E-mails on the Move: Do Performance Objectives Influence Modality Choice Whilst Driving?

Samantha Davies

Project report submitted in part fulfilment of the requirements for the degree of Master of Science (Human-Computer Interaction with Ergonomics) in the Faculty of Life Sciences, University College London, 2010

ACKNOWLEDGMENTS

Various people have contributed to the completion of this project. I would particularly like to thank my supervisors Duncan Brumby and Chris Janssen for their guidance, input and support throughout the project period. Special thanks to Chris Janssen and Justin Grace for their patience and generous time spent coding the program for the driving simulator – the investigation could not have happened without your help.

I would also like to thank all my friends and colleagues who volunteered to participate in the study, especially those who found time in their busy working schedules. My gratitude also extends to Nick Curzon for his encouragement and active interest in discussing the various stages of the project all hours of the day. A number of the narratives used in the materials were inspired and suggested by him. Finally, I would like to thank my parents for their unrelenting confidence and magnanimity - their support has been indirectly influential in my decision to start the MSc.

ABSTRACT

It has been shown that the choices people make are influenced by a number of factors and that these choices will vary in intuitively rational ways to maximise success rate. But how will these findings apply to a safety-critical dual-task situation, such as driving and reading an e-mail? An empirical study was conducted to investigate how people choose between multiple interaction output modalities offered by a device when driving under different task objectives. Participants either prioritized safe driving or fast searching on an e-mail target searching task. The searching task involved finding a target answer to a predefined question in a piece of narrative presented via a visual display or aurally. A choice/no choice paradigm was used to explore how people would choose between modalities after having utilized each beforehand. The main result of this study found that performance objectives influenced participants' modality choice in a rational manner, so that the chosen modality was most likely to aid them in achieving their objectives. The findings suggest that people are sensitive to time/accuracy trade-offs whilst driving and will make decisions that aid them to meet explicit goals whilst minimizing effort. These results highlight the need for designers of information-heavy in-car systems, such as e-mail, to consider the motivations of drivers, as poor aural modality efficiency might compel drivers to seek the information visually and take more risks whilst driving.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

With technology becoming increasingly ubiquitous, multitasking has become the norm of everyday life. For example, amongst young adults 29% of computer activity is simultaneous, whereby a phone call is made whilst surfing the internet for example (Ofcom, 2010). The time-saving opportunities that computers provide extend to the car, where drivers frequently choose to perform a variety of other tasks, such as using their mobile phones for calling, texting or even going online (Jamson, Westerman, Hockey & Carsten, 2004). Indeed, recent surveys have found that 46% of drivers 16 to 19 regularly text while driving (AAA, 2007).

There is a vast body of research highlighting the numerous dangers associated with using devices such as mobile phones and messaging systems whilst driving (e.g. Alm & Nilsson, 1994, 1995; Bellinger, Budde, Machida, Richardson & Ber, 2009; Caird, Willness, Steel & Scialfa, 2008; Cooper, Zheng, Richard, Vavrik, Heinrichs & Sigmund, 2003; Consiglio, Driscoll, Witte & Berg, 2003; Drews, Pasupathi & Strayer, 2008; Horberry, Anderson, Regan Triggs & Brown, 2006; Horrey & Lesch, 2009; Horrey, Lesch & Garabet, 2008; Horrey & Wickens, 2006; Iqbal, Ju & Horvitz, 2010; Jamson, et al, 2004; Lee, Caven, Haake, Brown, 2001; Lesch & Hancock, 2004; Maciej & Vollrath, 2009; Patten, Kircher, Ostlund & Nilsson, 2004; Strayer & Johnston, 2001). Despite this, vehicle manufacturers have announced the introduction of e-mail systems and internet browsing features in mass production cars such as Ford and Fiat (Tashev, Seltzer & Ju, 2009).

Previous research has explored the effects of various system input methods on driving performance, such as manual and speech-based interaction (e.g. Graham & Carter, 2000; Jamson et al, 2004; Ju & Paek, 2009; Kun, Paek & Medenuca, 2007; Lee et al, 2001; Maciej & Vollrath, 2009; McCallum, Campbell, Richman & Brown, 2004). A few studies have investigated how different output modality might impact driver safety (Liu, 2001; Sodnik, Dicke, Tomazic & Billinghurst, 2008; Zhao, Brumby, Chignell, Salvucci & Zhou, submitted) but these are limited to satellite navigation, mobile phone and music player interfaces. As e-mail systems may be introduced in everyday cars, a deeper understanding of the cognitive demands attributed to using different information modalities for presenting an extended amount of information appears necessary.

Aural properties are commonly found in most popular devices such as mobile phones or personal computers, but information is generally presented visually. Research suggests that people usually prefer having information presented aurally when driving as it does not take the eyes off the road (e.g. Graham & Carter, 2000; Liu, 2001; Sodnik et al, 2008; Zhao et al, submitted). However, auditory information has a reputation for being slow and users can encounter comprehension difficulties when listening to synthesized speech (Lai, Cheng, Green & Tsimhoni, 2001; Lai, Wood & Considine, 2008; Tsimhoni, Green & Lai, 2001). This might suggest that people would not use it when time is important

It has been shown that people are highly sensitive to time cost of interaction and will tolerate a decrease in performance in favour of saving time (Gray & Boehm-Davis, 2000; Gray & Fu, 2004). Furthermore, people adopt strategies and choose methods that will best aid them in meeting their objective (Brumby, Howes & Salvucci, 2007; Brumby, Rosario & Janssen, 2010; Brumby, Salvucci & Howes, 2009; Gopher, 1993; Janssen & Brumby, in press). In a safety-critical situation, such as driving, how do people choose between multiple interaction modalities offered by a device, and how is that choice affected by the driver's objective?

Consider the scenario of someone searching for the name of a restaurant in an e-mail whilst driving. Given the choice, how will the person decide how they would prefer the information to be represented? In this safety-critical setting, the driver must now consider the risks and benefits of using different modalities. For example, reading the e-mail from a display would require the person to take their eyes off the road and shift visual attention away from the task of driving to the task of reading the e-mail. Alternatively, a software program could read out the information. Although this allows the driver to allocate all their visual attention to the road, using the audio modality might be slower and difficult to understand (Lai et al, 2001). If the person is a safe driver, this may not be of importance, but if the driver is under time pressure, using a slower modality might not be an option.

In this dissertation, we will be exploring how people might choose between using audio and visual modalities whilst driving under varying task objectives, and inferring recommendations for safer in-car e-mail systems. The structure of the dissertation is as follows: Chapter 2 reviews relevant literature to driver distraction and theories surrounding human attention and the use of different modalities. Hypotheses regarding decision making and choices are also considered. Chapter 3 presents an experiment in which participants are asked to complete a lane-keeping task in a driving simulator while completing a target searching task. The target searching task involves locating the answer to a predefined question in a piece of narrative presented either visually or aurally. Participants are either instructed to prioritise the driving-task or the searching-task. The experiment used a choice/no choice paradigm (Duggan, Howes, Kalidindi, Lewis, & Tseng, in prep.; Siegler & Lemaire, 1997) to investigate how people make choices based on experience and under varying task objectives. It has been shown that people vary their choices in intuitively rational ways to maximise success rate (Janssen, Brumby, Dowell, Chater, 2010) so it was predicted that participants would choose the modality that allowed them to produce the best results for their assigned priority: participants with a safe driving focus would choose the audio modality more frequently than the visual modality and the opposite would hold for participants focusing on the searching task.

Finally, Chapter 4 interprets the findings with reference to previous research and draws out implications for modality preference and the design of safe interfaces in a dual-task environment. Limitations of the study and future directions are also discussed. This dissertation adds to current understandings of how people choose between multiple methods for completing a task on a computing device.

LITERATURE REVIEW

The aim of this literature review is to provide context to the investigation into behaviours and choices adopted in a multi-modal driving situation. This chapter will begin by describing current understandings of attention allocation in multitasking environments, and the influence of the nature of the tasks. Next, the use of different input and output modalities in dual-task situations will be discussed, drawing on theories regarding the use of multiple resources and cognitive models. The rest of the chapter will consider how people make choices and how these can be influenced by numerous factors such as performance objectives and personal preferences.

Multitasking and interference between tasks

A plethora of studies have investigated the effects of using attention-demanding devices whilst driving. Initially, it was suggested that the physical interaction with mobile phones or radios was the primary culprit for impaired reaction times and situational awareness (e.g. Brookhuis, De Vries & De Waard, 1991; McKnight & McKnight, 1993), but further studies since have indicated that driver distraction is not limited to the handling of devices (e.g. Horrey & Wickens, 2006; Salvucci & Beltowska, 2008). It has been shown that the simple act of having a hands-free telephone conversation impacts lane-keeping performance and compels drivers to adopt compensation mechanisms, such as slowing down (e.g. Alm & Nilsson, 1994; Drews et al, 2008) as well as significantly reducing reaction times to events such as red lights or sudden braking lead vehicles (e.g. Bellinger et al, 2009; Caird et al, 2008; Iqbal et al, 2010; Patten et al, 2004; McKnight & McKnight, 1993). It would appear that the cognitive demands of attention sharing between driving and speaking are limited and lead to a performance detriment in either activity.

In order to better understand the cognitive demands of the various separate aspects associated with having a telephone conversation in dual-task situations, Strayer & Johnston (2001) conducted a series of experiments investigating the effects of listening, assimilating, shadowing and generating words whilst completing a pursuit tracking task. Reaction times and errors were most significant for participants having a telephone conversation and those required to generate new words. Driving performance was not affected by listening to the radio, a book-on-tape or in the speech shadowing group. These findings imply that attending to auditory inputs requires less cognitive processing than generating new words. However, as the experiment was not performed on a driving simulator and was limited to measuring reaction times, applicability of the findings can be questioned.

In a follow-up study, Iqbal, Ju & Horvitz (2010) conducted a similar methodology to Strayer & Johnston (2001), using a highly realistic driving simulator but did not find that assimilating information from a book-on-tape negatively impacted collision rate and reaction time. Routes of varying difficulty where used and participants were interrupted with a number of telephone calls which would require either assimilation of a news headline, a retrieval response for a fact, or a more complex word generation task asking participants to provide directions between two points of interest.

This is consistent with results reported by Just, Keller and Cynkar (2008) who claim that a language comprehension task negatively impacts driving ability. Participants were required to listen to spoken sentences that they judged on-the-spot as true or false whilst performing a lane-keeping task in a driving simulator. As well as degradation in driving performance, a decrease in parietal lobe activation when listening to the sentences was noted. This implies that in a dual-task situation where verbal assimilation is involved, language comprehension draws mental resources from the primary task, producing deterioration in performance.

However, results from other studies contradict the findings by Iqbal et al (2010) and Just et al (2008) in that there is no interference from listening on a primary task in dual-task situations. In a series of experiments investigating concurrent multitasking, Borst, Taatgen & Van Rijn (2010) found that a listening comprehension task had very little influence on simultaneously performed text entry and subtraction tasks. These findings conform to results from a study by Kunar, Carter, Cohen & Horowitz (2008) who found that reaction times and accuracy was no different when listening to a book-on-tape when compared to baseline data. Participants completed a multiple object tracking paradigm whilst carefully listening to a narrative from a book-on-tape. Multiple-choice questions were asked after the trial to test aural attention.

Discrepancies in the literature could be justified by the set-ups of the experiments. Studies which found that listening had no effect on the secondary task performance did not use driving simulators (e.g. Borst et al, 2010; Kunar et al, 2008; Strayer & Johnson, 2001). However, other studies using driving simulators have also reported that listening to audio messages does not have a detrimental effect on driving performance (e.g. Recarte & Nunes, 2003; Tsimhoni, Green, Lai, 2001).

For examples, Recarte & Nunes (2003) investigated the effects of mental workload on visual search and decision making in simulated traffic conditions and found that attending to incoming verbal information did not affect visual behaviour, detection, or decision-making processes. The secondary tasks involved a series of verbal abstract tasks, the first of which required participants to carefully listen to an audio message for two minutes and try to remember the content for the following task.

Research investigating the effects of listening on a primary task seems to be inconsistent across findings. One explanation for these variances might be the nature of the tasks. Bargh (1997) suggests that multiple habitual processes, or 'automatised tasks', can occur simultaneously, involving minimal conscious control. It has been shown that for automatised tasks like driving, it may be possible to formulate strategies to perform other side tasks without significantly compromising driving ability (Brumby et al, 2007; Brumby, Salvucci, Mankowski & Howes, 2007). For example, listening to music does not have a detrimental effect on driving performance (Bellinger et al, 2009), whereas a memory-rehearsal task does

(Salvucci & Beltowska, 2008). Furthermore, the detriment in performance might manifest itself differently depending on the variables measured (Cooper et al, 2003). This implies that successful multitasking might be sensitive to the complexity and cognitive demands of both the primary driving task as well as the secondary task (Cooper et al, 2003; Lee et al, 2001; Patten et al, 2004; Recarte & Nunes, 2003; Tsimhoni et al, 2001).

Research seems to agree that visually demanding tasks and those commanding generation of speech are detrimental to driving performance. However there seems to be controversy regarding the cognitive demands associated with careful listening and its effects on driving performance. In the current experiment, participants were required to locate and identify a target whilst driving by either reading or listening to a narrative. Due to the discrepancies in the literature regarding the effects of listening on driving performance, expected outcome against baseline is uncertain. Different theories have been proposed in an attempt to explain why interference between tasks occurs in some multitasking situations but not others. Of particular interest to the current experiment are those concerned with the use of various modalities.

Multiple resource interfaces and driving

The work discussed in the previous section has illustrated how influential the secondary task can be in effects seen on driving performance: the more cognitively demanding the secondary task is, the more the primary task will bear a detrimental performance. In this section, the use of different modalities for information input and output whilst driving will be discussed. The examples will be cast within the Multiple Resource Theory of cognition (Wickens, 2002; Wickens, 2008) and the threaded cognition theory (Salvucci & Taatgen, 2008).

The Multiple Resources Theory (Wickens, 2002; Wickens, 2008) suggests that dual-task interference occurs if two tasks performed concurrently compete for similar cognitive, perceptual or motor resources. Furthermore, the theory proposes that there will be less interference between two concurrent tasks if different resources are utilised by each one. Take, for example a driving situation where visual attention is focused on the road. Now imagine the driver wants to read an e-mail that they have just received on the in-car system. They can either read from the display interface, shifting their visual attention from the road to the device, or they can use the aural modality to read out the information. The Multiple Resources Theory would predict that there would be less interference between the driving task and listening to the e-mail than if the driver were to look at the display to read it.

Sodnik, Dicke, Tomazic & Billinghurt (2008) conducted a study comparing the use of auditory and visual mobile phone interfaces in a driving simulator. Participants completed five different tasks on the mobile phone: writing a text message, changing the active profile of the device, making a phone call, deleting an image and playing a song. The visual menu used a secondary display, and the auditory information was provided via a network of speakers distributed around the participant. Driving performance significantly deteriorated for all tasks when using the visual display versus baseline driving. Use of the audio interface was also significantly safer than the visual interface. Unfortunately, driving performance was evaluated using video recordings of the participants driving and assessed using a points system which might be sensitive to subjective interpretation. In a study comparing separate visual and auditory in-car traveller information systems, Liu (2001) also found that using the audio display produced more correct responses and fewer major lane deviations than the visual display. Unfortunately, baseline data was not captured as to investigate the effects of audio information solely on driving performance.

As well as exploring output modalities, research has investigated input modalities. Being both hands-free and eyes-free, speech recognition interfaces have numerous potential advantages in a driving context, thus research has examined the effects of in-car speech-based systems. Speech-input interfaces have been found to be safer than visual and manual-input interfaces (Graham & Carter, 2000; Maciej & Vollrath, 2009; McCallum et al., 2004; Ranney, Harbluk & Noy, 2005). However, it has been found that verbal communication with in-car devices may not be as safe as expected. Voice-based interaction with in-vehicle computer systems whilst driving has been associated with a 30% increase in reaction time against baseline (Lee et al., 2001), significant attention impairment (Jamson et al, 2004; Ranney et al, 2005) and increased headway with lead vehicles, indicating a compensatory mechanism (Jamson et al., 2004). As separate resources are utilised, these findings suggest a constraint on cognitive resources at a central level.

Research has suggested that verbal generation impairs sustained visual attention due to a limit on attention resources, resulting in a cognitive bottleneck (Kunar et al, 2008; Strayer & Johnston, 2001). Building on the Multiple Resources Theory (Wickens, 2002; Wickens, 2008) is the threaded cognition hypothesis (Salvucci & Taatgen, 2008). Threaded cognition is a theory of human multitasking that postulates that behaviour can be characterised as a combination of parallel and sequential processes. Each task is represented by an independent cognitive thread which has its own control structure. All threads are processed together on a single processor which can only execute one thread at a time. This will inherently create a bottleneck when multiple threads require attention from the central processor. Additional interference can also arise when multiple threads require the same peripheral resource (e.g. if two tasks both require vision).

The research which has been discussed regarding verbal generation and speech-input systems whilst driving supports the concept of a central bottleneck. However, the literature surrounding the effects of listening whilst driving remains ambiguous. Many studies have investigated speech-input systems and the potential effects on driver distraction, but few have explored the use of an aural in-car system. Most existing research regarding the cognitive demands of visual versus auditory systems whilst driving has been limited to feedback (e.g. Zhao et al., submitted), providing simple directions (e.g. Liu, 2001) or involving further input actions from the participant (e.g. Sodnik et al, 2008).

However, Tsimhoni et al (2001) found that listening to messages of varying content, length and voice type did not negatively impact driving performance. The auditory information was presented as four-second navigation messages, 40-second e-mail messages or 80-second news headlines. Driving performance was measured by the steering wheel angle, the number of lane excursions and lateral lane position. Unfortunately, as the research was primarily aimed at investigating the effects of natural and synthesized voice comprehension whilst driving, the authors did not test for a visual display as to compare the results.

In this experiment, the situation where a driver receives an e-mail will be recreated. The information will be presented to the driver using either a visual or auditory modality and they must find a target answer in the narrative. Based on the Multiple Resources Theory (Wickens, 2002; 2008) it is expected that there will be a decline in driving performance when the visual display is used. Due to disparities in previous research findings, it is uncertain whether using the audio modality will significantly impair driving ability against baseline data.

Drivers may have more difficulty in filtering and remembering useful information by an auditory display due to the demands on short-term memory, adding a supplementary load on cognitive resources (Graham & Carter, 2000; Liu, 2001). Therefore it is expected that more errors - such as giving an incorrect response or forgetting the question - will occur when participants use the aural modality. But will the added cognitive load associated from using the different modalities have an influence on the choices participants make whilst interacting with the driving simulator? Although this investigation is concerned with elucidating the effects of different modalities on driving performance, it is principally interested in understanding what factors are involved when drivers are given a choice of modality to present information. More specifically, will performance objectives directly impact the choice of output modality whilst driving?

Decision-making

The work discussed in the previous section has illustrated that the type of modality used for information input and output whilst driving will determine the extent to which performance is affected. That is, eyes-free systems are safer than visual displays. However, existing studies have not explored which modality drivers will choose given the option and with a set goal in mind.

The question regarding how people make choices in their problem solving strategies is central to psychological research and various theories proffer explanations regarding the process by which users measure and compare costs between options. Many different hypotheses have been proposed, and formal models of human problem solving propose the existence of a strategy selection phase (e.g. Klein & Yadav, 1989; Lovett & Schunn, 1999; Payne, Bettman & Johnson, 1988). Within this strategy selection phase, different factors have been suggested which impact the choices people may make.

It has been suggested that strategy selection can be explained within a cost-benefit framework which assumes that choices will be selected as a function of the accuracy they will provide and the effort or mental resources required (Payne, Howes & Reader, 2001; Payne, Johnson, Bettman & Coupey, 1990). Research has shown that users choose to minimise the use of short-term memory in problem-solving tasks (e.g Ballard, Hayhoe & Peltz, 1995; Schunn & Reder, 2001). However, in another study refining the work of Ballard et al (1995), Gray, Sims, Fu & Schoelles (2006), rejected this hypothesis by suggesting that people select strategies based on a temporal cost-benefit trade-off. Further research found that people are affected by the temporal costs of interactions to the effect of milliseconds, and will tolerate a decrease in performance in favour of saving time (Gray & Boehm-Davis, 2000; Gray & Fu, 2004). Although the current experiment will not be examining second by second interactions, these findings are of interest as they might explain a decision-making process when participants are time-sensitive.

When executing complex tasks in real-world situations, users' behaviour and strategy choices are not simply aimed at reducing memory load or completion time. The goal or purpose of the task may also motivate how a task is addressed and influences strategies selected (Brumby et al, 2007; Eng, Lewes, Tollinger, Chu, Howes & Vera, 2006; Janssen & Brumby, in press.). In a concurrent multitasking situation where more than one task has to be completed, each task may hold a different purpose. Limits on cognitive processing will dictate the amount of tasks that can be performed simultaneously (e.g. Kunar et al, 2008), implying that the end purpose or objective will motivate priority between tasks.

Research investigating the effects of performance objectives on strategy selection in a dual-task environment has found that users are sensitive to explicit priority instructions and will adopt behaviours to most effectively meet these objectives (Brumby et al, 2007, 2009; Janssen & Brumby, in press). The authors conducted a series of experiments in which participants drove a simulated vehicle and occasionally dialled a telephone number on a mobile phone. Experimental instructions and feedback encouraged participants to focus on either driving as safely as possible or dialling the number as rapidly as possible. Authors found that participants adapted their task interleaving strategies to meet the required task objective. These findings are congruent with other studies that found that people are able to effectively prioritise tasks to enhance performance in their assigned focus (Brumby et al, 2010; Gopher, 1993; Horrey, Wickens & Consalus, 2006). This implies not only that performance trade-offs can be influenced by instructions, but also that people are sensitive to feedback received from a task.

Janssen, Brumby, Dowell & Chater (2010) conducted an experiment to test the hypothesis that people can hone their dual-task behaviour to maximize the payoff that is achieved purely based on performance feedback. A rational analysis model was developed to understand participants' strategy selection in dual-task situations. The model demonstrated that in three out of four conditions, human performance was optimal and that participants adopted dual-task strategies that provided the most benefit. These findings are in line with the notion that people will select strategies based on the information they have available about the likely success of each alternative (Lovett & Schunn, 1999).

As well as being sensitive to feedback and predicted success rate (e.g. Janssen et al, 2010), the strategies and choices people select may be influenced by: the structure and design of the task environment (Anderson, 1990; Johnson & Payne, 1985; Lovett & Schunn, 1999; Svendsen, 1991); the limitations of human cognition, such as individual ability (Schunn & Reder, 1998); and peoples' own past experience (Lovett & Anderson, 1996). Lovett & Schunn (1999) discuss the difficulty of making choices in an uncertain world where it is not always evident which option will lead to success. But if people are first exposed to two options and must then choose between them, will their choices be rational? More specifically, if people have experience of using two separate modalities and must later choose one, will they choose the one that helps them meet a predefined objective?

In simulated driving studies, it has been shown that people are aware of the safety benefits of audio compared to visual displays and prefer using them whilst driving due to a smaller mental workload (e.g. Graham & Carter, 2000; Liu, 2001; Sodnik et al, 2007; Zhao et al, submitted). However, prior research has not yet explored whether this preference might influence the choices made by participants in a dual-task environment when first presented with two different modalities and specific task instructions. It has been demonstrated that people adapt their behaviour to suit the circumstances of the task (e.g. Gray et al., 2006). Therefore, by manipulating task focus and introducing a choice/no choice paradigm (e.g. Duggan et al, in prep.; Siegler & Lemaire, 1997), this experiment will investigate whether people will flexibly adapt behaviour and select the modality that best allows them to meet set performance objectives, or whether choice will be dictated by other factors highlighted in this section. It was expected that participants would choose the modality that allowed them to produce the best results for their assigned priority: participants instructed to drive as safely as possible would generally choose the audio modality and conversely, participants in the fast searching-focus group would typically select the visual modality.

Summary

The literature suggests that people vary their choices in intuitively rational ways in response to various factors, such as the effort involved, the task environment, past experience, task instructions and likelihood of success. However, the literature has not yet explored how people choose between multiple interaction modalities offered by a device in a safety critical situation, such as driving, and how this choice might be affected by the user's objective. When people are given the choice, will they adapt their strategy choice rationally to meet performance objectives, or do other factors influence modality preference? An empirical experiment designed to answer the research questions raised in this section is described in the following chapter.

EXPERIMENT: INFORMATION MODALITY, PERFORMANCE OBJECTIVES AND CHOICE.

To investigate the influence of information representation and performance objectives on modality choice in a dual task environment, an experiment was devised in which participants completed a target detection task while driving a simulated vehicle. The driving task was a lane keeping task that required participants to remain in the centre lane of a three-lane highway. The target searching task required the user to find the answer to a predefined question in a sample of narrative that was presented either visually or via synthesized speech. A choice-no choice paradigm was used (Duggan et al., in prep.; Siegler & Lemaire, 1997) whereby in the first blocks, participants were not able to choose modality type, but in the last blocks participants had the opportunity to select the representation of their choice before the start of each trial. As well as collecting general measures of driving task and searching task performance, other measures such as the modality choice, error rate and subjective workload were also collected to develop a more complete view of the effects of performance objectives on information modality choice in a dual task setting.

To understand the effects of information representation on driving performance, the modality type used in the target searching task was varied within subjects. Based on the Multiple Resources Theory (Wickens, 2002, 2008), which proposes that time-sharing between two tasks is more efficient if the these utilise separate and independent mechanisms, it was predicted that lateral deviation would be less affected in the audio condition than in the visual condition.

In the target searching task, comprehension questions were asked at the start of each trial and participants were instructed to verbally inform the experimenter as soon as they had found the answer. The location of the target answer within the narrative was manipulated: primarily to ensure participants actively searched without assumption regarding position and covertly adding a factor for participants to consider when deciding which modality to choose when given the option.

To understand the effects of performance objectives on modality choice in a dual-task environment, task focus was varied between participants: participants either focused on the driving-task and keeping the lateral deviation as small as possible; or the searching-task where finding the target answer as quickly as possible was emphasized. In a similar method as Brumby et al (2009, 2010), the assigned task focus was instructed explicitly before the dual-task trials on the display and frequently reinforced through feedback which reflected the assigned task focus in lateral deviation or seconds. Due to limits on cognitive resources, it is expected that a classic speed-accuracy trade-off will occur so that participants focusing on safe-driving will have better overall performance but will be slower at the searching task. Conversely, participants prioritizing the searching task will have faster trial times at the detriment of their driving proficiency. In addition, different patterns should emerge between the two groups regarding modality selection when given the choice. Once having experienced both modalities, it is expected that participants in the safe driving-focus condition will choose the aural modality more frequently and reciprocally, participants in the target-identification condition will predominantly select the visual display.

Method

Participants

Twenty four participants (10 females; 14 males) were recruited for the study through flyers and electronic mailing lists. Participants were aged between 20- and 38 years (*M* = 27.0 years, *SD* = 4.0 years). All participants had a valid driver's license and a minimum of two years driving experience (*M* = 7.5 years, *SD* = 4.5 years).

Design

The experiment followed a 2x2x2 mixed factorial design. The independent variable of task focus (safe driving; fast searching) varied between subjects. The independent variables of modality (visual; audio) and choice of information representation mode (no choice; choice) varied within subjects. This created two groups of participants with separate foci to experience a choice- no choice paradigm.

Task focus was assigned to participants in alternation and an attempt was made to balance this across gender and non-native English speakers. The order of choice was assigned to participants in a particular order, starting with 'no choice', so that participants could familiarise themselves with both audio and visual information whilst driving, before choosing preferred modalities in the final block. The order of modality in the 'no choice' blocks was alternated but blocked by modality as to avoid participants becoming habitualised to one modality and simply continuing with this one in the final 'choice' block trials. Language comprehension questions used for the searching task were randomised and balanced for target location.

The dependent variables collected in this experiment were average trial time, root mean square error (RMSE) lateral deviation, modality choice, error rate, trial attempt and subjective workload (see table 3.2.1 for definitions).

Materials

For the driving task, a 30-inch monitor was used to display the driving simulator environment. The driving environment was the same as used in previous studies (Brumby et al, 2007, 2009, 2010; Janssen & Brumby, in press) with slight modifications for current purposes. A Logitech G25 Racing Wheel which was used to steer the simulated vehicle during the driving task was placed directly in front of the 30-inch monitor in an attempt to increase task realism. A 7-inch display positioned to the left of the participant presented the narrative text visually. The auditory information was produced from a laptop placed behind the participant. A schematic view and a photo of the experiment set-up are shown in Figure 3.1.1.

Copies of the NASA-TLX tool and insights questionnaire (see Appendices II and III) were used to assess participant subjective workload.

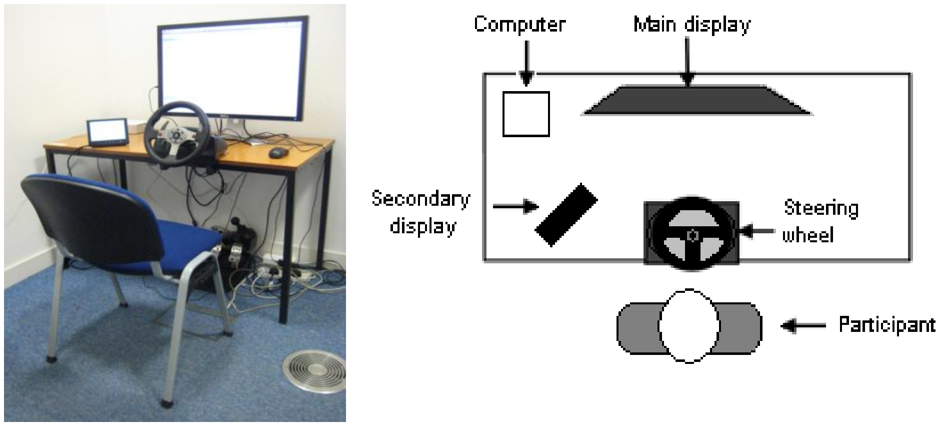

Figure 3.1.1 A photo and overhead schematic (not to scale) of the experiment set-up

Driving Task

The driving task required participants to interact with a simulated driving environment consisting of a unidirectional three-lane highway with safety cones on either side of the centre lane. This was done to encourage drivers to stay within boundaries of the simulator environment. A lead vehicle was arranged at a fixed distance in front of the participant vehicle. The constant-speed paradigm was used to avoid participants slowing down the vehicle as a response to the secondary task.

The objective of the driving task was to keep the vehicle as close as possible to the centre of the middle lane using the steering wheel. The vehicle began from stationary, accelerating at a steady rate for eight seconds until the maximum velocity of 55 mph was reached. In order to ensure active control of the vehicle by the participant, noise was added to the vehicle dynamics causing the vehicle to drift within the lane.

Searching Task

The searching task required participants to locate a target answer from a narrative text. Thirty different texts, of approximately 150-180 words in length, with subjects ranging from historical figures, monuments and popular culture were produced from information taken from Wikipedia.org and the BBC website. In the visual condition, the text was displayed on a 7-inch monitor to the left of the participant. Texts were made such that approximately eight words (roughly 45 characters) were displayed per line, ensuring words were not broken between lines. In the audio condition, a laptop placed behind the participant was used to read out loud the 60 second passages using text-to-speech (TTS) software 'SmartRead' at a pace of approximately 167 words per minute (2.8 words per second).

Two questions per topic were formulated, with each question prompting target search in either the first or the second half of the narrative. The participants were not made aware of which half an answer would be located in. As to avoid rapid visual detection, questions devised omitted the use of dates.

Subjective Workload Assessment

The NASA-TLX questionnaire, which holds a maximum score of 120 was used to assess subjective workload after each dual-task block. The tool is a multi-dimensional rating procedure that derives an overall workload score based on a weighted average composed from six 20-point subscales. Table 3.1.1, below, describes the six subscales. The lowest value corresponds to 'very low' and the highest value is 'very high', with the exception is the 'Performance' scale, where a high value is 'Failure' and a low value is 'Perfect'. A copy of the workload assessment can be found in Appendix II.

Table 3.1.1

The six subscales of the NASA-TLX subjective workload assessment questionnaire

Subscale	Description
Mental demand	How much mental and perceptual activity was required (thinking, deciding, calculating, remembering, etc.)?
Physical demand	How much physical activity was required?
Temporal demand	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?
Performance	How successful do you think you were in accomplishing the goal of the tasks set by the experimenter?
Effort level	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content and relaxed did you feel during the task?

Procedure

Figure 3.1.2., below, illustrates the experimental procedure. The experiment consisted of two practice blocks and six experimental blocks. The participants first completed a single-task practice block for driving, followed by a single-task practice block for target search with trials in each modality. Next, participants completed three dual-task blocks, combining the driving task and the searching task. In the first two blocks modality was predetermined, but in the final block participants could select between the audio or visual modality. Three single-task driving blocks separated the dual-task blocks to measure baseline performance. After each dual-task block, participants completed a NASA-TLX task load index subjective workload assessment questionnaire.

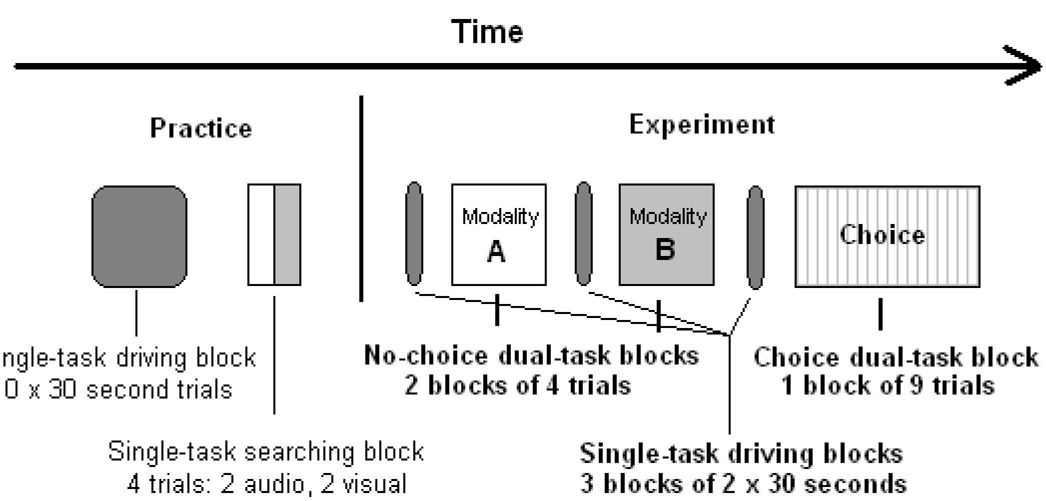

Figure 3.1.2 The experimental procedure

Single-task driving trials

The driving practice block consisted of ten 30-second trials. Participants were instructed to keep as close as possible to the centre of the middle lane. Feedback would be given to them at the end of each trial in the form of a score of lateral deviation, which they were told to try and minimise.

To provide baseline driving performance data which might improve over the duration of the experiment due to learning effects, participants completed three single task driving blocks, one before each of the dual-task blocks. The single-task blocks consisted of two 30 second trials.

Single-task searching trials

The searching practice block consisted of four trials, with two trials in the audio modality and two in the visual modality. Participants were presented with a question on the main display at the start of the trial and instructed to find the answer to the question which would be presented in the narrative. The practice trial ended when a participant correctly located the target answer through verbal announcement. Modality order was counterbalanced across participants.

Dual-task trials

At the start of the dual-task trials, participants were asked to perform both the driving task and searching task simultaneously but to prioritise either safe driving or fast searching. Participants were also reminded to ensure that they were confident of having identified the target answer correctly before submitting it.

Before each no choice dual-task block, a cue was shown on the driving display indicating the modality condition of the upcoming block. The target question was presented on the display screen before the start of each trial. The participants were instructed to read the question out loud and inform the experimenter when they were ready to begin the trial. Each no choice block consisted of four trials and the final choice block consisted of nine trials[1].

A dual-task trial began with the vehicle accelerating while a message box on the driving display instructed participants to wait and stay in the centre. Once the vehicle reached full-speed, the message box changed to indicate the start of the trial and either the audio or the visual narrative would be presented, depending on the block condition. The participants were given a maximum of 100 seconds in each trial. The task would end after the time had elapsed or when a participant provided an answer to the question asked at the start of the trial.

---

[1] Initial design included five trials in each no choice block and ten trials in the choice block. Due to a programming count error, the last trial of each block was not recorded.

After successfully completing the trial, participants were given feedback score dependent on their focus – lateral deviation for safe driving or trial time for fast searching. With each new trial the vehicle would start from a stationary position. Data was logged from the start of the trial, once the vehicle had reached maximum velocity. If the participant gave an incorrect response, the trial was aborted, the participant was informed by the experimenter and the trial was repeated. In the choice block, participants could change the choice of modality after an incorrect response, so that a different modality could be used for the consecutive attempts. Participants were discouraged from making errors by being instructed that they should only voice the answer if they were confident of a correct response and that the trial would be repeated until the correct answer was found.

Results

The dependent measures of interest were lateral deviation from the centre of the lane, trial time, modality choice, error rate, trial attempt and subjective workload. These are described in Table 3.2.1. From the raw data, error trials were excluded in order to compare measures across successful trials. Only first attempts at questions were investigated. Of a total of 443 trials, 68 trials (15.1%) were excluded due to participant error (an incorrect answer given), leaving 375 successful trials for analysis for lateral deviation: 185 trials in the safe driving-focus group and 190 trials in the fast searching-focus group.

Table 3.2.1

Definitions of dependent variables

Dependent Variable	Definition
Lateral Deviation	The average vehicle deviation from the centre of the lane during a trial.
Average Trial Time	The total duration of a trial from the moment the narrative information is presented (once the vehicle has reached full speed, after 8 seconds) to target identification through verbalisation.
Modality choice	The modality type (visual or audio) selected by the participant.
Error rate	The number of times an incorrect answer was given per trial.
Trial attempt	The attempt in which an answer is verbalised. For example, attempt 1 is the first encounter of the particular trial. Attempt 2 occurs if the first trial is incorrect and is rerun.
Subjective workload	The workload reported by the participant, using the NASA-TLX.

Data were first analysed for distribution. One participant was found to have general excessive lateral deviation in excess of four standard deviations so the data were treated as an outlier and excluded. A 2x2 mixed factorial ANOVA with variables of modality (audio; video) and task focus (driving; target searching) was used for statistical analyses of error data, lateral deviation and trial time for no choice trials. Paired-samples *t*-tests were used to analyse differences between baseline driving and no choice trials for lateral deviation and trial time. These were also used to analyse the differences between no choice and choice trials for lateral deviation and trial time. An alpha-level of .05 was used throughout for statistical significance.

Error Analysis

An error trial was recorded when a participant verbalized an incorrect response. A total of 34 errors were made out of 443 trials (7.67%). An equal number of errors were made in choice and no choice blocks. All incorrect trials were followed by a correct answer, meaning that no participant made more than two consecutive errors or had more than two trial attempts. Out of 24 participants, 17 made at least one error (M = 2, SD = 1.1). The most errors made by any one participant were four.

Error data was analysed using a 2 x 2 ANOVA. Figure 3.2.1, below, illustrates the findings. Out of a total of 34 errors, 23 were made in the audio and 11 in the visual modality, but modality type was not significant $F(1, 34) = .88$, $p = .36$. Participants in the safe driving group made more errors than participants in the fast searching focus group but this was not significant $F(1, 34) = .46$, $p = .50$.

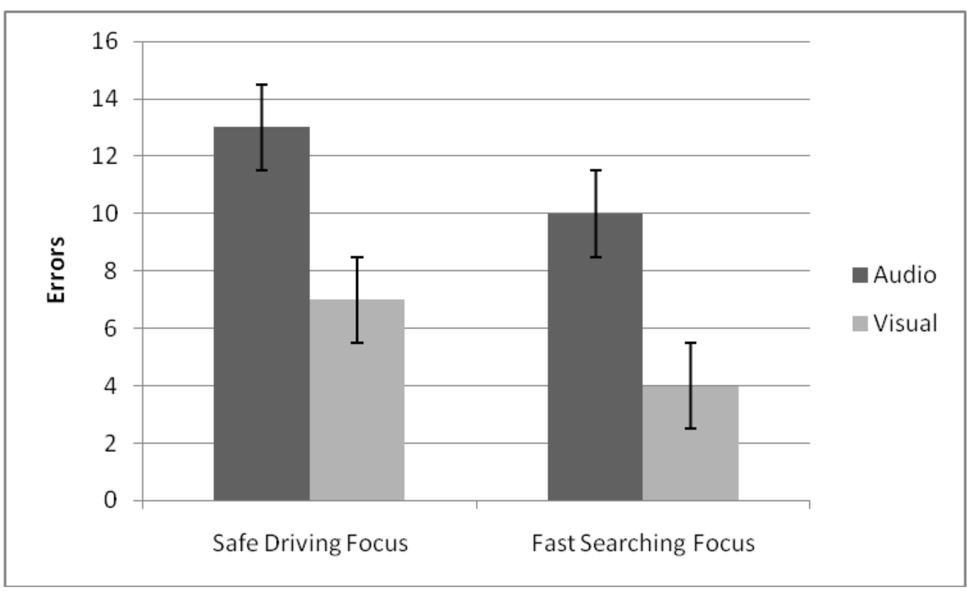

Figure 3.2.1 Errors made by modality between focus groups

No Choice Trials

Driving Performance

The dependent measure used to analyse overall driving performance was the root mean square error (RMSE) lateral deviation over the trial. The first analysis compared RMSE lateral deviation between the single-task baseline driving trials and the dual-task trials, between different modalities and task focus conditions. Figure 3.2.2 illustrates the RMSE lateral deviation of the two task-focus groups in the single-task driving blocks and the no choice dual-task blocks. A *t*-test showed no significant differences between baseline driving (M = .26m, SD = .05m) and audio modality (M = .28m, SD = .06m) $t(22)= -1.55$, $p = 0.136$. There was a significant difference between baseline driving and the visual modality (M = .84m, SD = .2m) $t(22)= -9.7$, $p < .001$. A one-way ANOVA revealed no significant differences in lateral deviation across focus groups for baseline driving, $F(1,23)= .235$, $p = .63$.

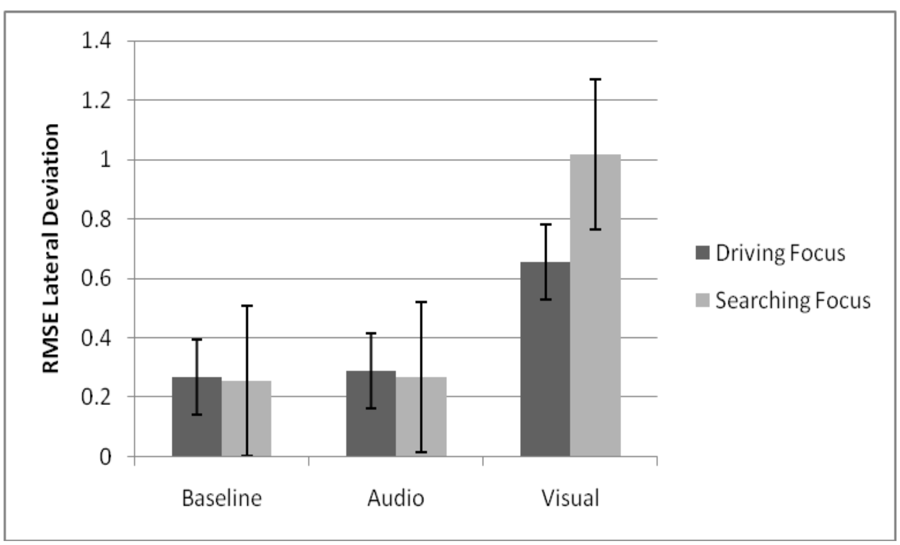

Figure 3.2.2 RMSE lateral deviation for single-task and dual-task trials for both task-focus groups across. Error bars are standard error of mean.

A 2x2 mixed factorial ANOVA was used for the analysis of lateral deviation with the variable of task focus (driving-focus; searching-focus) analysed between-subjects and the variable of modality (audio; visual) analysed within-subjects. A statistically significant main effect of modality was found, $F(1, 23) = 157.12$, $p < .001$. There was also a statistically significant main effect of task focus, $F(1, 23) = 14.56$, $p < .001$. Furthermore, there was a significant interaction between modality and task focus, $F(1, 46) = 18.61$, $p < .001$.

Target Searching Performance

The dependent measure used to analyse search task performance was trial time, which was defined as the time between the trial start message and the participant verbalizing an answer. A 2x2 mixed factorial ANOVA with the variable of task focus (driving-focus; fast searching-focus) was analysed between-subjects and the variable of modality (no choice audio; no choice video) was analysed within-subjects. A *t*-test was used to compare means between modalities.

Figure 3.2.3 demonstrates the results. When using the visual modality, participant trial times were lower (M = 26.2s, SD = 8.9) than when using audile information (M = 37.5s, SD = 3.5), $t(23)= 3.67$, $p = .001$. The 2 x 2 ANOVA revealed a statistically significant main effect of modality on trial time, $F(1, 24) = 18.26$, $p < .001$. There was not a statistically significant main effect of task focus, $F(1, 24) = 2.04$, $p = .160$. However, there was a significant interaction between modality and task focus, $F(1, 48) = 10.9$, $p = .002$.

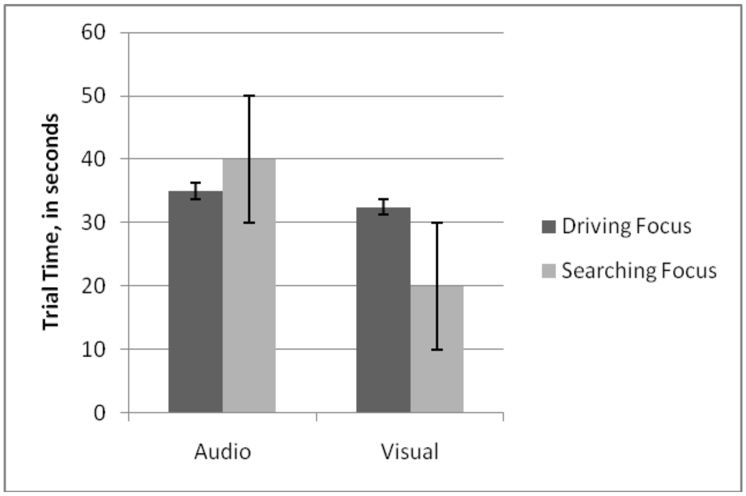

Figure 3.2.3 Trial times in no choice trials, between modality and task focus groups

Subjective Workload

NASA-TLX scores were analysed using a 2x2 ANOVA (Alm & Nilsson, 1994, 1995; Lee et al, 2001; Sodnik et al., 2010). Results are reflected in Figure 3.2.4 and demonstrate that modality significantly affected workload $F(1,12) = 15.67$, $p = .001$, but focus did not $F(1,12) = .037$, $p = .850$. There was not a significant interaction between modality and focus $F(1,24) = 0.31$, $p = .582$.

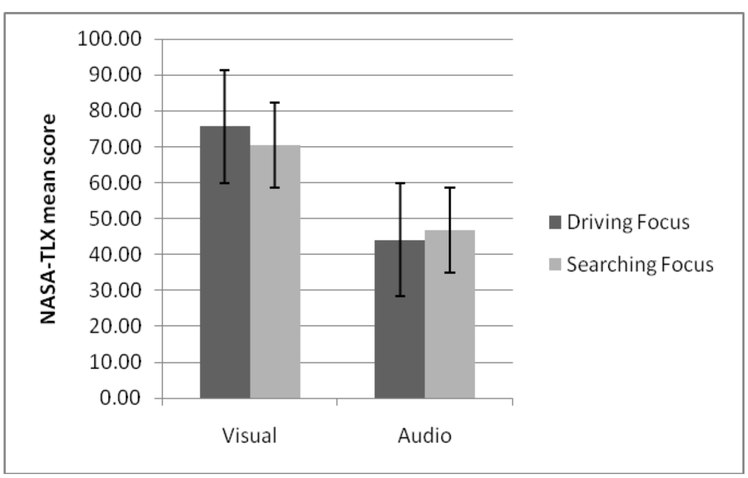

Figure 3.2.4 NASA-TLX scores between modality blocks and between task foci

Choice Trials

Modality choice

As shown in Table 3.2.2, when given the choice, participants more frequently chose the audio modality in the safe driving-focus group and participants in the fast searching-focus group predominantly chose the visual modality.

Table 3.2.2

Modality percentage choice (and standard deviation) between focus groups.

	Audio		Video	
Focus	Percentage	SD	Percentage	SD
Safe Driving	87.96%	0.16	12.04%	0.16
Fast Searching	33.33%	0.23	66.67%	0.23

At an individual level, Figure 3.2.5 below illustrates that more participants chose the audio modality 100% of the time than participants choosing the visual display. It also shows that participants in the fast searching group chose audio more frequently than participants in the safe driving group choosing the visual modality.

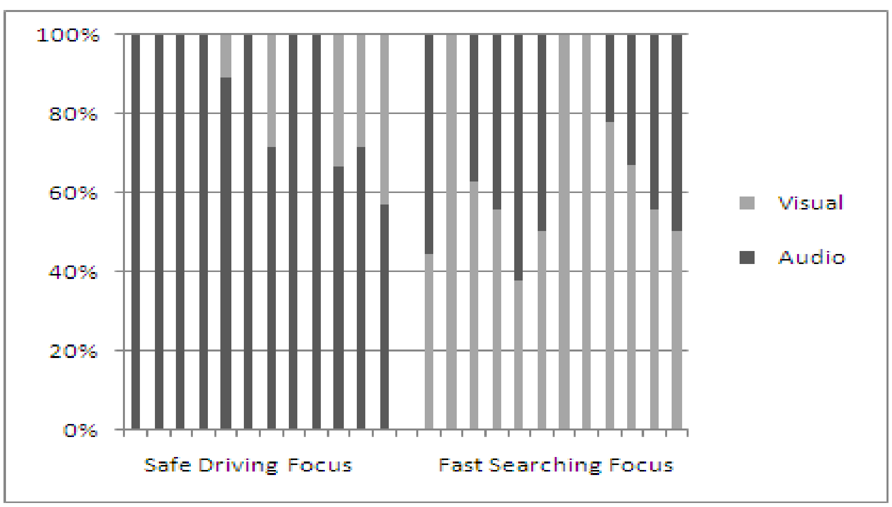

Figure 3.2.5 Individual participants' modality choices, in percentages.

Driving Performance

As per no choice trials, the dependent measure of RMSE lateral deviation was used to analyse driving performance. Paired-samples *t*-tests revealed that RMSE lateral deviation significantly decreased in choice blocks compared to no choice block, and this is visible for both audio(M = 0.28m, SD = .06) $t(22) = -4.69$, $p < .001$, and visual modalities (M = 0.84m, SD = .2) $t(22) = 7.72$, $p < .001$. A one-way ANOVA on lateral deviation revealed a significant effect of focus in the choice trials $F(1,22) = 21.38$, $p < .001$. These results are reflected in Figure 3.2.7.

Target Searching Performance

The dependent measure used to analyse searching performance was trial time. Paired-samples *t*-tests were used to analyse the data. Trial time decreased significantly between the no choice audio condition (M = 36.5s, SD = 83.5) and choice trials (M = 28.5s, SD = 8.9) $t(23) = -3.23$, $p = .004$. This was not the case between no choice visual (M = 26.2s, SD = 8.9) and choice trials $t(23) = -1.33$, $p = .19$. A one-way ANOVA on trial time revealed a significant effect of focus in the choice trials, $F(1,23) = 14.41$, $p = .001$. Figure 3.2.7 reflects the findings.

Subjective Workload

Paired-samples *t*-tests were used to analyse the difference in NASA-TLX scores between no choice trials and choice trials. As illustrated in Figure 3.2.6, there was a significant difference between the choice trials and no choice audio trials $t(12)$ = -

5.65, $p < .001$, and the no choice visual trials $t(12) = 7.85$, $p < .001$. A one-way ANOVA revealed no effect of focus in the choice trials, $F(1,11) = .11$, $p = .74$.

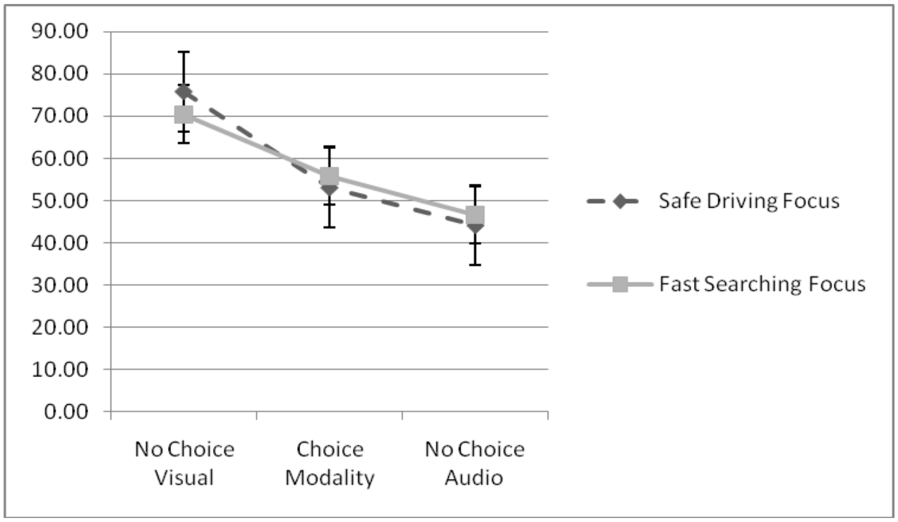

Figure 3.2.6 NASA-TLX between no choice and choice trials.

Speed-accuracy trade-off

Figure 3.2.7 illustrates choice and no choice trials split between modalities and focus, plotted against trial time and lateral deviation. The effect of performance objectives on no choice trials and choice trials is clearly demonstrated.

Regardless of focus, using the audio modality resulted in a driving performance comparable to baseline driving, but trial times were relatively slow. When using the visual modality, trial times for participants in the safe driving group remained similar as when using the auditory output, but with a decrement in driving performance. However, trial times between modalities in the fast searching-focus group are at opposite ends of the graph and show the strongest effect of a time-accuracy trade off: when looking for an answer quickly, the use of the visual modality was faster but associated with lateral deviation exceeding traffic lane boundaries; the use of audio was slow but safe.

Effects of performance objectives in choice trials are also demonstrated. Choice data for safe-driving participants shows lateral deviation and trial time as being almost equal with no choice audio and baseline data. However, in the fast searching focus group, trial time is almost as quick as no choice visual but with much less lateral deviation. When given the choice, fast searchers remained quick in finding answers but became much safer, in that they were no longer outside lane boundaries.

To summarise: participants with a safe driving focus had a better driving performance but slow trial times; participants with a fast searching focus had faster trial times but more lateral deviation. Interestingly, fast searchers in choice trials were faster than and as safe as safe-drivers using the visual modality.

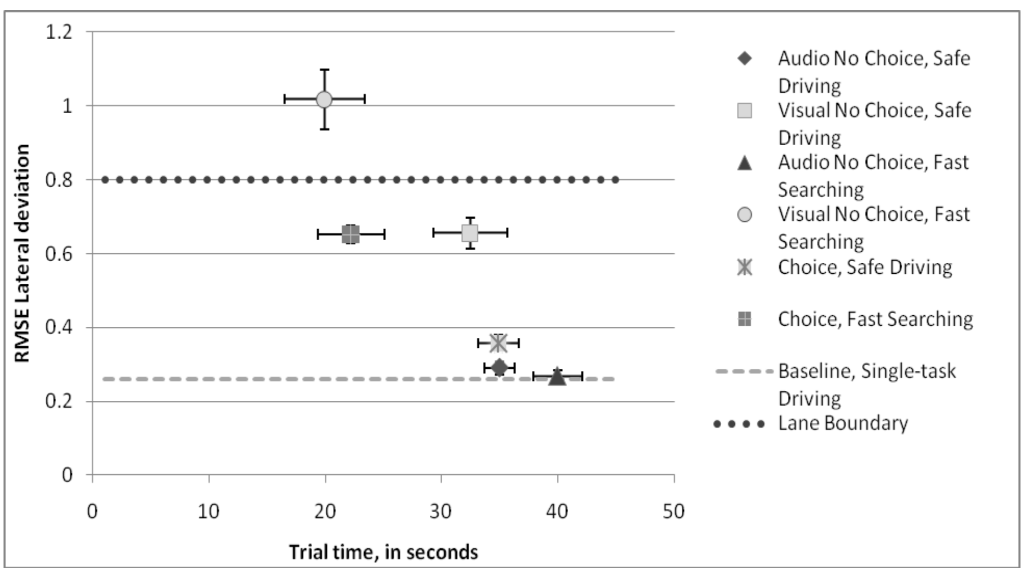

Figure 3.2.7 Speed-accuracy trade off between modalities, choice blocks and focus groups. Error bars are standard error of mean.

Discussion

The goal of this research was to investigate how people choose between audio or visual modalities in a driving situation given explicit priority instructions. The main result of this study found that performance objectives influenced participants' modality choice in a rational manner, so that the chosen modality was most likely to aid them in achieving their goal. When participants focused on driving as safely as possible, they chose the audio modality most frequently (88% of choices) as it allowed them to drive as safely as possible. When participants focused on searching for a target answer as quickly as possible, they chose the visual modality most frequently (68% of choices) as it allowed them to identify the target answer quickly, despite the affiliated decline in driving performance. A time-accuracy trade off occurred between focus groups: participants in the safe driving group had smaller lateral deviations but slower trials times; participants in the fast searching group had much greater lateral deviation but faster trials times. This finding is consistent with prior research where participants were told to prioritise one task over another in a dual-task environment (Brumby et al, 2007, 2009, 2010; Janssen & Brumby, in press).

However, it is interesting to note that a higher proportion of participants picked the 'irrational' modality in the fast searching-focus group than in the safe driving-focus group. That is, almost a third of the modality choices across participants in the fast searching group were the audio modality (32%). This suggests that despite generally choosing options that will lead to the best performance as instructed by the experimenter, people might be sensitive to other factors which might influence their choice preferences.

One of the additional factors that might have influenced modality choice was workload. The literature has found that people try to minimise effort when making choices (Payne et al, 2001; Payne et al, 1990). Using the visual modality was very mentally demanding and incurred high subjective workload scores on the NASA-TLX scale. This might suggest that people were sensitive to the high workload associated with using the visual display and picked the audio modality on occasion to lessen the effort, despite incurring slower trial times

Another factor which might explain why overall the audio modality was used more frequently than the visual modality was the task environment and participants' subjective capabilities. Certain participants struggled hugely with dual-task searching when using the visual display and their trial times were similar as when using the aural modality. For these participants, the rational choice of modality would have been audio, as they were assured to find the answer every time and with less effort. Similarly, some participants expressed particular concern about their decrement in driving performance when using the visual modality. These participants picked the audio modality occasionally despite being in the fast searching priority focus group and incurring slower trial times. These findings are consistent with the literature that reports that the decisions people make are influenced by the task environment (Anderson, 1990; Johnson & Payne, 1985;

Lovett & Schunn, 1999; Svendsen, 1991) and their own person abilities (Schunn & Reder, 1998).

Furthermore, it was also interesting to note the strategy that people in the fast searching-focus group reported using in the choice trials. Participants stated that they would assess the difficulty of the question and pick the modality that they thought would allow them to find the answer as quickly as possible. Although trial times did not become significantly faster between no choice and choice trials, lateral deviation significantly reduced. When using the no-choice visual modality, all participants in the fast searching focus group left the lane boundary which in reality would result in driving onto oncoming traffic. When given the choice, participants were significantly safer and trial times remained fast.

What these findings indicate is that people make choices that will allow them to meet their performance objectives but that these choices might be sensitive to other contextual factors, especially the effort involved. Results might also suggest that that people continuously evaluate each new problem and will pick the option most likely to allow them to meet their goal at that time. Further research would be required to explore whether this observation is purely hypothetical or whether people will spontaneously change decisions or strategies in goal-directed tasks.

A second major finding from this study was that when participants used the visual display, their lateral deviation was much higher than when they used the aural modality. This has been reported by other studies comparing the use of visual and audio modalities whilst driving (Liu, 2001; Sodnik et al, 2008; Zhao et al, submitted) and can be explained due to shared visual attention between the reading device and the road. Interestingly, there was no significant difference in lateral deviation between baseline data and use of the aural modality. These results are consistent with other studies that have shown that listening to messages does not affect driving performance (e.g. Recarte & Nunes, 2003; Tsimhoni et al; 2001).

These findings can be explained by a number of factors. Firstly, driving and listening required the use of two separate resources, entailing minimal interference between the tasks as hypothesised by the Multiple Resources Theory (Wickens, 2002, 2008). This would explain why participants were able to successfully tackle both tasks concurrently and is consistent with other studies which have found that people are able to listen to information whilst doing other tasks (e.g. Borst et al, 2010; Kunar et al, 2008). Secondly, it could be argued that both the driving and listening tasks were relatively simple, which could explain the lack of interference between them.

Recarte & Nunes (2003) suggest that complex or emotionally laden audio messages could prove more cognitively demanding than simple messages and negatively impact driving performance. In contrast, Tsimhoni et al (2001) suggest that driving performance is sensitive to the level of driving workload rather than the nature of the audio messages. Other authors argue that task complexity of both the primary and secondary task will impact successful concurrent multitasking (Cooper et al, 2003; Lee et al, 2001; Patten et al, 2004). This implies that the more complicated either task is, the greater the interference there will be on the other. This could explain why results from this experiment and some studies indicate that listening does not negatively impact primary task performance (e.g. Borst et al, 2010; Kunar et al, 2008; Recarte & Nunes, 2003; Strayer & Johnson, 2001; Tsimhoni et al, 2001), while other research has found the opposite (Iqbal et al, 2010; Just et al, 2008).

The question regarding whether it is dangerous to carefully listen to auditory messages whilst performing various specific driving tasks appears to remain unresolved. Furthermore, in a more complex scenario with realistic driving conditions, the effects of attentively listening to an audio message might prove different. Further research in this area could include more complicated driving tasks and measurement of alternative variables, such as reaction times to red lights. The use of eye-tracking data could also prove interesting to investigate whether people notice and react to on-screen events swiftly when listening and driving compared to purely driving.

Despite not having a significant effect on driving performance, participants made more errors when using the audio modality than when using the visual modality. More specifically, participants frequently forgot the question which they were required to find the answer to. This could be explained due to the demands on short-term memory: participants had to hold the target question in mind and drive the simulated vehicle until finding the answer in the narrative. If processing abilities were already busy with visual stimulus from the driving task, the additional cognitive load of listening and filtering to information might have caused interference with the short term memory (Liu, 2001). Cooper et al (2003) found that listening to messages whilst driving was associated with significantly riskier decision-making. This implies that even if people are able to successfully listen and drive (e.g. Recarte & Nunes, 2003; Tsimhoni et al, 2001), there might still be interference in processing abilities at a central level (cf. Just et al, 2008). This might explain why participants made more errors when using the aural modality in the present study.

Limitations and future research

There were some limitations to the current study which constrain generalisation of the results to a true driving scenario. Most importantly, this study only investigated the use of single modalities. The majority of existing technological devices such as personal computers, mobile phones and satellite navigation systems are able to present aural and visual information concurrently. Liu (2001) used a multimodal satellite navigation system and found that it was safer and preferred to the single-modality systems. Further research in the area would be required to explore whether this preference might also extend to the use of in-car e-mail systems, and how choice of modality would be affected by varying performance objectives. Would people choose the single-modality to reach their goals, or would the multi-modal system be preferential?

Another limitation to the generalisation of the findings from the current experiment lies in the artificial simplicity of the tasks that participants were required to complete. As the driving task only involved lane-keeping along a straight road, the findings from this experiment might not reflect the choices someone might make when actually driving in the real world where traffic conditions are largely variable. For example, in heavy traffic, someone might prefer using the audio modality as it would be safer, whereas if they were stopped at a red light, they might pick the visual display where they can quickly find information whilst the vehicle is stationary.

Horrey & Lesch (2009) argue that laboratory simulated driving tasks are not necessarily representative of real world situations. Indeed, the fact that a simulator was used might not reflect people's true choices in a safety-critical situation. Reed & Green (1991) have shown that effects found in driving simulators are typically also found in the real world but the study was limited to dialling a phone number whilst on a motorway. The authors did not investigate choices under varying task objectives.

Anecdotally, almost every single participant reported finding audio safer and preferred it to the visual display. Therefore, in a real life driving situation where danger is looming, would people still trade safety for time, or would they be more cautious in their choices? Further research involving actual road tests would not be feasible. However, testing participants' choices in diverse simulated driving events and conditions might provide additional insight into the susceptibility of people's trade-offs and how modality choice might be influenced by varying performance objectives under changing circumstances and complexities.

Implications

Theoretically, this dissertation adds to the body of research indicating that people are sensitive to trade-offs. Features like effort, time, safety, past experience and context will determine how people make choices in their problem-solving strategies. People will choose between options according to trade-offs between criterions to meet their performance objectives.

Practically, this study shows that people are time-sensitive and therefore may not choose an aural modality when driving despite the safety benefits. Therefore, designers of an in-car e-mail system would need to consider that people take risks in favour of saving time and devise interfaces that allow users to complete tasks quickly without necessarily requiring visual attention, which might put the driver in a dangerous situation. This might be met by presenting information via both visual and aural properties which would allow drivers to choose the modality that was most convenient for them given their personal and contextual circumstances.

CONCLUSION

To summarise, a study was conducted to investigate how people might choose between using audio and visual modalities whilst driving under varying task objectives. The novel results of this study revealed that people are sensitive to time/accuracy trade-offs whilst driving and modality choice reflected a rational decision making process to meet explicit goals whilst minimizing effort.

In the introduction to this dissertation, a scenario was described where a driver receives an e-mail and must find the name of a restaurant. The question was posed that when faced with a choice of aural or visual modalities, how might the driver make their decision, and would this choice differ depending on the urgency of the task?

The results of this study suggest that people are sensitive to the time cost of interactions and that they will make decisions and choices based on what will rationally lead them to their goal in the least effortful manner. These findings highlight the safety benefits associated with aural information systems whilst driving and indicate the necessity for designing in-car e-mail systems which allow the driver access to and choice of different modalities in order to choose what is most appropriate for their immediate personal and circumstantial preferences.

REFERENCES

Alm, H., & Nilsson, L. (1994). Changes in driver behaviour as a function of handsfree mobile phones-- A simulator study. *Accident Analysis & Prevention*, *26*(4), 441-451.

Alm, H., & Nilsson, L. (1995). The effects of a mobile telephone task on driver behaviour in a car following situation. *Accident Analysis & Prevention*, *27*(5), 707-715.

American Automobile Association (2007). The Dangers of Driving While Distracted – Survey. Retrieved September 3rd 2010 from http://www.aaanewsroom.net/main/Default.asp?CategoryID=7&ArticleID=554

Anderson, J. R. (1990). *The adaptive character of thought*. Hillsdale, New Jersey: Routledge.

Anderson, J. R., Matessa, M., & Lebiere, C. (1997). ACT-R: A theory of higher level cognition and its relation to visual attention. *Human-Computer Interaction*, *12*(4), 439–462.

Ballard, D. H., Hayhoe, M. M., & Pelz, J. B. (1995). Memory Representations in Natural Tasks. *Journal of Cognitive Neuroscience*, *7*(1), 66-80.

Bargh, J. A. (1997). The automaticity of everyday life. *The automaticity of everyday life*, *10*, 1–61.

Bellinger, D. B., Budde, B. M., Machida, M., Richardson, G. B., & Berg, W. P. (2009). The effect of cellular telephone conversation and music listening on response time in braking. *Transportation Research Part F: Traffic Psychology and Behaviour*, *12*(6), 441-451.

Borst, J. P., Taatgen, N. A., & van Rijn, H. (2010). The problem state: A cognitive bottleneck in multitasking. *Learning, Memory*, *36*(2), 363–382.

Brookhuis, K. A., de Vries, G., & de Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis & Prevention*, *23*(4), 309–316.

Brumby, D.P., Del Rosario, N., & Janssen, C.P. (2010). When to switch? Understanding how performance tradeoffs shape dual-task strategy. To appear in the *Proceedings of the 10th International Conference on Cognitive Modeling*.

Brumby, D. P., Salvucci, D. D., Mankowski, W., & Howes, A. (2007). A cognitive constraint model of the effects of portable music-player use on driver performance. In *Human Factors and Ergonomics Society Annual Meeting Proceedings* . Vol. 51, pp. 1531–1535.

Brumby, D. P., Howes, A., & Salvucci, D. D. (2007). A cognitive constraint model of dual-task trade-offs in a highly dynamic driving task. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 233-242). San Jose, California, USA: ACM.

Brumby, D. P., Salvucci, D. D., & Howes, A. (2009). Focus on driving: how cognitive constraints shape the adaptation of strategy when dialing while driving. In *Proceedings of the 27th international conference on Human factors in computing systems* (pp. 1629-1638). Boston, MA, USA: ACM.

Caird, J. K., Willness, C. R., Steel, P., & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis & Prevention*, *40*(4), 1282-1293.

Consiglio, W., Driscoll, P., Witte, M., & Berg, W. P. (2003). Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. *Accident Analysis & Prevention*, *35*(4), 495-500.

Cooper, P. J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., & Siegmund, G. (2003). The impact of hands-free message reception/response on driving task performance. *Accident Analysis & Prevention*, *35*(1), 23-35.

Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied*, *14*(4), 392–400.

Duggan, G.B., Howes, A., Kalidindi, K., Lewis, R.L., & Tseng, Y.-C. (in prep.). Bounded optimality in a cognitive utility learning paradigm.

Eng, K., Lewis, R. L., Tollinger, I., Chu, A., Howes, A., & Vera, A. (2006). Generating automated predictions of behavior strategically adapted to specific performance objectives. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (p. 630).

Gopher, D., & Koriat, A. (1999). *Attention and Performance XVII: Cognitive Regulation of Performance: Interaction of Theory and Application*. MIT Press.

Graham, R., & Carter, C. (2000). Comparison of speech input and manual control of in-car devices while on the move. *Personal and Ubiquitous Computing*, *4*(2), 155-164.

Gray, W. D., & Boehm-Davis, D. A. (2000). Milliseconds matter: An introduction to microstrategies and to their use in describing and predicting interactive behavior. *Journal of Experimental Psychology: Applied*, *6*(4), 322–335.

Gray, W. D., & Fu, W. T. (2004). Soft constraints in interactive behavior: The case of ignoring perfect knowledge in-the-world for imperfect knowledge in-the-head. *Cognitive Science*, *28*(3), 359–382.

Gray, W. D., Sims, C. R., Fu, W. T., & Schoelles, M. J. (2006). The soft constraints hypothesis: A rational analysis approach to resource allocation for interactive behavior. *Psychological Review*, *113*(3), 461–482.

Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J., & Brown, J. (2006). Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis & Prevention*, *38*(1), 185–191.

Horrey, W. J., & Lesch, M. F. (2009). Driver-initiated distractions: Examining strategic adaptation for in-vehicle task initiation. *Accident Analysis & Prevention*, *41*(1), 115–122.

Horrey, W. J., Wickens, C. D., & Consalus, K. P. (2006). Modeling drivers' visual attention allocation while interacting with in-vehicle technologies. Journal of Applied Experimental Psychology. *12*(2), 67.

Horrey, W. J., & Wickens, C. D. (2006). Examining the Impact of Cell Phone Conversations on Driving Using Meta-Analytic Techniques. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *48*(1), 196 -205.

Iqbal, S. T., Ju, Y., & Horvitz, E. (2010). Cars, calls, and cognition: investigating driving and divided attention. In *Proceedings of the 28th international conference on Human factors in computing systems* (pp. 1281-1290). Atlanta, Georgia, USA: ACM.

Jamson, A. H., Westerman, S. J., Hockey, G. R., & Carsten, O. M. (2004). Speech-based e-mail and driver behavior: Effects of an in-vehicle message system interface. *Human Factors*, *46*(4), 625.

Janssen, C. P., & Brumby, D. P. (in press). Strategic adaptation to performance objectives in a dual-task setting. *Cognitive Science*.

Janssen, C. P., Brumby, D. P., Dowell, J., & Chater, N. (2010). A Cognitively Bounded Rational Analysis Model of Dual-Task Performance Trade-Offs. In *Proceedings of the 10th International Conference on Cognitive Modeling 2010*.

Johnson, E. J., & Payne, J. W. (1985). Effort and accuracy in choice. *Management Science, 31*(4), 395–414.

Ju, Y. C., & Paek, T. (2009). A Voice Search Approach to Replying to SMS Messages in Automobiles. *Proceedings of Interspeech, Brighton, UK*.

Just, M. A., Keller, T. A., & Cynkar, J. (2008). A decrease in brain activation associated with driving when listening to someone speak. *Brain Research*, *1205*, 70-80.

Klein, N. M., & Yadav, M. S. (1989). Context effects on effort and accuracy in choice: An enquiry into adaptive decision making. *Journal of Consumer Research*, *15*(4), 411–421.

Kun, A., Paek, T., & Medenica, Z. (2007). The effect of speech interface accuracy on driving performance. *Interspeech 2007*, 27–31.

Kunar, M. A., Carter, R., Cohen, M., & Horowitz, T. S. (2008). Telephone conversation impairs sustained visual attention via a central bottleneck. *Psychonomic bulletin & review*, *15*(6), 1135.

Lai, J., Wood, D., & Considine, M. (2000). The effect of task conditions on the comprehensibility of synthetic speech. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (p. 328).

Lai, J., Cheng, K., Green, P., & Tsimhoni, O. (2001). On the road and on the Web?: comprehension of synthetic and human speech while driving. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 206-212). Seattle, Washington, United States: ACM.

Lee, J. D., Caven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effect of speech-based e-mail on drivers' attention to the roadway. *Human factors*, *43*(4), 631.

Lesch, M. F., & Hancock, P. A. (2004). Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis & Prevention*, *36*(3), 471–480.

Liu, Y. (2001). Comparative study of the effects of auditory, visual and multimodality displays on drivers' performance in advanced traveller information systems. *Ergonomics*, *44*(4), 425.

Lovett, M. C., & Anderson, J. R. (1996). History of success and current context in problem solving. *Cognitive Psychology, 31*(2), 168–217.

Lovett, M. C., & Schunn, C. D. (1999). Task representations, strategy variability, and base-rate neglect. *Journal of Experimental Psychology: General, 128*(2), 107–130.

Maciej, J., & Vollrath, M. (2009). Comparison of manual vs. speech-based interaction with in-vehicle information systems. *Accident Analysis & Prevention, 41*(5), 924-930.

McCallum, M. C., Campbell, J. L., Richman, J. B., Brown, J. L., & Wiese, E. (2004). Speech Recognition and In-Vehicle Telematics Devices: Potential Reductions in Driver Distraction. *International Journal of Speech Technology*, *7*(1), 25-33.

McKnight, A., & McKnight, A. (1993). The effect of cellular phone use upon driver attention. *Accident Analysis & Prevention*, *25*(3), 259-265.

Ofcom (2010) Communications Market Report. Retrieved August 25, 2010. http://stakeholders.ofcom.org.uk/binaries/research/cmr/753567/CMR_2010_FINAL.pdf

Patten, C. J. D., Kircher, A., Östlund, J., & Nilsson, L. (2004). Using mobile telephones: cognitive workload and attention resource allocation. *Accident Analysis & Prevention*, *36*(3), 341-350.

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1988). Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*(3), 534–552.

Payne, J. W., Johnson, E. J., Bettman, J. R., & Coupey, E. (1990). Understanding contingent choice: A computer simulation approach. *IEEE Transactions on Systems, Man and Cybernetics*, *20*(2), 296–309.

Payne, S. J., Howes, A., & Reader, W. R. (2001). Adaptively distributing cognition: a decision-making perspective on human-computer interaction. *Behaviour & Information Technology*, *20*(5), 339–346.

Ranney, T. A., Harbluk, J. L., & Noy, Y. I. (2005). Effects of Voice Technology on Test Track Driving Performance: Implications for Driver Distraction. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *47*(2), 439 -454.

Reed, M. P., & Green, P. A. (1999). Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task. *Ergonomics*, *42*(8), 1015.

Salvucci, D. D., & Beltowska, J. (2008). Effects of memory rehearsal on driver performance: Experiment and theoretical account. *Human factors, 50*(5), 834.

Salvucci, D. D., & Taatgen, N. A. (2008). Threaded cognition: An integrated theory of concurrent multitasking. *Psychological Review, 115*(1), 101–130.

Schunn, C. D., & Reder, L. M. (1998). Strategy adaptivity and individual differences. *Psychology of Learning and Motivation, 38*, 115–154.

Schunn, C. D., & Reder, L. M. (2001). Another source of individual differences: Strategy adaptivity to changing rates of success. *Journal of experimental psychology: General*, *130*(1), 59–76.

Siegler, R. S., & Lemaire, P. (1997). Older and younger adults' strategy choices in multiplication: Testing predictions of ASCM using the choice/no-choice method. *Journal of Experimental Psychology: General*, *126*(1), 71–92.

Sodnik, J., Dicke, C., Tomazic, S., & Billinghurst, M. (2008). A user study of auditory versus visual interfaces for use while driving. *International Journal of Human-Computer Studies*, *66*(5), 318-332.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological science*, *12*(6), 462.

Svendsen, G. B. (1991). The influence of interface style on problem solving. *International Journal of Man-Machine Studies*, *35*(3), 379–397.

Tashev, I., Seltzer, M. L., & Ju, Y. C. (2009). Speech and sound for in-car infotainment systems. *Automotive UI 2009*, 8.

Tsimhoni, O., Green, P., & Lai, J. (2001). Listening to natural and synthesized speech while driving: Effects on user performance. *International Journal of Speech Technology*, *4*(2), 155–169.

Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, *3*(2), 159–177.

Wickens, C. D. (2008). Multiple Resources and Mental Workload. *Human Factors: The Journal of the Human Factors and Ergonomics Society*,, 449 -455 vol. 50:

Zhao, S., Brumby, D., Chignell M., Salvucci D., Zhou X. (submitted) Multi-modality interfaces: Supporting Menu Search for Mobile Devices

BIBLIOGRAPHY

Bach, K. M., Jæger, M. G., Skov, M. B., & Thomassen, N. G. (2009). Interacting with in-vehicle systems: understanding, measuring, and evaluating attention. In *Proceedings of the 2009 British Computer Society Conference on Human-Computer Interaction* (pp. 453-462). Cambridge, United Kingdom: British Computer Society.

Barón, A., & Green, P. (2006). Safety and Usability of Speech Interfaces for In-Vehicle Tasks while Driving: A Brief Literature Review. *University of Michigan Transportation Research Institute. Technical Report UMTRI, 5.*

Basacik, D., & Stevens, A. (2008). Scoping Study of Driver Distraction. *Transport Research Laboratory*. *Road Safety Research Report*, *95*.

Brewster, S., Lumsden, J., Bell, M., Hall, M., & Tasker, S. (2003). Multimodal 'eyes-free' interaction techniques for wearable devices. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 473-480). Ft. Lauderdale, Florida, USA: ACM.

Burke, J. L., Prewett, M. S., Gray, A. A., Yang, L., Stilson, F. R. B., Coovert, M. D., Elliot, L. R., et al. (2006). Comparing the effects of visual-auditory and visual-tactile feedback on user performance: a meta-analysis. In *Proceedings of the 8th international conference on Multimodal interfaces* (pp. 108-117). Banff, Alberta, Canada: ACM.

Burnett, G. E., Summerskill, S. J., & Porter, J. M. (2004). On-the-move destination entry for vehicle navigation systems: Unsafe by any means? *Behaviour & Information Technology*, *23*(4), 265–272.

Elslande, P. V., Jaffard, M., Fouquet, K., & Vatonne, V. (2008). Variety of attentional failures in traffic accidents. In *Proceedings of the 15th European conference on*

Cognitive ergonomics: the ergonomics of cool interaction (pp. 1-5). Funchal, Portugal: ACM.

Levy, J., Pashler, H., & Boer, E. (2006). Central interference in driving. *Psychological Science*, *17*(3), 228.

Palladino, D. K., & Walker, B. N. (2008). Navigation efficiency of two dimensional auditory menus using spearcon enhancements. In *Human Factors and Ergonomics Society Annual Meeting Proceedings* (Vol. 52, pp. 1262–1266).

Rydström, A., Grane, C., & Bengtsson, P. (2009). Driver behaviour during haptic and visual secondary tasks. In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 121-127). Essen, Germany: ACM.

Schunn, C. D., Lovett, M. C., & Reder, L. M. (2001). Awareness and working memory in strategy adaptivity. *Memory & Cognition*, *29*(2), 254.

Siewiorek, D., Smailagic, A., & Hornyak, M. (2002). Multimodal Contextual Car-Driver Interface. In *Proceedings of the 4th IEEE International Conference on Multimodal Interfaces* (p. 367). IEEE Computer Society.

Spence, C., & Read, L. (2003). Speech Shadowing While Driving. *Psychological Science*, *14*(3), 251-256.

Walsh, M. M., & Anderson, J. R. (2009). The strategic nature of changing your mind. *Cognitive psychology*, *58*(3), 416–440.

Ward, K., & Novick, D. G. (2003). Hands-free documentation. In *Proceedings of the 21st annual international conference on Documentation* (p. 154).

Young, K., Regan, M., & Hammer, M. (2007). Driver distraction: A review of the literature. *Distracted driving. Sydney, NSW: Australasian College of Road Safety*, 379–405.

APPENDIX I – EXPERIMENT INFORMATION SHEET

Study: Information presentation whilst driving.

Samantha Davies, Dr. Duncan Brumby, and Chris Janssen, MSc

You are being invited to take part in a research study. Please take time to read the following information. Ask us if there is anything that is not clear or if you would like more information. Take as long as you like to decide whether or not you wish to take part.

1. What is the purpose of the study?

In this study we investigate human multitasking behaviour in a driving situation. During the experiment you have to drive in a simulated vehicle. Just before you start driving, you will be asked a question to a general knowledge topic. Information in which you have to find the answer will then be presented to you either in a visual or auditory format.

Your goal is to find the correct answer as quickly as possible whilst keeping the car as close as possible to the centre of the middle. If you make a mistake, the trial will end and you will have to start a new trial again.

You will start the experiment by practising driving in the simulator only, and then having a couple of practice questions for both the visual display and audio type. After the practice block, there will be 3 experimental blocks. The first 2 blocks will have 5 questions each, and you will have to find the question to the answer in the information provided, either visual or audio. In the last block there are 10 questions and you will be able to choose which modality you would prefer the information to be displayed to you at the start of each trial (every new question). After completing the experimental blocks you have to fill out a short questionnaire.

The results will give a better insight in human multitasking, in particular whilst driving. The results will lead to a better understanding of human cognition and can be used to help design safer in-car devices, such as e-mail or internet browsing systems.

2. Do I have to take part?

Participation in this study is voluntary. You can withdraw from participation at any moment during the study. The data that is collected during this experiment is anonymized, and can in no way be traced back to you. Data will be treated confidentially.

3. Contact for Further Information

You can discuss this study with the person who gave you this information sheet, or contact Dr. Duncan Brumby (D.Brumby@cs.ucl.ac.uk), Chris Janssen (c.janssen@ucl.ac.uk) or Justin Grace (j.grace@ucl.ac.uk) at University College London Interaction Centre.

Thank you for taking part in this study.

APPENDIX II – NASA-TLX SUBJECTIVE WORKLOAD ASSESSMENT TOOL

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

APPENDIX III – POST EXPERIMENT QUESTIONNAIRE

Gender: female / male

Age: _____ years

I am: left-handed / right-handed

Nationality:

Mother tongue:

How would you rate your level of English?

First language 1 2 3 4 5 Beginner

How long have you had your driver's license? ________ years

How many hours do you drive a month, approximately? _______hours

How familiar are you with text-to-speech software, like the one used in this study?

very familiar 1 2 3 4 5 very unfamiliar

Have you ever used your phone (calling or text messaging) while driving?

very often 1 2 3 4 5 never

How often do you play racing games?

very often 1 2 3 4 5 never

How often do you use a game steering wheel?

very often 1 2 3 4 5 never

1. Did you use a particular strategy during the experiment? Please explain.

……

……

……

……

……

2. How well do you think you performed?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

---

3. Which information delivery method (audio or visual) did you prefer? Why?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

---

4. Which method (audio/ visual) did you think was most effective for your focus?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

---

5. Which information delivery method did you think was safest? Why?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

That's the end of the study. Thank you for taking part.