount of freedom to the participant. In doing this, these studies can offer a glimpse into what happens when a driver chooses to attend to a secondary task when completely unprompted. Following this, it is then important to consider the ways in which drivers may be persuaded to drive in a safer manner. In summary, the main thesis aims are:-

- To determine which beliefs and attitudes are the most important predictors of technology use while driving.
- To investigate whether a novel technology may assist drivers by informing them of their accident risk.
- To design an experimental paradigm that imitates a natural situation in which drivers have the option to engage with technology.
- To investigate whether information on accident risk affects the use of in-car technology.
- To pilot an intervention aimed at reducing technology use while driving.

STUDY ONE – USING THE THEORY OF PLANNED BEHAVIOUR TO UNDERSTAND DRIVER DISTRACTION

There is increasing evidence that the use of technology while driving compromises driver safety, in particular, the use of mobile phones. Where once drivers may have just engaged in making or receiving calls or text messages, there is now the opportunity to interact with social media applications and gaming, still just on one device. Technological advances have increased the functionality of the humble mobile phone to the point that now the device may act as a games platform, satellite navigation system or MP3 player. Increased availability and reduction in cost means that many drivers own these devices, however, ownership does not equate to use while driving. Accurately estimating the use of these devices is difficult, but what is more unclear is what motivates drivers to do this. Past research has been criticised for its lack of theoretical constructs in explaining behaviour (Walsh et al, 2008), and as a result, recent studies have most predominantly used the theory of planned behaviour to explain how attitudes, social norms and feelings about control can contribute to intentions and behaviour.

Theory of planned behaviour

The theory of planned behaviour (Fig 2.1) (Ajzen, 1985) is a model which attempts to explain behaviour in terms of the relationship between intentions and actual behaviour, through predicting intentions from beliefs. Attitudes toward the behaviour, subjective norms and perceived behavioural control have been found, along with intentions, to explain a large proportion of

the variance in actual behaviour (Ajzen, 1991). An intention to perform a behaviour is thought to be the largest predictor of behaviour as intention is thought to signify the level of effort that one is willing to put into a behaviour, as long as the behaviour is volitional (Ajzen, 1991). A person's actual control over the behaviour is governed by resources such as money, time and skills (Ajzen, 1985) and so the behaviour may bypass intention if the individual does not have sufficient control. Perceived behavioural control is a construct which was added from the original theory of reasoned action (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980) to make up the theory of planned behaviour. Perceived behavioural control gives a measure of an individual's perception of their ability to carry out a behaviour, based on control beliefs which may help or hinder the execution of a behaviour. Subjective norm is the perception of social stressors of whether or not to carry out a behaviour, and is governed by normative beliefs of what behaviours those most important to us (normative referents) may carry out. Finally, attitudes toward the behaviour measure how positive or negative the resulting behaviour may be, based on the behavioural beliefs of this behaviour and the expected positive or negative outcomes. The theory of planned behaviour is useful within driving research as it enables researchers to discover what underlies behaviour and assess what aspects of attitude, norms, control and intentions to target when forming an intervention.

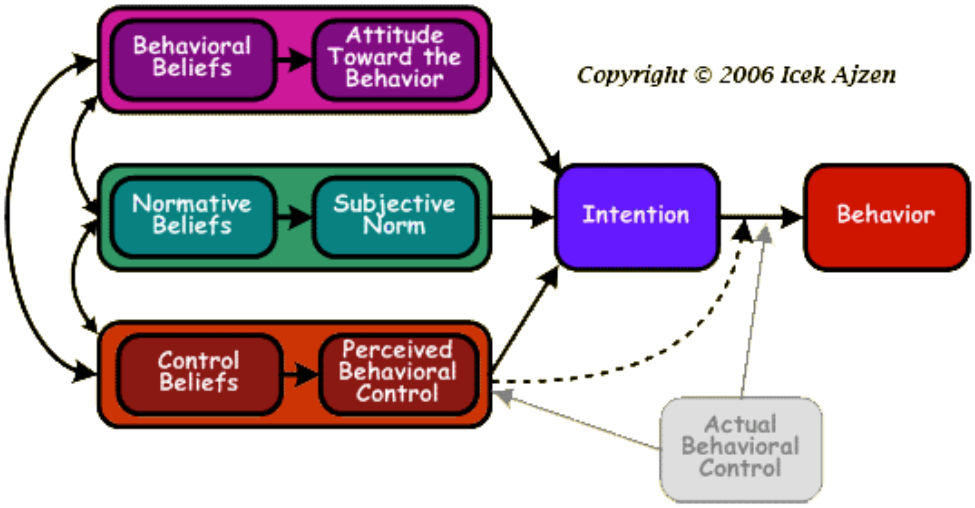


Figure 2.1. Theory of planned behaviour (Ajzen, 1985, 2006).

The theory of planned behaviour has been employed to investigate many aspects of driver distraction, most notably, speeding and other driving violations. Studies on speeding behaviour in relation to the theory of planned behaviour have reliably found intentions and attitudes to predict behaviour (Warner & Aberg, 2006; Elliot, 2010; Elliott & Thompson, 2010).

Studies on risky driving behaviours can often include the use of technology while driving. Rowe et al (2016) used the theory to explain intentions to perform risky behaviours in novice drivers. Using around 77 drivers, models explained 41-69% of variance in intentions to drive over the speed limit, drive over the alcohol limit, drive while talking on a hand-held mobile phone and driving while very tired. Attitude was a large significant predictor for all behaviours, while subjective norms and perceived behavioural control were only predictors of driving over the speed limit and talking on a hand-held mobile phone.

Research is scarcer when looking at mobile phone use exclusively. White, Hyde, Walsh and Watson (2010) conducted a survey examining theory of planned behaviour constructs on mobile phone use while driving (n= 796). Those who reportedly used a hands-free phone while driving were analysed separately to those who reportedly used a hand-held phone while driving. Analyses were performed comparing frequent and infrequent users of both hand-held and hands-free mobile phone users. Frequent and infrequent hands-free users differed only on one behavioural belief; 'using time effectively'. Frequent hands-free users were significantly more likely than infrequent users to suggest that 4 out of 6 normative referents were likely to approve of their mobile phone use while driving. Overall, frequent hands-free users were significantly more likely to report that significant others approve of their mobile phone use (subjective norm), that hands-free mobile phone use while driving was an effective use of time (attitude) and that less obstructions were apparent in whether they used their hands-free phone (perceived behavioural control), compared to infrequent users. This is what one would expect as hands-free mobile phone use while driving is a legal behaviour and so behavioural beliefs are more positive and normative referents are more likely to approve of this behaviour. Regression analysis was able to distinguish frequent and infrequent hands-free users using all beliefs (72.8%; 86.4% frequent, 46% infrequent), however, behavioural beliefs did not affect the probability of frequent hands-free mobile phone use. Regarding hand-held users, participants' beliefs differed on almost all of the behavioural, normative and control beliefs tested. Frequent hand-held users were also, surprisingly, more likely to report than infrequent hands-free users that 'being distracted

from driving' and 'being fined by police' would probably happen due to their mobile phone use. Further analyses found 72.8% (30.6% frequent, 90% infrequent) of all hand-held users could be correctly identified as either frequent or infrequent users. This study indicates that drivers who engage in mobile phone use while driving are aware of the negative risks associated and nevertheless, continue despite the possible consequences. The reasons for this, outlined by the study are that they receive more approval from others and state more benefits of using a mobile phone while driving. This study is important as it highlights the differences in the factors underlying hands-free and hand-held mobile phone use while driving. Due to the high social approval for mobile phone use while driving, authors suggest campaigns targeting the perceived benefits of this behaviour. However, the issue of statistical power must be raised in relation to this study as out of 796 participants, only 36 qualified for the infrequent hands-free phone use condition and so this may not be enough data to confirm these findings.

Another study examined the possible differences in hand-held and hands-free mobile phone use. Zhou et al (2009) compared drivers beliefs on theory of planned behaviour measures (n = 164) and found all TPB measures to differ between hand-held and hands-free mobile phone use. When analysed separately, attitudes, subjective norms and perceived behavioural control were all significant predictors of intentions, with perceived behavioural control being the largest predictor for both technologies.

Others have broken down mobile phone use further than just hands-free and hand-held into the different ways we use our phones to communicate. Walsh et al (2008) used a large sample of drivers (n = 801) to determine

beliefs on theory of planned behaviour measures as well as risk for text messaging and making and receiving calls while driving. Drivers had stronger intentions to call while driving rather than text message. Attitude and subjective norm were significant predictors of intention, while perceived behavioural control was not. These studies often analyse results in terms of general mobile phone use and then analyse specific behaviours. Chen et al (2016) reported that attitudes, descriptive norms and perceived control significantly predicted engagement with technology while driving. For general mobile phone use, attitudes and subjective norms were significant predictors of intentions. Intentions to make calls while driving were always predicted by attitudes, while subjective norms became significant predictors in scenarios where the respondent was to imagine they were running late. For text messaging alone, attitudes were the only significant TPB variable to predict intentions.

Texting behaviour was addressed once more in American college students (Sandlin, Sandlin and Keathley, 2015). Out of 777 respondents, 35.5% intended to send a text while driving in the next week and 48.8% planned to read a text while driving. Participants believed that their friends would also perform these behaviours but largely felt that text messaging while driving was 'bad' and 'unwise'. This indicates that these students had the 'right' attitudes, but these did not translate to intentions.

What some studies may lack is the comparisons of TPB measures to actual behaviour. Nemme and White (2010) measured 17-24 year olds (n= 169) on theory of planned behaviour measures related to text-messaging behaviour while driving. After one week, participants then reported their

actual text-messaging behaviour while driving based on the last week. Intentions to read and send messages were found to be predicted by attitudes (45.8% and 48.3% respectively). Subjective norm or perceived behavioural control did not predict text-messaging behaviour. Although phone records were not obtained to verify reported behaviour, this study provides an insight into specific text-messaging behaviour, which is little reported.

Extensive literature searches have found no evidence to suggest other authors have examined theory of planned behaviour constructs in terms of satellite navigation or MP3 player use. The theory of planned behaviour enables us to discover the predictors of intention and behaviour so that an intervention may be formulated. A pilot questionnaire will first be presented which aimed to identify the leading technological distractions which drivers use while driving and what factors influence the degree to which these drivers interact with these technologies.

STUDY ONE - PREVALENCE QUESTIONNAIRE

Introduction

A first aim of the PhD was to determine how often individuals are distracted by technological devices while driving. A paper survey was deemed the most appropriate method for this aim. Drivers are known to participate in a range of distracting behaviours while driving and the literature on the subject is well established (Stutts et al, 2005; Lee, 2008; Young & Regan, 2010). For example, after analysing crash data from 1995-99 in America, it was found that the most prevalent technological distraction was a CD/radio/cassette player, contributing to 11.4% of crashes (Stutts, 2001). However, as the second aim of the study was to identify key technology based distractions to inform the next stage of research, it was necessary to design a questionnaire and obtain real data on the prevalence of behaviours in our local drivers. It was expected that the analysis of questionnaire items would produce distinct distraction categories that could be utilised in a further questionnaire based on the theory of planned behaviour.

Method

Participants

35 drivers (12 male, 19 female, 4 unknown) were recruited in total via a snowball method. The mean age of participants was 36.8 (SD = 2.35; range = 21-60) and the average number of years driving was 15.7 (SD = 2.06; range = 2.5-37).

Materials

Questionnaire.

A list of driver distractions was obtained from Regan et al (2009), who assembled a comprehensive list of distractions derived from a range of authors. From this list, 29 distracting behaviours were selected to create a questionnaire. All behaviours included in the Regan et al (2009) list were present in the questionnaire; however, similar behaviours were grouped together, such as eating and drinking in the interest of efficiency. Of these 29 items, 17 non-technological distractions and 12 technological distractions were included, which a person may experience while driving (See appendix). Participants were asked to rate how often they found themselves distracted by each item. These items were scored on a 7-point likert scale from '1, Never' to '7, Every time I drive'. The maximum score was 203 and the minimum, 29. A section at the end of the questionnaire gave respondents the opportunity to include any distractions that were not included in the questionnaire.

Procedure

Questionnaires were distributed to family, colleagues, friends and friends of friends via a snowball method. All questionnaires were administered in paper format and, on average, took around five minutes to complete. Respondents were informed that the questionnaire was concerned with their experience of distractions while driving and that any responses given would remain confidential and no identifying data would be obtained.

Results

Descriptive Statistics.

Mean questionnaire scores (Table 2.1) suggest the most prevalent technology based distraction was using a CD/cassette player or radio. This was followed by satellite navigation use and receiving hands free calls. As one might expect, hands-free use is more prevalent than hand-held mobile phone use.

Table 2.1
Means (M) and standard deviations (SD) for technological distractions.

Distraction	M	SD
CD/Radio/Cassette	3.31	0.25
SatNav	2.66	0.27
Receiving hands-free calls	2.09	0.24
Reading text messages	1.89	0.19
External MP3 player	1.86	0.24
Making hands-free calls	1.83	0.23
Sending text messages	1.66	0.23
Receiving hand-held calls	1.57	0.17
Making hand-held calls	1.29	0.14
Reading emails	1.26	0.13
Browsing mobile phone applications	1.11	0.07
Sending emails	1.09	0.09

Cluster Analysis

The technique of cluster analysis was used as data were not robust enough for a factor analysis. Data were not standardised as all items were measured on the same scale. Therefore, a cluster analysis was run from questionnaire data, using SPSS 20, on each of the 29 distractions. A hierarchical cluster analysis using Ward's method and squared Euclidean distances produced eight clusters (Table 2.2). The number of clusters was determined by examining the coefficients shown in the agglomeration schedule

and looking to the dendrogram to give support for this. The coefficients suggested 4 distinct clusters, with 4 additional minor clusters, which is supported by the dendrogram. An ANOVA to assess whether the clusters were significantly different from one another was not conducted, as the sample size was not large enough. Overall, five of the eight clusters are of interest in terms of technological distractions. The five categories consist of five distinct types of technological distraction; (1) entertainment (CD/radio/cassette use), (2) hand-held mobile phone use, (3) hands-free mobile phone use, (4) portable devices used to send/receive information or to choose/listen to music (text messaging and external MP3 use) and (5) satellite navigation.

Table 2.2
Distractions according to cluster groups.

Cluster	Distraction
1	Animals (pets, insects), documents (books, newspapers, maps, mail), mechanical problems, advertising or billboards.
2	Food and drink, cognitive distractions (daydreaming, emotional problems), CD, radio or cassette.
3	Grooming, receiving hand-held calls, making hand-held calls, browsing mobile phone applications, reading emails, sending emails.
4	Smoking, child passengers.
5	Receiving hands-free calls, making hands-free calls, crash scenes.
6	Reading text messages, sending text messages, external MP3 player.
7	Satnav, scenery, talking/singing, adult passengers.
8	Vehicle controls, road signs, other drivers, weather.

Discussion

The results from the questionnaire suggest that despite some of the activities being illegal, a proportion of the public still engage in these behaviours. The most distracting technological activity reported was

CD/radio/cassette use, which is consistent with crash analyses (Stutts et al, 2001) and in-car observation data (Stutts et al, 2005). Hand-held mobile phone use is an illegal activity and so low scores on these items suggest that respondents either do not participate in this behaviour, or they are unwilling to disclose this information. Participants may have been reluctant to confess to this behaviour, on paper, with the researcher present. This is a problem which will may well be overcome with the discretion of the final questionnaire, which will be published online and will provide more privacy and confidentiality.

Of course, results may not be generalised to a wider population due to the small sample size and lack of diversity in the sample population. However, responses were sufficient enough to justify the use of data to inform a further pilot questionnaire as distractions which were rated similarly were clustered together. Although only a small sample size, the cluster analysis allowed for a reduction in the number of distractions, therefore ensuring that the subsequent questionnaire is as comprehensive and brief as possible. For example, receiving hands-free and making hands-free calls are within the same cluster and so further questions are to be asked with respect to both making and receiving hands-free calls. Other distractions in this category such as 'reading/sending emails' and 'browsing mobile phone applications' will not be investigated in further detail in order to keep the further questionnaires as short as possible.

The second questionnaire will gain data on behavioural outcomes (advantages/disadvantages of performing behaviour), normative referents (who approves/disapproves of the behaviour) and control factors (factors which

make it easier/more difficult to perform the behaviour). These three categories will obtain data for each of the five clusters and will be the basis for a full-scale survey on the theory of planned behaviour.

In summary, this first questionnaire gives an indication that drivers do indeed engage with distracting activities while driving. The cluster analysis has provided distinct groups of these technologies which will be expanded on in the next questionnaire.

THEORY OF PLANNED BEHAVIOUR PILOT QUESTIONNAIRE

Introduction

The aim of the second questionnaire was to find the perceived advantages and disadvantages (behavioural beliefs) of using each of the five types of technology while driving, the groups or individuals who would approve or disapprove (normative referents) of this use and the factors which would make it difficult or easy (control factors) for the individual to use these technologies while driving. Normative referents obtained from other driver behaviour studies have commonly identified significant others (spouses/partners), family members (parents/children), the police and other drivers to be the most important individuals in determining normative beliefs (Parker et al, 1992; Elliott, Armitage & Baughan, 2005; Zhou et al, 2012). Behavioural beliefs about the positive and negative effects of technology while driving have centred around preventing boredom, relaxing, distraction and the law (Zhou et al, 2012) while control beliefs have found driving conditions and distraction to influence the use of technology (White et al, 2010). The pilot questionnaire process is necessary to elicit beliefs for each type of technology in order to create items for a full-scale theory of planned behaviour questionnaire, as per the guidelines of Fishbein and Ajzen (2010).

Method

Participants

Participants were recruited in the same manner as the previous questionnaire. 20 drivers were recruited in total (10 male, 10 female). Only

one driver had been involved in an accident in the past two years and only one participant held penalty points.

Materials

Questionnaire.

A theory of planned behaviour pilot questionnaire was created using guidelines from Fishbein and Ajzen (2010). Five target behaviours were identified in regards of target, action, context and time (Fishbein & Ajzen, 1975) relating to each of the five technology based behaviours found in the first questionnaire. These were (1) hand-held mobile phone use, (2) hands-free mobile phone use, (3) electronic satellite navigation use, (4) music player use and (5) portable device use (See Table 2.2.1). Items were asked on the basis of the next month's behaviour, e.g. I intend to use my hand-held mobile phone while driving in the next month, scored on a scale from (1) agree, to (7) disagree. The objective of this questionnaire was to obtain relevant behavioural outcomes, normative referents and control factors in relation to technological distractions while driving. As well as direct measures using numbered scales, open ended questions were included so as to obtain the respondent's opinion of the advantages/disadvantages of technology use, the people who would approve/disapprove of this use and the factors which would make it more/less likely that they would use the technology (See appendix).

85 theory of planned behaviour measures were included along with 18 additional measures for demographics and access to technology. Of these 85 items, some addressed the same theory of planned behaviour constructs and so appeared to be very similar. To ensure that similar questions did not confound

one another, the order of questions was randomised using a random number generator.

Table 2.2.1
Questionnaire technologies and descriptions

Technology	Description
Hand-held mobile phone use	Making/receiving hand-held calls
Hands-free mobile phone use	Making/receiving hands-free calls
Portable device use	Using portable devices to send/receive information or to choose/listen to music (e.g. MP3 players, text messaging, email use)
Music player use	Listening to or manipulating CD/radio/cassette player
Satellite navigation use	Following directions or manipulating settings

Procedure

Questionnaires were distributed via a snowball method. All questionnaires were administered in paper format and, on average, took around 30 minutes to complete. Due to the magnitude of the questionnaire, the five technologies were counterbalanced using a Latin square design. This ensured that any effects of fatigue would be spread throughout all technologies. Respondents were informed that the questionnaire was concerned with drivers' attitudes and interactions with in-car technology and that any responses given would remain confidential. No identifying data would be obtained. Participants were warned to read questions carefully as some questions appeared to be very similar.

Results

Demographics.

The mean age of participants was 43.2 (SD = 2.32; range = 23-57) and the average number of years driving was 21.8 (SD = 2.04; range = 1.5-35). The average number of miles driven in the last 12 months was 11,535 (SD = 2,279; range = 500-45,000).

Questionnaire scoring.

Scores from the questionnaire have been reverse scored in order to reflect greater positive attitude, greater approval, greater perceived control, greater intention and more prevalent past behaviour with higher scores. Analyses were then conducted in turn for each of the target behaviours.

Hands-free mobile phone use.

Table 2.3.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for hands-free mobile phone use, including mean and standard deviation values. Attitudes were significantly correlated with subjective norm, intentions and past behaviour. Subjective norms were also significantly correlated with intentions and past behaviour, with intentions and past behaviour showing the highest significant correlation.

Path analysis.

Data were checked for normality, homogeneity of variance, linearity and collinearity before the path analysis and were found to be consistent with

the assumptions of regression analysis. The path model for hands-free mobile phone use (Fig 2.2.1) shows a classic structure of the theory of planned behaviour with standardised regression weights. The classic structure of the TPB model (Fig 2.1) shows direct paths from attitude, subjective norms and perceived behavioural control leading to intentions and then onto behaviour. It is this classic structure which Ajzen (2006) proposed would suit most behaviours. Statistical analysis of this model suggests an acceptable fit $\chi^2(3, N = 16) = 3.278$, $p = .351$, RMSEA = .079, RMSEA confidence interval (.00, .45), NFI = .95, CFI = .99, PCLOSE = .368. Only attitude and intentions were found to be significant predictors ($p<.01$). The greatest effect on behaviour was seen through intention (.92), which conforms to most TPB research (Ajzen, 1991). Attitude was the greatest predictor of intention (.80), meaning those who intend to use a hands-free mobile phone while driving have more positive attitudes towards hands-free mobile phone use. Overall, 85% of the variance in past behaviour was accounted for by the model.

Table 2.3.1
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for hands-free mobile phone use (n = 16)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a hands-free mobile phone while driving in the next month would be (extremely good/extremely bad) My using a hands-free mobile phone while driving in the next month would be (extremely pleasant/extremely unpleasant)	4.31	1.97				
SN	Most people like me will use a hands-free mobile phone while driving in the next month Most people who are important to me approve of my using a hands-free mobile phone while driving in the next month	5.19	1.53	.818**			
PBC	It is up to you whether you choose to use a hands-free mobile phone while driving in the next month I have complete control over whether I use my hands-free mobile phone while driving in the next month	5.60	2.14	.215	.321		
I	I intend to use my hands-free mobile phone while driving in the next month	4.31	2.73	.783**	.642**	.269	
PB	In the past month I have used my hands-free mobile phone while driving	4.75	3.00	.772**	.710**	.347	.923**

**correlation is significant at the 0.01 level (2-tailed)

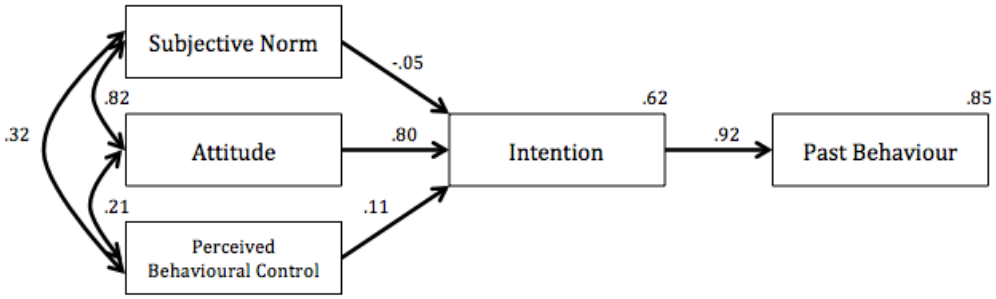


Figure 2.2.1. Path model of TPB factors and prediction of intention and past behaviour for hands-free mobile phone use.

Hand-held mobile phone use.

Table 2.3.2 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for hand-held mobile phone use, including mean and standard deviation values. Attitudes

were significantly correlated with subjective norm, intentions and past behaviour. Significant correlations are seen between subjective norms, intentions and past behaviour as well as between intentions and past behaviour.

Table 2.3.2
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for hand-held mobile phone use (n = 19)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a hand-held mobile phone while driving in the next month would be (extremely good/extremely bad) My using a hand-held mobile phone while driving in the next month would be (extremely pleasant/extremely unpleasant)	2.11	1.69				
SN	Most people like me will use a hand-held mobile phone while driving in the next month Most people who are important to me approve of my using a hand-held mobile phone while driving in the next month	2.95	1.99	.826**			
PBC	It is up to you whether you choose to use a hand-held mobile phone while driving in the next month I have complete control over whether I use my hand-held mobile phone while driving in the next month	6.13	1.64	.100	.036		
I	I intend to use my hand-held mobile phone while driving in the next month	1.89	1.56	.848**	.788**	.125	
PB	In the past month I have used my hand-held mobile phone while driving	2.74	2.49	.720**	.665**	.267	.622**

**correlation is significant at the 0.01 level (2-tailed)

Path analysis.

Data were checked for normality, homogeneity of variance, linearity and collinearity before the path analysis. Data showed signs of heteroscedasticity and so variables were transformed to a normal distribution using lg10. As a result, data met all assumptions. The path model for hand-held mobile phone use (Fig 2.2.2) shows an alternative structure of the theory of planned behaviour with standardised regression weights. The RMSEA value for this model suggests a poor fit (RMSEA = .320, RMSEA confidence

interval (.00, .80)). However, other statistical analyses were more positive $\chi^2(1, N = 18) = 2.736$, $p = .098$, NFI = .956, CFI = .97, PCLOSE = .105. No alternative structure to the model made any improvement on overall fit. Attitude and subjective norm were found to be significant predictors ($p<.05$). The greatest effect on past behaviour was seen through attitude (.52), which was also the greatest predictor of intention (.50), meaning those who intend to use and have used a hand-held mobile phone while driving in the past, have more positive attitudes towards hand-held mobile phone use. Subjective norm had a significant direct effect on past behaviour, suggesting those who use a hand-held mobile phone while driving have greater perceptions of others performing the same behaviour, or greater acceptance of the behaviour by others. Overall, 87% of the variance in past behaviour was accounted for by the model.

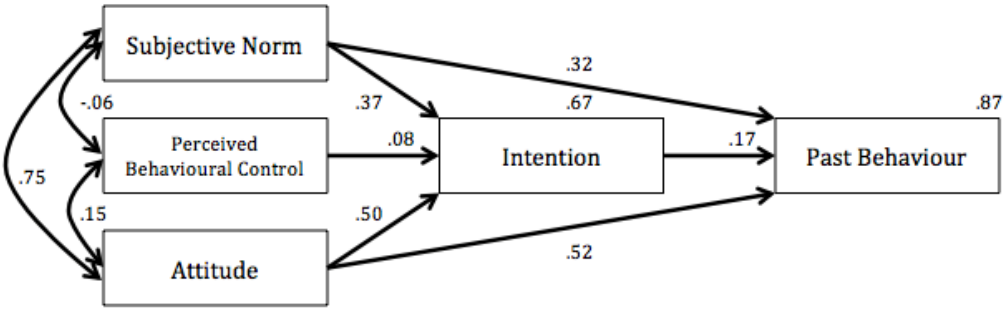


Figure 2.2.2. Path model of TPB factors and prediction of intention and past behaviour for hand-held mobile phone use.

Electronic satellite navigation use.

Table 2.3.3 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for electronic

satellite navigation use, including mean and standard deviation values. Attitudes were significantly correlated with subjective norm, intentions and past behaviour. Intentions and past behaviour showed the highest significant correlation.

Path analysis.

Data were checked for normality, homogeneity of variance, linearity and collinearity before the path analysis and data were all found to comply with regression assumptions. The path model for electronic satellite navigation use (Fig 2.2.3) shows a classic structure of the theory of planned behaviour with standardised regression weights. Statistical analysis of this model suggests a good fit $\chi^2(3, N = 17) = 1.762$, $p = .623$, RMSEA = .00, RMSEA confidence interval (.00, .00), NFI = .956, CFI = 1.00, PCLOSE = .638. Attitude and intentions were found to be significant predictors ($p<.01$). The greatest direct effect on behaviour was seen through intentions (.80), meaning those who had greater intentions to use electronic satellite navigation devices reported higher past behaviour. Attitude was the greatest predictor of intention (.86), meaning those who intend to use electronic satellite navigation devices while driving, have more positive attitudes towards the behaviour. Overall, 64% of the variance in past behaviour was accounted for by the model.

Table 2.3.3
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for electronic satellite navigation use (n = 17)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using an electronic satellite navigation system while driving in the next month would be (extremely good/extremely bad) My using an electronic satellite navigation system while driving in the next month would be (extremely pleasant/extremely unpleasant)	4.41	2.06				
SN	Most people like me will use an electronic satellite navigation system while driving in the next month Most people who are important to me approve of my using an electronic satellite navigation system while driving in the next month	5.56	1.22	.599*			
PBC	It is up to you whether you choose to use an electronic satellite navigation system while driving in the next month I have complete control over whether I use an electronic satellite navigation system while driving in the next month	6.32	1.19	.205	.126		
I	I intend to use an electronic satellite navigation system while driving in the next month	4.94	2.41	.712**	.245	.259	
PB	In the past month I have used an electronic satellite navigation system while driving	5.47	2.60	.499*	.148	.049	.802**

**correlation is significant at the 0.01 level (2-tailed), *correlation is significant at the 0.05 level (2-tailed)

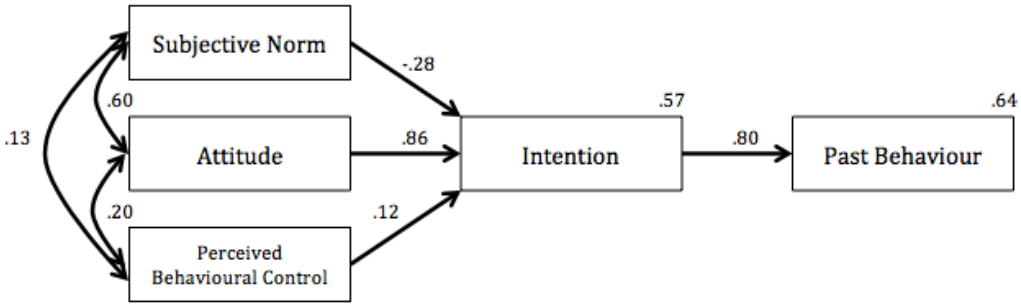


Figure 2.2.3. Path model of TPB factors and prediction of intention and past behaviour for electronic satellite navigation use.

Music player use

Table 2.3.4 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for music player

use, including mean and standard deviation values. High values for all variables were seen for all measures as the behaviour is legal and highly common. Therefore, there was little variation in the data. All factors were significantly correlated with the exception of perceived behavioural control.

Further analysis.

Any path analysis was not an option as the data violated most assumptions due to non normality and with there being almost no variance in the data. Therefore the existence of questions relating to this technology in a further questionnaire must be reviewed.

Table 2.3.4
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for music player use (n = 20)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a music player while driving in the next month would be (extremely good/extremely bad) My using a music player while driving in the next month would be (extremely pleasant/extremely unpleasant)	6.23	1.00				
SN	Most people like me will use a music player while driving in the next month Most people who are important to me approve of my using a music player while driving in the next month	6.40	1.11	.848**			
PBC	It is up to you whether you choose to use a music player while driving in the next month I have complete control over whether I use a music player while driving in the next month	6.78	.70	.414	.617**		
I	I intend to use a music player while driving in the next month	6.60	1.39	.744**	.758**	.228	
PB	In the past month I have used a music player while driving	6.70	.80	.741**	.765**	.721**	.736**

**correlation is significant at the 0.01 level (2-tailed)

Portable device use

Table 2.3.5 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for portable device use, including mean and standard deviation values. Attitudes were significantly correlated with subjective norm, intentions and past behaviour. Past behaviour was also significantly correlated with intentions.

Table 2.3.5
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for portable device use (n = 18)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a portable device while driving in the next month would be (extremely good/extremely bad) My using a portable device while driving in the next month would be (extremely pleasant/extremely unpleasant)	2.14	1.70				
SN	Most people like me will use a portable device while driving in the next month Most people who are important to me approve of my using a portable device while driving in the next month	3.11	2.08	.656**			
PBC	It is up to you whether you choose to use a portable device while driving in the next month I have complete control over whether I use a portable device while driving in the next month	6.39	1.55	.112	.150		
I	I intend to use a portable device while driving in the next month	1.95	1.66	.740**	.403	.112	
PB	In the past month I have used a portable device while driving	2.67	2.38	.695**	.294	.133	.844**

**correlation is significant at the 0.01 level (2-tailed).

Path analysis.

Data were checked for normality, homogeneity of variance, linearity and collinearity before the path analysis. The residuals were not normally distributed and so variables were transformed to a normal distribution using

lg10. As a result, data met all assumptions. The path model for portable device use (Fig 2.2.4) shows a classic structure of the theory of planned behaviour with standardised regression weights. The RMSEA value for this model suggests a poor fit (RMSEA = .175, RMSEA confidence interval (.00, .48)). However, other statistical analyses were more positive $\chi^2(3, N = 17) = 4.563$, $p = .207$, NFI = .91, CFI = .96, PCLOSE = .224. Attitude and intentions were found to be significant predictors ($p<.01$). The greatest direct effect on behaviour was seen through intentions (.85), meaning those who had greater intentions to a portable device while driving reported higher past behaviour. Attitude was the greatest predictor of intention (.77), meaning those who intend to use portable devices while driving, have more positive attitudes towards the behaviour. Overall, 73% of the variance in past behaviour was accounted for by the model.

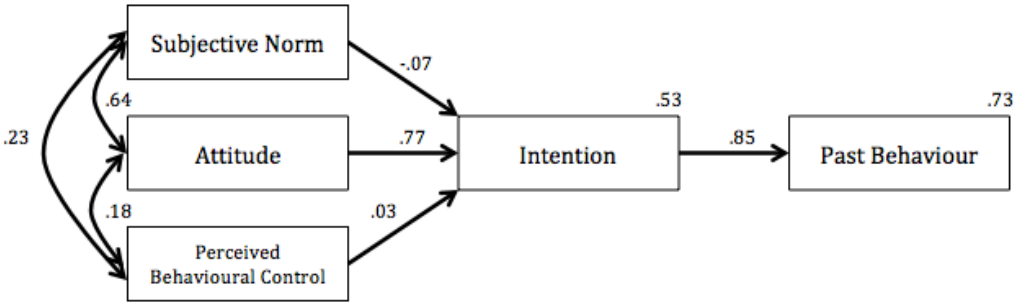


Figure 2.2.4. Path model of TPB factors and prediction of intention and past behaviour for portable device use.

Coding of responses

The responses to the open questions were coded to create items which encompassed similar responses. This was necessary as responses were to form

items for the subsequent questionnaire, using guidelines set out by Fishbein and Ajzen (2010). The responses of behavioural outcomes included quite similar phrases, for example, for perceived disadvantages of using a hand-held mobile phone while driving, responses included; '3 points on licence if caught', 'against the law', and 'fines', amongst others. In the interest of efficiency, these responses were coded as 'risk of prosecution', which was used to describe any legal consequence.

To ensure no bias entered this process, a set of rules was put into place. These rules stipulated that responses might only be included in the final set of outcomes if more than one person mentioned them. This rule was necessary to discard eccentric answers without handpicking. Another reason for his rule was that each outcome would be used as an item for the next questionnaire and so a process of data reduction was needed to ensure the number of questions for the full survey was manageable. Overall, between five and seven behavioural outcomes were found for each behaviour, along with four to nine normative referents and between four and eight control factors for each behaviour.

In order to test whether the coding was successful, a second coder was asked to place each survey response into the new coded categories. An agreement rate of 93.3% was found which indicated a high level of agreement.

Discussion

Of great interest is the distinction between the hand-held and hands-free path models. Much research has found the distracting effects of hand-held and hands-free mobile phone use to be equal (Strayer & Johnston, 2001;

McEvoy et al, 2005; McEvoy, Stevenson & Woodward, 2007). However, the path models show that drivers differ in their attitudes, subjective norm and intentions towards the two behaviours. Presumably, this difference is due to the legality of one behaviour (hands-free use) and the illegality of the other (hand-held use). Intentions to use a hand-held mobile phone while driving were found to be very low, whilst past behaviour was slightly higher, suggesting that the people surveyed had good intentions not to use their hand-held mobile phone, even though they had performed the behaviour in the past. Attitudes and subjective norm were significant predictors of past behaviour, suggesting that those with more positive attitudes towards and those who perceive others to have more positive attitudes were more likely to use a hand-held mobile phone relating to past behaviour. This is an important finding as any intervention would aim to target both attitudes and subjective norm as well as intentions. Conversely, subjective norm had no significant direct effect on hands-free mobile phone use, perhaps because the behaviour is legal and so drivers are less interested in the perceived approval of others. This may also be true of electronic satellite navigation use.

As the category of portable devices includes an element of illegality (text messaging), one would expect a similar pattern to hand-held mobile phone use. However, this was not found. The responses to the questionnaire items may give an explanation for this in that it appears respondents focussed more on the MP3 player element of the question and often neglected to mention factors specific to text messaging. This is crucial as while using an MP3 player while driving is not necessarily legal, the fact that text messaging is more widely known to be illegal may force a participant to respond to

questions in terms of only one of these technologies. This has implications for the full-scale questionnaire, as combining these two technologies may not offer a true picture of the beliefs that underlie portable device use. Therefore, a split of these technologies into separate categories must be considered.

Another category that warrants further consideration is the use of a music player. The use of a music player while driving, including a radio, CD, or cassette player was found to be extremely common with mean questionnaire scores all above six (out of a possible 7). This shows that respondents use and intend to use their music players often, have positive attitudes towards, feel little or no boundaries to use and perceive others as doing the same. Therefore, if music players are to be included in the full-scale questionnaire, the 'use' of a music player must be more specific. Perhaps a better definition of 'use' would be 'the changing of CD, track, station or cassette while driving'. Alternatively, the use of controls while on different road types or in different traffic conditions may present more variance across respondents. This would eliminate any thought of simply listening to music or radio without any manipulation of controls, which many find an acceptable behaviour.

Although these initial results look promising, the models created are sensitive to low sample sizes as 'if the sample size is too small, the estimates of the parameters are unstable, reflected in larger standard errors' (Streiner, 2005, pp.121), therefore resulting in inaccurate t values. Despite this, these path analyses give a preliminary indication of what the full-scale survey may find.

Relating to the open ended section of the questionnaire, the responses gained are comparable to those seen in other research. The normative referents

obtained from respondents was consistent with other studies, with spouses and partners featuring heavily along with family members and especially the police when considering illegal behaviours (Parker et al, 1992; Elliott, Armitage & Baughan, 2005; White et al, 2010; Zhou et al, 2012). Many respondents listed 'distraction' as a negative behavioural belief for most of the five technologies, as well as concerns about the legality of the behaviour and the consequences of being caught, alike other similar studies (White et al, 2010; Zhou et al, 2012). The control beliefs found are also consistent with other studies, with road conditions and the presence of police being mentioned by many respondents (White et al, 2010).

In conclusion, the pilot questionnaire was successful in obtaining the relevant behavioural outcomes, normative referents and control beliefs needed for the full questionnaire. Early analyses of the direct measures used suggest an interesting difference in attitudes, subjective norm and intentions to use hand-held and hands-free mobile phones while driving.

FULL SCALE THEORY OF PLANNED BEHAVIOUR QUESTIONNAIRES

Using the data obtained from the previous questionnaires, five full scale questionnaires using the theory of planned behaviour are presented below.

Method

Participants

Participants (n = 541, split between 5 questionnaires) were recruited in two ways. Firstly, adverts were placed on the university intranet system which was viewable by staff and students across the University of Nottingham. These respondents were entered into a prize draw (with their consent) which gifted £100 to one respondent two months after the questionnaire was made live. After a disappointing response from the university, a company called Research Now was employed to recruit the remaining respondents. These respondents gained 'points' from Research Now which accumulated to a small monetary value. Only respondents who were registered as drivers with full licences were given the opportunity to complete the questionnaire.

Questionnaire allocation

Participants were required to click a URL link in order to access the questionnaire. This link was programmed as such so that the respondent was automatically randomly allocated to one of the five questionnaires (hand-held, hands-free, text messaging, satellite navigation & MP3 player use). The

respondent was not able to choose which questionnaire they would like to complete and the use of internet cookies prevented a respondent from completing more than one questionnaire.

Hand-held mobile phone use

109 participants (53 male, 59 female) were asked a range of technology based and demographic questions at the beginning of the questionnaire. Participants age ranged from 19-81 (M = 53.19, SD = 15.91). Respondents drove an average of 6265.45 miles per year (SD = 5359.91) and had an average of 31.58 years driving experience (SD = 15.52). 3 participants had an accident in the last 2 years; one of these claimed responsibility. It was important to ascertain whether respondents had access to a hand-held mobile phone before investigating whether they ever drive while using one. All respondents claimed to have access to a mobile phone, with 33.94% of these having access to a hands-free kit for their car. 18.35% stated that they used their hands-free kit all of the time while driving, while 76.15% claimed to never use their mobile phone while driving.

Hands-free mobile phone use

109 participants (52 male, 57 female) drove an average of 5821.64 miles per year (SD = 4502.81) and had an average of 36.15 years driving experience (SD = 15.83). Participants age ranged from 19-84 (M = 57.82, SD = 14.97). 10 participants had an accident in the last 2 years, with 3 admitting fault. 106 participants had access to a mobile phone, with 32.11% having access to a hands-free kit for their car. 14.68% reported using their hands-free

kit all of the time while driving, while 75.15% claimed to never use their mobile phone while driving.

Text messaging

104 participants (47 male, 57 female) drove an average of 6005.96 miles per year (SD = 4610.55) and had an average of 30.09 years driving experience (SD = 15.14). Participants age ranged from 19-82 (M = 52.69, SD = 15.30). 4 participants had an accident in the last 2 years, with 1 admitting fault. 100 participants had access to a mobile phone with 26.92% having access to a hands-free kit. 16.35% reported using their hands-free kit all of the time while driving, while 77.88% claimed to never use their mobile phone while driving.

Satellite navigation use

112 participants (50 male, 62 female) drove an average of 5574.38 miles per year (SD = 5371.62) and had an average of 31.97 years driving experience (SD = 16.34). Participants age ranged from 23-83 (M = 54.31, SD = 15.69). 6 participants had an accident in the last 2 years, with 3 admitting fault. 57.14% of participants had access to a portable satellite navigation system, 8.93% had access to a vehicle integrated system and 26.79% had access to a phone application system. 64.29% of participants reported using their satellite navigation system ‘some of the time’, compared to ‘all of the time’ (1.79%), ‘most of the time’ (8.93%) and ‘never’ (25.00%).

MP3 player use

107 participants (50 male, 57 female) drove an average of 6,984.21 miles per year (SD = 4632.48) and had an average of 34.10 years driving experience (SD = 14.97). Participants age ranged from 22-83 (M = 56.22, SD = 14.88). 5 participants had an accident in the last 2 years, with 3 admitting fault. 54.21% of respondents had access to an MP3 player. 21.49% admitted to using their MP3 player while driving.

Materials

Questionnaire.

Using guidelines from Fishbein and Ajzen (2010), questionnaire measures were developed using the behavioural outcomes, normative referents and control factors from the previous questionnaire. Due to the length of the questionnaire, it was impossible to include the five technologies within one questionnaire. As well as demographic factors, questions aimed to gain information about what kinds of technology people possessed, how often they used it while driving and how willing they were to use more than one technology at once. As well as this, direct measures of attitudes, perceived behavioural control, social norms, intentions and past behaviour were recorded. Fishbein & Ajzen, (2010) recommend that behavioural data is taken at a different time point and so a second questionnaire was also made available to participants after one month, with the purpose of eliciting behavioural scores relating to their last month's driving experiences with technology.

Procedure

The questionnaire was published on www.lifelongdriving.org. This website is run by the University of Nottingham and aims to provide tests which allow drivers to measure and improve driver safety whilst encouraging drivers to take part in current driving studies at the university. The five technologies of hands-free mobile phone use, hand-held mobile phone use, electronic satellite navigation, mp3 player and text messaging were each assessed on separate questionnaires, meaning drivers who wished to complete a questionnaire were randomly allocated to one of the five technology types could only respond to questions on that specific technology. Each participant was allocated a unique code. This was used by Research Now to contact respondents after one month in order to obtain measures of behaviour. Participants who were not part of Research Now were asked to leave an email address and permission to be contacted after the month period.

Results

Technology Use

Table number 2.4 demonstrates the types of technologies drivers were willing to use whilst also using another primary technology. Drivers using hands-free mobile phones were the most likely (33.94%) to use another technology alongside. Comfortingly, the illegal behaviours of text messaging and hand-held mobile phone use were much less likely to be used in conjunction with other technologies.

Table 2.4
Percentage (%) of participants who reported using multiple technology whilst driving.

	MP3 Player	Text Messaging	Hand-Held	Hands-Free	SatNav
MP3 Player		4.81%	7.34%	6.42%	8.04%
Text Messaging	2.8%		7.34%	1.83%	5.36%
Hand-Held	1.87%	2.88%		7.34%	1.79%
Hands-Free	15.89%	11.54%	13.76%		22.32%
SatNav	15.89%	10.58%	12.84%	23.85%	
Any Technology	30.84%	22.12%	23.85%	33.94%	20.54%

Theory of Planned Behaviour Measures

Scores from the questionnaire have been reverse scored in order to reflect greater positive attitude, greater approval, greater perceived control, greater intention and more prevalent past behaviour with higher scores.

All data were checked that they met the assumptions for regression, including multicollinearity and homoscedasticity. For all five questionnaires, data were first analysed in a hierarchical regression using the enter method. Step one aimed to predict past behaviour from intentions and step two aimed to predict past behaviour from intentions, subjective norms, attitudes and perceived behavioural control. Intentions were then analysed in a separate model, with subjective norms, attitudes and perceived behavioural control as predictors. Data were then presented in path models.

Behaviour at time two

Participants were given the opportunity to complete a second very short questionnaire after a one month period which asked how often (on the same

seven point likert scale) respondents had used their allocated technology while driving in the past month. The reason for this second questionnaire was that the theory of planned behaviour guidelines suggest that behaviour measures be taken at a different time point to the other questionnaire measures. Behaviour scores were then compared between time points.

For hand-held mobile phone use, 46 participants completed the second questionnaire and only five of these reported a change in use of technology from time one to time two. A repeated measures t test found overall, respondents did not report past behaviour differently between the two time points [$t(45) = -1.43$, $p = .16$]. For hands-free mobile phone use, 43 participants completed the second questionnaire and only eight responses differed between time one and two. A repeated measures t test found no difference in reported behaviour between time points [$t(42) = -1.84$, $p = .07$]. For MP3 player use, 42 participants completed the second questionnaire, with twelve participants reporting marginally different values for their engagement while driving. A repeated measures t test found no differences in behaviour between time points [$t(41) = .22$, $p = .83$]. For satellite navigation system use, 43 participants completed the second questionnaire, with 23 of these having changed their answers from the first questionnaire, these changes were very minor, with most being by one point. A repeated measures t test found no differences in behaviour between the two time points [$t(42) = -.73$, $p = .47$]. Finally, for text messaging while driving, 42 participants completed the second questionnaire, with only two participants reporting different values of behaviour. A repeated measures t test found no differences in behaviour between time points [$t(41) = .00$, $p = 1.00$].

As no differences were found in behaviour between time one and two, data were therefore analysed just in terms of past behaviour from the first questionnaire. This allowed a larger number of participants to be included in the analysis.

Hands-free mobile phone use

Table 2.5.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for hands-free mobile phone use, including mean and standard deviation values. All measures were significantly correlated with each other, excluding perceived behavioural control and past behaviour (p = .052).

Table 2.5.1

Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for hands-free mobile phone use (n = 109)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a hands-free mobile phone while driving in the next month would be (extremely good/extremely bad) My using a hands-free mobile phone while driving in the next month would be (extremely pleasant/extremely unpleasant)	3.16	1.94				
SN	Most people like me will use a hands-free mobile phone while driving in the next month Most people who are important to me approve of my using a hands-free mobile phone while driving in the next month	3.59	1.91	.84**			
PBC	It is up to you whether you choose to use a hands-free mobile phone while driving in the next month I have complete control over whether I use my hands-free mobile phone while driving in the next month	5.71	1.61	.29**	.35**		
I	I intend to use my hands-free mobile phone while driving in the next month	2.83	2.34	.86**	.77**	.18*	
PB	In the past month I have used my hands-free mobile phone while driving	2.26	2.00	.74**	.65**	.16	.82**

**correlation is significant at the 0.01 level (1-tailed), *correlation is significant at the 0.05 level (1-tailed)

Table 2.5.2 shows the regression coefficients for each step. For step one, it was found that intention explains a significant amount of the variance in past behaviour [$F(1, 107) = 211.89$, $p < .001$, $R^2 = .66$, $R^2_{Adjusted} = .66$]. Intention was a significant predictor of past behaviour in this first model ($\beta = .82$, $t(107) = 14.56$, $p < .001$). For step two, the model once again explained a significant amount of the variance in past behaviour [$F(1, 107) = 52.92$, $p < .001$, $R^2 = .67$, $R^2_{Adjusted} = .66$] but did not contribute towards the first model significantly ($p = .59$). Intention was a significant predictor of past behaviour in this second model ($\beta = .68$, $t(107) = 5.91$, $p < .001$). Attitude, subjective norms and perceived behavioural control were not significant predictors.

Table 2.5.2

Hierarchical regression coefficients for Intention on Past Behaviour (Step 1) and Intention, Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Past Behaviour (Step 2) for hands-free mobile phone use.

	B	SE *B*	β
Step 1			
Constant	0.28	0.18	
Intention	0.70	0.05	.82**
Step 2			
Constant	0.16	0.42	
Intention	0.58	0.10	.68**
Subjective Norm	0.09	0.11	.01
Attitude	0.16	0.14	.15
PBC	-0.01	0.08	-0.01

Note: $R^2 = .66$ for Step 1, $\Delta R^2 = .006$ for Step 2 ($p = .59$). **significant at the 0.01 level (1-tailed)

A separate linear multiple regression (Table 2.5.3) was conducted to predict intentions from subjective norms, perceived behavioural control and attitude. The model explained a significant amount of the variance in intentions [$F(3, 105) = 110.74$, $p < .001$, $R^2 = .76$, $R^2_{Adjusted} = .75$]. Subjective norm was a significant predictor of intention ($\beta = .22$, $t(107) = 1.99$, $p = .049$),

along with attitude (β = .74, t(107) = 8.51, $p < .001$). Perceived behavioural control was borderline significant (β = -.10, t(107) = -1.95, $p = .052$).

Table 2.5.3
Hierarchical regression coefficients Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Intentions for hands-free mobile phone use.

	B	SE *B*	β
Constant	0.06	0.42	
Subjective Norm	0.22	0.11	.18*
Attitude	0.89	0.11	.74**
PBC	-0.14	0.07	-0.10

Note: $R^2 = .76$. *significant at the 0.05 level, **significant at the 0.01 level (1-tailed)

Path analysis.

A path model was created using AMOS 20.0. The path model for hands-free mobile phone use (2.3.1) shows a classic structure of the theory of planned behaviour with unstandardised regression estimates. Statistical analysis of this model suggests an acceptable fit [$\chi^2(3, N = 107) = 1.99$, $p = .351$, RMSEA = .00, RMSEA confidence interval (.00, .14), NFI = .99, CFI = 1.00, PCLOSE = .68]. Attitude ($p < .001$), subjective norms ($p = .04$) and perceived behavioural control ($p = .048$) were all significant predictors of intentions. The greatest effect on behaviour was seen through intention (.70), which conforms to most TPB research (Ajzen, 1991). Attitude was the greatest predictor of intention (.90), meaning those who intend to use a hands-free mobile phone while driving have more positive attitudes towards hands-free mobile phone use.

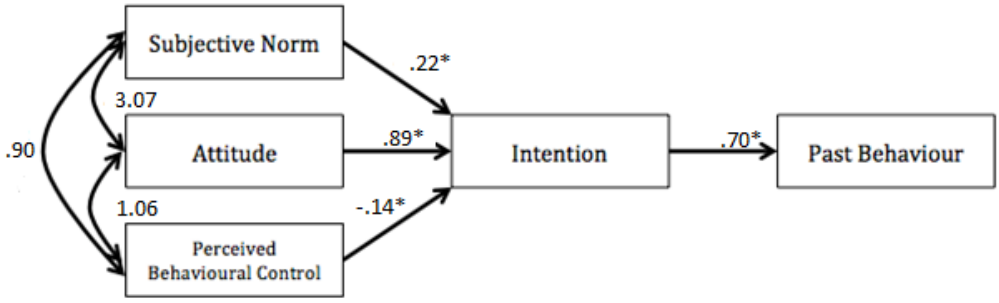


Fig 2.3.1. Path model of TPB factors for hands-free mobile phone use with unstandardized coefficients.

Hand-Held mobile phone use

Table 2.6.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for hand-held mobile phone use, including mean and standard deviation values. Attitudes were significantly correlated with subjective norm, intentions and past behaviour. Subjective norms were also significantly correlated with intentions and past behaviour, with intentions and past behaviour showing the highest significant correlation.

Table 2.6.1

Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for hand-held mobile phone use (n = 109)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a hand-held mobile phone while driving in the next month would be (extremely good/extremely bad) My using a hand-held mobile phone while driving in the next month would be (extremely pleasant/extremely unpleasant)	1.71	1.22				
SN	Most people like me will use a hand-held mobile phone while driving in the next month Most people who are important to me approve of my using a hand-held mobile phone while driving in the next month	2.12	1.27	.744**			
PBC	It is up to you whether you choose to use a hand-held mobile phone while driving in the next month I have complete control over whether I use my hand-held mobile phone while driving in the next month	5.25	1.92	.008	.090		
I	I intend to use my hand-held mobile phone while driving in the next month	1.54	1.40	.731**	.648**	.126	
PB	In the past month I have used my hand-held mobile phone while driving	1.46	1.28	.771**	.651**	.076	.776**

**correlation is significant at the 0.01 level (1-tailed)

Table 2.6.2 shows the regression coefficients for each step. Step one found that intention explains a significant amount of the variance in past behaviour [$F(1, 107) = 161.53$, $p < .001$, $R^2 = .60$, $R^2_{Adjusted} = .60$]. Intention was a significant predictor of past behaviour in this first model ($\beta = .78$, $t(107) = 12.71$, $p < .001$). For step two, the model once again explained a significant amount of the variance in past behaviour [$F(1, 107) = 58.65$, $p < .001$, $R^2 = .69$, $R^2_{Adjusted} = .68$] and contributed to the model significantly ($p < .001$). Intention was a significant predictor of past behaviour in this second model ($\beta = .44$, $t(107) = 5.29$, $p < .001$), along with attitude ($\beta = .40$, $t(107) = 4.23$, $p < .001$). Subjective norms and perceived behavioural control were not significant predictors.

Table 2.6.2
Hierarchical regression coefficients for Intention on Past Behaviour (Step 1) and Intention, Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Past Behaviour (Step 2) for hand-held mobile phone use.

	B	SE *B*	β
Step 1			
Constant	0.36	0.12	
Intention	0.71	0.06	.78**
Step 2			
Constant	-0.06	0.23	
Intention	0.40	0.08	.44**
Subjective Norm	0.07	0.09	.07
Attitude	0.42	0.10	.40**
PBC	0.01	0.04	.01

Note: R^2 = .60 for Step 1, ΔR^2 = .09 for Step 2 (p < .001). **significant at the 0.01 level (2-tailed)

A separate linear multiple regression (Table 2.6.3) was conducted to predict intentions from subjective norms, perceived behavioural control and attitude. The model explained a significant amount of the variance in intentions [$F(3, 105) = 46.09$, $p < .001$, $R^2 = .57$, $R^2_{Adjusted} = .56$]. Subjective norm was a significant predictor of intention (β = .21, t(107) = 2.21, $p = .03$), along with attitude (β = .57, t(107) = 5.92, $p < .001$).

Table 2.6.3
Hierarchical regression coefficients Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Intentions for hand-held mobile phone use.

	B	SE *B*	β
Constant	-0.47	0.29	
Subjective Norm	0.24	0.11	.21*
Attitude	0.65	0.11	.57**
PBC	0.07	0.05	0.10

Note: R^2 = .57. *significant at the 0.05 level, **significant at the 0.01 level (2-tailed)

Path analysis.

A path model is not presented for these data as the final model did not meet expectations of overall fit criteria.

Satellite Navigation use

Table 2.7.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for electronic satellite navigation use, including mean and standard deviation values. All variables were significantly correlated with each other, excluding perceived behavioural control and past behaviour.

Table 2.7.1

Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for electronic satellite navigation use (n = 112)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using an electronic satellite navigation system while driving in the next month would be (extremely good/extremely bad) My using an electronic satellite navigation system while driving in the next month would be (extremely pleasant/extremely unpleasant)	4.58	1.50				
SN	Most people like me will use an electronic satellite navigation system while driving in the next month Most people who are important to me approve of my using an electronic satellite navigation system while driving in the next month	4.58	1.47	.76**			
PBC	It is up to you whether you choose to use an electronic satellite navigation system while driving in the next month I have complete control over whether I use an electronic satellite navigation system while driving in the next month	6.31	1.18	.35**	.39**		
I	I intend to use an electronic satellite navigation system while driving in the next month	4.02	2.01	.77**	.78**	.25**	
PB	In the past month I have used an electronic satellite navigation system while driving	2.61	1.73	.60**	.57**	.14	.72**

**correlation is significant at the 0.01 level (2-tailed)

Table 2.7.2 shows the regression coefficients for each step. For step one, it was found that intention explains a significant amount of the variance in

past behaviour [$F(1, 111) = 116.05$, $p < .001$, $R^2 = .51$, $R^2_{Adjusted} = .51$]. Intention was a significant predictor of past behaviour in this first model ($\beta = .72$, $t(111) = 10.77$, $p < .001$). For step two, the model once again explained a significant amount of the variance in past behaviour [$F(1, 111) = 29.39$, $p < .001$, $R^2 = .52$, $R^2_{Adjusted} = .51$] but did not contribute towards the first model significantly ($p = .52$). Intention was a significant predictor of past behaviour in this second model ($\beta = .53$, $t(111) = 5.21$, $p < .001$). Attitude, subjective norms and perceived behavioural control were not significant predictors.

Table 2.7.2
Hierarchical regression coefficients for Intention on Past Behaviour (Step 1) and Intention, Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Past Behaviour (Step 2) satellite navigation use.

	B	SE *B*	β
Step 1			
Constant	0.13	0.26	
Intention	0.62	0.06	.72**
Step 2			
Constant	0.33	0.65	
Intention	0.53	0.10	.62**
Subjective Norm	0.01	0.14	.01
Attitude	0.16	0.13	.14
PBC	-0.11	0.11	-.07

Note: $R^2 = .51$ for Step 1, $\Delta R^2 = .01$ for Step 2 ($p = .52$). **significant at the 0.01 level (2-tailed)

A separate linear multiple regression (Table 2.7.3) was conducted to predict intentions from subjective norms, perceived behavioural control and attitude. The model explained a significant amount of the variance in intentions [$F(3, 108) = 77.49$, $p < .001$, $R^2 = .68$, $R^2_{Adjusted} = .67$]. Subjective norm was a significant predictor of intention ($\beta = .48$, $t(111) = 5.64$, $p < .001$), along with attitude ($\beta = .43$, $t(111) = 5.19$, $p < .001$).

Table 2.7.3
Hierarchical regression coefficients Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Intentions for satellite navigation use.

	B	SE *B*	β
Constant	-0.73	0.61	
Subjective Norm	0.65	0.12	.48**
Attitude	0.58	0.11	.43**
PBC	-0.15	0.10	-.09

Note: R^2 = .68. **significant at the 0.01 level (2-tailed)

Path analysis

The path model for satellite navigation use (Fig 2.3.2) shows a classic structure of the theory of planned behaviour with unstandardised regression estimates. Statistical analysis of this model suggests an acceptable fit [$\chi^2(3, N = 112) = 2.34$, $p = .51$, RMSEA = .00, RMSEA confidence interval (.00, .15), NFI = .99, CFI = 1.00, PCLOSE = .62]. Attitude ($p < .001$) and subjective norms ($p < .001$) were significant predictors of intentions. Intentions were found to be significant predictors of past behaviour ($p < .001$). Subjective norms were the greatest predictor of intention (.65), meaning those who intend to use a satellite navigation system while driving perceive others as performing the behaviour and being more approving of the behaviour.

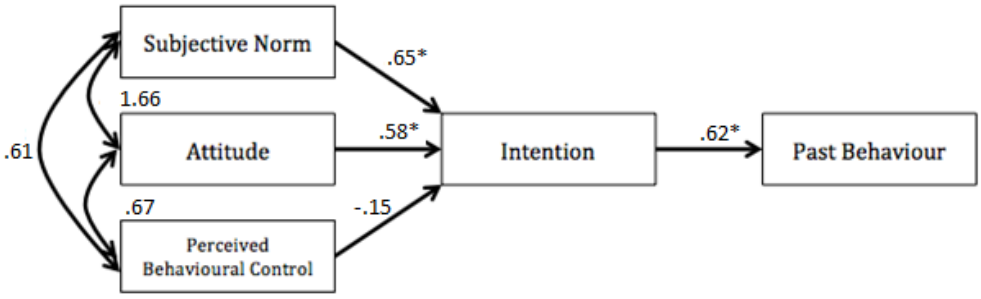


Figure 2.3.2. Path model of TPB factors for satellite navigation use with unstandardized coefficients.

MP3 Player use

Table 2.8.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for MP3 player use, including mean and standard deviation values. All variables were significantly correlated with each other, excluding perceived behavioural control, which was only significantly correlated with past behaviour.

Table 2.8.1

Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for music player use (n = 107)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a music player while driving in the next month would be (extremely good/extremely bad) My using a music player while driving in the next month would be (extremely pleasant/extremely unpleasant)	2.45	1.73				
SN	Most people like me will use a music player while driving in the next month Most people who are important to me approve of my using a music player while driving in the next month	2.79	1.64	.75**			
PBC	It is up to you whether you choose to use a music player while driving in the next month I have complete control over whether I use a music player while driving in the next month	5.23	1.84	.17*	.25**		
I	I intend to use a music player while driving in the next month	1.91	1.61	.79**	.63**	.11	
PB	In the past month I have used a music player while driving	1.56	1.37	.56**	.52**	.03	.71**

*correlation is significant at the 0.05 level (1-tailed), **correlation is significant at the 0.01 level (1-tailed)

Table 2.8.2 shows the regression coefficients for each step. For step one, it was found that intention explains a significant amount of the variance in past behaviour [$F(1, 106) = 106.56$, $p < .001$, $R^2 = .50$, $R^2_{Adjusted} = .50$]. Intention was a significant predictor of past behaviour in this first model (β =

.71, t(106) = 10.32, $p < .001$). For step two, the model once again explained a significant amount of the variance in past behaviour [$F(4, 106) = 27.77$, $p < .001$, $R^2 = .52$, $R^2_{Adjusted} = .50$] but did not contribute towards the first model significantly ($p = .30$). Intention was a significant predictor of past behaviour in this second model (β = .68, t(106) = 6.09, $p < .001$). Attitude, subjective norms and perceived behavioural control were not significant predictors.

Table 2.8.2
Hierarchical regression coefficients for Intention on Past Behaviour (Step 1) and Intention, Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Past Behaviour (Step 2) music player use.

	B	SE *B*	β
Step 1			
Constant	0.41	0.15	
Intention	0.61	0.06	.71**
Step 2			
Constant	0.50	0.30	
Intention	0.58	0.10	.68**
Subjective Norm	0.16	0.09	.19
Attitude	-0.08	0.10	-0.10
PBC	-0.05	0.05	-.07

Note: $R^2 = .50$ for Step 1, $\Delta R^2 = .018$ for Step 2 (p = .30). **significant at the 0.01 level (1-tailed)

A separate linear multiple regression (Table 2.8.3) was conducted to predict intentions from subjective norms, perceived behavioural control and attitude. The model explained a significant amount of the variance in intentions [$F(3, 106) = 56.26$, $p < .001$, $R^2 = .62$, $R^2_{Adjusted} = .61$]. Only attitude was a significant predictor of intention (β = .72, t(106) = 7.79, $p < .001$).

Table 2.8.3
Hierarchical regression coefficients Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Intentions for music player use.

	B	SE *B*	β
Constant	0.19	0.31	
Subjective Norm	0.10	0.91	.10
Attitude	0.67	0.09	.72**

PBC	-0.04	0.06	-.04

Note: R^2 = .62. **significant at the 0.01 level (1-tailed)

Path analysis

The path model for MP3 player use (Fig 2.3.3) shows a classic structure of the theory of planned behaviour with unstandardised regression estimates. Statistical analysis of this model suggests an acceptable fit [$\chi^2(3, N = 107) = 3.83$, $p = .28$, RMSEA = .05, RMSEA confidence interval (.00, .18), NFI = .99, CFI = .99, PCLOSE = .39]. Attitudes ($p < .001$) were significant predictors of intentions and intentions were found to be significant predictors of past behaviour ($p < .001$).

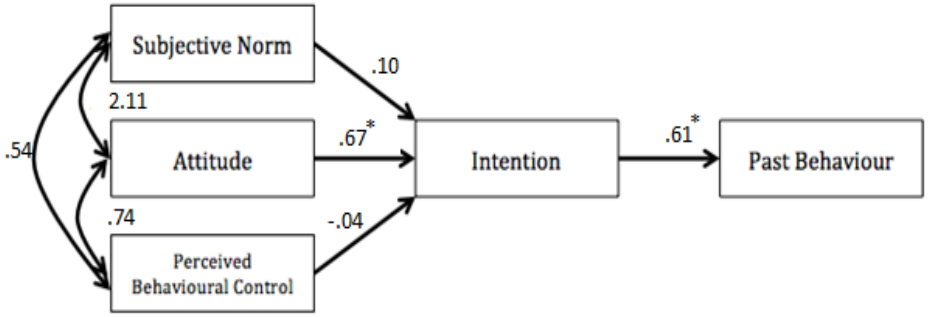


Figure 2.3.3. Path model of TPB factors for MP3 player use with unstandardized coefficients.

Text Messaging

Table 2.9.1 shows the correlation matrix for attitudes, subjective norm, perceived behavioural control, intentions and past behaviour for text messaging while driving, including mean and standard deviation values. All variables were significantly correlated with each other, excluding perceived behavioural control which did not correlate with any other variable.

Table 2.9.1
Means (M), standard deviations (SD) and item correlations for attitudes (A), subjective norm (SN), perceived behavioural control (PBC), Intentions (I) and past behaviour (PB) for portable device use (n = 104)

TPB factor	Description	M	SD	A	SN	PBC	I
Attitude	My using a portable device while driving in the next month would be (extremely good/extremely bad) My using a portable device while driving in the next month would be (extremely pleasant/extremely unpleasant)	1.40	0.99				
SN	Most people like me will use a portable device while driving in the next month Most people who are important to me approve of my using a portable device while driving in the next month	1.72	1.03	.18*			
PBC	It is up to you whether you choose to use a portable device while driving in the next month I have complete control over whether I use a portable device while driving in the next month	4.85	2.43	.02	.03		
I	I intend to use a portable device while driving in the next month	1.26	1.00	.28**	.25**	.11	
PB	In the past month I have used a portable device while driving	1.26	0.86	.34**	.36**	.05	.55**

*correlation is significant at the 0.05 level (1-tailed), **correlation is significant at the 0.01 level (1-tailed)

Table 2.9.2 shows the regression coefficients for each step. For step one, it was found that intention explains a significant amount of the variance in past behaviour [$F(1, 103) = 43.13$, $p < .001$, $R^2 = .30$, $R^2_{Adjusted} = .30$]. Intention was a significant predictor of past behaviour in this first model ($\beta = .55$, $t(103) = 6.57$, $p < .001$). For step two, the model once again explained a significant amount of the variance in past behaviour [$F(4, 99) = 15.00$, $p < .001$, $R^2 = .38$, $R^2_{Adjusted} = .35$] and contributed to the model significantly ($p < .001$). Intention was a significant predictor of past behaviour in this second model ($\beta = .44$, $t(103) = 5.22$, $p < .001$), along with subjective norms ($\beta = .21$, $t(103) = 2.58$, $p = .01$) and attitudes ($\beta = .18$, $t(103) = 2.14$, $p = .03$).

Table 2.9.2
Hierarchical regression coefficients for Intention on Past Behaviour (Step 1) and Intention, Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Past Behaviour (Step 2) for text messaging while driving.

	B	SE *B*	β
Step 1			
Constant	0.67	0.12	
Intention	0.47	0.07	.55**
Step 2			
Constant	0.27	0.20	
Intention	0.38	0.07	.44**
Subjective Norm	0.18	0.07	.21*
Attitude	0.16	0.07	.18*
PBC	-0.003	0.03	-.01

Note: R^2 = .30 for Step 1, ΔR^2 = .08 for Step 2 (p < .001).). *significant at the 0.05 level (1-tailed), **significant at the 0.01 level (1-tailed)

A separate linear multiple regression (Table 2.9.3) was conducted to predict intentions from subjective norms, perceived behavioural control and attitude. The model explained a significant amount of the variance in intentions [$F(3, 100) = 4.90$, $p < .01$, $R^2 = .13$, $R^2_{Adjusted} = .10$]. Attitude (β = .24, t(103) = 2.52, $p = .03$) and subjective norms were significant predictors of intention (β = .20, t(103) = 2.15, $p = .01$).

Table 2.9.3
Hierarchical regression coefficients Subjective Norm, Attitude and Perceived Behavioural Control (PBC) on Intentions for text messaging while driving.

	B	SE *B*	β
Constant	0.39	0.28	
Subjective Norm	0.20	0.09	.20*
Attitude	0.24	0.10	.24*
PBC	0.04	0.04	0.10

Note: R^2 = .13. *significant at the 0.05 level (1-tailed).

Path Analysis

A path model is not presented for these data as the final model did not meet expectations of overall fit criteria.

Hand-held versus hands-free

Measures for hand-held and hands-free mobile phone use were compared to investigate the differences between an illegal and legal behaviour. Independent t tests were performed on each measure. For all measures, ratings were higher for hands-free mobile phone use, with drivers reporting a higher instance of past behaviour [$t(183.95) = 3.51$, $p < .01$], greater intentions [$t(176.59) = 4.96$, $p < .001$], more positive attitudes [$t(181.72) = 6.58$, $p < .001$], a greater perception of approval from others [$t(187.92) = 6.72$, $p < .001$] and more sense of control, although this difference was borderline [$t(209.95) = 3.51$, $p = .055$].

Discussion

The main aims of the questionnaires was to attempt to explain intentions and behaviour using the theory of planned behaviour model. In all cases, significant predictions were found for intentions and behaviour, suggesting this framework is successful in explaining the variance in our models.

Summary of findings

For hands-free mobile phone use, intentions were a significant predictor of past behaviour, suggesting those who intend to use their hands-free mobile phone will most likely follow through with their intentions. Overall, intentions explained 66% of the variance in past behaviour. Attitudes, subjective norms and perceived behavioural control were added to this model but did not contribute significantly and were not significant predictors in this model, however, all three of these became significant predictors for intentions in a separate regression, with the model explaining 76% of the variance in intentions. Attitude was the largest predictor of intentions, showing those with more positive attitudes towards hands-free mobile phone use have higher intentions to perform the behaviour. The path model confirmed these findings and suggested the classic theory of planned behaviour structure was a good fit for these data.

For hand-held mobile phone use, intentions were once again a significant predictor of past behaviour, with intentions explaining 60% of the variance in past behaviour. When attitudes, subjective norms and perceived

behavioural control were added to this model, only attitudes were found to be a significant predictor. This improved the model significantly and explained 69% of the variance in past behaviour. Both attitudes and subjective norms were significant predictors in a separate regression on intentions. This suggests that those with more positive attitudes towards hand-held mobile phone use and those who perceive others as approving of the behaviour will have higher intentions to perform the behaviour.

For satellite navigation use, intentions significantly predicted past behaviour, explaining 51% of the variance in past behaviour. No other variables were significant predictors when added to this model, however, attitudes and subjective norms became highly significant when a separate regression was performed on intentions. Subjective norms were the highest predictor of intentions, over attitudes. The path model confirmed this and suggested the classic structure of the model was a good fit for these data.

For MP3 player use, intentions were a significant predictor of past behaviour, explaining 50% of the variance. When the other variables were added to this model, none were significant predictors and did not contribute to the first model. However, in a separate regression on intentions, attitude was found to be a significant predictor of intentions. The path model confirmed this, with intentions significantly predicting past behaviour and attitudes significantly predicting attitudes, with a good fit of the data.

For text messaging, intentions were again a significant predictor of past behaviour and explained 30% of the variance, much lower than the other four technologies. When the other variables were added to this model, attitudes and subjective norms were found to be significant predictors and increased the

models explanation of variance to 38%. A separate regression on intentions also found attitudes and subjective norms to be significant predictors of intentions.

Interestingly, perceived behavioural control was a significant predictor only in relation to hands-free mobile phone use, suggesting perhaps that some may not have had access to proper hands-free facilitation and so felt the use of this technology was out of their control. Attitudes were large predictors of intentions for all five technologies, while subjective norms were significant predictors of intentions for all but MP3 players, suggesting that for most, more positive attitudes and a higher perception of others approving of the behaviour will amount to increased intentions.

Relation to past literature

Results from these five studies fit broadly with previous research and support the use of the theory of planned behaviour to predict intentions. Significant predictors were found for all technologies and explained 61-75% of the variance in intentions for hand-held, hands-free, MP3 player and satellite navigation use. Predictors only accounted for 10% of the variance in text messaging, yet was still significant. With regards to general driver distraction, attitudes, subjective norms and perceived behavioural control have all found to be predictors of intention or engagement, with attitudes being the most likely predictor, consistent with these findings (Chen et al, 2016). These results are consistent with general mobile phone use studies have found attitudes and subjective norms to be significant predictors of intentions (Walsh et al, 2010).

In terms of hands-free mobile phone use specifically, the results broadly support previous research which suggests users are more likely to

believe that others approve of their mobile phone use (White et al, 2010). Subjective norms and attitudes are most likely predictors in this case as hands-free mobile phone use is a legal behaviour and is seen as a positive alternative to hand-held mobile phone use. Others have found perceived behavioural control to be the largest predictor in intentions to use both a hand-held and hands-free mobile phone while driving (Zhou et al, 2009). While perceived behavioural control was a borderline predictor for hands-free mobile phones, the same was not found for hand-held mobile phones and attitudes in this analysis eclipsed all others.

Text messaging research has found that intentions to read and send messages while driving were predicted by attitudes but not by subjective norms or perceived behavioural control (Nemme & White, 2010; Walsh et al, 2010). The current research supports this, but also found subjective norms to significantly predict intentions which is supportive of Sandlin, Sandlin and Keathley (2015) who found college students had a higher perception that friends would also text while driving.

Subjective norms were significant predictors of intentions in hands-free mobile phone use and satellite navigation use. This approval and validation of others fits with the idea that as perfectly legal behaviours, others will approve of another performing these behaviours. Subjective norms significantly predicted intentions in hand-held mobile phone use, an illegal behaviour, as people look to their reference group when deciding how to act in these situations (Johnston & White, 2003; Levin, Dato-on & Manolis, 2007). As mean scores on past behaviour in this group are very low, it is more likely that

participants are aware that others do not perform this behaviour and so choose themselves not to use their hand-held mobile phone while driving.

Consistent with Zhou et al (2009), theory of planned behaviour measures between hand-held and hands-free mobile phone use differed significantly, showing that participants were able to differentiate their use of a hands-free mobile phone from a hand-held device and did not answer these questions in terms of general mobile phone use. These differences also show that drivers have more negative feelings towards hand-held mobile phone use which is a positive indication that current law and education are having an effect on drivers' beliefs.

Limitations

The sample used in this study had a mean age of around fifty years old. The literature on driver distraction suggests that much younger drivers are those most likely to interact with technological devices while driving (Walsh, White & Young, 2008) and are also the most vulnerable to distraction (Hosking, Young & Regan, 2009). Therefore, this sample is not as representative of the younger population as one would like. Additionally, the drivers in this experiment were quite infrequent users of these technologies, in that mean past behaviour scores did not reach over 2.61 out of 7. This was perhaps due to the sample age, or could have been due to the unwillingness of drivers to admit engaging in these behaviours while driving. However, even legal behaviours were not frequently performed.

Conclusion

It is clear from the results that attitudes play a large role in predicting intentions and therefore behaviour. Subjective norms are also important in predicting intentions, to a lesser extent with intentions always significantly predicting past behaviour. A very large amount of the variance in past behaviour were accounted for by the models, showing that the theory of planned behaviour is a useful tool in relation to driving technology research.

CHAPTER 3 – USING REAL ACCIDENT STATISTICS TO INDUCE A SENSE OF RISK IN SIMULATED DRIVING.

Much emphasis is given to how distracting technologies can be to drivers. However, there is a possibility that technology can serve as a positive influence and contribute to successful driving. While driver assistance systems can be seen as a great development in driver safety, driver adaptation theories suggest caution. Study two will employ a driver assistance technology, giving participants information about their risk of accident while driving. Such technologies are discussed further along with behavioural adaptation theory.

Behavioural adaptation

In 1964, Taylor discovered that the galvanic skin response of drivers correlated with accident probabilities. Furthermore, he found that GSR[1] was maintained by drivers adjusting their speed and first proposed the idea that drivers may have a certain level of risk that they are willing to tolerate. Wilde (1982) then evolved this idea into risk homeostasis theory and later, Fuller adapted this once more by introducing task difficulty into the fray.

Theories of risk compensation, behavioural adaptation and risk homeostasis are based on the assumption that our behaviour is dependent on our perceived level of risk. If this perceived level increases, we are inclined to be more careful and if our perceived level of risk decreases, we might be less careful. Figure 3.1 shows the homeostatic mechanism first described by Wilde

[1] Galvanic skin response is a measure of electrodermal activity of the skin. An rise in conductivity may indicate an increase in mental workload or emotional states such as anxiety (Chen et al, 2016).

(1982). This is a closed loop process which in some ways is governed by the target level of risk one is comfortable with. The premise of this model is that people will try to optimise their level of risk. To begin with, four main 'utility factors' are considered; the expected benefits of risky behaviour, the expected costs of risky behaviour, the expected benefits of safe behaviour, and the expected costs of safe behaviour. For example, in the case of adhering to the speed limit (or not), one might consider the benefits to be the shorter journey time for speeding or the insurance benefits of not speeding. The costs associated may be the fines for getting caught or a longer journey time. These will be taken into account to create a target level of risk. Calculations are made constantly between perceived risk and target level of risk, so that incongruities can be balanced and behaviour changed accordingly. As well as these perceived costs and benefits, perceptual, decision and vehicle handling skills also play a role in the resulting accident loss, however, Wilde (1998) postulates that these variables, including environmental factors, have little effect on the overall system**.**

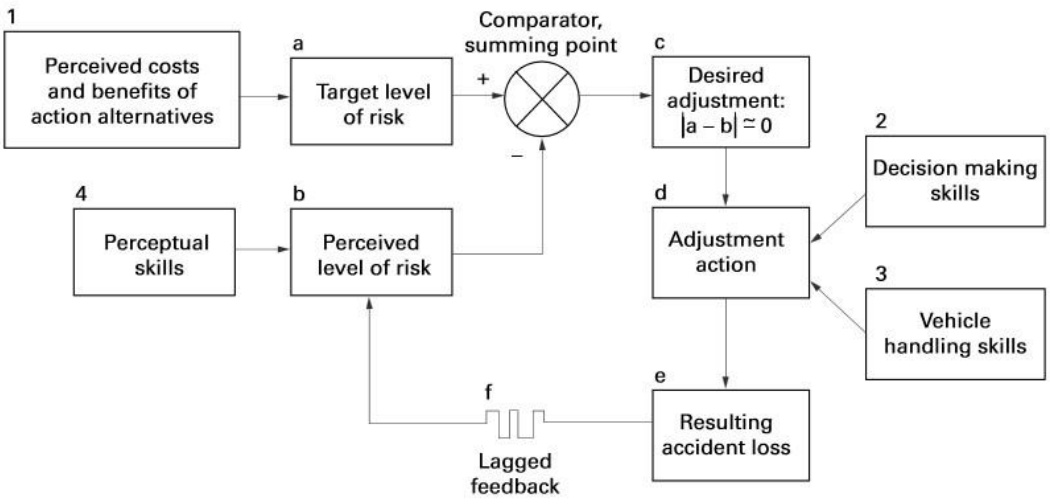


Figure 3.1. Homeostatic mechanism (Wilde, 1982).

Evidence for this model comes largely from studies which have analysed differences in driver behaviour when changes have been made to roads or vehicles. For example, the analysis of accident statistics after new legislation is implemented. It was observed that after Swedish vehicles changed from driving on the left to driving on the right side of the road, a clear reduction was seen in accident fatality rates (although rates returned to normal after 18 months) (Wilde, 1998). Others have suggested that drivers involved in minor accidents may draw the 'wrong' conclusions and may imagine that "it's not so dangerous after all" (Hale & Glendon, 1987).

Risk homeostasis theory would suggest that drivers' perception of risk increased to a point above drivers' own target level of risk and so an adjustment was made to driver behaviour. Other studies have not been so bold as to claim evidence for risk homeostasis and rather prefer the term 'behavioural compensation' or 'behavioural adaptation'. In a simulator study involving mobile phone related tasks, it was found that with increased workload (which in turn increased heart rate and presumably risk [Fuller, 2008]), drivers compensated by reducing their speed (Haigney, Taylor & Westerman, 2000). The reverse of this is that when drivers feel safer, i.e. when wearing a seat belt or when driving a vehicle with anti-lock brakes, they may actually start to drive faster, or closer to the vehicle in front to maintain their target level of risk (Janssen, 1994; Aschenbrenner & Biehl, 1994 cited in Wilde, 1994). However, after analysing safety data from 1985-2002, an NHTSA funded study found any individual evidence of behavioural adaptation to be insignificant as, since the introduction of seat belts, they

found a significant reduction in traffic fatalities (Houston & Richardson, 2007).

A central feature of the risk homeostasis model is that drivers seek out risk and strive to maintain a target level of risk. Näätänen and Summala (1974, 1976) argue the opposite in that driver behaviour is not constantly altered depending on risk. Under normal road conditions, Näätänen and Summala posit that the driver feels no risk at all as they have built up experience and confidence in their personal driver skills. Therefore, it is only when a certain threshold of risk is breached that the driver feels risk. Risk compensation mechanisms are then employed to reduce the risk back to zero. Summala argues that most drivers understand how to avoid a collision (although the risk threshold of some drivers may be too high) and so driving 'becomes a habitual activity which is based on largely automised control of safety margins in partial tasks' (Summala, 1986, p.10).

Similarly, Fuller (2005) believed that risk of accident is not relevant when discussing driver behaviour. Instead, the difficulty of the driving task is the most relevant factor. Fuller argued that the speed reduction observed in hazardous or unfamiliar situations is due to increased task difficulty and not due to increased perceptions of risk. To illustrate this idea, Fuller proposed the task capability-interface model (Fuller, 2000, see figure 3.2). In this model, task difficulty is a product of the interaction between task demands (D) and capability (C). When capability surpasses task demands, the driver will find the task to be easy. However, when task demands are equal to capability, the driver is functioning at the bounds of their abilities and the

task becomes more challenging. Where task demands outweigh capability, the task becomes too difficult and the driver will experience a loss of control.

Loss of control in this case does not spell an instant collision. Instead, this could denote a change in lane position. Additional tasks external to driving may increase overall demand and therefore overwhelm capability. Similarly to the risk homeostasis theory, the TCI model suggests that drivers will decide upon a level of task difficulty which they are comfortable with and attempt to maintain this level throughout the drive, mostly by means of speed. This was named 'task homeostasis'.

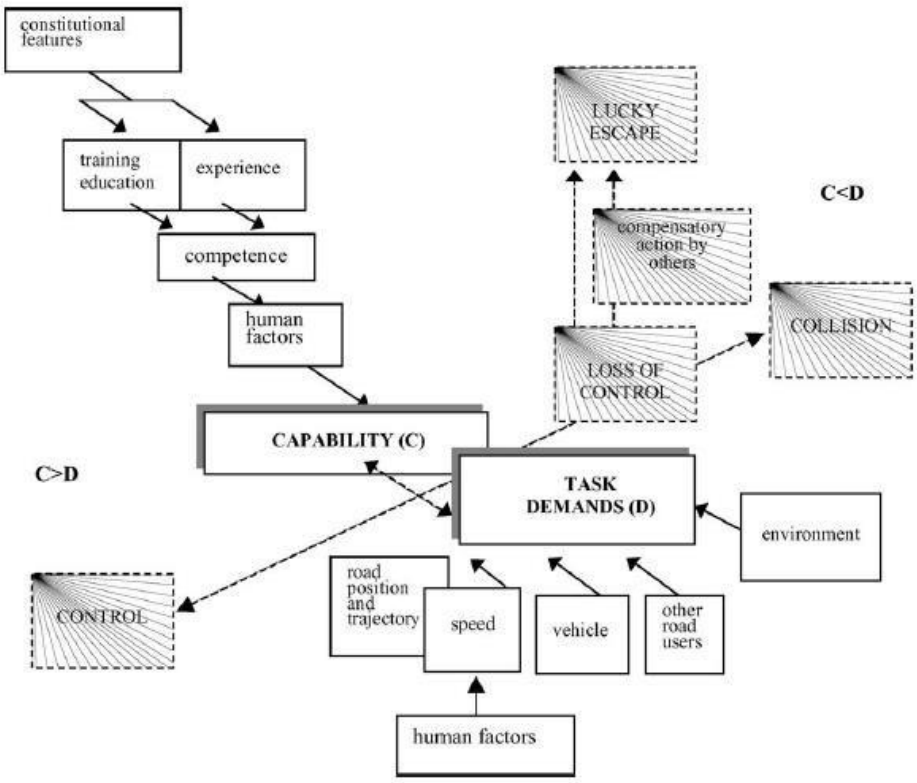


Figure 3.2. Task-capability interface model

A central prediction of this model was that feelings of risk, or risk perception, should correlate with ratings of statistical risk (Fuller, 2000). However, this was not found to be the case. In a study of 30 participants, first person clips were presented from the interior of a car showing the journey of

the vehicle at different speeds. Participants were asked to rate each clip on statistical risk of collision, task difficulty and personal feeling of risk (Fuller, McHugh & Pender, 2008). Ratings of statistical risk lingered around zero until a critical higher speed was reached, regardless of feelings of personal risk. Interestingly, task difficulty and perceived risk were extremely highly correlated (r = .97). After an on road test drive of 12 routes, Grayson et al (2003) also found ratings of danger and difficulty to be highly correlated. To explain this, Fuller reasoned that perceived risk may be employed as an indication of task difficulty. For example, when task demand increases towards the maximum level of capability, feelings of risk increase. This feeling of risk then forewarns the driver that the difficulty of the task is increasing so the driver can make adjustments to maintain a certain level. Based on these results, Fuller updated his model to form the risk allostasis model (Fuller, 2008). In this version, a drivers' chosen level of risk is open to change as they re-evaluate their capability. Support for this model comes from a similar study based on subjective ratings where participants watched a series of clips and then drove the routes in a simulator (Lewis-Evans & Rothengatter, 2009). Once again, it was found that task difficulty and feeling of risk were highly related with one another. However, contrary to Fullers' findings, the relationship with these variables and speed only began to appear linearly after a certain speed threshold. Feelings of risk and task difficulty only began to increase after observed and driven speeds reached around 50kmph for residential roads and 110kmph for dual carriageways and even at these speeds, only a moderate correlation existed.

Physiology

Physiological measures are important to discuss as feelings of risk are often accompanied by physical arousal. Studies examining the effects of risk and task difficulty on driver performance have often included physiological measures. In a simulator study of 121 participants, results found that increased cognitive load, or task difficulty, caused heart rates to increase (Mehler, Reimer, Coughlin & Dusek, 2009). Other studies have found increased heart rate to correlate with 'stress' (a proxy for task demand) in real world driving (Healey & Picard, 2005) and task difficulty in simulated and real flight in pilots (Jorna, 1993).

In-car technology has also been linked to increased physical arousal. A simulator study involving the use of both hand-held and hands-free phones found heart rates to increase when the driver was using the device (Brookhuis, de Vries & de Waard, 1991). Interpretations of this effect consider the increase in workload to be the cause of heart rate increase, however, it could be argued that the risk associated with using a mobile phone while driving (even in a driving simulator) could have had an impact on heart rates. However, one study in an early driving simulator did not find heart rate to predict workload level, and instead found subjective opinion scales to be more reflective of current workload (Hicks & Wierwille, 1979). Similarly, Engström, Johansson and Östlund (2005) did not find any change in heart rate variability under higher workload, but did find differences in skin conductance. Heart rate variability will be measured in the following studies as a product of risk perception, not as a result of cognitive workload (although the risk warning system may increase cognitive load).

Others have found difficulties in inducing physiological changes within a driving simulator. Testing the effects of perceived risk, participants performed a car following task at a reduced headway in order to induce feelings of risk and increase workload (Heino, van der Molen & Wilde, 1996). Results found heart rate increased while driving compared to a rest period, especially in sensation avoidant participants, but did not find any change in heart rate between free driving and driving at a reduced headway. Participants did report an increase in risk during the following task but this did not translate on a physiological level, possibly due to being in the safety of the driving simulator.

Risk warning

Often research is focussed on in-car technology as the cause of driver distraction and accidents on the road. These pieces of technology serve to make driving a more pleasurable and convenient activity but also have the potential to affect road safety. Fortunately, there is a body of research which aims to implement technology in-vehicle which has the capacity to make the journey safer. However, there is still the possibility that these driver assistance systems may also degrade driver performance in that they may become distracting or even 'annoying' to the driver (Maltz & Shinar, 2004).

Various warning systems have been investigated to alert drivers to lane position (Kozak et al, 2006) and proximity to other vehicles (Cheng, Hashimoto & Suetomi, 2002). While testing the effectiveness of a lane departure warning system, participants were first required to drive in a simulator with warnings present with no prior knowledge of what the warnings

meant (Suzuki & Jansson, 2003). These warnings came in the form of steering wheel vibrations or auditory signals. Results found that lane departure warnings were effective 'especially when drivers did not know the meanings of the warnings' (Suzuki & Jansson, 2003, p.65). These results are consistent with another experiment involving vibratory wheel warnings which found the improvements in reaction times to be even more pronounced when the wheel vibration was coupled with an auditory warning (Navarro, Mars & Hoc, 2007). This indicates that warning systems have the capacity to provoke improved driver performance, regardless of their meaning. However, these warning systems may have adverse effects. In a simulator experiment, a traveller advisory system was created to warn drivers of upcoming weather conditions or incidents (the presence of a snow plough). Results found that message warnings were effective at reducing speeds in areas where warnings had been issued, however, drivers compensated for this loss of speed by increasing speed in other areas (Boyle & Mannering, 2004).

When presenting the warning tone to participants, it is important that the tone be consistent and frequent. An investigation into the effects of hand-held compared to hands-free mobile phones found evidence for compensatory behaviour for only the hand- held conditions (Patten et al, 2004). Despite increased workload for both mobile phone types, only hand-held phones caused drivers to reduce their speed. Authors did not believe this was due to the manual demands of the hand-held phone and instead suggested that the phone served as a constant reminder of the secondary task and the accompanied increased workload. In terms of this experiment, the

regular sound of risk level in the form of a low, medium or high pitched tone will serve as a continuous reminder of participants' risk of accident.

Audio only information will be given in this experiment, so as not to overload the driver with additional visual information. Ho, Reed and Spence (2007) acknowledged that visual warning signals in-vehicle may unnecessarily add to the already quite large visual demands of driving. Instead they tested auditory, tactile and auditory plus tactile warning systems for safe headway distance in a driving simulator (n = 18). Brake response times were faster for tactile plus auditory drives compared to auditory and tactile drives alone. Others have found tactile warnings to be the most successful (Scott & Gray, 2008).

However, prospective warning systems have varied the ways in which alerts are presented to participants. Kramer et al (2005) presented twenty young and twenty older participants with collision signals via visual only, auditory only, visual plus auditory and tactile plus visual warnings as well as a no warning condition as a control drive. Warnings were successful in reducing collisions, with the auditory plus visual warning system being the most effective and prompted the quickest response. Surprisingly, older drivers responded as quickly to warnings as younger drivers. These findings are consistent with other collision warning systems (Ben-Yaacov, Maltz & Shinar, 2002; Maltz & Shinar, 2004).

The problems with these systems arise when drivers become accustomed to their warnings and any feelings of risk once felt are now faded. False alarms from systems can also reduce the effectiveness of warning drivers (Parasuraman, Hancock & Olofinboba, 1997). These false alarms may also

take the driver's attention away from the road when completely unnecessary, or even distract the driver from another very real hazard (Maltz & Shinar, 2004). In one study, younger drivers were particularly affected by false alarms, resulting in them driving with shorter headways using a collision warning system on-road (Dingus et al, 1997). Others have found drivers can become overly dependent on these systems which may become dangerous if the system fails or if a warning is missed (Young & Stanton, 2000). Some longitudinal success has been found however. Ben-Yaacov, Maltz and Shinar (2002) examined the effectiveness of a collision warning system, specific in avoiding small headways. Participants (n = 30) drove a real car on a real motorway and were instructed to stay behind particular vehicles. The warning system would sound at predefined short headways as well as intended false alarms. Findings suggested the warning system helped participants to more accurately estimate headway. This effect was maintained when participants were tested six months post-experiment, driving with no warning system. These warnings can even have other positive effects such as reduced road rage and feelings that the driving task is less difficult (Maag, Mühlbacher, Mark & Krüger, 2012).

Specific safety interventions have been successful in behavioural change when there is an implication of risk. Michael, Leeming and Dwyer (2000) tested two interventions whereby a sign was displayed at the roadside displaying either 'Please don't tailgate' or 'Help prevent crashes, please don't tailgate'. The first had no effect on drivers' headway whereas the second prompted drivers to significantly increase headway. By including the word 'crash', an implication of consequence and therefore risk was inferred and so

behaviour was adjusted. With including actual crash statistics in the current study, in particular those crashes that resulted in a casualty, it is hoped that a similar effect will be observed.

The major problem with driver assistance systems is that drivers may become over reliant on warnings and fail to attend to the road properly, assuming the device will notify them of any problem. To overcome this, the following studies will not offer the driver any warning of impending collisions in terms of spatial area, instead, the warning system will inform drivers of the *probability* of an accident. As a result, drivers may choose to increase their level of attention to the road.

Inducing feelings of risk in a driving simulator is difficult as virtual roads lack the ecological validity to generate a sense of danger for the participant. The participant is always going to feel safe in the knowledge that no harm can come to them no matter how badly they drive. However, the following experiments offer a novel solution to this problem in that the simulated roads are identical to real roads which the participants often see, drive on, walk on and take buses through. Together with actual accident statistics from these areas, it is hoped that the simulated roads will offer a greater submersion into the driving task. A beep tone indicating the statistical level of risk of accident for these roads will be played to participants as they drive. The aims of this study are to investigate the possibility of risk compensation and to determine whether feelings of risk may be experienced in a simulated environment.

It is expected that:

- Driving performance measures will show a difference in the presence of the risk tone, in particular it is expected that speed will decrease in the presence of a high risk tone.
- Heart rate will increase in the presence of the tone and increase as a function of risk level.

Method

Design.

All participants drove the simulated route twice, once in each direction and once with a risk tone sounding. Therefore, the experiment used a 2x3 within-subjects design with factors of Warning (on/off) and Risk (high/medium/low). The direction of route (clockwise, anticlockwise) was counterbalanced in terms of which direction was driven first, along with the presence of the tone, thus creating four groups of six participants.

Participants.

Twenty-four participants were recruited from the undergraduate population of the University of Nottingham with equal numbers of males and females (mean age 20.46, SD .59, range 20-22). All participants held full UK drivers licences (M = 3.05 years, SD 1.01 years) and drove an average of 2215.71 (SD 3006.30) miles per year. Only one participant had been involved in an accident within the last two years.

Apparatus and Measures

Simulator.

The study was conducted in the Nottingham Integrated Transport and Environment Simulation facility (NITES) at the University of Nottingham, using NITES 1. This is a high fidelity simulator with a six degrees of freedom motion platform. Mounted on the motion platform is a projection dome which contains a full BMW Mini. Eye movements were recorded using two seeing machines, eye trackers running FaceLab 5 and linked to provide 120 degrees of eye tracking. The motion base feature requires two experimenters to operate the equipment due to safety procedures. This was not possible for any experiments and so the simulator remained stationary.

Physiology.

Physiology was recorded using a Biopac MP150 biopotential amplifier using the bionomadix remote recording system. Pulse rate was recorded using a BN-PPGED remote unit with pulse attached to a BN-PULSE-XDCR pulse transducer attached to the distal phalange of the right hand. To check for movement artefacts, a bionomadix BN-ACCL3 triaxal accelerometer was attached to the right forearm. As previous literature has shown mixed findings on heart rate alone, a respiratory monitor was used. However, this equipment failed and so only heart rate data will be presented.

Workload.

Workload was measured using the NASA-TLX paper version. This measure estimates workload split into six components; mental demand,

physical demand, temporal demand, own performance, effort and frustration.

Simulator sickness questionnaire (SSQ).

The simulator driving involved in this experiment was fairly long, averaging around forty minutes of driving. To ensure participants were monitored correctly and so they could recognise the symptoms for themselves, the simulator sickness questionnaire was used. Participants completed this measure before the experiment began, once again after their practice drive and again after each subsequent experimental drive. An increase in symptoms indicated by the questionnaire halted the experiment.

Test route.

The NITES facility is unique in that participants can drive a simulated route of Nottingham. This is a twelve mile LIDAR scanned route of Nottingham city centre and for the purpose of this experiment, was divided into six sections, where the route is naturally broken by major junctions, roundabouts and one-way systems. This ensured that the route could be driven exactly in each direction. For each section, the number of casualties was calculated using data from Nottingham City Council. These statistics included the location of each accident from 2009-2012 and only included road traffic accidents which resulted in a casualty. In order calculate a level of risk for each section of the route, traffic flow data was taken into account. Official traffic flow statistics could not be obtained from Nottingham City Council and so experimenters aimed to calculate a rough estimate. This was achieved by

driving the actual route once in each direction (clockwise/anticlockwise) at a mid- afternoon time of relatively low traffic density and counting the number of vehicles seen on the opposite side of the road. Traffic flow was then averaged between two experimenters' tallies direction of route. Individual risk of accident was then calculated by dividing the accident casualty numbers by the typical traffic flow for each section of the route (see table 3.1). Road sections were thus divided into three types; low, medium and high risk, with two exemplars of each**.**

Table 3.1
Number of casualties compared to traffic flow for each route section

	No. of Casualties	Traffic Flow	Risk Level	Risk Level
1	12	12.75	0.94	High
2	22	25.75	0.85	High
3	47	66.75	0.7	Medium
4	11	29.75	0.37	Medium
5	9	36.25	0.25	Low
6	11	176	0.06	Low

Risk Tone.

A loud speaker was placed inside the simulator vehicle to play the risk tone. This tone used a high pitched beep for high risk areas, medium for medium risk and a low tone for low risk areas. This tone was tested prior to the study to ensure that participants could distinguish the differences in pitch. In the conditions where the tone was present, the tone would start as soon as the participant drove into a section. The tone would then sound three times, go silent and would then intermittently sound every thirty seconds until the participant reached the next road section. The tone was presented to

participants prior to the experiment to ensure they could distinguish between the three pitches.

Procedure

After giving informed consent, participants completed a brief questionnaire on driving history. This gained information such as the number of years driving, miles driven per year, accident information etc. A simulator sickness questionnaire was also completed at this point to gauge a baseline to compare to after each drive. Anyone reporting high symptoms at this point was asked not to complete the study. Participants then drove a five minute practice drive to become accustomed with the simulator and then completed a second simulator sickness questionnaire. Physiological sensors were then fitted and eye trackers were then calibrated. At this point, the accident warning system was explained and participants were informed that the tone would be present for one drive only. Each tone was briefly played at this moment to ensure that participants could distinguish between each level of the tone. Participants then drove the route in one direction with either the tone on or off and then completed a NASA TLX workload measure and an additional simulator sickness questionnaire. Finally, participants drove the route once more in the opposite direction with the tone on or off and once again completed the NASA TLX and a final simulator sickness questionnaire. Participants then rated their familiarity with each section of the route, firstly by how often they had driven it personally and secondly by how often they had travelled each section on foot or by public transport. This was measured on a scale from 1-7 with one representing never driven it before and seven

representing driving it every day. Participants were then debriefed and asked not to drive a real car for at least 30 minutes.

Results

Workload

For all subscales, apart from 'effort', participant self-ratings of workload were higher when the tone was present compared to when the tone was off, although some differences were marginal. Mean values indicated larger differences in workload subscales of physical demand, temporal demand and performance (Table 3.2.1). T tests suggested that participants rated themselves as significantly more of a failure in terms of performance when the tone was present [$t(23) = 2.08$, $p = .049$]. Participants also rated the task as significantly more physically demanding when the tone was present [$t(21) = 2.26$, $p = .03$]. A significant difference was also found with participants reporting higher temporal demands when the tone was present [$t(22) = 2.54$, $p = .019$], indicating that the tone added an extra time pressure. Mental demand [$t(22) = .218$, $p = .83$], effort [$t(23) = -.368$, $p = .72$] and frustration [$t(22) = 1.308$, $p = .20$], were not found to have any significant differences.

Table 3.2.1
Means (M) and standard deviations (SD) for NASA TLX measures.

Measure	Tone On		Tone Off	
	M	S	M	S
Mental	8.96	5.06	8.25	4.8
Effort	10.13	4.43	10.25	4.4
Frustration	8.88	5.02	7.92	4.5
Physical	5.42*	3.94	4.29*	3.1
Temporal	8.13**	3.93	6.29**	3.8
Performance	9.5*	4.84	8.29*	4.6

**means are significantly different between tone on and tone off at the 0.01 level (2-tailed)
*means are significantly different between tone on and tone off at the 0.05 level (2-tailed)

Heart Rate

Heart rate was measured continuously throughout the driving task. However, due to the placement of the equipment (on the right middle finger), the recording was sometimes interrupted. Therefore, the heart rate was taken at the beginning and end of each road section and so the location at which the heart rate was recorded was taken into consideration in the ANOVA. Figure 3.3 shows heart rates were consistently higher when the tone was present compared to when the tone was off. At the same time, heart rate is increased in high risk areas compared to low risk areas regardless of the presence of the tone. A 2x3x2 ANOVA was conducted (Warning tone [On/Off] x Risk level [High/Medium/Low] x Location [Start/End]) and a main effect of warning was found [$F(1, 23) = 7.48$, $p = .012$]. A main effect of risk level was also found [$F(2, 46) = 16.67$, $p<.001$] and is illustrated in figure 3.3. No main effect of location was observed [$F(1, 23) = .14$, $p = .71$], indicating no differences between heart rates at the beginning and end of each section. A borderline interaction was found between warning and risk level [$F(2, 46) = 2.99$, $p = .060$].

Post Hoc

Post hoc tests using a Bonferroni correction revealed significant differences in heart rate between high and medium tone conditions ($p<.001$) with heart rate higher in the high risk condition and a significant difference between high and low risk conditions ($p<.001$), with heart rate higher once again in the high risk condition. An overall difference was found between tone on and tone off conditions ($p = .012$).

Speed

Average speed was calculated for each route and then averaged across risk level. Mean speed was lower for high risk areas regardless of the presence of the tone (Table 3.2.2). The only marked increase of speed is shown when the tone is not present in a low risk area compared to when the tone is present. A 2x3 ANOVA was conducted (Warning [On/Off] x Risk [High/Medium/Low]) and a main effect of risk was found [$F(2, 46) = 82.01$, $p<.001$]. This effect was not shown with standard deviation of speed.

Post Hoc

Post hoc tests using a Bonferroni correction revealed significant differences in speed between high and medium conditions ($p<.001$) and high and low conditions ($p<.001$), with speed always being lower in the high risk condition. No difference was found between medium and low risk conditions.

Table 3.2.2
Means (M) and standard deviations (SD) of speed.

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	25.48	3.96	25.77	2.94
Medium	39.50	6.18	38.48	5.77
Low	34.83	7.00	37.34	4.96

Eye movements

Eye movements were analysed separately according to fixation durations, horizontal movements and vertical movements. 2x3 ANOVA's were conducted (Warning [On/Off] x Risk [High/Medium/Low]). No effects

were found for fixation durations or vertical movements. However, a main effect of risk was found for horizontal movements [$F(2, 40) = 13.28$, $p<.001$].

Post Hoc

Post hoc tests using a Bonferroni correction revealed significant differences in horizontal eye movements between high and medium risk conditions ($p<.001$) and high and low conditions ($p = .032$), with horizontal eye movements having a greater range in the high risk condition. No difference was found between medium and low risk conditions.

Other measures

2x3 ANOVA's were again conducted on simulator variables (Warning [On/Off] x Risk [High/Medium/Low]). Braking [$F(1.6, 37) = 31.42$, $p<.01$] and steering angle [$F(2, 46) =122.73$, $p<.0$]1 were found to have a main effect of risk with higher risk areas showing greater variation in steering angle and greater instances of braking.

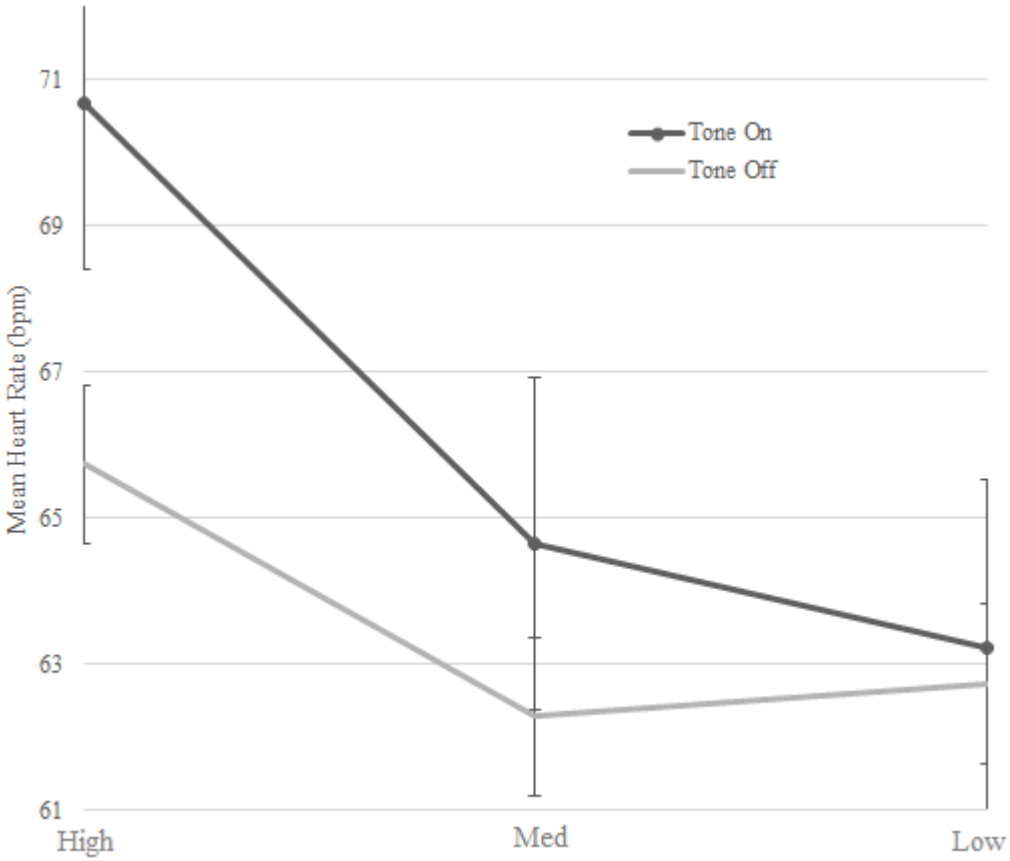


Figure 3.3. Mean heart rate for each section of high (1), medium (2) or low (3) risk when the tone was present and not present.

Discussion

Summary of findings

Contrary to what was predicted, the warning tone had no effect on driving performance measures of speed, eye movements, steering position or braking. Main effects of risk level were found, but these effects were largely due to the differences in road types between the three risk levels. However, a borderline interaction was found for heart rate, suggesting that heart rates increased when the tone was present and were elevated in higher risk areas. Post hoc tests confirmed significant differences in heart rate between high and medium tone conditions and between high and low tone conditions, with heart rates higher in the high tone conditions. Tests for subjective workload revealed significant differences in physical demand, temporal demand and performance. This suggests the tone added a feeling of time pressure and in some way made the task feel more physically demanding. Participants also felt they performed worse when the tone was present.

Heart Rate

The increase in heart rate observed when the warning tone was present was surprising considering no such trends were seen with driver performance variables. However, other researchers have suggested that driving measures alone fail to show differences in levels of workload (Mehler, Reimer & Coughlin, 2012). In their simulator study, drivers were required to complete three working memory tasks of different difficulty levels while driving. Physiology was also measured. Only heart rate and skin conductance were

significantly affected by cognitive load, or task demand. This effect increased incrementally along with task difficulty, suggesting that physiological measures are more sensitive to task demands than are traditional driver performance measures. In the present study, subjective ratings of workload increased on the subscales of physical demand, temporal demand and performance, along with heart rate. This may suggest that task difficulty did increase when the tone was present, which simulator measures were unable to detect. Of course, this is assuming that risk is an indication of task difficulty (Fuller, 2008). The increased heart rates seen in high risk areas may suggest a psychological effect of risk in the absence of behavioural changes. Referring to the risk allostasis model (Fuller, 2008), the perception of risk, and therefore task difficulty, produced by the warning tone may not have been sufficient to elicit an adjustment to behaviour.

The absence of significant differences in driving behaviour measures poses a problem for interpreting the heart rate results. Without changes in driver behaviour, the idea that heart rate differences are due to perceived risk is unconvincing. It may be that the raised heart rates seen in the high risk areas (with the high pitched tone) may be due to the warning tone itself. High pitched sounds, such as infant cries, have been found to raise heart rate (Crowe & Zeskind, 1992).

Speed

Mean speeds did not differ between tone on and tone off conditions in this study. Fuller (2008) found task difficulty and feelings of risk to increase with speed, where others found these variables to only increase

once a critical speed was reached (over 50kmph for residential roads and 110kmph for dual carriageways) (Lewis-Evans & Rothengatter, 2009). Our participants were encouraged to comply with speed limits, however, these speed limits were just at the point of these critical speeds observed by Lewis-Evans and Rothengatter, suggesting that feeling of risk and task difficulty would remain at a low level and thus, our participants would feel no need to modify behaviour. Further experiments may seek to increase task difficulty by raising speed limits.

Fuller (2005) rejected the notion of statistical risk as a determinant of driver behaviour and instead believes that task difficulty, holds the most influence. Therefore, the notion of eliciting changes in driver behaviour through risk perception alone may be ineffective and may be an explanation for our non-results. According to the risk allostasis model, driver behaviour will only change when there exists a discrepancy between task demands and capability. However, introducing simulated hazards to produce 'difficult' tasks and thus overwhelm capability could only seek to prove that drivers perform differently when confronted with hazards.

Risk tone as a driver assistance system

The risk tone gave participants an idea of accident likelihood, which meant that participants were free to choose how to use this information, whether it be slowing down in high risk areas or just generally being more vigilant. Our drivers appear to have adopted the tactic of vigilance and arousal, shown through increases in heart rates. The tone was successful in this respect, however, drivers reported themselves as significantly more of a

failure in terms of driving performance when this tone was present. No observable driving measures corroborated this claim, although participants also felt the risk tone added extra time pressures and was physically more demanding. This is regrettable, as Maltz and Shinar (2004) suggest that driver performance may suffer if a driver finds the system to be distracting or annoying.

Nevertheless, the advantage of a driver assistance system such as this, is that drivers are presented with accident information rather than warnings of imminent danger such as past experiments (Cheng, Hashimoto & Suetomi, 2002; Kozak et al, 2006). Suzuki and Jansson (2003) found their lane departure warning system was most effective when participants were free to interpret the warnings. Warning systems in past experiments often alert participants to hazards in the seconds before. In this experiment, no such hazards were introduced and so it is not known whether the risk tone could have a positive effect. Additionally, when using the whole route of this Nottingham simulation, traffic can be quite sparse, meaning that the driving task rarely requires drivers to interact with other vehicles (overtaking, sudden braking etc.). Driving around a vastly empty track might explain why there were no differences in driver performance measures.

Limitations

An important detail to note in this study is that the road types between low, medium and high risk areas were fundamentally different. Low risk roads were long, high speed carriageways whereas high risk areas were urban, slow moving, high traffic areas. Because of this, the main

effects of risk found in the analysis cannot be unambiguously interpreted. The main effect of risk found for variables such as steering wheel position, speed and eye movements are almost certainly due to the differences in road type.

A more general limitation of the study is that risk is extremely difficult to elicit within a driving simulator as participants are aware at all times that they are safe. Other studies have employed tactics such as a competition element so as to give the participant the idea that they are 'losing' something if they fail to drive safely (Jackson & Blackman, 1994).

Conclusions

More research is needed to investigate whether perceived risk of accident can provoke a change in behaviour within a simulator setting. Further participants are also needed to examine whether the heart rate effects found can be replicated when the tone is reversed. If this is the case, this independent effect of risk level on heart rate suggests a new finding that perceived risk may be a purely physiological phenomenon in the absence of any actual risk.

STUDY TWO POINT FIVE

Introduction

The previous experiment aimed to find whether a form of in-car technology could have a positive effect on driving behaviour. This technology gave participants an indication of what their chances were of being in an accident on specific roads, in real life. While this had no effect on participants' actual driving behaviour between conditions (speed, lane position, eye movements etc.), an effect was found suggesting the heart rates of participants varied depending on what risk level they were experiencing. More specifically, heart rates increased on the high risk roads where the risk tone was present. Interestingly, a trend was also present showing that heart rates tended to increase in high risk areas even when the tone was not present. It was hoped that a reduction in speed or other changes in driver behaviour would support the notion that this risk tone induced some arousal in participants and made them more cautious drivers. However, with an absence of actual driving behaviour to support this evidence, the question still remains of whether this change in heart rate was due to perceived risk or simply whether the high pitched noise forced a spike in heart rates. Therefore, the next logical step was to reverse the risk tones.

The new warning tone in study two point five will be a reverse of the current warning tone, with low risk areas receiving a high pitched noise and high risk areas receiving a low pitched noise. If the heart rate findings are true for this study, it is expected that the heart rates will increase in high risk

areas, though perhaps with a smaller effect as it is not instinctive to match a high risk area with a low pitched noise.

Although other limitations were discussed in relation to the previous experiment, no other variables will be changed so as to identify solely whether the heart rate effects are genuine.

Method

Design.

The method for this second experiment was identical to the previous, in that all participants drove the same simulated routes in the NITES 1 simulator while hearing a noise to signify their risk level.

Participants.

Twenty-four participants were recruited from the undergraduate population of the University of Nottingham with 14 females and 10 males (mean years of age = 22.08, SD = 3.22, range = 18-27). All participants held full licences (M = 3.88 years, SD = 3.22) and drove an average of 6175.83 miles per year. Four participants had been involved in an accident within the last two years.

Apparatus and measures

The risk tones for this experiment were reversed, meaning that the same high pitched tone now indicated low risk and the low pitched tone now indicated a high risk level. All crucial aspects of the last experiment were kept constant, including the heart rate monitor, experimental materials (information sheet, consent form, debrief) and the routes in the simulator.

Procedure

The experimental procedure remains consistent with the previous experiment with the addition of the reversed risk tones.

Reverse Risk Results

Results in this section will begin with the 24 participants who took part in the reverse tone experiment. Heart rate results from the first risk experiment will then be accumulated and presented.

Workload

In contrast to the previous experiment, all mean ratings for workload were higher in conditions where the risk tone was absent (See table 3.3.1). The differences in scores are very marginal and t tests for mental demand [t(23) = .06, p = .95], physical demand [t(23) = .03, p = .98], temporal demand [t(23) = -.085, p = .93], performance [t(23) = -1.40, p = .18], effort [t(23) = -1.61, p = .12] and frustration [t(23) = -.29, p = .78] confirmed that there are no significant differences between scores when the tone was on and off.

Table 3.3.1
Means (M) and standard deviations (SD) for NASA TLX measures.

Measure	Tone On		Tone Off	
	M	SD	M	SD
Mental	10.54	4.57	10.92	5.20
Effort	10.38	4.06	11.54	3.99
Frustration	7.21	4.10	7.75	4.28
Physical	5.45	2.87	5.79	3.84
Temporal	6.79	3.72	7	3.89
Performance	7.63	4.06	8.5	2.67

Heart Rate

Heart rate was once again measured continuously throughout the task and measurements were taken at the beginning and end of each road section. The location was once again included in the analysis so ensure that no

differences were down to location. Table 3.3.2 shows heart rates were higher in the high risk condition when the tone was present compared to lower risk conditions. A 2x3x2 ANOVA was conducted (Warning tone [On/Off] x Risk level [High/Medium/Low] x Location [Start/End]) and a main effect of risk level was found [$F(2, 42) = 5.82$, $p = .006$]. No main effect of location was found [$F(1, 21) = .014$, $p = .91$], indicating no differences between heart rates at the beginning and end of each road section and no main effects of the presence of the tone were found [$F(1, 21) = 1.82$, $p = .19$]. However, an interaction was found between the presence of the tone and risk level $F(2, 42) = 3.25$, $p = .049$.

Post Hoc

Post hoc tests using a Bonferroni correction revealed significant differences in heart rate between high and medium tone conditions ($p = .03$) with heart rate higher in the high risk condition and a significant difference between high and low risk conditions ($p = .09$), with heart rate higher once again in the high risk condition. Simple main effects analysis on the interaction between the presence of the tone and risk level found no differences in heart rate between tone on and off conditions for medium and low risk roads, but did find a difference in heart rates when the tone was on and off at the highest risk level ($p = .031$), as is shown in fig 3.3. Differences in heart rate were only found when the tone was present, between high and medium risk ($p < .001$) and high and low risk conditions ($p < .001$).

Table 3.3.2
Means (M) and standard deviations (SD) of heart rate.

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	69.16	2.66	67.29	3.05
Medium	66.38	2.65	66.27	3.14
Low	66.56	2.51	66.40	2.94

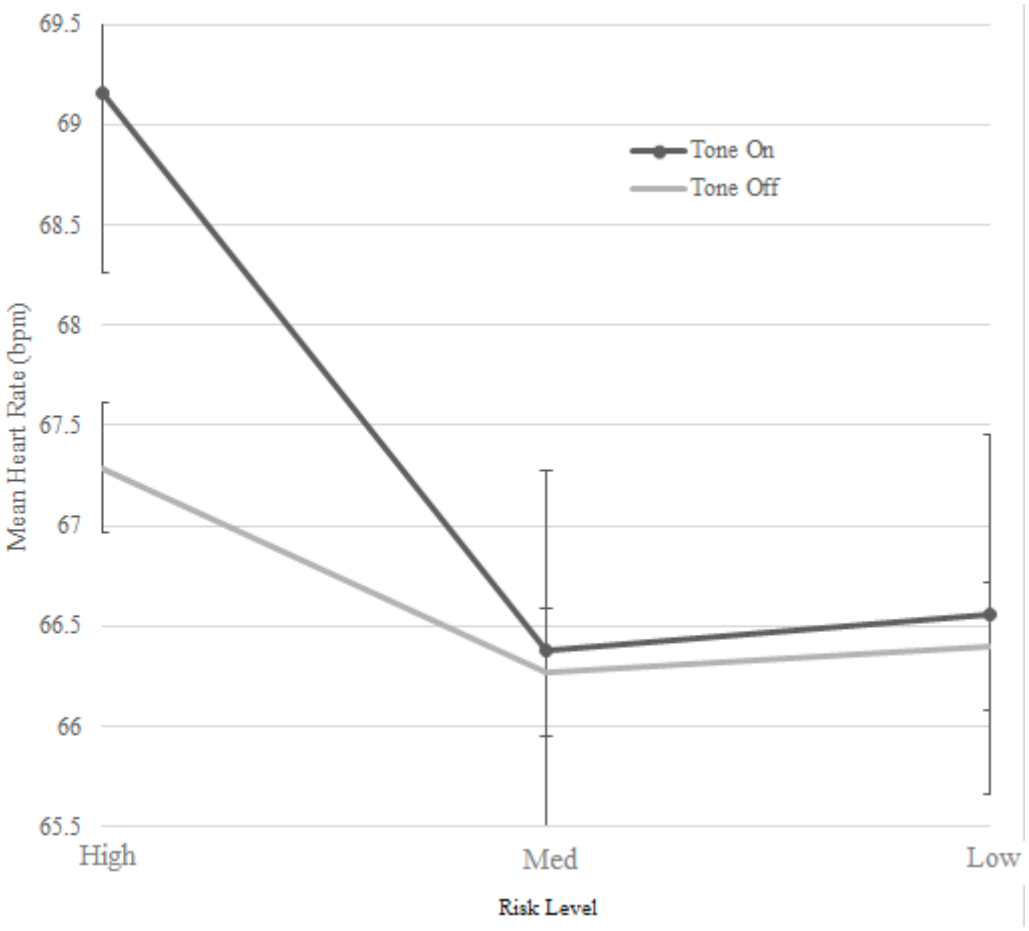


Figure 3.3. Mean heart rate for each section of high (1), medium (2) or low (3) risk when the tone was present and not present.

Speed

Mean values for speed (table 3.3.3) were very similar with the risk tone on and off and only differed between risk levels. A 2x3 ANOVA was

conducted (Warning [On/Off] x Risk [High/Medium/Low]) and a main effect of risk was found $F(2, 46) = 133.88$, $p<.001$. Post hoc tests with Bonferroni correction found differences in speed between high and medium conditions ($p<.001$) and high and low conditions ($p<.001$), with speed always being lower in the high risk condition. A difference was also found between medium and low risk conditions ($p = .003$) which was not present in the previous experiment.

Table 3.3.3
Means (M) and standard deviations (SD) of speed (mph).

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	24.04	6.19	25.63	4.07
Medium	38.91	4.59	38.69	5.49
Low	35.81	6.09	34.12	6.25

Eye movements

A problem with the eye tracking devices in the simulator meant that meaningful data could not be obtained for this experiment.

Heart Rate Accumulated

The aim of this second experiment was to clarify whether the heart rate results in the first experiment were due to perceived risk of accident, or whether they were due to the high pitched noise of the high risk tone. This reversed experiment, with tones reversed, has found that the high pitched tone was not the cause of the peak in heart rates in the high risk condition. Heart rate data can therefore be accumulated from both experiments (n = 46).

A 2x3x2 ANOVA was conducted (Warning tone [On/Off] x Risk level [High/Medium/Low] x Location [Start/End]) and a main effect of risk

level was found $F(2, 90) = 20.35$, $p<.001$. No main effect of location was found [$F(1, 45) = .15$, $p = .70$], indicating no differences between heart rates at the beginning and end of each road section. A main effect of the presence of the tone was found [$F(1, 45) = 8.94$, $p = .005$]. An interaction was also found between the presence of the tone and risk level $F(1.16, 75.58) = 4.77$, $p = .017$.

Post Hoc

Post hoc tests using a Bonferroni correction revealed significant differences in heart rate between high and medium tone conditions ($p< .001$) with heart rate higher in the high risk condition and a significant difference between high and low risk conditions ($p< .001$), with heart rate higher once again in the high risk condition. Simple main effects analysis on the interaction found there was a difference in heart rates between high and medium ($p <.001$) and high and low risk levels ($p <.001$) when the tone was present. This effect was present even when the tone was off between high and medium ($p = .004$) and high and low ($p = .006$) risk areas. Differences in heart rate were only found between tone on and off conditions at the highest risk level ($p = .001$).

Discussion

Summary of findings

Although all workload measures were higher when the risk tone was absent, no significant differences were found. Once again, main effects of risk level were found for speed, which serve to highlight the differences in speed limits between the road types. In terms of heart rate, a main effect of risk level was found, along with an interaction between the presence of the tone and risk level. Heart rates were significantly different between high and medium ton conditions and between high and low conditions, with high risk conditions showing higher heart rates. Differences in heart rate were only seen between tone on and off conditions in high risk conditions. Accumulated heart rate scores together from the previous experiment again found a main effect of risk level. In addition to this, a main effect of warning tone was found which was not present when analyses were done on the separate experiments. Cumulating these results once again found an interaction between the presence of the tone and risk level, with a larger effect.

The changes in heart rate were replicated in this second experiment despite the risk tone being reversed. The fact that heart rates were significantly different between high and medium and high and low risk areas even when the tone was off indicates that perhaps the road type naturally increased arousal in drivers. High risk roads were inner-city, winding roads with lots of junctions compared to low risk straight roads and so it would make sense for drivers to be naturally more aroused on these roads. There is a chance however that these effects (while the tone was not present) could be a hangover from participants who completed the tone on drive first. Regardless of this,

differences in heart rate were significant between tone on and off conditions for high risk roads, meaning that the risk tone was responsible for this change.

Neither this study, nor the previous one found any evidence for behavioural adaptation. These theories would suggest that a low risk tone may provoke participants into modifying their behaviour to maintain their preferred risk level. No such change in behaviour occurred. These data most likely support zero risk theory or task difficulty models in that the driving task did not become difficult enough or dangerous enough to force a change in behaviour.

Drivers in the previous experiment reported more failures in performance, more physical demand and more temporal demand when the tone was present. No significant differences were found for any workload measure in this experiment which is preferable when considering the device as a viable driver assistance system as 'annoying' systems can be detrimental to driver performance (Maltz & Shinar, 2004). Zero risk theory (Näätänen & Summala, 1974; Näätänen & Summala, 1976) suggests that drivers feel little or no risk during the driving task. Because of this, they may become complacent. A technological intervention such as this may raise drivers' threshold for risk by raising their awareness of potential road danger. However, according to behavioural adaptation theories, there is a danger that once drivers have become accustomed to driving through high risk areas with no ill effects, they may start to ignore the risk information. Or even that drivers may be more reckless in a low risk environment. No changes in behavioural data were detected in this experiment however.

The limitations of this experiment are largely the same as the previous experiment in that no hazards were presented to participants and so reaction times to these could not prove the effectiveness of a risk warning system. However, it was necessary to maintain the original set-up to ensure that heart data could be accumulated.

The fact that this experiment was able to influence participants' heart rate in a driving simulator is extremely positive, both for the manipulation of risk level and in terms of relating simulated driving to the real world. The influence of risk perception has increased arousal in drivers, and although not investigated here, has the potential to make drivers better equipped at dealing with hazards.

MUSIC PREFERENCE & MP3 PLAYER USE ON SIMULATED DRIVING PERFORMANCE

One aim of the PhD was to experimentally investigate the distracting effects of popular technologies on driving in safe and hazardous situations. Simulator studies were deemed the most appropriate method for this aim. Drivers are known to participate in a range of distracting behaviours while driving and the literature on the subject is well established (Stutts et al, 2005; Lee, 2008; Young & Lenne, 2010). For example, after analysing crash data from 1995-99, it was found that the most prevalent technological distraction was a CD/radio/cassette player, contributing to 11.4% of crashes (Stutts, 2001). A study by Horberry et al (2006) found the manipulation of a simulated vehicle's entertainment system to be more distracting, in terms of driver performance, than a hands-free mobile phone conversation.

MP3 players in particular, in recent years, have become a staple in many users' lives, offering a mood enhancing solitude to accompany their daily activities, often including driving (Bull, 2005). 18.8% of college students for example (n = 428) reported that they use their MP3 players while driving every day (Hoover & Krishnamurti, 2010). Vehicle manufacturers have implemented features within their cars to make the use of external MP3 players easier, with docking stations or at least a mini jack socket present in most new vehicles. Likewise, mobile phone manufacturers have integrated media playing software into their devices as well as increasing memory capacity; giving the user two devices for the price of one. It is for these

reasons why research must be conducted on how the use of these features may affect driver performance.

Driving Simulator Studies Using an MP3 Player

One might assume that MP3 players are a natural and safe progression from FM radios, which were first introduced to vehicles in the 1950's. Lee et al (2012) have demonstrated how the increased use of MP3 players in-car can be more dangerous than traditional radio use. This simulator study (n = 50) assessed the 21 negative effects of scrolling through playlists of varying lengths (short, medium & long) on an MP3 player or 'aftermarket controller', compared to tuning to a particular radio station. Searches through long playlists resulted in greater standard lane deviations and speed variability compared to other searches and tasks. Participants also glanced at the device more times and spent longer in these glances to complete the search tasks of all difficulties compared to the radio task. This time grew with each task difficulty. Results found no differences between the after-market controller and the MP3 player alone, suggesting the after-market devices do not offer a significant advantage over the MP3 player alone.

Research specific to Apple iPod use has found the negative effects on driving performance to be similar to those seen in drivers dialling a hand-held mobile phone (Salvucci et al, 2007). In a simulator study (Chisholm, Caird & Lockhart, 2008), drivers (n = 19) were required to avoid hazards in three conditions; a control drive, an easy iPod drive (performing easy actions on the iPod such as powering on and off) and a difficult iPod drive (performing difficult actions such as selecting specific songs). Response times to hazards

were greatest when performing difficult iPod actions compared to control and easy actions. However, response times were not significantly worse for iPod manipulations than the control drive when the hazard was an emerging pedestrian. More collisions were recorded in both iPod conditions. With practice, response times improved, although times remained significantly longer than the easy and control conditions and eye glances were significantly longer in-car with a difficult iPod task. The National Highway Traffic Safety Administration (NHTSA, 2012) recommends that all in car tasks should take no longer than 12 seconds to complete and that glances off road should be no more than an average of two seconds to be deemed safe. Despite the fact that mean glance durations in this experiment did not exceed 1.15 seconds (during the difficult iPod task), the task had an obvious and potentially dangerous effect on responses to hazards.

Two other studies have also adapted the MP3 interface to examine the effects of presentation on driver performance. Firstly, Garay-Vega et al (2010) investigated the effects of MP3 player use on driver performance, comparing a manual MP3 set up (single iPod) to two other voice activated controls with wheel-mounted remotes. The participants recruited (n=17) were required to have owned an iPod for at least a month and use the device at least twice per week. Participants performed three iPod related tasks; finding any song by a particular artist, finding any song in a particular album and finding a specific song. The iPod was situated in a dashboard holder, however, participants were permitted to handle the device during tasks if they wished. The aftermarket controller used required some manual input as well as voice commands, however, the manual interface operated much like an iPod. The final voice

controller did not require the participant to remember particular commands and instead worked by requesting music similar to a voice activated search engine. Participants drove two routes for each condition including control drives, with scenarios split between urban and suburban. For each successful song choice, participants were given 10 seconds to listen to the song as a reward. Participants were given two minutes to complete the song choice before moving onto the next. Results found a main effect of interface on the time taken to complete the task with the voice activation only system being the quickest, followed by the iPod alone, however, glance durations at the interface were longer for the iPod alone. This was found to be significant from voice only interface but not for the manual and voice controller. No significant effects were found for hazard anticipation or lane deviations. These results are supported by Shutko et al (2009) who found the integrated voice interface of a vehicle (Ford SYNC) to minimise the distraction effects of performing the same actions on a hand-held device.

In another presentation manipulation study, Mistopolos-Rubens et al (2010) examined three different music interfaces in relation to driver performance. Interfaces were either presented in a linear list, a 'fish eye' design where items increase in size the closer they are to the one selected and a 'cover wheel' design where album covers are arranged alphabetically around a turntable. Participants (n=30) were required to choose specific songs or albums (after having voice instructions) whilst performing the lane change task on a low fidelity simulator. A cognitive task (number addition) was also introduced to compare workload. No differences in lane deviation were seen between control drives and the cognitive task condition, however, mean

deviations increased for all music related tasks and similar results were seen for NASA workload measures.

Two further experiments have found MP3 player use to be detrimental to driving, even in very basic simulator studies. Harvey and Carden (2009) recruited 32 drivers, 14 of whom owned an Apple iPod to take part in a low fidelity simulator experiment. Using a popular driving game (Need for Speed V) with a steering wheel set-up, participants were required to drive while selecting songs from various albums on an iPod Nano. Participants also drove in another counterbalanced drive, listening to music but with no iPod interaction. Authors were concerned with anxiety rates and so measures were taken before and after drives. Drives were coded in terms of error severity; with more severe errors gaining more points. Participants' error scores and anxiety scores were significantly higher in the iPod interaction condition.

In addition, Young et al (2012) recruited drivers (n = 37) to perform a simulated task on a PC system whilst selecting music on an Apple iPod Touch. Four song search tasks were used, two which were short, where songs were easier to find and two which were harder. One short and one long task were interrupted and participants were required to begin the task again. Driver performance suffered as a result of iPod tasks in terms of standard deviation of lane position, lane excursions and car following. Participants also spent a significant amount of time looking away from the road while completing iPod tasks. Although the simulators used here are of low fidelity, these experiments show that the difficulty in using an iPod (scrolling through albums to find specific songs) can potentially be very dangerous if a person behaved in the same manner on a real road.

MP3 player use has been compared to text messaging as both usually require manual control of a device. Crisler et al (2008) investigated the effects Apple iPod use, along with conversational tasks, text messaging and word games. Results found lane keeping to be compromised in manual tasks (text messaging and iPod manipulation) and all tasks were found to elicit significant changes in speed variation. Similarly, Mouloua et al (2012) found driving errors increased in a further study on text messaging and iPod use (Mouloua et al, 2012). In their previous study (without text messaging), Mouloua et al (2011) used a song searching task in a simulator experiment. Participants (n=30) were to choose songs, artists and albums from an iPod while driving in a simulator. This was compared to two drives; pre iPod and post iPod. No further information given on how songs were chosen or how many. iPod use showed a significant effect on theta activity which the authors believe is evidence of inattention. More lane deviations were also reported in the iPod drive compared to control drives.

General road safety has also investigated how MP3 player use can affect pedestrians. Neider et al (2010) aimed to show the distracting effects of mobile phone and iPod use on pedestrians crossing. Participants (n = 36) were required to walk through a simulated route (on a treadmill) and cross a virtual road while conversing with the experimenter (using standardised questions) or while listening to an iPod. Listening to an iPod did not have any effect on successful road-crossing, while conversing on a mobile phone did significantly reduce successful road-crossing. This shows the level of distraction that a device such as an MP3 player can have on a person who is not operating a complex vehicle.

Music and driving

In addition to the manual task of MP3 use, driving performance will also be analysed in terms of whether the music is pleasant or unpleasant to the participant. Music has become a source of background entertainment for many everyday activities from household chores to enjoying a meal (North, Hargreaves & Hargreaves, 2004) and music is something which has been fully integrated into the driving experience (North & Hargreaves, 1999). The possible effects of music on task performance have been discussed in terms of added cognitive load and a reduction in attentional resources available (Konecni, 1982). Spinney (1997) found driving reaction times to hazards to be decreased when listening to music. However, the presence of music while driving has its advantages; the arousal due to music helps to avoid fatigue (Dibben & Williamson, 2007) driver stress and road rage (Wiesenthal, Hennessy & Totten, 2003). Driving reaction times to hazards have even decreased when listening to music (Spinney, 1997). In a review of the effects of music on task performance, authors could not conclude either way whether music while driving was a positive thing. Authors found both positive and negative effects which result in some drivers being calmer and others performing more poorly at driving tasks (Dalton & Behm, 2007).

Personally rated pleasant music has been found to increase arousal (heart rate) and have a positive effect on driving performance in a simulator (Ünal, de Waard, Epstude & Steg, 2013). This arousal is assumed to be responsible for the increased concentration on the driving task. In terms of unpleasant music, Cassidy and McDonald (2010) found participants performed

worse on a driving game when listening to experimenter selected music, citing a distracting effect of unfamiliar or less liked music. Authors even recommend pleasant music to increase task performance (Cassidy & Mc Donald, 2009; North & Hargreaves, 1999).

The influence of music alone is suggested to be less distracting when driving demands are low as there is less of a struggle between the task of listening to music and the act of driving for attentional space (van der Zwaag et al, 2012). In a recent study, researchers requested that participants rate a range of songs for valence and energy in order to select eighteen songs per participant (9 positively rated songs, 9 negatively rated songs). Three songs of each valence were used for an induction, three for a high demand drive and three for a low demand drive in a driving simulator (van der Zwaag et al, 2012). Results found that either type of music increased energy ratings, while the presence of music had no effect on lane positions. Music did not increase self-reported effort, but had a marginal effect on speed in that participants drove faster when no music was present. However, authors suggest the music used in this experiment was not of a high enough intensity to result in degraded driving performance.

Tempo is important to control as faster paced music can affect how a person drives (Konz & McDougal, 1968). Brodsky (2001) gave participants a driving task on a PC based simulator with attached steering wheel and pedals. Faster tempo music was related to increased speeding as well as more traffic violations such as lane violations, collision and disregard for red lights prompting researchers to appeal for greater awareness and education about the effects of music while driving.

The volume of music has also been found to negatively affect performance on tasks. Ayres and Hughes (1986) found loud music (107db) negatively affected the performance of participants on a visual acuity task. Interestingly, this effect was not seen with just loud noises. Turner, Fernandez and Nelson (1996) created a driving hazard task (via computer) where participants were to brake at unexpected red lights. When listening to music around their personal comfort levels (70db) participants were faster to respond to red lights than they were at 60 or 80db. Therefore researchers suggest that music at a comfortable volume may improve driving performance. Many of us will have noticed that it becomes easier to concentrate on the road when the volume of music is turned down. North and Hargreaves (1997) confirmed this, finding that drivers tend to lower music volume in heavy traffic.

The literature seems to suggest that familiar music can improve attendance to the driving task, while loud music can impair driving performance. For the purpose of this experiment music is a way of provoking participants into interacting with an MP3 player, without explicitly asking them to, in order to observe 'natural' engagement with the device in the security of the laboratory.

The MP3 studies in this thesis will exploit the music playing ability of an Apple iPhone 5s. This device was chosen to mimic how a proportion of the population currently listens to music in-car, i.e. by way of mobile phone. A similar paradigm to the Chisholm, Caird and Lockhart (2008) study was adopted, with an easy and difficult task. The aims of this experiment are to successfully design a 'natural' setting in which participants are not forced to interact with a device, to discover how driver performance is affected by

technology engagement and to determine whether pleasant/unpleasant music can affect driver performance. It is predicted that:

- Lane deviations will be significantly higher for difficult MP3 tasks as well as easy tasks compared to a control condition.
- Eye movements will show more time spent looking away from the road.
- Speed will reduce when engaging with the device as a compensatory behaviour.

STUDY THREE

Method

Participants

Seventeen participants were recruited from the student population at the University of Nottingham. Participants were 10 females and 7 males (mean age = 23.9 SD = 6.28). Participants all held full UK driving licences, barring one female driver who did not yet have a full licence but was due to complete her test. Drivers had an average of 3.8 years driving experience, driving an average of 2714 miles per year. No participants had been involved in an accident in the past two years. All participants were given monetary compensation for their time. Participants were informed about the risk of simulator sickness prior to consent and were advised not to drive for thirty minutes post-experiment.

Design

The study was a within subjects design with all participants taking part in five conditions; a control drive (no music), pleasant drive (personally rated pleasant music), unpleasant drive (personally rated unpleasant music), an 'easy skip' and a 'hard skip' drive (both with alternating pleasant and unpleasant songs). Conditions were pseudo-counterbalanced, with participants always completing the easy drive before the hard drive. This was to ensure that the participant had enough interaction with the easy portion of the task so that the hard task was not too difficult to complete. Bespoke playlists were made for each participant and drivers were permitted to skip songs they found unpleasant in the easy/hard skip conditions if they wished. However, drivers

were not able to skip any tracks in the pleasant or unpleasant drives. The easy skip drive involved one press of the touch screen to skip a song while the difficult skip required a number of actions including unlocking the keypad. The unpleasant songs in these conditions served to provoke a 'natural' skipping response from participants. Instead of instructing participants to skip at certain intervals, this created a situation whereby participants could judge for themselves whether they felt confident and safe enough to skip, hopefully mimicking actual on road behaviour as closely as possible. Participants were measured on a variety of variables including speed, lane position and eye tracking data. Raw eye tracking data measured scanning behaviour on the x and y axis and mean fixation durations. Video coding data was then used to measure glance durations off road.

Apparatus

Simulator.

The study was conducted in the Nottingham Integrated Transport and Environment Simulation facility (NITES) at the University of Nottingham using NITES 1. This is a high fidelity simulator with a six degrees of freedom motion platform. Mounted on the motion platform is a projection dome which contains a full BMW Mini. Eye movements were recorded using two seeing machines, eye trackers running FaceLab 5 and linked to provide 120 degrees of eye tracking. The motion base was not used for this experiment.

MP3 player.

An Apple iPhone 5s was used as the MP3 player in this experiment for two reasons. The first being that the majority of smartphones available have integrated MP3 players which many people choose to use over a dedicated MP3 player. The second reason being that the user interface of the iPhone was such that it allowed manipulation of the difficulty in song selection. Participants were not screened in terms of the brand of their personal mobile phone. However, participants were given practice time with the iPhone and were supervised in doing so. No participant showed any difficulty in operating the device.

Music and skipping tasks.

To include the favourite songs of all participants would have been an impossible task. Therefore, compilation albums were obtained from 6 genres of music (pop, indie, metal, dance, RnB & 80's). This ensured an objective selection of music (376 songs in total) from genres that were likely to be relevant to most participants. Each compilation album included at least twenty songs. Four personal playlists were created for each participant; one with top rated music (pleasant), one with least rated music (unpleasant) and two mixed playlists for the easy and hard skip conditions. All songs were set to one minute in length to ensure at least 5 songs were played in each drive. Playlists for the easy and hard skip tasks always began with a pleasant song and alternated with unpleasant songs (as rated by the participant). Participants were made aware that they were permitted to skip unpleasant songs at any time during the skipping conditions, but not to skip pleasant songs.

Test route.

A three lane motorway simulation with low traffic was used for all experimental drives. Participants' five minutes driving time began when they had joined the motorway from a slip road and reached the first gantry overhead. No artificial hazards were introduced and participants were advised to follow normal motorway rules of speed keeping and lane changing. This route was identical for all conditions. Participants were stopped after 5 minutes of driving for each of the five drives.

Simulator sickness questionnaire (SSQ).

Participants were given the simulator sickness questionnaire explained in previous experiments. Symptoms were measured prior to the experiment to gauge a baseline and after each subsequent drive. Participants were advised to stop the experiment if these symptoms worsened.

Workload.

Workload was measured using the NASA-TLX paper version. This measure estimates workload split into six components; mental demand, physical demand, temporal demand, own performance, effort and frustration. Six subscales are used to measure each of these facets of workload.

Procedure

After giving informed consent, participants completed a brief questionnaire on driving history. This gained information such as the number

of years driving, miles driven per year, accident information etc. A simulator sickness questionnaire was also completed at this point to measure baseline symptoms. Anyone reporting higher symptoms after subsequent drives was asked not to complete the study. Participants were then given a list of 6 genres of music, presented on a spreadsheet. This equated to 376 songs which participants were asked to quickly browse and rate the songs that they were familiar with on a scale of one to ten with one being 'extremely dislike' and ten being 'extremely like'. It was expected that participants were familiar with enough of the songs that this process was fairly swift. These rated songs were then used to create playlists for each of the drives with equal numbers of equally rated songs where possible. If an insufficient number of songs were rated, the participant was then asked to listen to unfamiliar tracks and rate them until playlists were filled. This situation arose once, when the participant failed to recognise artists' names but could recognise their songs when played. Participants were encouraged to listen to these songs via the iPhone. At this point, participants were asked to acquaint themselves with the iPhone and become familiar with the tasks they were required to perform. Four playlists were then made; one with high rated songs, one with low rated songs and a third and fourth with a mixture of high and low rated songs. The lowest rated songs are included to give an incentive to the participant to skip a song they have a lower preference for. No song was used twice.

Participants then drove a five minute practice drive to become accustomed with the simulator and then completed a second simulator sickness questionnaire. Physiological sensors were then fitted and eye trackers were then calibrated. Participants next drove in five experimental conditions which

were counterbalanced. The first involved an 'easy skip' where the participant need only perform one action to skip a song. The second condition involved a 'difficult skip', requiring the participant to unlock the iPhone and to enter a passcode in order to skip a song. This passcode was set to '1234' firstly to ensure that the task was not overly difficult and secondly, so that it could be easily remembered so as not to increase cognitive demand. Participants were made aware that they are able to skip any unpleasant song, but were not obliged to do so. Participants were asked not to skip pleasant songs as the playlists had a finite length. In addition to these interaction conditions, participants also completed a control drive with no music or manual task, a pleasant drive in which the participant drove with their highly rated pleasurable songs and an unpleasant drive in which the participant drove with their lowest rated unpleasant songs. Participants were not permitted to skip songs in these conditions. Simulator sickness questionnaires were also completed after each drive. Participants were then debriefed and asked not to drive a real car for at least 30 minutes.

Results

Workload

Higher scores on workload measures indicate higher workload and an increase in mental and physical effort. In the case of 'performance', greater scores indicate larger feelings of failure. Table 4.1 shows the mean values for each condition.

ANOVA's with repeated measures were used to analyse workload data for each music type (control, pleasant, unpleasant, easy skip and hard skip). No effects were found between groups for mental demand [$F(2.18, 28.31) = 2.05$, $p = .14$], physical demand [$F(4,52) = .49$, $p = .74$], temporal demand [$F(4,44) = 1.37$, $p = .26$], performance [$F(2.18, 30.52) = .1.06$, $p = .36$] and effort [$F(2.43, 33.95) = 2.03$, $p = .14$]. However, music condition did have an effect on frustration scores [$F(4, 52) = 4.07$, $p = .006$]. Post hoc tests using a Bonferroni correction found frustration scores to be borderline significantly higher in the unpleasant condition compared to the control drive ($p = .051$).

Number of skips

The number of skips was recorded in both the easy skip and hard skip conditions. As expected, participants skipped less in the hard skip condition, with a mean of 1.53 skips (SD = 1.23) compared to a mean of 2.18 skips in the easy condition (SD = 2.07). A repeated measures t test found no difference in the number of skips between groups [$t(16) = 1.54$, $p = .14$].

Table 4.1
Means (M) and standard deviations (SD) for NASA TLX measures (n = 16).

Measure	Control		Pleasant		Unpleasant		Easy Skip		Hard Skip	
	M	SD	M	SD	M	SD	M	SD	M	SD
Mental Demand	6.81	5.84	7.94	5.92	9.44	5.10	9.19	4.97	10.25	5.13
Physical Demand	4.25	3.59	4.38	3.59	4.69	3.77	5.19	4.07	6.13	4.47
Temporal Demand	3.5	2.90	4.56	4.03	5.75	3.38	5.44	4.26	6.19	4.92
Performance	8.75	6.32	7.94	4.64	8.94	5.94	9	4.95	9.63	4.72
Effort	7.5	5.63	8	5.85	9.19	5.01	8.63	5.26	10.19	4.78
Frustration	3.56	4.13	4.19	3.75	7.88	4.27	5.69	5.04	6.25	5.09

Song Ratings

In order to ensure that participants were listening to songs that they actually liked and disliked, their personal ratings for their playlists were analysed. Participants gave their 'pleasant' songs a mean rating of 8.74 [SD = 0.99] (out of 10) and their 'unpleasant' songs a mean rating of 1.54 [0.69] (out of 10). A t test found there was a significant difference in song ratings between the two groups [$t(196) = 85.28$, $p<.001$].

Song Tempo

It is important to consider the types of songs that people enjoy. Some may find slow songs unpleasant and fast songs uplifting. These may have their own effects on participants' driving and so the tempo of each song was analysed and compared. The mean tempo for songs rated as 'pleasant' was 124.05bpm (SD = 19.21), very similar to songs rated as unpleasant, with a mean of 123.92bpm (SD = 17.56). A t test confirmed there was no difference

in tempo between pleasant and unpleasant rated songs [t(214) = .084, *p* = .933].

Driving Measures

All three speed variables (mean speed, maximum speed and percentage of time spent over the speed limit) were consistent across conditions (see table 4.2), showing no notable differences.

Table 4.2
Means (M) and standard deviations (SD) across conditions for mean speed (mph), maximum speed (mph), percentage of time spent over the speed limit (%), standard deviation of lane position and mean fixation durations (ms).

Measure	Control		Pleasant		Unpleasant		Easy Skip		Hard Skip	
	M	SD	M	SD	M	SD	M	SD	M	SD
Mean Speed	69.50	4.56	68.44	3.67	68.29	4.05	68.51	2.83	68.95	3.08
Maximum Speed	76.97	7.72	78.54	7.79	77.65	5.83	76.94	4.59	77.70	5.65
% of time over speed limit	46.37	37.12	37.00	30.76	39.41	32.75	37.71	27.78	40.60	30.04
SDLP	1.05	0.13	1.06	0.12	1.09	0.19	1.08	0.15	1.05	0.10
Mean Fixation Duration	924.79	329.94	840.10	374.09	757.09	199.70	879.73	490.63	761.33	275.34

Lane position was again consistent, with perhaps a small increase in the unpleasant and easy skip conditions. Further analysis confirmed no differences for mean speed [$F(1.63, 24.49) = .41$, $p = .63$], maximum speed [$F(1,78, 26.74) = .39$, $p = .66$], percentage of time spent over speed limit [$F(1.63, 24.38) = .26$, $p = .73$] and standard deviation of lane position [$F(4, 60) = .18$, $p = .95$], Fixation durations were shorter in unpleasant and hard skip

conditions. A repeated measures ANOVA showed an overall effect of road type on fixation durations [$F(4, 60) = 3.19$, $p = .019$]. Post hoc tests with a Bonferroni correction showed no differences between the groups, however, the Least Significant Difference test showed a difference in mean fixation durations between the control and unpleasant condition ($p = .030$) and the control and hard condition ($p = .013$).

Video Coding

While running the experiment, it was clear that participants were running into difficulty when interacting with the iPhone. Participants would swerve across lanes, have to brake suddenly or consciously or unconsciously slow down to compensate. It is for these reasons why the in-simulator video footage was coded by an independent researcher who was not aware of the results discussed. Criteria were agreed between three experimenters. Video coding began at the first glance to the iPhone (during a successful skip) and ended when the participant had skipped successfully (signalled by the change in music). These sections were coded every time a participant skipped in the easy and hard skip conditions. The video included eye tracking information which was shown via a circle which showed where the participant was looking. The same point in time in the control condition was also coded, for the same duration, to investigate whether the driver performed more poorly whilst skipping. Not all participants chose to skip and so numbers for comparison are small. The driving simulator facilities allow for the video to include the car gauges and dials so that speed could be taken accurately in respect to what the participant was doing.

Duration.

The duration of each skip was the seconds between the first attempt and the skip. The first attempt here is the point at which the participant touches the iPhone. Skip duration is the amount of time taken for a participant to skip. These are compared between easy and hard conditions for each participant (providing they skipped at least once in both conditions). When participants skip more than once, these have been averaged to provide an average score of skipping for each participant. Not every participant skipped and so data for only 11 participants are compared. Duration of skips was much higher, as expected, in the hard skip condition (M = 10.87sec, SD = 5.55) compared to the easy skip condition (M = 4.23sec, SD = 5.67). Data were transformed using LOG10 as they were not normal. A repeated measures t test found a significant difference in skip duration between groups [t(10) = -5.03, p = .001].

Glances.

The glance duration was the amount of seconds the participant spent looking away from the road. The glance total was the sum of these glances. Also observed was the duration of glances not to the iPhone.

Easy skip.

Glance total in the easy skip condition was higher (M = 2.87sec, SD = 2.73) than in the control drive (M = 1.53sec, SD = 3.18). A repeated measures t test found this difference to be significant [t(11) = 5.70, $p < .001$].

Hard skip.

Glance total was again higher in the hard skip condition (M = 6.18sec, SD = 3.00) than the control condition (M = 3.00sec, SD = 2.70). A repeated measures t test found this difference to be significant [t(11) = 4.097, p = .002].

Easy vs hard skip.

Means differed slightly from the previous statistics as not all participants skipped in both conditions. Nevertheless, glance totals were still much higher in the hard skip condition (M = 6.33sec, SD = 3.11) than the easy skip condition (M = 3.02sec, SD = 2.96). A repeated measures t test confirmed this difference was significant [t(10) = -4.74, p = .001].

Lane Data.

Lane deviation was measured by holding a ruler up to the video screen. This then measured the maximum, minimum and deviation of lane position during the skip. The deviation of lane position was averaged across skips and compared with control data.

Easy skip.

An apparent large difference was seen between average deviation of lane position values, with the skip condition showing a larger deviation (M = 6.19, SD = 9.15) than the control drive (M = 2.59, SD = 2.34). A repeated measures t test did not find this difference significant [t(12) = .73, p = .48].

Hard skip.

There was a smaller difference in mean deviation for the hard skip condition, with the skip drive showing slightly higher deviation in lane position (M = 6.95, SD = 5.30) than the same point in the control drive (M =

5.07, SD = 1.91). A repeated measures t test did not find this difference significant [t(11) = .93, p = .37].

Easy vs hard.

Only a small difference was seen in easy versus hard skip lane deviation, with hard skips once again having slightly higher deviation (M = 7.07, SD = 5.55) than easy skips (M = 6.84, SD = 9.86). A repeated measures t test did not find this difference significant [t(10) = -.08, p = .94].

Speed data.

Speed was recorded throughout the skipping period, allowing for measures such as minimum speed, maximum speed, speed at the start of skipping, speed at the end of skipping and the ranges between these.

Speed across time.

Only very small differences in speed were seen between skip levels before and after skips. Only small differences in speed were seen. Repeated measures t tests found no differences in speed before and after easy skips [t(12) = .797, *p* = .44] and no differences in speed before and after hard skips [t(11) = -1.34, *p* = .21].

Speed deviation.

Easy vs easy controls.

Speed during easy skips varied by around 3.93mph (SD = 4.36), twice as much as speed deviation during easy controls at 2.00mph (SD = .99). A repeated measures t test did not find this difference in speed variation to be significant [t(11) = 1.75, p = .11].

Hard vs hard controls.

Speed deviation for hard skips was higher (M = 6.95mph, SD = 5.30) than speed deviation for hard controls (M = 5.07mph, SD = 1.91). A repeated measures t test did not find this difference in speed variation to be significant [t(11) = 1.58, *p* = .14].

Easy vs hard.

The maximum and minimum speeds were used to calculate speed deviation. Speed during easy skips varied by around 2.16mph (SD = 1.74), much less than speed deviation during hard skips at 5.14mph (SD = 3.51). A repeated measures t test found the difference in speed variation to be significant [t(10) = -3.28, p = .008].

Discussion

Summary of findings

In contrast to previous studies, the use of the MP3 player had only minimal effects on driver performance. Regarding simulator driving measures, no differences were found between conditions for speed variables or standard deviation of lane position. However, an effect was discovered for fixation durations which found fixation durations to be shorter in the unpleasant condition compared to the control drive and shorter fixation durations in the hard condition compared to the control drive.

No differences in subjective measures of workload were found between groups for mental demand, physical demand, temporal demand, performance or effort. Frustration scores were affected by condition however, with frustration scores significantly higher in the unpleasant music condition compared to the control drive. No differences were found in the number of skips between easy and hard skip conditions, although it was reassuring that participants did skip less (in terms of mean numbers) in the hard music condition which indicates that the hard skip was harder to perform. It was also reassuring in terms of experimental design that the song ratings for pleasant and unpleasant music were rated significantly different from each other, but also that the tempos of these songs were not significantly different from one another.

Measures taken from the video coding found the duration of skips to be significantly longer in the hard skip condition, confirming that the hard skip task was actually harder to perform than the easy task. Glance durations found

participants to spend significantly more time looking away from the road for easy skips compared to controls, hard skips compared to controls and for hard skips compared to easy skips. No differences in lane deviation were found between any combination of skips or controls and speed before and after skips showed no differences. Similarly, speed deviation was not significantly different between easy skips and controls or hard skips and controls. However, a difference was found between easy skips and hard skips.

The experimental design used in this experiment was most similar to Chisholm, Caird and Lockhart's (2008) study which investigated the effects of iPod use on reactions to simulated hazards. While this study cannot compare response times, eye movement data were similar to the current experiment in that glances in-vehicle were significantly longer in the difficult iPod task which were echoed in our video coding results.

No differences were found in driving performance between the pleasant and unpleasant music conditions. Pleasant music in particular is said to increase task performance (Ünal, de Waard, Epstude & Steg, 2013; Cassidy & Mc Donald, 2009; North & Hargreaves, 1999) while unpleasant music has been linked to worse performance (Cassidy & McDonald, 2010). This study was unable to detect any differences, possibly as 'task performance' in this study was a basic driving task on a fairly straight motorway and so a more complex driving task could have highlighted any possible differences. However, the driving task in this study needed to be at a manageable level as music skipping was optional. If the driving task was more difficult, participants may feel they are unable to interact with the device safely and so choose not to. This would be a failure of the natural experiment as the aim is

to measure what happens when participants perform this secondary task without them being prompted to.

Although no performance differences were found between pleasant and unpleasant music, the unpleasant music condition was found to have significantly shorter fixation durations and higher scores on frustration than the control condition. Longer fixation durations are generally attributed to increased workload (Chapman & Underwood, 1998; Velichkovsky et al, 2002), although in this case, it is more likely that boredom was the cause of these longer fixation durations. Despite previous research showing visual tunnelling effects when using secondary devices (Reyes & Lee, 2008) this study did not find any differences between conditions. In addition, the frustration scores at the very least show that participants were listening to music that they did not like and that this was successful in provoking skipping behaviour.

The first limitation of the experiment was obviously the small sample size. This was less of a problem when comparing over five conditions, however, analysing the video coding data reduces the sample even further as not all participants interacted with the device, and of those that did, not all of them interacted with the device in both easy and hard conditions. A further limitation of the study was that there was very little variability in the driving task. Although participants were driving on a simulated motorway, this was largely empty and so there was little opportunity to overtake other vehicles. The speed limit was also consistent at 70mph and so initial simulator measures could not detect any changes. These are issues that will be addressed in the following experiment.

Conclusions

The experimental design of the iPhone skipping task was a success in this first experiment for two reasons. Firstly, participants were able to recognise enough of the music available to them in order to rate songs as both very pleasant and very unpleasant, meaning the song list provided was comprehensive enough. Secondly, participants spontaneously engaged with the device and showed that the easy and hard skip tasks were distinct in terms of difficulty. This validates the use of this paradigm and justifies further experimentation. Therefore, the next experiment will expand by introducing a larger number of participants.

STUDY FOUR INTRODUCTION

The previous study was successful in creating an experiment which allowed participants to interact with the device at their leisure, making the driving task feel as natural as possible. Despite there being differences in speed deviations from the video coding data, simulator data did not show any differences across conditions. Differences were only noticeable upon closer inspection of the video data as the accelerations and fluctuations in speed only occurred when a participant was skipping. These differences were therefore not apparent in the average speed from the whole condition as the rest of the drive was fairly uneventful and participants were able to maintain their speed with no complications i.e. overtaking, sudden braking.

The solution to this was to increase variance in the data by introducing a temporary speed limit around a third of the distance into the drive. As a result, it is hoped that the differences seen in video coding data will be apparent in the simulator data.

Method

Design

The method for this experiment was identical to the previous, in that all participants drove the same simulated routes in the NITES 1 simulator with the same five conditions involving music. However, a 'hazard' warning was given on the motorway gantry with 40mph signs requiring the driver to slow to this speed for around two minutes of driving until national speed limit signs appeared once again on the motorway gantry. This change in speed was designed to produce more variability in the data and perhaps signify whether participants were attentive enough to spot the change in speed.

Participants

24 participants were recruited from the staff and student population at the University of Nottingham. Poster adverts were placed across the university inviting drivers to take part. Participants were 15 females and 9 males (mean years of age = 20.92, SD = 1.20). The majority of participants held full UK driving licences, however, some drivers were included who held foreign licences, but who had driven on UK roads. Drivers had an average of 2.58 years driving experience (SD = 2.02) driving an average of 710.41 miles per year. One participant had been involved in an accident in the past two years but was not at fault. All participants were given monetary compensation for their time. Participants were informed about the risk of simulator sickness

prior to consent and were advised not to drive for thirty minutes post-experiment.

Apparatus and measures

All crucial aspects of the last experiment were kept constant, including the heart rate monitor, experimental materials (information sheet, consent form, debrief) and the routes in the simulator. The single difference in this experiment is the addition of the gantry messages with the speed change.

Procedure

The procedure for this experiment was identical to the previous in that all participants completed the same five conditions of the control drive, easy skip, hard skip, pleasant and unpleasant music conditions. Participants again rated music and playlists were created based on their tastes. Drivers were not informed that there would be any speed change during the drive.

Results

Workload

Average scores of workload (see table 4.3) showed some differences. Self-rated scores for mental demand were lower in the pleasant drive condition (6.17) and highest in the unpleasant (8.54), easy skip (8.04) and hard skip (8.29) conditions. Physical demand and performance scores were fairly consistent across conditions. Temporal demand scores were highest in the hard skip (6.42) and unpleasant (6.17) conditions compared to control (4.54), pleasant (3.58) and easy skip (4.67) conditions, suggesting participants felt more rushed during the hard skip and unpleasant music drives. Scores for effort dropped in the pleasant condition, where frustration scores were also lowest.

ANOVA's with repeated measures were used to analyse workload data for each drive type (control, pleasant, unpleasant, easy skip and hard skip). No effects were found for mental demand [$F(2.99, 68.94) = 2.094$, $p = .11$], physical demand [$F(2, 92) = 1.14$, $p = .34$], performance [$F(2.74, 63.02) = .60$, $p = .60$] and effort [$F(2.52, 57.85) = 1.95$, $p = .14$].

However, road type did have an effect on temporal demand scores [$F(4, 92) = 7.02$, $p < .001$]. Post hoc tests using a Bonferroni correction found temporal demand scores to be significantly higher in the unpleasant condition compared to the pleasant drive ($p = .007$) and significantly higher in the hard skip condition compared to the pleasant drive ($p = .003$). Frustration scores were also found to differ significantly between conditions [$F(4, 92) = 4.85$, $p = .001$]. Post hoc tests using a Bonferroni correction found frustration scores to

be significantly higher in the unpleasant condition compared to the pleasant drive (p = .008) and borderline significantly higher in the unpleasant condition compared to the control drive (p = .054).

Table 4.3
Means (M) and standard deviations (SD) for NASA TLX measures (n = 24).

Measure	Control		Pleasant		Unpleasant		Easy Skip		Hard Skip	
	M	SD	M	SD	M	SD	M	SD	M	SD
Mental Demand	7.46	4.88	6.17	4.71	8.54	4.96	8.04	4.93	8.29	5.00
Physical Demand	4.67	3.71	4.17	3.46	5.42	4.00	5.25	3.81	5.5	3.35
Temporal Demand	4.54	3.51	3.58	2.88	6.17	4.56	4.67	3.87	6.42	4.50
Performance	7.04	5.41	6	3.72	6.46	4.32	7	4.33	7.13	3.62
Effort	8.29	5.07	6.67	5.29	9	4.33	8.17	4.49	9.08	4.34
Frustration	4.75	3.72	3.92	3.51	7.5	4.73	5.25	4.05	6.71	4.43

Number of Skips

Participants in the easy condition skipped an average of 2.67 times (SD = 2.06) compared to the hard skip condition in which participants skipped an average of 3.08 times (SD = 1.64). A paired samples t test found no significant difference in these values [t(23) = -1.16, p = .26].

Song Ratings

In order to ensure that participants were listening to songs that they actually liked and disliked, their personal ratings for their playlists were analysed. Participants gave their 'pleasant' songs a mean rating of 9.03 [SD = 0.89] (out of 10) and their 'unpleasant' songs a mean rating of 1.72 [0.79] (out

of 10). A t test found there was a significant difference in song ratings between pleasant and unpleasant songs [t(235) = 89.68, p<.001].

Song Tempo

The mean tempo for songs rated as 'pleasant' was 121.63bpm (SD = 22.33), very similar to songs rated as unpleasant, with a mean of 122.20bpm (SD = 21.74). A t test confirmed there was no difference in tempo between pleasant and unpleasant rated songs [t(135) = -.24, *p* = .81].

Driving Measures

The simulator data has been split into three zone types. Zone one begins at the start of the drive and ends at the first speed change gantry to 40mph, zone two begins at this gantry and ends at the next speed change gantry to the national speed limit and zone three begins at this gantry and ends six minutes after the start time. The distance of these gantries have been staggered in such a way that a participant will spend around two minutes in each of the zones at proper speed limits. Therefore, two national speed limit (70mph) areas are implemented (zones one and three) and one area with 40mph signs. Additional driving measures were analysed in this study such as steering angle, acceleration and standard deviation of lane position. These were not included in the previous experiments as differences in these variable would only reflect changes in the road types used. As this experiment used the same road type, more specific driving measures could be used. Repeated measures ANOVAs were conducted in the same manner for all simulator variables and pairwise comparisons used the Bonferroni correction in all cases. Where sphericity is violated, the Greenhouse-Geisser correction is used.

Mean speed.

From figure 4.1 it is clear that participants did modify their speed in zone two in response to gantry messages. Mean speed values are also higher for all music types in zone three compared to zone one. The unpleasant drive shows the lowest average speed while the hard drive shows the highest mean speed.

A 3 x 5 repeated measures ANOVA (Zone [1, 2 & 3] X Music type [Control, Easy, Hard, Pleasant & Unpleasant]) found a main effect of zone [$F(1.18, 27.04) = 14.66$, $p < .001$]. Pairwise comparisons revealed significant differences between zone one and zone two ($p = .01$) between zone two and zone three ($p < .001$) and surprisingly, significant differences between zone one and zone three ($p = .03$). A main effect was not found for music type, although this was borderline [$F(4, 92) = 2.31$, $p = .064$] and no interaction was found [$F(4.29, 98.75) = .50$, $p = .75$].

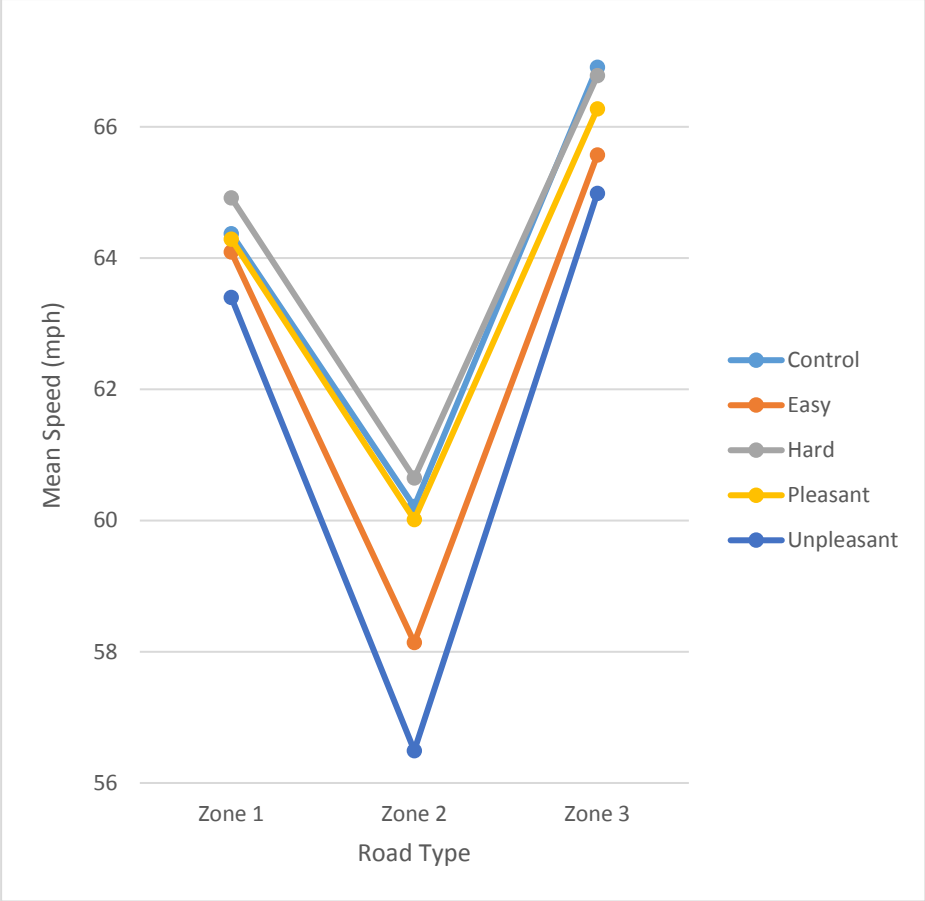


Figure 4.1. Mean speed across zone types for all music conditions.

Standard deviation of speed.

Standard deviation of speed differed only slightly between zones whereas the easy condition (7.18mph) showed much greater changes in speed deviation when compared to other music conditions and the control condition in particular (5.04mph).

No main effect of zone was found [$F(2, 46) = .58$, $p = .56$] and no interaction was found between zone and music type [$F(3.22, 74.05) = .54$, $p = .67$]. However, a main effect of music type was found [$F(2.24, 51.51) = 3.98$, $p = .021$]. Pairwise comparisons found significant differences in speed deviation between control and easy conditions ($p = .02$).

Maximum speed.

Maximum speeds were highest during the hard condition (74.62mph) closely followed by the easy condition (74.55mph). Maximum speeds then decreased to 73.91mph for the pleasant condition and were very similar for the unpleasant (72.81mph) and control conditions (72.44mph). A borderline effect was found for music type [$F(2, 92) = 2.43$, $p < .05$]. Pairwise comparisons found a significant difference between control and hard conditions ($p = .01$).

When split by zone, maximum speeds were predictably lowest in zone two (70.82mph) and higher for zone one (73.83mph) and zone three (76.35mph). A main effect of zone was found [$F(2, 46) = 33.88$, $p < .001$]. Pairwise comparisons found maximum speeds to be significantly different between zone one and two ($p = .001$), zone two and three ($p < .001$) and zone one and three ($p = .002$). No interaction was found between zone and music type [$F(8, 184) = 1.04$, $p = .41$].

% of time spent over 70mph.

Zone two was not included in this analysis due to the 40mph speed signs in zone two. Participants seemed to spend a greater amount of time speeding during the hard condition (27.82%) compared to speeding during the unpleasant drive in particular (20.14%). The control drive (24.12%), easy condition (23.38%) and the pleasant drive (24.44%) were very similar. However, no effect of music type was found [$F(4, 92) = 1.24$, $p = .30$] and no interaction between music type and zone was found [$F(4, 92) = .24$, $p = .92$].

The percentage of time spent speeding showed a large difference between zone one (19.25%) and zone three (28.71%). A main effect was

found for zone [$F(1, 23) = 17.83$, $p < .001$] showing that participants spent a significantly larger amount of time speeding during zone three.

Acceleration.

Acceleration was calculated as the average change in speed over time not taking into account direction – thus including accelerations and decelerations together. Acceleration was lowest in the control condition (0.35) compared to the easy (0.42), hard (0.41), pleasant (0.42) and unpleasant (0.42) conditions. Acceleration was markedly higher during zone two (0.46) compared to zone three (0.35) and zone one (0.40). A main effect of zone was found [$F(1.54, 35.49) = 18.61$, $p < .001$]. Pairwise comparisons found differences between all zone types, between zone one and two ($p = .046$), one and three ($p = .001$) and two and three ($p < .001$). A main effect was also found for music type [$F(4, 92) = 3.24$, $p = .016$]. Pairwise comparisons found differences only between control and easy conditions ($p = .042$). No interaction was found between zone and music type [$F(4.38, 100.69) = .75$, $p = .57$].

Steering angle.

Steering angle was recorded continuously and processed to obtain a measure of the standard deviation of steering angle in each zone. The lowest steering angle value was in the control condition (2.60) and increased to the highest value of 3.46 in the easy condition while the hard condition (2.89), pleasant (2.94) and unpleasant (2.89) conditions were very similar. A main effect of music type was found [$F(2.22, 50.99) = 4.28$, $p = .016$]. Pairwise

comparisons found steering angle to be significantly higher in the easy condition compared to the control condition (p = .01).

Zone two (2.60) showed smaller amounts of steering change compared to zone one (3.10) and zone three (3.17). A main effect of zone was found [$F(2, 46) = 3.89$, p = .027]. Pairwise comparisons found steering angle to be significantly higher in zone three compared to zone two (p = .05). No interaction was found between zone and music type [$F(3.15, 72.52) = .41$, p = .76].

Standard deviation of lane position.

Standard deviation of lane position (SDLP) was distinctly lower within zone two (0.48) compared to zone one (1.11) and zone three (1.28). A main effect was found for zone $F(2, 46) = 310.61$, p <.001. Pairwise comparisons found significant differences between all variables (p <.001).

SDLP was relatively consistent across music types and ranged from the lowest in the unpleasant condition at 0.92 to the highest in the control condition at 0.98. No main effect was found for music type [$F(2.94, 67.59) = 1.97$, p = .13] and no interaction was found between zone and music type [$F(8, 184) = 1.15$, p = .33].

Eye Tracking Data

Six participants were removed from the eye tracking analysis due to missing or incomplete data.

Mean fixation durations.

Mean fixation durations were highest in the pleasant music condition (946.78ms) compared to the unpleasant music condition (775.75ms), hard (746.52ms), easy (765.29ms) and control (837.82ms) conditions. A main effect was not found for music type [$F(1.85, 31.44) = 1.84$, $p = .18$] and no interaction was found between zone and music type [$F(1.45, 24.69) = 1.18$, $p = .31$].

Mean fixation durations were noticeably lower in zone two (744.63ms) compared to zone one (889.00ms) and zone three (809.66ms). A main effect was found for zone [$F(1.51, 25.58) = 3.71$, $p = .05$]. Comparisons using LSD showed a significant difference between zone one and two ($p = .042$).

Video Coding

As with the previous experiment, participant videos were coded. All coding was conducted using the same criteria.

Duration.

Skip duration is the amount of time taken for a participant to skip. Again, these are compared for each participant only if they skipped in both the easy and hard conditions. As previously, if the participant skipped more than once, these durations were averaged. Not all participants skipped and so data for only 19 participants are compared. Data were comparable to the previous experiment in that the duration of skips was much higher in the hard condition (M = 9.31secs, SD = 2.60) than the easy skip condition (M = 2.27secs, SD = 1.16). Data were transformed using LOG10 as they were not normal. A

repeated measures t test found a significant difference in skip duration between easy and hard conditions [t(18) = -13.81, p<.001].

Glances.

The glance duration was the amount of seconds a participant spent looking away from the road. The glance total was the sum of these glances. Glances were observed and compared between easy, hard and control conditions. Eye glances were measured using the same protocols as the previous experiment which is explained fully in study three.

Easy skip vs control.

Glance total in the easy skip condition was higher (M = 2.09sec, SD = 1.01) than in the control drive (M = .25sec, SD = .41). A repeated measures t test found this difference to be significant [t(20) = 9.71, p<.001].

Hard skip vs control.

Glance total was again higher in the hard skip condition (M = 5.94sec, SD = 1.73) than the control condition (M = 1.40sec, SD = 1.04). A repeated measures t test found this difference to be significant [t(20) = 14.77, p<.001].

Easy vs hard skip.

Not all participants skipped in both conditions and so means differ slightly in this comparison. Glance totals were much higher in the hard skip condition (M = 5.78sec, SD = 1.20) than the easy skip condition (M = 2.10sec, SD = 1.06). A repeated measures t test confirmed this difference to be significant [t(18) = -10.80, p<.001].

Lane Data.

Easy skip vs easy control.

A small difference was seen in lane deviation, with easy skip lane deviation higher (M = 2.44, SD = 1.95) than easy controls (M = 1.77, SD = 2.06). A repeated measures t test found this difference to be significant [t(20) = 2.74, p = .013].

Hard skip vs hard control.

There was a larger difference in the hard skip condition with hard skip lane deviations (M = 6.81, SD = 3.74) higher than hard controls (M = 4.00, SD = 1.65). A repeated measures t test found this difference to be significant [t(20) = 6.33, p< .001].

Easy vs hard.

When comparing easy and hard skips, as expected, hard skips produced a much higher deviation in lane position (M = 6.82, SD = 3.89) than easy skips (M = 2.64, SD = 1.96). A repeated measures t test found this difference to be significant [t(18) = -7.74, p< .001].

Speed Data

Speed across time.

Similar to the previous experiment, only small differences were seen in speed before and after skips, although speed was always reduced after skips. Repeated measures t tests found no differences in speed before and after easy skips [t(20) = .36, p = .72] and no differences in speed before and after hard skips [t(20) = .93, p = .37].

Speed deviation.

Easy vs control.

Speed deviation for easy skips was only slightly higher (M = 1.68mph, SD = 1.45) than speed deviation for easy controls (M = 1.31mph, SD = 1.61). A repeated measures t test did not find this difference significant [t(20) = .89, p = .39].

Hard vs control.

Speed deviation for hard skips was higher (M = 5.10mph, SD = 1.95) than speed deviation for hard controls (M = 3.28mph, SD = 1.85). A repeated measures t test found this difference to be significant [t(20) = 3.77, p = .001].

Easy vs hard skips.

The maximum and minimum speeds were used to calculate speed deviation. Speed during easy skips varied by around 1.70mph (SD = 1.44), much less than speed deviation during hard skips at 4.90mph (SD = 1.91). A repeated measures t test found the difference in speed variation to be significant [t(18) = -7.69, p <.001].

DISCUSSION

Summary of findings

The current experiment was successful in building on variability of data and increasing participant numbers. In terms of driving measures from the simulator, participants were shown to slow down during zone two (the 40mph area) indicating that they were able to attend and respond to visual information on the road. However, the average speed for zone two was much higher than the speed limit for this area, suggesting that either participants were interacting with the device and failed to spot the speed change, or drivers noticed but did not comply. Previous research has found that young drivers in particular are less likely to respond to traffic signs (Fisher et al, 2002).

The main effect of music type for mean speed was borderline, however, a main effect was found for standard deviation of speed, indicating that participants in the easy condition were more variable in speed than in the control condition. Acceleration was higher during zone two, possibly showing how drivers sped up when drivers spotted reappearance of the national speed limit sign.

Subjective scores of workload found no effects for mental demand, physical demand, performance or effort. Temporal demand scores were found to be significantly higher in the unpleasant drive compared to the pleasant music drive and significantly higher in the hard skip condition compared to the pleasant drive. Frustration scores, not surprisingly, were found to be higher in the unpleasant music condition compared to the pleasant drive.

Although participants did skip more in the easy skip condition, this difference was not significant. Results for music data were ideal in that once

again, song ratings were significantly different between pleasant and unpleasant songs, but tempo ratings between these songs were not significantly different.

Video coding data found glance durations to be significantly higher in the easy skip condition compared to controls, higher in the hard skip condition compared to controls and higher in the hard skips compared to easy skips. Lane deviations were significantly higher in easy skips compared to easy controls, higher in hard skips compared to hard controls and higher in hard skips compared to easy skips. No differences were found between speed before and after skips in either skip difficulty. Speed deviation measures found no differences between easy skips and easy controls, but did find significant differences between hard skips and hard controls and hard skips compared to easy skips, with skips displaying a higher amount of speed deviation.

Relation to past research

Large differences in speed deviation between skipping conditions and controls in the video coding and simulator data suggest that drivers may not have had their full attention on speed maintenance during interaction with the device. In addition, acceleration data found easy conditions to have significantly higher acceleration than control conditions. These results are mirrored in Reed and Green (1999) who also found that the standard deviation of speed was smaller when driving with no device compared to driving with a phone task and the standard deviation of throttle position was more variable during a phone task. Authors suggested the reason for this variability in speed

is down to the cognitive and visual demands of the phone task in that when interacting with the phone, their visual attention is taken away from maintaining proper speed and so more speed corrections are needed resulting in higher acceleration and more variability in speed.

Steering angle was significantly higher in in the easy condition than the control condition. This is consistent with a previous experiment on iPod use while driving, where results found interacting with the iPod resulted in larger steering wheel adjustments, particularly on motorways (Chisholm, Caird & Lockhart, 2008). However, previous research has not always found secondary tasks to influence steering angle (Rakauskas, Gugerty & Ward, 2004).

Differences in zones were found for most simulator data. In particular, mean speed, maximum speed and percentage of time spent over the speed limit were highest during zone three. One possible reason for this is that divers became bored towards the end of the drive. Heslop et al (2010) found that drivers report to increasing their speed when bored in order to make the drive more stimulating. Another explanation is that drivers compensate for their loss of speed when speeds were recently reduced by speeding up after (Boyle & Mannering, 2004). As we might expect, drivers within zone two had higher acceleration, had shorter fixation durations and less variability of lane position, presumably due to the speed reduction in this zone.

The fact that differences between music types in simulator measures were found only for easy versus control conditions (with the exception of maximum speed) is puzzling, especially as differences were found with hard conditions in the video coding data. A possible explanation is that this is a result of the order in which participants completed the tasks. Drivers always

performed the easy task before the hard task to ensure that the hard task was not overly difficult in that participants had already driven while interacting with the phone.

Relation to previous experiment

Workload findings built on results from the previous experiment. Frustration scores found that once again that participants experienced more frustration in the unpleasant music condition compared to other drives. No other effects were found in the previous experiment, however, temporal demand in this experiment was significantly affected by music condition, with participants the hard and unpleasant drives feeling under time pressure. Consistent with the previous experiment, participants skipped more in the easy skip condition compared to the hard skip condition, although once again this difference was not significant.

Differences in simulator data were found between conditions in this experiment which were not present in the previous study. This may be due to the increase in participant numbers or the increase in variability due to zone differences. However, while fixation durations were consistent with the previous study, none were significant between music types. Both experiments have found differences in easy and hard conditions in terms of video coded speed deviation during skips which has shown that the hard skip condition has more variability in speed than the easy skip condition. No simulator differences were found in the first experiment, however surprisingly, this second experiment found differences in simulator data with easy conditions showing the highest speed variability. Steering angle discussed above also

showed the easy condition to have larger variation in steering angle than the control condition. The fact that the hard condition was not significantly different from the easy condition, or even controls, may suggest that the order of conditions had an effect.

Video coding data found similar results for glance durations, with skips having longer glance durations than controls. The previous experiment found no differences in lane deviation, whereas the present experiment found deviations to be significantly higher during skips compared to controls and when skips were compared.

Conclusions

This study addressed some of the limitations of the first MP3 experiment by introducing different speed zones. To a lesser extent, this study also suffered from a small sample as the video coding data could only analyse participants who skipped and again, not all participants chose to skip music. However, simulator and coding data have been able to detect differences in speed variation and lane position which were not detected in the previous experiment. As it has been found that participants are willing to engage with the device in the simulator, an important question is whether they can be dissuaded to do so using the risk monitor technology. The risk monitor technology has the potential to increase arousal from participants and so the next study will assess whether this information about accident risk has an effect on music skipping behaviour.

STUDY 5 - THE EFFECTS OF ACCIDENT INFORMATION ON THE USE OF AN MP3 PLAYER IN A DRIVING SIMULATOR.

Literature discussed previously has outlined how in-car technology has the capacity to both help and hinder a driver's performance. The risk monitor used in study 2 and 2.5 demonstrated how information on accident risk may raise participants' heart rates, which has the potential to create safer drivers. The current study aims to couple this risk monitor with the music skipping design used in studies 3 and 4 with the aim of investigating whether an in-vehicle information system can influence drivers' interactions with a second, potentially distracting task.

Previous studies have used collision warning systems in conjunction with secondary tasks. In a driving simulator study, participants were required to interact with a touch screen, in a task which authors suggested was typical of devices such as MP3 players (Lees & Lee, 2007). A collision warning system was either not present, accurate, under false alarm mode or under unnecessary alarm mode. Hazard warnings assisted distracted drivers in their response times to hazards. In particular, these drivers were quicker to release the accelerator pedal when warnings were accurate. Importantly, the presence of the collision warning system did not prompt drivers to interact with the secondary task more frequently. This is essential as an extra sense of safety can lead drivers to perform more dangerous tasks (Janssen, 1994; Aschenbrenner & Biehl, 1994 cited in Wilde, 1994).

Another collision warning system used a visual icon and auditory warning to alert drivers to rear end collisions to a simulated vehicle ahead.

Distracted drivers were required to detect the number of times the number four appeared in a visual array of numbers while driving (Lee et al, 2002). These drivers were compared to a no distraction condition. Both groups of drivers benefited from the collision warnings, however there was no interaction between distraction and warning.

A further rear-end collision warning system was tested alongside drivers' mobile phone use (Mohebbi, Gray & Tan, 2009). Sixteen participants were required to drive in three conditions, without a mobile phone, with a hands-free mobile phone with simple conversation and with a hands-free mobile phone with complex conversation (maths questions). The collision warning was either not present, in tactile or in auditory form. Brake response times were significantly higher for simple conversations compared to none with an auditory warning, but no difference was found when tactile warnings were used. Response times were even shorter during complex conversations compared to no warnings when tactile warnings were used.

The current experiment will combine the risk monitor experiment with the MP3 player task and compare the amount of times participants interact with the device and how much they are willing to listen to unpleasant music when the tone is present. The aim in this experiment is to understand whether information about accident risk can influence to what degree a driver will interact with a secondary device and to determine whether a technological device may be helpful in deterring other technology use. It is expected that:

- Drivers in high risk conditions, with the tone present, will skip music less.

- Drivers in low risk conditions will spend a smaller amount of time listening to unpleasant music.
- Drivers may reduce their speed in high risk areas.

Method

Participants

24 participants were recruited from the staff and student population at the University of Nottingham. Poster adverts were placed across the university inviting drivers to take part. Participants were 12 females and 12 males (mean years of age = 23.25, SD = 3.27). The majority of participants held full UK driving licences, however, some drivers were included who held foreign licences, but who had driven on UK roads. Drivers had an average of 4.88 years driving experience (SD = 3.23) driving an average of 1787.5 miles per year. Three participants had been involved in an accident in the past two years. All participants were given monetary compensation for their time. Participants were informed about the risk of simulator sickness prior to consent and were advised not to drive for thirty minutes post-experiment.

Design

All participants drove the simulated route twice, once in each direction and once with a risk tone on. Therefore, the experiment used a 2x2 within-subjects design with factors of Warning (on/off) and risk (high/low). Music was played to participants in all four drives. The direction of route (clockwise, anticlockwise) was counterbalanced in terms of which direction was driven first, along with the presence of the tone, thus creating four groups of six participants.

Apparatus

Materials and equipment used in this study were a combination of the risk monitor task discussed in chapter three and the MP3 experiment discussed earlier in this chapter. The NITES 1 simulator was used once again, along with the Apple iPhone 5s as the MP3 player and the risk monitor using a high pitched tone for high risk areas. The simulated route of Nottingham city centre was employed once more to ensure that participants were aware that the real life accident risk statistics applied on the simulated roads. The route differed however, from the risk monitor experiment in that only two sections of road were used; one high risk section and one low risk section. Participants drove these two roads twice, once in each direction and once with the risk tone present. Roads were separated in terms of risk in the same manner as the risk monitor experiment i.e. high and low risk roads were deemed as such based on the real accident statistics obtained from Nottingham City Council and traffic density measures.

Music

Playlists were made in the same way as the previous experiments in that participants rated songs and their most and least favourite were added to playlists. Music was present in all drives of this experiment as skipping behaviour was being investigated in relation to the presence of the risk tone. Therefore, playlists were always mixed valence, always starting with a pleasant song and alternating with unpleasant songs for the duration of the drive. Participants were permitted to skip unpleasant songs at any time but were asked not to skip pleasant songs. Songs in this experiment were set to 45

seconds in length to increase the opportunity for a participant to skip. The difficult skip from the previous experiment (using the passcode '1234') may have been too tricky for this study as the Nottingham roads are more urban with more visual scenery. Therefore, the difficulty of the skipping task was modified slightly from the previous experiments to ensure that the task was not so difficult that no participant skipped, but not so easy that all participants skipped at every opportunity. Consequently, for participants to skip in this experiment, they needed to unlock the phone first with a swipe on the touch screen and then just one touch press on the skip button. Once again, the phone was locked remotely after every skip or attempt.

Procedure

Participants began in the same fashion as previous experiments, first giving informed consent before completing a brief driver questionnaire and a simulator sickness questionnaire as a baseline. Participants then rated the 376 songs and a large mixed valence playlist was made while participants were completing a five minute practice drive. Participants were then encouraged to interact with the iPhone and practice skipping behaviour to ensure that non-iPhone users were familiar with the task. The risk monitor was then explained to participants and risk tones were played so that participants could distinguish between high and low risk tones. Participants then drove in four experimental conditions which were counterbalanced e.g. (1) clockwise tone on (high risk), (2) clockwise risk tone on (low risk), (3) anticlockwise tone off (high risk), (4) anticlockwise tone off (low risk). Simulator sickness questionnaires and workload measures were completed after each drive.

Results

Workload

Mental demand and physical demand scores dropped slightly on the high risk roads in the tone off condition compared to other road types (Table 4.4). Temporal demand scores increased slightly on low risk roads in the tone on condition compared to other road types. Performance scores peaked in high risk conditions when the tone was both on and off. Effort and frustration decreased in the high risk road condition where the tone was not present.

Table 4.4
Means (M) and standard deviations (SD) for NASA TLX workload measures between tone on and off conditions for high and low risk roads.

	On				Off			
NASA TLX Measure	High		Low		High		Low	
	M	SD	M	SD	M	SD	M	SD
Mental Demand	6.42	4.74	6.08	4.36	5.46	4.34	6.75	5.20
Physical Demand	4.42	3.44	4.75	3.29	4	3.30	4.96	4.23
Temporal Demand	4.96	4.10	5.42	4.18	4.38	3.44	4.38	3.55
Performance	6.21	4.52	7.04	4.78	6	4.76	6.79	4.95
Effort	6.67	4.82	6.71	4.71	5.63	3.99	5.92	4.31
Frustration	4.21	4.10	4.13	3.57	3.25	2.63	4.46	4.40

2 x 2 ANOVAS [risk level (high/low) x tone presence (on/off)] were conducted for each workload measure. An interaction was found for mental demand [$F(1, 25) = 6.11$, $p = .021$]. Simple main effects analysis did not find significant differences across variables, only a marginal difference in mental demand scores between high and low conditions when the tone was off (p =

.07). No effects of risk level [$F(1, 25) = 3.77$, $p = .06$], tone present [$F(1, 25) = .19$, $p = .84$] or interaction [$F(1, 25) = 1.79$, $p = .19$] were found for physical demand. No effect of risk level [$F(1, 25) = .50$, $p = .49$] or interaction [$F(1, 25) = .48$, $p = .49$] was found for temporal demand. However, a main effect of tone presence was found [$F(1, 25) = 5.39$, $p = .03$]. Post hoc tests using a Bonferroni correction found a significant difference in temporal demand scores between tone on and tone off conditions ($p = .03$), with tone on conditions reporting higher scores of temporal demand. No effects of risk level [$F(1, 25) = 3.08$, $p = .09$], tone present [$F(1, 25) = .21$, $p = .66$] or interaction [$F(1, 25) = .003$, $p = .96$] were found for performance. Similarly, no effects of risk level [$F(1, 25) = .11$, $p = .75$], tone present [$F(1, 25) = 3.85$, $p = .06$] or interaction [$F(1, 25) = .075$, $p = .79$] were found for effort. An interaction was found between tone presence and risk level for frustration scores [$F(1, 25) = 4.64$, $p = .04$]. Simple main effects found a difference in frustration scores between high and low risk roads when the tone was not present ($p = .025$).

Song Ratings

In order to ensure that participants were listening to songs that they actually liked and disliked, their personal ratings for their playlists were analysed. Participants gave their 'pleasant' songs a mean rating of 8.97 [SD = 1.09] (out of 10) and their 'unpleasant' songs a mean rating of 1.72 [0.87] (out of 10). A t test found there was a significant difference in song ratings between the two groups [$t(218) = 74.68$, $p<.001$].

Song Tempo

The mean tempo for songs rated as 'pleasant' was 124.63bpm (SD = 20.21), slightly higher than songs rated as unpleasant, with a mean of 120.09bpm (SD = 19.95). A t test confirmed there was no difference in tempo between pleasant and unpleasant rated songs [t(129) = 1.71, p = .09].

Skipping Behaviour

Participants skipping behaviour is first analysed in terms of the number of skips and then as the average amount of time a participant spent listening to an unpleasant song (see table 4.5). This was necessary as some participants drove more slowly and so had more opportunity to skip.

Table 4.5
Means (M) and standard deviations (SD) for the time spent listening to self-reported unpleasant music (sec) and number of times participants skipped self-reported unpleasant music.

	Tone On				Tone Off			
	High Risk		Low Risk		High Risk		Low Risk	
	M	SD	M	SD	M	SD	M	SD
Time spent listening to unpleasant songs	31.34	14.13	32.03	13.29	30.77	13.71	28.17	14.27
No. of skips	1	1.10	1.71	1.71	1.17	1.13	1.92	1.67

No. of Skips

Participants skipped 65 times in the tone on conditions and 74 times in the tone off conditions (difference not significant [t(50) = -1.52, p = .13]). This translates to 86 skips in the low risk condition and 53 in the high risk condition (difference significant [t(47) = 3.84, p < .001]). A 2 x 2 repeated measures ANOVA found a main effect for risk level [F(1, 23) = 15.06, p = .001]. Post hoc tests with a Bonferroni correction found a difference in high

and low risk roads, with participants on low risk roads skipping more than on high risk roads (p = .001).

Average time spent listening to unpleasant music

Each song, both pleasant and unpleasant, lasted for 45 seconds and so the mean time spent listening to unpleasant was calculated as an additional measure of skipping behaviour. Average time spent listening to unpleasant music drops slightly in the tone off conditions compared to tone on drives (see table 4.5). A 2 x 2 repeated measures ANOVA found a main effect for tone presence [$F(1, 23) = 6.13$, p = .02]. Post hoc tests with a Bonferroni correction found a difference in tone on (M = 31.70) and off (M = 29.47) conditions, with participants spending less time listening to songs they do not enjoy when the tone was off (p = .02).

Driving Measures

Repeated measures ANOVA's were conducted for all driving measures using a 2 x 2 design [Risk Level (High/Low) x Tone Presence (On/Off]. Main effects of risk level are assumed to be due to differences in road types as the speed limits and terrains of these roads are very different. All variables were measured in the same manner as previous experiments.

Mean speed.

Mean speeds were very similar in high risk conditions between tone on and tone off drives (see table 4.6). A slight difference was found however between tone on and off drives in the low risk conditions.

A repeated measures ANOVA found a main effect of risk level [$F(1, 23) = 748.61$, $p < .001$] while an effect for tone presence approached significance [$F(1, 23) = 3.60$, $p = .07$]. No interaction was found between risk level and tone presence [$F(1, 23) = .46$, $p = .51$].

Table 4.6
Means (M) and standard deviations (SD) for mean speed (mph).

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	29.34	2.26	29.68	1.98
Low	45.53	3.81	46.47	4.35

Standard deviation of speed.

Standard deviation of speed did not appear to differ. High risk roads were similar for tone on (3.81mph) compared to tone off (3.55mph) conditions, similar for low risk roads between tone on (10.04mph) and tone off (10.16mph) conditions.

A repeated measures ANOVA found a main effect of risk level [$F(1, 23) = 188.302$, $p < .001$], no effect of tone presence [$F(1, 23) = .02$, $p = .89$] and no interaction [$F(1, 23) = .25$, $p = .62$].

Maximum speed.

Maximum speeds differed in that speeds appeared to be lower when the tone was present (see table 4.7). A repeated ANOVA found a main effect of risk level [$F(1, 23) = 480.09$, $p < .001$] and a main effect of tone presence [$F(1, 23) = 8.43$, $p < .01$]. No interaction was found [$F(1, 23) = 2.34$, $p = .62$]

meaning that maximum speeds were higher on low risk roads and also higher between tone on and off conditions.

Table 4.7
Means (M) and standard deviations (SD) for maximum speed (mph).

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	36.80	3.42	37.79	3.69
Low	62.23	6.48	63.85	6.68

Mean acceleration.

Mean acceleration did not differ between tone on (0.44) and tone off (0.44) conditions for high risk roads. There was a slight difference between tone on (0.45) and tone off (0.46) conditions for low risk roads, however a repeated measures ANOVA found no main effect of risk level [$F(1, 23) = 1.536$, $p = .23$], no main effect of tone presence [$F(1, 23) = .42$, $p = .52$] and no interaction [$F(1, 23) = .15$, $p < .70$].

Steering wheel angle.

Mean values of standard deviation of steering wheel angle differed only slightly between high risk (tone on = 1.75, tone off = 1.64) and low risk (tone on = 6.32, tone off = 6.49) conditions. A main effect of risk level was found [$F(1, 23) = 1630.54$, $p < .001$], while no main effect was found for tone presence [$F(1, 23) = .05$, $p = .82$] and no interaction was found [$F(1, 23) = 2.47$, $p = .13$].

Standard deviation of lane position.

Mean values of standard deviation were very similar in high risk (tone on = 1.13, tone off = 1.15) and low risk (tone on = 2.74, tone off = 2.69) conditions. Once again, a main effect of risk level was found [$F(1, 23) = 1940.70$, $p < .001$] while no main effect of tone presence was found [$F(1, 23) = .08$, $p = .79$] or interaction [$F(1, 23) = .31$, $p = .58$].

Mean fixation durations.

Five participants were removed from these data due to incomplete or missing data. Table 4.8 shows large differences in fixation durations between tone on and off conditions. However, no main effects of risk level were found [$F(1, 18) = .57$, $p = .46$] or tone presence [$F(1, 18) = 1.58$, $p = .23$] and no interaction was found $F(1, 18) = .31$, $p = .59$].

Table 4.8
Means (M) and standard deviations (SD) for fixation durations (ms).

Risk Level	Tone On		Tone Off	
	M	SD	M	SD
High	946.50	727.60	1411.46	1806.32
Low	1180.90	1342.03	1757.23	3518.57

DISCUSSION

Summary of findings

Most driving simulator measures found significant effects for risk level which serves to highlight the differences in road type. High risk roads were urban, with low speed limits and broken by traffic lights while low risk roads were long stretches of high speed dual carriageway. Therefore, differences in speed measures and steering angle for example are understandable. Main effects for tone presence approached significance with mean speed with values showing a tendency towards lower speeds when the risk tone was present. No effect was found for standard deviation of speed, however, analyses of maximum speed found a significant difference between tone on and off conditions with the highest speeds occurring when the tone was not present. Mean values of fixation durations looked to show large differences in tone on and off conditions in that tone off conditions had much longer mean fixation durations. However, further tests found no significance, although large standard deviations and low participant numbers may be the reason for this.

Mental demand scores were found to be marginally different between high and low conditions when the tone was off, while temporal demand scores were higher in tone on conditions. Strangely, participants felt more frustration when the tone was not present, in low risk roads compared to high risk. No effects were found for physical demand, performance or effort.

Although participants skipped more in tone off conditions compared to tone on condition, this difference was not significant, while there was a

significant effect for risk level. Participants on low risk roads skipped more than on high risk roads and participants in tone off conditions were found to spend less time listening to songs they find unpleasant.

Relation to past research

The tendency towards lower mean speeds when the tone was present, coupled with how maximum speeds were higher when the tone was off suggests that the risk tone was partially successful in increasing the safety of drivers, regardless of risk level.

However, this effect could be evidence of behavioural adaptation. The fact that maximum speeds were higher when the tone was not present together with how participants in tone off conditions were found to spend less time listening to songs they find unpleasant may suggest that participants felt less risk and so sought to optimise their level of risk by increasing speed and engagement with the device (Wilde, 1982). There is the possibility that speeds were reduced in conditions where the tone was present because the added auditory stimulus was enough to increase task difficulty to the point that a change in behaviour occurred (Fuller, 2005). Mohebbi, Gray and Tan (2009) suggested the reason tactile warnings were more successful that auditory warnings in their mobile phone conversation experiment was due to the added load on the auditory system. This may be a factor in why no differences in skipping behaviour were found between tone on and off conditions.

It is important that the risk information system did not prompt drivers to interact with the device more frequently (Lees & Lee, 2007). Although participants spent less time listening to music they did not enjoy during

conditions where the tone was not present, there was no difference found in the number of skips between these conditions. This suggests that the risk tone delayed skipping onset, although ultimately this had no effect on eventual skipping behaviour.

Limitations

Heart rate could not be measured in this experiment due to equipment failure and so it is disappointing that this experiment cannot add to our previous findings on risk. In addition, without a control condition it is difficult to suggest that interacting with the device had adverse effects on driver performance. However, while it is already established that interaction with MP3 players negatively affect driver performance, this study instead focussed on how a risk information system could deter this use. Once more, previous studies have focussed on how safety systems affect response times to hazards and so without testing response times here, it is difficult to compare efficacy.

In terms of future directions, running further participants may give power to the apparent large differences in fixation durations between the tone on and off conditions.

Conclusions

Skipping behaviour was reduced on low risk roads compared to high risk, regardless of the presence of the tone. This suggests that either low risk roads were less complex and therefore participants were comfortable interacting with the device, or that there was a carryover effect from participants who completed the tone on conditions first. However, participants

spent more time listening to unpleasant music when the tone was present, suggesting that there is the potential for a device such as this to deter interaction while driving.

STUDY SIX - THEORY OF PLANNED BEHAVIOUR BASED INTERVENTION

Previous literature outlined in chapter two has consistently found that drivers continue to use mobile phones while driving despite knowing the risks of being caught by police or being involved in an accident. It is for these reasons why interventions are needed to persuade drivers to drive more safely for the sake of themselves and others.

Fear strategies

Many interventions focus on inducing fear and rely on horrific images of car accidents which have resulted in death or serious injury to a driver or an innocent passenger or pedestrian. A large number of these driver interventions are based on the Extended Parallel Process Model [EPPM] (Witte, 1992). This model endeavours to predict how the public will react when presented with fear inducing appeals. The individual will first appraise the message in terms of threat and if they believe they are susceptible or vulnerable to this threat (response-efficacy), they will then appraise the appeal on whether the message suggests achievable and valuable strategies (message self-efficacy). The individual will then decide whether to eliminate their fear by positively adapting to change or by negatively denying the problem or avoiding thinking about it. Negative reactions may even have the opposite effect (called a Boomerang effect) on behaviour in which a person will do the opposite of what the message had intended to prevent. This is perfectly illustrated in a study on distracted driving (Lennon, Rentfro & O'Leary, 2010).

The authors attempted to use fear appeals in the form of videos to suggest that talking on a mobile phone, texting, eating and playing music while driving are distracting. While participants (n = 840) did rate these behaviours as more distracting, they also stated increased intentions to perform these behaviours. Others have found similar effects on smoking cessation, where efforts to scare college smokers resulted in participants craving a cigarette (Wolburg, 2006) and where anti-drug materials were found to reduce negative attitudes towards drug taking (Feingold & Knapp, 1977).

Lewis, Watson, Tay and White (2007) acknowledge that while these appeals are effective in attracting attention, their effects on behaviour are less important than other factors. Another study found that although appeals involving greater injuries relating to drink-driving induced more fear, this fear did not have any effect on behavioural responses (Whitehill & Reid, 1990). A meta-analysis on the effects of these fear appeals in driving between 1990 and 2011 found that although materials had significant effects on increasing fear, these ultimately had no effect on eventual driving behaviour (Carey, McDermott & Sarma, 2013).

Others have adapted the model to produce appeals that are based on other emotions, not just fear. Lewis, Watson and White (2013) used the EPPM model to create four appeals based on fear, annoyance, pride and humour for road safety. Message acceptance was significant for annoyance, pride and humour campaigns but not for the fear based appeal, suggesting that the model would perhaps be more successful when inducing different emotions.

Child Education

Road safety researchers realised that they could target drivers even before they were old enough to drive to try and instil positive driver behaviour before these individuals made it to the road. High school students in America were more likely to become licence holders after an enhanced driver education program (Lund, Williams & Zador, 1986). These students were also more likely to be involved in car accidents, although this was explained by their earlier licence acquisition. Building on this study, Vernick and colleagues (1999) who reviewed nine high-school driver education studies and Roberts and Kwan (2001) who reviewed three studies found that these did not contribute to lower accident involvement. Conclusions were similar to the previous study in that these education programmes could actually increase accident statistics as these young drivers were on the road sooner.

Studies on even younger children have shown promise. Hazinski, Eddy and Morris (1995) educated young children on seat-belt use in car and found through observations that these children showed significantly higher seat-belt and this translated on a familial level.

Other studies put more emphasis on parenting than explicit driver education. Some have suggested that parents need to control teenage driving and make agreements with their children about proper behaviour (Simons-Morton & Hartos, 2003). Parents were urged to monitor teenage driving in a 6 month long study (Zakrajsek et al, 2013), using agreements made with parents and teenagers that they would refrain from driving on weekend evenings, on high speed roads and in adverse weather. Although no differences in accident

involvement were found between intervention teens and controls after six months, intervention teens reported less risky driving.

Theory of Planned Behaviour Interventions

Educating children on safe driving is a positive step in ensuring that the next generation of drivers is safer than the last. However, interventions must also focus on current drivers and how measures can be taken to curb unsafe driving. Fear appeals discussed above have had mixed or only temporary success and so other interventions must be considered, such as those that stem from the theory of planned behaviour. From chapter two, we have learned about how perceived behavioural control, subjective norms and attitudes in particular can predict intentions and behaviour. Theory of planned behaviour guidelines (Ajzen, 2006) for creating an intervention based on these beliefs is incredibly vague and so interventions can vary massively between studies. Some researchers choose to use face to face discussions, adverts placed in newspapers or TV or informational leaflets. These interventions are then shown or distributed in relevant areas and the possible impacts are then measured over time. There are some theory of planned behaviour interventions which involve fearful images or videos, however these have been tailored to target specific beliefs. Rather than just trying to scare drivers into changing their behaviour, these interventions are challenging the ideas that participants think they are good drivers and that these scary things would never happen to them.

Most intervention studies using the theory of planned behaviour have been conducted in the field of health research, encouraging patients to take

vitamins (Sheeran & Orbell, 1999), perform breast examinations (Orbell, Hodgens & Sheeran, 1997), wear sun cream (White et al, 2015) and improve their diets (Kothe, Mullan & Butow, 2012). Very few, if any, studies have implemented a theory of planned behaviour based intervention for technology use. Therefore, the different kinds of intervention approaches used will be discussed in terms of how these interventions are formed and implemented in other areas of road safety.

An article by Rowden and Watson (2014) highlighted the fact that in Australia and perhaps in many other countries, crash risk is significantly increased when drivers are using their mobile phones and yet drivers still confess to this illegal use. This is in spite of many efforts by researchers and governments to enforce the law and increase public education. Authors suggest that targeting attitudes along with enforcement of law may result in a culture change adequate enough to reduce these behaviours while driving. It is for these reasons why a study by Gauld, Lewis, White and Watson (2016) aimed to gain the critical beliefs on smartphone use while driving. These beliefs were elicited from theory of planned behaviour measures and possible strategies were put forward to tackle each of these beliefs. Drivers in this study reported that 'feeling at ease when receiving an expected communication' was a positive behavioural belief towards smartphone use while driving. Authors suggested future studies may emphasise other aspects of driving which may make a driver feel at ease, for example, travelling or arriving at a destination safely. Although not published, future studies from these authors will use these to form relevant materials which can then be used in public education messages to change driver behaviour.

Attitudes were successfully changed in a mass media intervention campaign on speeding based on the theory of planned behaviour (Stead et al, 2005). This campaign was shown on television and cinema screens in Scotland and aimed to target those who speed the most (25-44 year old males). Attitudes, subjective norms and perceived behavioural control each received their own adverts, aimed specifically at changing that particular belief. Theory of planned behaviour measures were taken from respondents periodically over a three year period. Attitudes were successfully changed over this time, however, subjective norms and perceived behavioural control were not as successful. It is unclear whether attitudes are more susceptible to change than subjective norms or control, however, authors believe the attitude specific advert may have been more powerful than the other ads. In addition, the attitude ad was the first to be screened and so may have profited from exposure the other ads, in that they followed the same format. Videos have been successful in changing attitudes in previous studies also (Parker, Stradling & Manstead, 1996).

Poulter and McKenna (2010) aimed to gauge the attitudes and beliefs of high school children on road safety across the UK and align them with an interventional education program to improve road safety in the event of these children learning to drive in the future. Using a video based intervention with a fatal crash, results found that attitudes and some subjective norms were modified post intervention. However, this result vanished in a 5-month follow-up and some measures even became significantly worse than pre-intervention. This finding is similar to the Boomerang effects discussed from earlier fear appeal studies. However, others have been more successful in

changing the behaviour of children. Quine, Rutter and Arnold (2001) compared two groups of UK school children (n = 97) on cycle helmet wearing before and after a leaflet-based intervention. Control, normative, intentions and behavioural beliefs were all significantly more positive post-intervention which was maintained five months post-intervention. One quarter of experimental participants reported wearing their helmets while cycling compared to none of the control participants.

Measures of perceived behavioural control have been successfully changed for the better. Increasing feelings of control in participants is important as it increases feelings of confidence in performing a particular behaviour. Elliot and Armitage (2009) aimed to change the speeding behaviours of participants (n = 300) with an intervention leaflet containing persuasive messages targeted at each TPB construct. TPB questionnaires were taken before intervention and one month post intervention via postal questionnaires. Following the intervention, experimental participants reported significantly more control related to speeding than did controls and this control change was directly responsible for behaviour change.

Others have found success in changing teenagers' behaviour towards drink driving and being a passenger to a drink driver (Sheehan et al, 1996). In an early systematic review of TPB interventions, it was found that around half of published work reviewed (n = 30) was successful in changing intentions, and around two thirds successfully changed behaviour (Hardeman et al, 2002).

A possible weakness of the theory of planned behaviour is that when intentions to perform a behaviour are high, actual behaviour may not reflect this intention. If this is found to be the case, an intervention must be directed

at translating intentions into actual behaviour. Implementation intentions are one such solution. This approach suggests that if a person gives themselves a goal and attaches a specific situation to them, success will be more likely, e.g. 'when situation x arises, I will perform response y' (Gollwitzer, 1993, 1999). This approach has found some success, mainly in health research (Schweiger-Gallo et al, 2009) in helping people to give up smoking (van Osch et al, 2010) and to become more physically active (Latimer, Martin-Ginis & Arbour, 2006).

Implementation intentions have been used by Elliott and Armitage (2006) for the first time in the area of driver distraction in an attempt to ensure drivers comply with speed limits. In this study, 258 drivers were given questionnaires before and after a period of a month. All participants answered questions on their own speeding behaviour as well as theory of planned behaviour measures, intentions and compliance with speed limits. Participants randomly allocated to the implementation condition (n = 129) were asked to write down how, when and where they would comply with speed limits in the next month. Results found that those in the implementation condition were significantly more likely to comply with speed limits compared to the control group. However, this was self-reported compliance and so participants may have displayed demand characteristics.

The questionnaire study in chapter two found attitudes to be the largest predictors for intentions for most technologies. Therefore, attitudes will be targeted in the following intervention study. The aims of the study are to reduce positive attitude towards mobile phone use while driving with the use

of an attitude based intervention and to reduce actual skipping behaviour in the simulator portion of the experiment. It is predicted that:

- Intervention group participants' attitude scores will decrease after the intervention.
- Intervention group participants will choose to skip less frequently than controls in another iPhone music skipping task.

Method

Design

A mixed design was used. Participants first took part in a decoy experiment using occlusion goggles. This experiment was necessary so that the intervention could be presented to participants without their knowledge. This intervention came in the form of a debrief at the end of the occlusion experiment where control participants received a normal debrief about their participation and experimental participants received a debrief outlining the dangers of looking away from the road while driving. After the occlusion goggle experiment, participants were invited to complete another experiment in a higher fidelity simulator. Participant numbers were lower in this experiment as some participants from the occlusion study suffered from simulator sickness and could not complete the second experiment.

Regardless of group, all participants completed the same intervention experiment, looking at MP3 player use while driving (similar to previous studies). Participants were once again played self-rated pleasant and unpleasant music and were allowed to skip any unpleasant songs in easy skip and hard skip conditions.

To test whether the intervention had changed attitudes towards using technology while driving, theory of planned behaviour measures were once again used and compared with attitude scores given by each participant from the occlusion experiment. The number of times each participant skipped music was tested between and within subjects. Within-subjects driving variables

(e.g. speed) compared participants performance in normal driving and while occluded.

Participants

40 participants (20 control, 20 experimental) were recruited aged between 19 and 59 (mean years of age = 26.6, SD = 6.48). Participants all held full driving licences, mainly UK licences, although some participants were included who had full foreign licences who had driven on UK roads. Participants were mainly students or staff from the University of Nottingham, however, some were recruited via posters who were not part of the university. All participants were given monetary compensation for their time. Participants were again informed about the risk of simulator sickness prior to consent and were advised not to drive for thirty minutes post-experiment.

Control Group

12 males and 8 females were included (mean years of age = 26.05, SD = 3.49) with an average of 6.75 years driving experience (SD = 3.94). Participants in this group drove an average of 3146 miles per year. One participant had been involved in an accident in the past two years, but was not at fault.

Experimental Group

13 males and 7 females were included (mean years of age = 27.15, SD = 8.57) with an average of 8.65 years driving experience (SD = 9.38). Participants in this group drove an average of 3145 miles per year. Three

participants had been involved in an accident in the past two years, only one was at fault.

Occlusion Goggle Experiment

Design

A repeated measures design was used. All participants drove the same simulated route twice, once while wearing the occlusion goggles and once without. Conditions were counterbalanced for the order of occlusion goggle drives.

Materials and apparatus

Debrief.

The debrief following the occlusion experiment acted as the intervention. Control participants received a standard debrief thanking them for their participation in the occlusion study and gave them a small amount of information as to why the study was conducted. Experimental participants received a debrief which outlined the various dangers and accident statistics associated with looking away from the road. These were based on relevant beliefs which were elicited from the pilot questionnaire in chapter two, but also new beliefs were included as theory of planned behaviour guidelines on intervention formation suggest that it may be easier to introduce new beliefs rather than modify old beliefs. These facts required the participant to tick each statement and sign to indicate that they had read and understood the debrief. A short tick box questionnaire on these facts was given to these participants at

the end of the intervention experiment to assess whether participants had actually attended to the information.

Risk questionnaire.

The Risk Orientation Questionnaire (ROQ) (Rohrmann, 1997, 2001) was used to measure participants' attitudes towards risky decisions. This is a twelve item questionnaire in which respondents are asked to rate their feelings on a seven point likert scale e.g. 'my decisions are always made carefully and accurately' from one 'no, not at all' to seven 'yes, very much so'. This was used in order to determine whether there was any correlation between self-reported risk and the amount of time drivers spent driving while occluded.

Driving simulator.

The study was conducted in the Nottingham Integrated Transport and Environment Simulation facility (NITES) at the University of Nottingham. This medium fidelity simulator (NITES 2) gives a 180 degree view on a five metre screen. The participant is situated within a portable car rig, consisting of a drivers' seat, steering wheel, pedals and gear stick. The simulated roads in this experiment were of real Nottingham roads.

Occlusion goggles.

PLATO (portable liquid-crystal apparatus for tachistoscopic occlusion) goggles were used to block the view of the driver. These goggles are widely used in place of a distracting technology to simulate the amount of time a driver may take their eyes off the road, without having to use specific

technologies such as mobile phones or satellite navigation systems (Pettitt, Burnett, Bayer & Stevens, 2006). In this case, the goggles were controlled by a button situated on the steering wheel of the simulator rig. This allowed for easy access but could not be accidentally pushed. One press occluded the goggles and a further press cleared them.

Mini Driver Behaviour Questionnaire.

This questionnaire is the short version of the Driver Behaviour Questionnaire (DBQ) (Reason et al, 1991; Martinussen, Lajunen, Moller, & Özkan, 2013). This questionnaire consists of nine items on a zero to five scale and aims to measure aberrant driver behaviour e.g. 'deliberately disregarding the speed limits late at night or very early in the morning'. Three items each measure driving violations, driving errors and lapses.

Theory of Planned Behaviour Measures

Attitude towards using technology while driving was measured using theory of planned behaviour guidelines (Ajzen, 1985; Ajzen, 1991). Two direct measures were used to measure attitude and were averaged. These were on a zero to five point scale and asked 'My using a mobile phone while driving in the next month would be' zero 'extremely bad' or five 'extremely good'. The attitude measures were mixed in with the mini DBQ in an attempt to ensure that participants did not recognise these questions when asked again in the intervention study.

Procedure

After fully consenting to the experimental procedure, participants first completed the mini Driver Behaviour Questionnaire, the Risk Orientation Questionnaire (ROQ), a short theory of planned behaviour questionnaire and a Simulator Sickness Questionnaire (SSQ). Participants were then introduced to the occlusion goggles and encouraged to get accustomed to wearing the goggles while occluded. Participants were again reminded that the simulator, especially while wearing the goggles, can induce simulator sickness and any unusual feelings must be reported. Participants were then given a practice drive, a few minutes in length, to get used to the controls of the car. The participant then drove two drives, both the same stretch of Nottingham roads. One drive required the participant to wear the occlusion goggles. Participants were encouraged to occlude as much as possible while maintaining safety. After the experiment participants were debriefed and given compensation for their time. A simulator sickness questionnaire was given at the start of the experiment and once again after every subsequent drive to ensure participants were not feeling any ill effects from the simulation.

Intervention Experiment

Materials & Apparatus

Simulator.

The study was conducted in the high fidelity NITES 1 simulator at the Nottingham Integrated Transport and Environment Simulation facility (NITES) at the University of Nottingham. One stretch of motorway was used for both conditions. Participants were reminded of normal motorway rules.

Theory of Planned Behaviour measures.

Attitude towards using technology while driving was measured using theory of planned behaviour guidelines (Ajzen, 1985; Ajzen, 1991). The two direct measures used to measure attitude in the occlusion experiment were repeated again, on a one to seven scale instead of the first zero to five scale. The first attitude measures in the occlusion experiment were presented with the mini Driver Behaviour Questionnaire and were presented on a five point scale along with the other items. In this experiment, direct measures of attitude were measured alongside other theory of planned behaviour constructs; social norm, perceived behavioural control, intentions and past behaviour and all were presented on a seven point scale. These attitude measures have been presented in such a way i.e. on different scales and part of other questionnaires so as not to alert the participant to the purpose of the experiment. These scores were then averaged and rescaled.

iPhone 5s

An Apple iPhone 5s was used in this experiment to play music for participants in the simulator. The phone was mounted in a holder to the left of the driver on the main console.

Procedure

After fully consenting to the experimental procedure, participants first completed the theory of planned behaviour questionnaire. At this point, participants then rated a list of songs with exactly the same method as the

previous experiments involving music i.e. rating familiar music on a scale of 1 to 10. Participants were then given a practice drive in the simulator while personalised playlists were made. Participants were then encouraged to interact with the iPhone 5s and practise some of the actions that they may have wanted to perform in the simulator. Playlists were made in the same fashion as previous experiments and participants drove in two conditions; easy skip and hard skip conditions. These lasted for six minutes each, on the same stretch of simulated motorway as previous experiments and also contained the 40mph speed restriction in a proportion of the motorway. The easy skip condition again involved only one button press to skip an unwanted song and the hard skip condition again involved entering the '1234' passcode to unlock the phone in order to skip the unwanted song. A simulator sickness questionnaire was given at the start of the experiment and once again after every subsequent drive to ensure participants were not feeling any ill effects from the simulation.

Results

Workload

Average self-reported workload scores increased for every measure in the hard skip condition (see table 5.1). T tests with repeated measures found significant differences between easy and hard skip conditions for mental demand [$t(39) = -4.18$, $p<.001$], physical demand [$t(39) = -3.86$, $p<.001$] and effort [$t(39) = -2.64$, $p = .012$]. Significant differences were not found for performance [$t(39) = -1.76$, $p = .09$], frustration [$t(39) = -1.94$, $p = .06$] or temporal demand [$t(39) = -2.01$, $p = .051$], although the latter was borderline.

Table 5.1
Means (M) and standard deviations (SD) of NASA TLX workload measures for easy and hard skip conditions.

	Easy		Hard	
NASA TLX Measure	M	SD	M	SD
Mental Demand	6.08	4.85	8.15	4.85
Physical Demand	3.2	2.74	4.93	4.00
Temporal Demand	4.93	3.96	5.93	4.33
Performance	6.3	4.65	7.48	4.19
Effort	6.28	4.85	8.08	5.13
Frustration	4.8	4.10	5.88	4.55

Intervention understanding

Participants were given a short 5 item, tick-box questionnaire at the end of the experiment in order to determine whether the experimental debrief following the shutter goggle experiment was read and properly comprehended.

71% of answers on this questionnaire were answered correctly and so it is assumed that debrief information was at least moderately understood.

Theory of Planned Behaviour Measures

Attitude.

Attitude was measured before the shutter goggle experiment (Time 1) and again before the intervention experiment (Time 2) for both control and experimental groups. As attitude measures at each time point were measured on different scales (1-5 at time one/ 1-7 at time two), measures were then rescaled so that they could be directly compared. Scales were shifted to fit a new -5 to +5 scale, with higher numbers indicating more positive attitudes towards device use while driving. Control participants exhibited only slight differences in attitude scores between time one (M = -2.55, SD = 2.95) and time two (M = -2.92, SD = 2.53). Experimental participants' scores were slightly lower than controls, although there was still only a slight difference in scores between time one (M = -3.45, SD = 1.76) and time two (M = -3.33, SD = 1.81). A mixed ANOVA (Group Type [Control/Experimental] x Time [Time 1 x Time 2]) found no main effect of time [$F(1, 38) = .12$, $p = .73$], or interaction between time and experimental condition [$F(1, 38) = .45$, $p = .50$]. In terms of between subject effects, no effect was found for experimental condition [$F(1, 38) = 1.06$, $p = .31$].

Music skips

In total, the control participants skipped 55 times in the easy skip condition (M = 2.75, SD = 2.07) compared to 44 times in the hard skip

condition (M = 2.2, SD = 1.74). Surprisingly, experimental participants skipped 73 times in the easy condition, considerably more than controls (M = 3.65, SD = 1.53). Skips were more comparable in the hard condition with experimental participants skipping an average of 51 times (M = 2.55, SD = 1.28). A mixed ANOVA (Group Type [Control/Experimental] x Skip Level [Easy/Hard]) found a main effect of skip level [$F(1, 38) = 14.62$, $p < .001$]. Post hoc tests using a Bonferroni correction found a significant difference in the number of skips between easy and hard skips ($p < .001$). No interaction was found between skip level and group type [$F(1, 38) = 1.63$, $p = .21$] and no between subject effect of group type was found [$F(1, 38) = 1.66$, $p = .21$].

Music skips were then correlated with global risk orientation scores from the Risk Orientation Questionnaire (ROQ) administered prior to the occlusion goggle experiment. Spearman's rank order correlations were used to determine the relationship between self-reported risk taking and the number of skips on both the easy and hard skip task. No correlation was found between risk and the number of times participants skipped in the easy skip condition [$r_s(38) = -.14$, $p = .40$] and no correlation was found between risk and the number of times participants skipped in the hard skip condition [$r_s(38) = -.098$, $p = .55$].

Correlations were then performed on music skips with violation, error and lapse scores of the mini driver behaviour questionnaire. No correlation was found between the number of easy skips and violations [$r_s(38) = .27$, $p = .098$], errors [$r_s(38) = -.14$, $p = .38$] or lapses [$r_s(38) = .09$, $p = .60$] and no correlation was found between the number of hard skips and violations [$r_s(38) = .21$, $p = .19$], errors [$r_s(38) = -.04$, $p = .81$], or lapses [$r_s(38) = -.07$, $p = .67$].

The correlation between easy skips and violations tended towards significance and so a one-tailed test was used to provide additional understanding of this effect as the direction was the one that would be predicted from most theory. When one-tailed tests were used a significant positive correlation was found between easy skips and violations [$r_s(38) = .27$, $p = .049$] meaning those who scored highly on violations skipped more frequently in the easy skip condition

Driving Simulator Measures

As before, driving simulator measures were split into three zones. The primary differences between the three zones was the speed limit signage on the motorway. Zones one and three showed national speed limit signs (70mph) while zone two showed 40mph signs. Each zone took approximately two minutes to drive through.

All variables were analysed using a mixed ANOVA with condition as a between subjects factor (Music Type [Easy/Hard] x Zone [1/2/3] x Condition [Control/Experimental]). Post hoc tests used the Bonferroni correction.

Mean speed.

Mean speed was similar between easy (62.23mph) and hard conditions (63.25mph). When speed was split between zones, a drop was noticed in zone two (58.62mph) compared with zone one (63.54mph) and zone three (66.05mph).

A significant main effect was found for zone [$F(1.25, 47.66) = 29.09$, $p < .001$]. Pairwise comparisons indicated significant differences between all zones ($p < .001$). A main effect was not found for music type [$F(1, 38) = 2.31$,

$p = .14$] or experimental condition [$F(1, 38) = 1.11$, $p = .32$] and no interactions were found between any variables.

Standard deviation of speed.

Standard deviations of speed were comparable for easy (6.46mph) and hard (6.06mph) conditions. However, differences occur when data are split between zones with zone three (5.08mph) showing less deviation than zone one (6.89mph) and zone two (6.82mph).

No main effects were found for music type [$F(1, 38) = .58$, $p = .45$] or experimental condition [$F(1, 38) = .89$, $p = .35$] and no interactions were found. A main effect was found however for zone [$F(2, 76) = 4.45$, $p = .015$]. Pairwise comparisons found zone one and three ($p = .017$) to be significantly different from one another, while zones two and three were borderline ($p = .055$).

Maximum speed.

Maximum speeds were not dissimilar between easy (72.36mph) and hard (73.10mph) conditions. However, the speed change in zone two did seem to have an effect on maximum speeds at 70.10mph compared to 72.87mph and 75.25mph for zones one and three respectively.

No main effect was found for music type [$F(1, 38) = 1.76$, $p = .19$] or experimental condition [$F(1, 38) = 2.25$, $p = .14$] and no interactions between any variables were found. A main effect of zone was found [$F(2, 76) = 36.62$, $p < .001$]. Pairwise comparisons indicated significant differences between all zones (all at $p < .001$ level).

Percentage of time spent over 70mph.

Zone two was not included for this analysis due to the 40mph speed restriction in this area. Participants showed a greater level of speeding for hard conditions (23.80%) compared to easy conditions (17.69%). To a greater extent, participants spent more time speeding in zone three (26.07%) than they did in zone one (15.42%).

A main effect was found for zone [$F(1, 38) = 28.01$, $p < .001$] meaning that participants spent more time speeding in zone three than zone one. A main effect was also found for music type [$F(1, 38) = 9.85$, $p = .003$] meaning that participants spent more time speeding in the hard condition than the easy condition. No effect was found for experimental condition [$F(1, 38) = .45$, $p = .51$] and no interactions were found.

Acceleration.

Mean values of absolute acceleration were very similar for easy (0.43) and hard (0.41) conditions. Acceleration did appear to change in relation to zone however, with zone two experiencing the highest acceleration (0.51) compared to zone one (0.41) and three (0.34).

No effects were found for music type [$F(1, 38) = .77$, $p = .39$], experimental condition [$F(1, 38) = 1.79$, $p = .19$] and no interactions were found. A main effect was found for zone [$F(1.46, 55.34) = 24.513$, $p < .001$]. Pairwise comparisons found all zones to be significantly different from one another in terms of acceleration (all $p < .01$).

Steering wheel angle.

Standard deviation of steering wheel angle was largely similar across zones and music types, ranging from 2.82 to 3.29. No main effects were found for zone [$F(2, 76) = 1.74$, $p = .24$], music type [$F(1, 38) = .76$, $p = .39$] or experimental condition [$F(1, 38) = .97$, $p = .33$]. No interactions were found between any variables.

Standard deviation of lane position.

SDLP was almost identical for easy (0.95) and hard (0.96) conditions. However, lane standard deviation of lane position was vastly different between zone two (0.47) and zones one (1.13) and three (1.26).

Again, no effects were found for music type [$F(1, 38) = .19$, $p = .66$], or experimental condition [$F(1, 38) = .25$, $p = .62$] and no interactions were found. A main effect was found for zone [$F(2, 76) = 412.54$, $p < .001$]. Pairwise comparisons found significant differences between all zones (all $p < .001$).

Mean fixation duration.

Eight participants were removed from eye tracking analysis due to incomplete or missing data. Data were removed across conditions and so conditions remained equal, however, this removal may have affected statistical power.

There looked to be differences between easy (824.35ms) and hard (903.21ms) conditions, although no main effect was found for music type [$F(1, 30) = .738$, $p = .40$]. Zone two appeared to produce longer fixation durations

(896.36ms) than zone one (845.31ms) and zone three (849.68ms), although no main effect of zone was found [$F(1.65, 49.39) = .41$, $p = .63$]. No effect of experimental condition was found [$F(1, 30) = 2.33$, $p = .14$] and no interactions were found between any variables.

DISCUSSION

Summary of findings

Workload measures for mental demand, physical demand and effort increased significantly in the hard skip condition compared to easy skips. No differences were found in attitude scores between time one and time two and no differences were found between experimental participants and controls. No differences in the number of skips were found between easy and hard skips and no differences in the number of skips were found between experimental participants and controls.

While most correlations were not significant, a significant correlation was found between the number of easy skips and scores on violation measures of the mini driver behaviour questionnaire, with higher scores on violation correlating with higher numbers of music skips. This is especially interesting as the number of easy skips did not correlate with errors or lapses, suggesting that the questionnaire was effective in measuring driving violations.

In terms of driving simulator measures, no differences were found between easy and hard conditions with the exception of the percentage of time spent over the speed limit where participants spent a larger amount of time speeding in the hard skip condition compared to the easy skip condition. Main

effects were found for zone for all variables apart from steering wheel angle and fixation durations. These differences in zone serve to show how drivers responded to the speed change in zone two of each condition. Finally, experimental condition had no effect on any of the driving simulator measures, suggesting the intervention had no effect on eventual driving behaviour.

Relation to simulator studies

Previous studies have often found that when participants experience an increase in workload, they will compensate by increasing headway and lowering speed. However, this study showed that participants in the hard skip condition spent a larger amount of time speeding than the easy condition despite workload scores being significantly higher. This could possibly be explained by the increase in the amount of time spent looking at the MP3 player in that, as a harder task, skipping music required more time and so less time was spent on maintaining speed (Reed & Green, 1999).

The correlation found between easy skips and violations is interesting as it seems to show a correlation between the deliberate action of interacting with the device and other deliberate violations such as 'deliberately disregarding speed limits', 'getting into unofficial races with other cars' and 'driving close or flashing another driver'. This is interesting as errors and lapses are accidental behaviours and misjudgements which did not correlate with any other measure. This shows support for the mini driver behaviour questionnaire as an accurate tool. However, it is unclear as to why this correlation was not found for the number of hard skips.

Success of intervention

No change in attitudes were found between participants. Although attitudes have been successfully changed for speeding behaviour (Stead et al, 2005), no published study has used a theory of planned behaviour intervention for mobile phone use and so it is unclear whether this is an appropriate method for discouraging behaviour. However, fear appeals have been utilised to no success (Lennon, Rentfro & O'Leary, 2010). Skipping behaviour was also used in this study as a measure for intervention efficacy. Experimental condition had no effect on skipping behaviour and so we must conclude that the intervention had no effect on attitudes, nor a direct effect on behaviour.

The fact that attitudes were already quite negative towards mobile phone use at the beginning of the study may have been why attitudes did not see much change. Guidelines on creating an attitude intervention posit that there must be room for change for an intervention to be successful (Ajzen, 2006). However, it could be argued that participants in this experiment had attitudes that did not translate to behaviour as participants skipping behaviour was very frequent. In addition, the fact that control condition participants also took part in the occlusion goggle experiment could have been a factor as to why no behavioural differences were found. The occlusion goggle study may have highlighted the need for vision while driving and so drivers were more careful, or had the opposite effect, in that participants may have successfully driven while blind and so felt more confident driving using an MP3 player.

Limitations

A perfect comparison between attitude measures cannot be made due to the different scales used. However, this was necessary in ensuring that participants did not relate the first occlusion goggle experiment to the intervention in any way. Additionally, other measures such as perceived behavioural control, subjective norms and intentions were not measured again at time two, therefore we do not know if the intervention affected any of these variables, although it is unlikely.

Conclusions

We were unable to manipulate drivers' attitudes in this study, however the reason for this may have been that drivers' attitudes towards mobile phone use were already quite low. Participants did not believe that driving using a mobile phone was a good idea and did not report engaging in the behaviour often. Therefore, it was difficult to decrease these feelings even further.

The main advantage of this experiment was that any change in attitudes could have manifested in behaviour changes in the driving simulator skipping experiment. However, low participant numbers meant the study suffered from a lack of power.

GENERAL DISCUSSION

This thesis has attempted to better understand what influences drivers in choosing to engage in technology while driving and to analyse what effects this behaviour has on driver performance. Theory of planned behaviour measures for each of the five questionnaire studies broadly support past research in that intentions are highly predictive of past behaviour, while in most cases, attitudes are highly predictive of intentions. The risk monitor tasks gave an insight into how technology might be useful while driving and though no actual driving effects were found, heart rates suggested participants were affected by risk information. The music skipping tasks were novel in giving participants a choice to interact with a device, much like real driving. Video coding was able to look at the specific events in which proper driving was compromised. The combination of the risk monitor and music skipping task then sought to identify whether risk information could reduce interaction with a distracting device.

Summary of results

The questionnaire study suggested up to a third of drivers would use two technologies at once while driving, while most do not approve of any technology use. Though questionnaires were based on different technologies, attitudes were found to be large predictors for all intentions. A distinction was made also between hand-held and hands-free mobile phone use in that all measures of attitudes, subjective norms, control and intentions were higher for hands-free mobile phone use. It is a positive indicator that laws and penalties

against hand-held mobile phone use are reflected in these views. These results fit broadly with existing literature on mobile phone use but also expand current knowledge with the addition of MP3 players and satellite navigation systems.

The major limitation of this study was that the majority of drivers who partake in technology use while driving are young, much younger than the mean age of participants in this study. Moreover, the respondents in these questionnaires reported little use while driving which is also incongruent with younger drivers. Therefore it is misrepresentative of the target population and perhaps underplays potential findings of a younger population. The reason for this was that students at the University of Nottingham were deterred by the length of the questionnaire, which meant that paid respondents were necessary to boost numbers. Future studies could target a larger, younger, non-student population in order to increase the power of the analysis and elicit the opinions of those who are more likely to use technology while driving.

Studies two and two point five were conducted to investigate how an in-car information system may help or hinder a driver. Behavioural adaptation theories here suggested that in response to a low risk situation, participants may increase their sense of risk by increasing their speed. No such effects were present here, however, the risk monitor was able to provoke a change in risk on a physiological level. This is encouraging as it seems to suggest that feelings of risk can be manipulated in an artificial setting, which is extremely positive when considering the ecological validity of simulator research.

While it is excellent that the risk monitor affected the physiology of participants, it may be unrealistic to suggest a similar device in the real world. The major problem with most warning/safety systems is that the participant

will either become immune to its effects, decide to turn off the feature or even become reliant upon it. Automatic braking systems introduced in new vehicles have created a system whereby the braking is sharp and jerks the driver in order to make the experience unpleasant (Thatcham Research Centre, 2016). This in an effort to dissuade the driver from relying on the car to brake. Regarding the risk monitor, there is the potential that drivers will become compliant on low risk roads. If this were to be implemented in vehicle, it may be safer to include only very high risk roads to ensure that the driver does not become annoyed by the device or become immune to its warnings.

Studies three and four adopted a novel design to investigate the potentially distracting effects of MP3 player use and music while driving. These studies were unique in that participants were not asked to interact with the device, only that they could if they wanted to. This gave an insight into natural behaviour. Speed and lane deviations were found to differ while interacting with the device while glance durations were much longer during music skipping. Previous research has suggested that tempo is the most significant factor which affects driver performance. This may be the reason why pleasant and unpleasant music had no effect on driver performance as tempos between these did not differ. However, this study was successful in examining the spontaneous use of technology while driving and through video coding, was able to observe exactly what happens during these interaction events.

Often, simulator studies will require participants to do a number of tasks whilst driving and so it is not remarkable that their performance suffers for it. In this study, the aim was to make the environment as close to real

driving as possible and that meant the secondary task had to be voluntary. Every experiment runs the risk of producing demand characteristics, however, the fact that some participants skipped music a lot and some did not skip music at all leads to the tentative conclusion that this could be an insight into how the participant would behave normally. To be confident in this conclusion, further studies would have to be conducted with the same participants, perhaps using diary entries to log when and how often these participants behaved in a similar way in their own vehicles.

Study five combined the music skipping study with the risk monitor to determine whether the use of a distracting technology could be influenced by the use of a technology meant to aid the driver. Results found significantly more music skips on low risk roads compared to high risk roads. With no interaction with the presence of the risk tone, we may conclude that differences in skipping behaviour were due to inherent differences in these road types, rather than the risk level. However, further analysis found that participants spent more time listening to music they found unpleasant when the tone was present which indicated that the tone deterred them from interacting with the device.

There was the potential for demand characteristics to become a problem in this study in that participants were fully aware of the research and may have wanted to please the researcher. However, skipping behaviour showed that the tone had no effect which would suggest that participants were not modifying their behaviour.

Study six aimed to modify attitudes on mobile phone use by creating a design where participants did not know the true meaning of the study. The

concern with intervention studies is that participants are aware or can guess the aims and so there is always the risk that significant results are due to demand characteristics. Considerable effort was made in this study to ensure that participants were not aware of the intervention by inserting the intervention materials into a debrief of a seemingly unrelated experiment. However, no effects were found in attitude measures or in music skipping behaviour, although the study suffered from lack of power.

Despite the intervention not being successful in changing attitudes, the method remains a useful one in that behaviour was directly measured after the intervention in the form of the music skipping experiment. This avoids having to rely on self-report measures which are open to bias.

These studies contribute to the field of driver safety by presenting natural experiments where drivers are observed interacting with technology in the controlled environment of the simulator. In addition, the surveys presented show support for the theory of planned behaviour for use with other technologies, not just mobile phone use which past research has tended to focus on. The heart rate findings from the risk monitor experiments have also highlighted how it is possible for participants to feel a sense of reality in a simulated environment which adds support for the use of simulators in driving research.

Implications

The results from these studies have wide ranging implications. Firstly, for the everyday driver, these simulator results highlight the distracting effects of engaging with technology while driving in a natural situation. In this type

of experiment, drivers have presumably assessed the situation and deemed the road safe enough to proceed with the skipping task. However, results show that despite participants' best efforts, their driving performance was still impaired.

Policy makers may use the results from the questionnaires to inform initiatives aimed at changing behaviour. For example, attitudes were the most important predictor of intentions for most technologies and so interventions aimed at changing attitudes may be beneficial. Simulator studies such as these also serve to highlight the potential dangers that drivers face when engaging with secondary devices. Although accidents may not always occur, the use of these devices certainly decreases safety margins and so the use of these, hands-free or not, must be questioned. However, the recent law change in the UK has begun to take this problem more seriously by increasing penalties associated with mobile phone use.

In terms of the technology itself, the easy and hard skip tasks emphasise the importance of manufacturing devices to be as easy to use as possible. Easy and hard tasks differed in terms of driving performance on a variety of measures, perhaps the most important of which was glance duration away from the road. Difficult to use technology has the potential to distract drivers for a significant amount of time and thus impact on safety.

The impacts of these types of experiments may be short lived in that vehicle manufacturers are increasingly leaning towards autonomous designs. In a world where cars drive themselves, drivers may be able to read a book or check their emails. However, focus then shifts towards how capable drivers

are in switching attention and taking over manual control when the system fails. In this sense, driver distraction is still an important field of research.

General Limitations

Technology is constantly being upgraded and invented meaning that the technologies used in this experiment may not be relevant in years to come. However, the distracting effects of a secondary task will always be applicable to new devices. Car companies are making great strides in integrating our favourite technologies in-vehicle meaning that those who would not be inclined to use these on separate devices may be persuaded to use these in the 'safety' of their integrated vehicle. This creates increasing avenues of research into how new and built-in devices may affect driver performance.

The main drawback to using a simulator is the lack of ecological validity. However, the NITES 1 simulator is extremely high fidelity and so participants felt completely immersed into the virtual environment. This coupled with the simulated Nottingham city environment has allowed participants to drive around their home town which authenticated the experience further. However, simulator sickness is another large problem which hampered data collection massively in studies involving lots of 90º turns. 50% of participants were lost in these studies compared to around 20% loss in studies using motorways with no turns. This has implications for potential government initiatives which aim to train non-drivers off the road, or even retrain specialist police drivers. These may not be cost effective if half of drivers are unable to complete training.

Future directions

Future directions may introduce hazards into the simulator experiments in order to test whether the increased heart rates aided response times and whether technology hindered these even when the interaction is voluntary. Further aims may attempt to reproduce the effects found in simulator experiments by testing in an instrumented vehicle. While it would be illegal for participants to interact with a mobile phone on real roads, a test track may offer more ecological validity than a simulator.

Demanding participants perform secondary tasks while driving is important as it gives us an insight into how accidents may occur. However, offering participants the option of interaction with the iPhone gives the results a certain credence in that a sort of natural behaviour may be observed. A wealth of literature exists on the various dangers of technology use and therefore future studies must seek to determine how participants might behave in their natural environments. Participants are often told when and how to use devices in simulators, but on the real road, how do drivers determine when it is safe to do so and more importantly, when accidents do happen, where does the failure occur?

Furthermore, work is needed to produce cost effective, implementable interventions in order to reduce the prevalence of technology use on UK roads. Historically, governments have relied on policy change and fear strategies to influence behaviour change to limited success. Targeted interventions aimed at challenging specific beliefs may influence those who have been immune to previous attempts.

General conclusions

The aims of the thesis were to (1) understand the salient beliefs behind intentions and use of technology while driving, (2) to investigate whether technology could improve driver performance, (3) to observe participants' engagement with devices in as natural setting as possible, (4) to determine whether feelings of risk may affect the use of technology and (5) to pilot an intervention based on the theory of planned behaviour.

Together, the results of the thesis fulfil these aims in the following ways:

- The questionnaires implemented in study one have supported previous research regarding mobile phones and built upon this with the introduction of satellite navigation systems and MP3 players. It has become abundantly clear that the attitudes of a driver play a crucial role in their intentions to engage with technology.
- Studies two and two point five showed that while participants' driving behaviour did not change, they were physiologically susceptible to information about risk. This is a significant finding for simulator researchers as being able to induce risk in a simulated environment goes some way in validating the use of simulators in research.
- Studies three and four showed that observing natural behaviour is possible within a simulated environment. The novel use of music in this scenario replicated reality and gave participants the choice to interact with the device. Data showed that driver performance was impaired while skipping music despite the best efforts of the driver in choosing an appropriate time to skip.

- Study five merged the risk monitor experiment with the music skipping task and found that while driver performance measures were not affected, participants were less willing to engage with technology while the risk tone was present, illustrated by a longer amount of time listening to unpleasant music. In addition, drivers skipped less on high risk roads, independent of the risk tone. This is a positive indication that drivers are able to assess risk and act appropriately, in this case refraining on engaging with the device while on high risk roads.
- Study six implemented another novel design to improve on previous literature. Often intervention studies are criticised as they fail to measure actual behaviour and rely upon questionnaire responses. Study six used the same music skipping task to determine whether an intervention could reduce skipping behaviour in a simulated environment. No reduction in skipping behaviour was found for the intervention group, however, future studies may improve upon this task to influence attitude change.

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