Enhancing the user-centred design of Mobile Location Services through the application of 'value'

by

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ABSTRACT

This thesis is concerned with the problem of designing Mobile Location Services (MLS) - also commonly termed Location-Based Services – that meet user needs. MLS are applications that users access via a portable device such as a mobile phone. They provide services (i.e. information or other functionality) to end-users based on knowledge of the location of individuals and other entities within the environment. The market failure of many mobile services, including MLS, has been attributed in part to failing to provide 'value' to the end user. This thesis reviews different theoretical approaches to help understand the notion of 'value', and how value may be used to inform design (Chapter 2). Research methods are also discussed, including the particular challenges with doing 'mobile' research (Chapter 3).

A survey of UK consumers (Chapter 4) demonstrates a current lack of use, and lack of awareness of most forms of MLS in the UK. However, overall positive attitudes, and a range of behavioural and demographic data, suggest that MLS have the potential to be successful if they can be designed to meet user needs. A qualitative study of users' travelling behaviour (Chapter 5) then demonstrates how effective mobile information delivery can provide considerable value within a dynamic, uncertain and location-varying environment. This added value is highly dependent on contextual and situated factors, including existing information sources, variances in possible outcomes and the intrinsic qualities of information provision.

The thesis then focuses on a particular application domain for MLS – drivers navigating in an unfamiliar environment. A literature review (Chapter 6) investigates how drivers navigate, and what their information needs are. Three experimental studies (Chapters 7 to 9) then investigate what information adds value within a navigation context, the impact of contextual influences on driving and navigation performance, and the impact of the quality of the navigation cue on task performance. *Good landmarks* (such as traffic lights) are shown to add value for drivers navigating an unfamiliar route, depending on the context at particular manoeuvres.

This thesis discusses (Chapter 10) how a multi-disciplinary perspective can help maximise the acceptance and effectiveness of MLS. 'Value' can be used to design specific services for users, based on offering new freedoms to the individual within a mobile context, employing time and location sensitivity to maximise relevance, taking into account user knowledge, existing information sources and contextual factors, and ensuring impact on real-world outcomes. In conclusion (Chapter 11), specific contributions and avenues for future work are highlighted.

Keywords: value, multi-disciplinary, user-centred design, mobile location services, MLS, location based services, LBS, navigation, landmarks

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1 INTRODUCTION

1.1 The mobile phenomenon

The consumer adoption of mobile devices (and mobile phones in particular) is one of the most remarkable consumer phenomena to emerge in the last 20 years. The first basic 'mobile telephone service' was launched in the USA in 1946, and in Europe (Sweden) in 1955 (Hamill 2005). Since then, worldwide cellular connections passed 1 billion in 2002 and then 2 billion in September 2005 (WirelessIntelligence 2005).

As the technological capabilities of telecoms networks and handsets have increased, an increasing range of communication and information-based mobile services have been made available to the consumer. Despite investment in the development of advanced, non-voice services, and considerable marketing effort, many have been rejected by the consumer and been commercially unsuccessful. Two such examples are WAP (a wireless protocol that enables mobile information access) and location-based services (services that use location attributes to provide functionality to the user).

In 2000 Ahmed and Hurst (2000) described how WAP in Germany (where it was widely available) was used by less that 1% of cellular subscribers, and those who *did* use WAP to access the Internet only did so about once a week. Keen and Mackintosh (2001) described customers reporting the WAP experience as one that 'stinks'. Similarly, location-based services were launched in the mobile marketplace with much hype and hope. In 2000, Bill Gates of Microsoft described location-based services as one of the four big trends in software (Mountain 2003).

Mountain and Raper (2001) highlighted how location-based services were being unrealistically described as the next 'killer app' of the mobile information revolution. This caution was justified. The first services launched were not successful and consumer adoption was minimal. Several reasons are given for this failure (Schiller and Voisard 2004):

- The services were relying on technology that was immature and very slow in penetrating the market (WAP phones).
- The user interface (small monochrome displays) did not enable an easy and satisfying interaction.
- Location capability (network positioning via cell ID) was not accurate enough for many services.
- Services such as 'find-my-nearest' were initially launched with a wait-and-see mentality, and little effort was put into their marketing, design and development.

The first location-based services did not offer enough to the customer, were too slow, too much effort to use and not engaging enough. As a result, they were rejected by the consumer, and many operators turned away from them.

However, while some heavily promoted services have been unsuccessful, others have been unexpected and spectacular successes. Text messaging is one such example (Taylor and Vincent 2005). Another example of a highly (and partly unexpected) success is i-Mode which was launched in Japan by NTT-DoCoCo in 1999. Using a single press of a button, a user can access thousands of official and other mobile internet sites. By July 2001 27 million i-Mode subscriptions were taken up (Lindgren et al. 2002), and by 2004 paying subscribers had risen to more than 40 million (Fasol 2004). i-Mode users typically use it several times a day for sending emails, undertaking banking transactions, purchasing tickets, downloading music and finding information (the most popular content site is the weather). It is estimated that the wider economic impact of the mobile internet (comprising i-Mode, EZweb, Vodafone-Live and other smaller mobile internet services) in Japan will be at least US$ 100 billion in the near future (Fasol 2004).

1.2 The need to provide 'value'

Against the backdrop of the widespread adoption of mobile phones, and the failure of many advanced services, there is a fundamental issue that must be addressed by the telecoms industry. This is succinctly stated by Lindgren et al. (2002): 'the mobile marketplace has to offer added value if people are to start using it'.

Keen & Mackintosh (2001) re-iterate this message by describing the mobile commerce challenge as one of creating 'appealing distinctive new value for customers', and state that 'unless customers can connect with a moment of value they soon stop wasting time'. Jarvenpaa et al. (2003) state that 'consumers may lack a compelling motivation to adopt new for-pay service offerings unless they create new choices where mobility really matters'. Similarly, Couzens (2001) states the 'need to sell value, not price, product or technology', and Ahmed and Hurst (2000) state that 'customers will only use the wireless devices and services that quickly and easily add some value to the customer's lives'. Venkatesh et al. (2003b) highlight the commercial implications: 'opportunities for success in m-commerce will go to those companies that focus on creating compelling value for customers, founded on a deep understanding of the mobile experience.'

Despite these messages being promoted several years ago, there is still a lack of understanding of how to provide 'value' to the mobile consumer by incorporating value considerations into the design of mobile services. 'Value' is a vernacular term used within everyday language. When used within more specific research context, it usually relates to the beneficial aspects of human action, with a variety of defined or implied meanings. Marketers such as Lindgren et al. (2002) describe value as motivating consumer behaviour. Kaasinen (2005) describes value as driving technology adoption. Within human-computer interaction, Cockton (2004a) describes value in terms of the benefits derived from using technology within a broad context of use. Information perspectives, e.g. Badenoch et al. (1994), describe monetary, outcome-based and subjective perspectives on the value attached to information conveyed to an end user. Cockton (2006) highlights how 'value' with HCI design can additionally be interpreted in terms of (1) capitalist economics or (2) design based on sensitivity to morals and ethics.

The aim of this thesis is to explore 'value' and then incorporate value considerations in the user-centred design of mobile services. A simple, broad working definition of value was used throughout the thesis thus:

> 'Value is the actual, net benefit, that an individual derives from a service'

It is apparent that many of the mistakes that were made initially with the WWW are being repeated with mobile services. Hurst (2000), (in the context of dotcom survival) described the need for: focussing on the customer and providing simplicity (not complexity), service (not technology), and enabling customers to accomplish goals rather than using features. The understanding of the mobile consumer presents a particular challenge due to mobile interactions with services being embedded within the complexity of mobile lifestyles. In many respects, the mobile consumer is very different to the user of fixed commerce: (1) the mobile consumer is often multi-tasking, with constant distractions (Tamminen et al. 2003); (2) they encounter 'windows of opportunity' that open and close and are consumed by time (May 2001) ; and (3) the range of contexts of use of services is far greater than with static computing due to the portability and personal nature of devices (Dunlop and Brewster 2002). However, although the mobile (as opposed to the static) experience has been described as fundamentally a different use context (Venkatesh et al. 2003b), in other respects, the consumers' basic requirements do not differ. As Hurst (2000) highlighted with the WWW, they require services that are easy to use, are based on meeting their needs (rather than providing technological features), and make a real difference to them such that they would be missed if they were taken away.

The great majority of consumers (and particularly the younger age groups) regard mobile technology as something that engenders freedom (Lindgren et al. 2002). Andersson and Heinonen (2002) describe two main reasons for users wanting to use mobile services:

- Where the user wanted to achieve something clearly defined, such as being more informed about current occurrences in the near environment.
- Emotional reasons such as social belonging and amusement.

Mobile technology (and accompanying services), has potential to 'shape' the nature of society through the emerging digital revolution (Hamill and Lasen 2005). With reference to the far east (where the market is most advanced), there are projections that 'there will be a total meshing of mobile services into the fabric of Japanese society and economy' (Fasol 2004). The success of i-Mode in Japan demonstrates that consumers *will* adopt services which are perceived as meeting their needs.

1.3 Consumer trends: implications for mobile services

As well as rapid technological change, such as described by the UMTS (2003), - there are a number of consumer trends that are helping to shape the market for mobile services. These provide both opportunities for the provision of services to the consumer, and also challenges in terms of their successful design and development. These trends are shown below, adapted from Lindgren et al. (2002), together with opportunities and challenges for mobile services.

Consumer trend (Lindgren et al. 2002)	**Opportunities for mobile services**	**Design challenges arising**
Individualism - separating the individual from the collective	Empowering the individual to make their own decisions	Personalisation of services
High tech - high touch- the more technology in our lives, the greater the need for physical meetings, real experiences, sensory experiences	Enabling and enhancing real experiences (e.g. supporting in-person shopping)	Not assuming that mobile 'high tech' is the whole solution, avoiding pushing features at the consumer
I... free choice, individualization, multiple identities - being seen as autonomous individuals who may have multiple identities	One to one marketing of services. Customisation of services, enabling personalisation, adaptive systems.	One size does not fit all. Services must be configurable to cope with an individual assuming several different roles.
Open all the time - expecting to be able to do anything at any time due to lack of time	Making services available all the time (e.g. location of the Tourist Office)	Interfacing with other businesses that are not open all the time (Tourist Office may not be open).
Multi-tasking - people getting better at doing several things at once, and with dealing with large amounts of complex information	The multi-threading nature of the mobile channel can be capitalised upon. Small and temporary windows of opportunity and convenience can be capitalised on.	The need to design services that can be used when doing other things (e.g. when walking, when talking, when making phone calls)
Relevance - people becoming extremely demanding about only receiving information which is relevant and accessible.	To differentiate the mobile by reacting to dynamic influences on relevance	The ever rising expectations of the consumer, the need for the mobile channel to be better than the alternatives
Reduced decision making - consumers unable to make decisions with all the information being made available - need help making decisions	To act as decision agents, to help consumers make choices, to fuse lower level data into higher level information that has more meaning	The need to avoid presenting increasing amounts of information to the user, to determine how enhanced meaning can be portrayed
Tales and experience – more emphasis on positioning a product within a context or set	Promoting services based on the context and experiences	The difficulty of actually providing consumers with

Consumer trend (Lindgren et al. 2002)	Opportunities for mobile services	Design challenges arising
of experiences	surrounding it	engaging experiences with mobile devices due to the impoverished interfaces
So what! Surprise me, then! – consumers don't want a predictable existence, they want to experience new things	New services and content can be used to surprise the consumer	More is expected of new products before consumers are prepared to go out and buy them
Consumers as consumers - becoming more aware in our role as consumers	The use of the mobile channel as a new marketing medium	The increasing sophistication of the consumer, and the implications for effective marketing messages
Increasing receptiveness to technology -takes less time for technology to establish itself	The potential willingness for early adopters to try out new technologies and services	Whether the bridge between the early adopters and the pragmatists[1] can be bridged
Professionalism - increasing demand for precision in adapting to individual needs – 'consumer is very particular, and very conscious of quality'	The ability to deliver customised services to the consumer, to adapt to context, and enable personalisation by the individual	The need for reliable services that live up to expectations, the need to create impressions of quality
Privacy becoming more import - How much information about ourselves are we prepared to divulge? 'What can the information be used for, might it be used against me or in a way that goes against my wishes?'	To capitalise on the personal aspect of the mobile phone to enable interaction with services and content that are perceived as 'private'.	Whether consumers will be willing to use services that leave traces of usage, whether positioning services (e.g. friend finder) will be seen as two intrusive.
Increasing advertising exhaustion – consumers increasingly shielding themselves from advertising	The opportunity for the mobile channel to differentiate itself from other information channels	Unwillingness to receive 'pushed' messages, greater demand for relevant and exciting advertising
Convenience - people expect their requirements to be met quickly with high quality and convenience, without any trouble	The opportunities for mobile services to increase the convenience of mobile lifestyles	The need to focus on ease of use to ensure that future services are more convenient to use
Less loyalty to brands - you buy from a supplier that can deliver what you want, when you want at a price that suits	Capitalising on the fact that individuals may identify with different brands in different situations, using the value of brands to	The 'fickle' nature of consumers, the need for services to prove themselves to the consumer
More consumer power through virtual communities - e.g. homepages, virtual communities, gossip, feedback, planetfeedback.com	The quick diffusion of good experiences with mobile services, the opportunity to build market share	The quick diffusion of poor experiences with mobile services, the need to design services right first time
More people buying mobile	Capitalising on the mobile	Increasing expectations

[1] Termed the 'early majority' by Rogers (2003).

Consumer trend (Lindgren et al. 2002)	Opportunities for mobile services	Design challenges arising
technology – increasing consumption of hardware such as PDAs and handheld computers	workforce, supporting the business user	regarding integration of technology and corporate networks
'Chaos on the staircase of life' - less difficult to use age as a basis for segmentation	The ability to promote services to wider ranges of the population	More difficult to use age as a basic for segmented design and marketing of services

Table 1.1 Consumer trends (Lindgren et al. 2002) and opportunities and challenges for mobile services

As highlighted in the second and third columns, these trends present particular opportunities and challenges for mobile services and there are clearly substantial opportunities for tapping into and supporting these trends by providing mobile services to the consumer. It is clear that many of these consumer trends relate to individual choice, freedom and empowerment. In addition, the consumer is becoming increasingly sophisticated and aware of attributes such as quality and relevance; these are of particular interest in this thesis.

1.4 Opportunities for location-based services

Despite the early failure of location-based services, it is now being suggested that they are making a comeback (Schiller and Voisard 2004), with several important drivers including: the appearance of new mobile phones with high-resolution colour screens and increased processing power; faster data connections; implementation of high performance positioning technologies; and greater emphasis by the telecoms operators on data services to compensate for the levelling off of revenues from voice and SMS. Fagerberg (2005) also suggests that location-based services are set for a comeback, highlighting that although revenues from location-based services in the European market were only € 108 million in 2004, this figure is expected to grow to € 2,183 million over the ensuing five years, and will account for 4.5 percent of total non-voice revenues.

Fearon (2004) is more sensational when he states that:

> 'If I were a venture capitalist, then I'd be pouring every spare penny I had into mobile location-based services'.

The point being made by Fearon (2004) is that the technology underpinning location-based services *works*, and it provides opportunities for addressing needs that it wasn't possible to serve previously. Rao and Minakakis (2003) suggest that location-based services can be a new source of revenue for the stakeholders in the mobile value chain. Recent projections by ABI Research (Hyers 2006) offers encouraging signs for the LBS market, based on inclusion of GPS in more mobile phones. They forecast that the number of GPS-enabled LBS subscribers will reach 315 million in 2011, up from 12 million in 2006. This represents a rise from less than 0.5% of total worldwide wireless subscribers at present, to more than 9% in 2011, with greatest growth expected in Europe and North America.

The apparently rosy future for location-based services is also highlighted by the recent DTI technology mission to Japan (DTI 2005), the aims of which were to better understand the current adoption and future of Japanese location-based services. (Japan is the world leader in using GPS for location-based services in both mobile handsets and in-vehicle systems). Current uptake is mixed, with only about 10% of one operator's phones that have GPS enabled actually subscribed to a location-based service. However, it was made clear that the network operators and content providers see 'location' as one of the cornerstones of future services, and that the Japanese view current location-based services offerings as a stepping stone to more highly integrated solutions. The key conclusion drawn from the DTI mission is that location-based services can work, and there are customers for such services. Although there are some technical challenges, the Japanese view is that location-based services may move from being a niche business to a highly profitable mass market one.

1.5 Overview of mobile, and mobile location services

The key characteristics of mobile services are that they are personal and ubiquitous: 'what makes mobility such an interesting proposition are attributes such as ubiquity, reachability, security, convenience, localisation, instant connectivity and personalisation' - Müller-Veerse (2001) quoted in Ng-Kruelle et al. (2002). 'Mobile services benefit from three major factors that boost information value to the end-user: personality, time-criticality, and location-dependency' (Nokia 2001). Current mobile telecom networks in the developed world support a wide range of services, targeted at both the consumer and business user, as shown below:

Mobile service	Example	Willingness to pay
Communication	Voice calls, mail, SMS, chat, video calls	Low
Transaction services	Ticket booking, banking	Relatively high
Entertainment	Music downloads, network games, film, radio	Variable
Information services	News, cinema listings, weather, directory enquiries, encyclopaedias, price comparison	Variable
Position services	Road directions, restaurant tips, locating one's children, friend finder	Variable
Security services	Turning electricity on and off, checking who is ringing the doorbell	Variable

Table 1.2 Taxonomy of mobile services, adapted from Lindgren et al. (2002)

Table 1.2 shows the range of different types of mobile services available to the consumer, in addition showing that the willingness of consumers to pay for services is highly variable. Location-based services are a subset of the services shown above. They are those mobile services (applications) that use the location attributes of people, places or things to provide functionality to an end user. They can essentially be services that are accessible *via a* mobile device such as a phone, or applications that *run on* these devices. The functionality derived from location can be made available to that mobile user, another mobile user, or a non-mobile user (e.g. via the web). These services were launched as 'location-based' services to indicate how their capabilities were *based on* locating technologies i.e. falling within the 'position services' of Table 1.2. The term 'location-aware' services is a better descriptor, since it describes how a service does not necessarily need to be based on location, but can use location as an *enabler* (this is a theme discussed within this thesis). However, the term currently popular within the mobile marketplace is 'mobile location service' (MLS) since this emphasises the mobility aspect, and this is the term used henceforth within this thesis.

In contrast to other mobile services or applications that are available over mobile phone networks, the location-specific nature of MLS enables a specific range of functionality as outlined in Table 1.3 below. It can be seen that many of these are consistent with the consumer trends shown in Table 1.1. In addition, different MLS tend to have different interaction characteristics as shown below.

Mobile location service	Example applications	Typical characteristics of the service
Infotainment services	Finder applications (e.g. route, location, friends, stores, restaurant, petrol station, parking, other amenities) Information requests (e.g. tourist, travel, news, weather)	Interaction initiated by the mobile user, query-based and request-driven Model based on pull of services by the user Location information can be transmitted with request, or calculated by service
Tracking services – goods, people and vehicles	People (e.g. childcare, elderly, sick) Security of entities (e.g. cars) Maintenance and assistance, workforce dispatching, supply chain and inventory management (mostly relevant to a business market)	Tracking request may be initiated by a remote entity and not by the mobile entity being tracked Can be pull-based and push-based
Selective information dissemination	Targeted content dissemination (e.g. advertisements, context relevant information)	Information is pro-active and pushed to the consumer, based on events occurring and triggered by a specific trigger (e.g. approach of a consumer to a specific location)
Location-based games	Treasure hunts Territory defence and claiming	Interactions are pro-active, event-based and triggered by a specific condition May be based on the location of multiple mobile terminals
Emergency support services	Tracing of emergency call Emergency services dispatching Roadside assistance	Initiated by the mobile user Based on pull from the mobile user
Location-sensitive billing	Billing for phone calls Toll payment Purchases of goods and services	Can be pro-active, event-based and triggered when a certain condition is met, or based on user initiation

Table 1.3 Classification of mobile location services, based on Schiller (2004)

As well as technological advances, there appear to have been some subtle changes within the telecoms industry that mean that MLS are now more likely to be successful. There is acknowledgement of a shifting emphasis away from high tech research, and towards the user, understanding their behavioural factors, needs and social aspects of use (Lindgren et al. 2002), and see Appendix 1A. With regard to MLS in particular, there is an increasing realisation, e.g. Schiller (2004) that location can be used as an enabler: as well as directly enabling services (e.g. turn-by-turn navigation or child-tracking), it can enhance existing services (e.g. provide more localised transport information); or increase the usability of services (e.g. act as an indication of context with presence-based services). Table 1.2 shows only one category of services – the position services – having a location element. However a wider view of location as an enabler, enhancing the meaning portrayed by an interface, implies that all of the mobile services shown in Table 1.2 can be enhanced by the incorporation of location information.

1.6 Aims and scope of the thesis

The overall aim of this thesis was to contribute to the design of successful future mobile services. It was assumed that three key means of achieving this were a focus on the user (Preece et al. 2002), the provision of 'value' by these services (Lindgren et al. 2002), and the use of location attributes within these services (DTI 2005). The underlying discipline within this thesis was human factors. However, the understanding of a consumers' relationship with new technology required a multidisciplinary view, and hence a range of theoretical perspectives contributed to the thesis. These are outlined in Chapter 2.

The early part of the thesis considered value in relation to a broad category of mobile location services. The thesis then concentrated on a specific mobile location service - driver navigation - in order to apply 'value' concepts within user-centred design. The synthesis of results and conclusions to the thesis were undertaken from both a specific (driver navigation) and a broader (mobile and mobile location services) perspective.

The following research questions (labelled RQ1, RQ2, RQ3, RQ4, RQ5) were addressed within this thesis:

RQ1: Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?

- Literature review (Chapter 2)

RQ2: How are mobile location services fairing in the current consumer marketplace?

- Literature review (Chapter 2)
- Survey (Chapter 4)

RQ3: What is user 'value' in the context of mobile location services?

- Literature review (Chapter 2)
- Exploratory study (Chapter 5)

RQ4: How can a specific mobile location service (driver navigation) be enhanced using a value perspective?

- Literature review (Chapter 6)
- Requirements study (Chapter 7)
- Experimental studies (Chapters 8, 9)
- Overview and synthesis (Chapter 10)

RQ5: What general recommendations can be made for mobile location services research and design?

- Overview and synthesis (Chapter 10)

1.7 Chapter summary and structure of the thesis

This chapter, **Chapter 1** has introduced the topic, described the phenomena of interest and provided relevant background information. It has also outlined the scope of the thesis and identified the aims and objectives of the research, and the research questions that were tackled.

Chapter 2 (Research Questions 1, 2, 3) was a literature review. The two main purposes of this were to understand the mobile marketplace, and to identify relevant theoretical perspectives that can be used to inform the research process. It was clear that there were multiple perspectives that were useful in addressing the user-focussed design of MLS, and that could influence the following research. Several areas were particularly relevant, namely user-centred design; technology adoption and innovation; information value; and context (and location) aware computing.

Chapter 3 focuses on research methods. It outlined the various perspectives on scientific research, different approaches that may be taken, and the main recommendations for undertaking human-centred research. In particular, it highlighted the need to understand and test human behaviour, and the benefits of multiplicity of approaches and measures. Particular challenges associated with mobile computing were summarised. This chapter then set out the research questions, and outlined the research methods appropriate in each case.

Chapter 4 (Research Question 2) reports the first empirical study - the results of a web-based survey, comprising a total of 1270 respondents. This was undertaken in order to understand consumer behaviour and attitudes in relation to MLS and set the context for the research. A sizeable proportion of the respondents were found to be *potential* early adopters of MLS, based on demographic characteristics, holding early adopter views to new technology and having positive attitudes to most MLS. However, in general, MLS were little used by respondents, the highest level of use of services being approximately 20% for local traffic information. Levels of awareness of services were mixed. The conclusions were that MLS are currently failing to add value to potential consumers.

Chapter 5 (Research Question 3) investigated influences on 'value', and opportunities and challenges for mobile services in general, given that Chapter 4 had shown that MLS were not being used widely by consumers. This qualitative study based on 20 structured interviews used a contextual enquiry approach to investigate consumer information seeking behaviour, and outcomes, in a location and time critical situation – that of travelling. It was apparent that a wide range of contextual factors influenced the consumers' assessment of value (where value was conceptualised as the ability of an external information source, such as a mobile device, to 'make a difference' within a given context of use).

In order to investigate a specific context of use (and derive application-based design results according to Research Question 4) the thesis then focused on a specific MLS – driver navigation systems. These are location and time sensitive, but do not adapt their behaviour to wider aspects of context in order to maximise the value, or net benefit to the driver. The first half of **Chapter 6** was a further literature review; focusing on driver navigation. In particular, this review identified: (1) models of driver navigation that can be used to help guide the empirical studies; (2) the information cues that add value to the driver when navigating; (3) the limited research discussing context and 'value add'. The second half of the chapter discussed the review implications in terms of providing and/or assessing driver value when navigating an unfamiliar route.

A requirements study was undertaken in **Chapter 7**, the first of the application-specific studies (Research Question 4). This study used a value perspective to understand the information cues needed to navigate an unfamiliar route. The method was based on 36 participants generating navigation instructions to enable a driver to navigate a specific unfamiliar route. Over 2600 resulting cues were coded to identify what cues were needed, when and how they were used, and the importance attached to them. Landmarks, junction descriptions, lane positioning information and road signs were the most frequently generated cues. Most cues were used to identify the location of a forthcoming manoeuvre, and in a primary (as opposed to redundant) role. A simple method was used to associate value with individual cues, and in addition, the impact of manoeuvre context was investigated. Landmarks were shown to add value, although their apparent usefulness varied considerably.

Chapter 8 (Research Question 4) built on the results of the previous study, Chapter 7 which provided evidence of the types of information cues that add value within a navigation context, and where they may add greatest value. However Chapter 7 only enabled an experimenter *assessment* of the impact of context, due to its non-situated design. Chapter 8 was an explorative, empirical road study. It provided evidence of the impact of the context of a manoeuvre on the driving and navigating performance of the driver. This study showed that there were specific opportunities for adding value to a driver, over and above the benefits of basic distance-to-turn information and junction layout (which is that used by current navigation systems to identify forthcoming manoeuvres).

A final, deductive study is described in **Chapter 9** (Research Question 4), comprising an empirical road study. This final study tested the extent to which enhanced navigation instructions *actually do* add value to a driver following an unfamiliar route, in contexts where the potential value-add is high. Specifically, this study tested the relative value-add of good landmarks when compared to (1) poor landmarks, and (2) distance information, when used as the main information to locate a forthcoming manoeuvre. Results showed the importance of only using good landmarks within future navigation instructions, that good landmarks provide generally provided greater value to a driver than distance-to-turn information, and that performance was influenced by the context surrounding manoeuvres.

Chapter 10 summarised and brought together the main findings from the thesis (Research Questions 4 and 5). Some outputs were specifically related to driver navigation systems, including the cues that add greatest value, the impact of context, the need to incorporate *good* landmarks, and recommendations for future design. Other outputs related to mobile location services more generally, including: the potential contributions from different theoretical perspectives, a snapshot of current consumer behaviour as relevant to MLS, and some insights into how value and willingness to pay are created for a mobile consumer.

The thesis was concluded in **Chapter 11**. This stated what are felt to be the most important contributions of the thesis, and identified future research questions that have emerged.

The structure of the thesis is shown below. This indicates the relationship between the research questions posed within the thesis, existing knowledge, and the studies undertaken to address specific research questions.

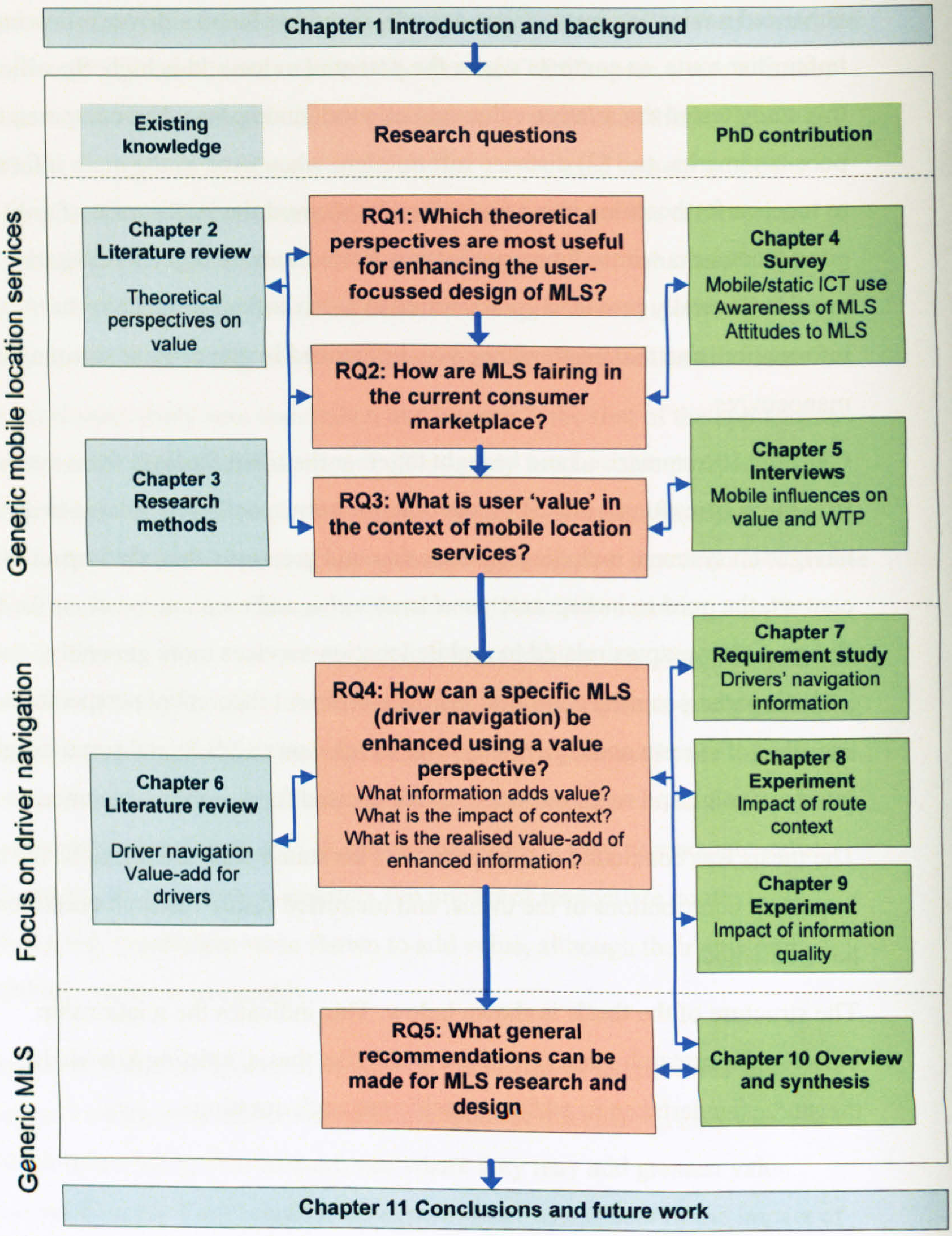


Figure 1.1 The structure of the thesis

1.8 Acknowledgements

This thesis was undertaken on a part time basis from 2001 to 2007 while the author was a member of staff at the Ergonomics and Safety Research Institute at Loughborough University, UK. Most of the work contained in the thesis was undertaken while the author and colleagues were working on the EPSRC-funded REGIONAL and VALUED LBS projects. The exact contributions made by the author are detailed below:

Chapters 1 (Introduction), 2 (Literature Review) and 3 (Research Methods). All work within these chapters was undertaken and written by the author specifically for this thesis.

Chapter 4 (Survey). This study used a web-based survey. The design of the survey was undertaken within a project team, with the author contributing approximately 50%. The coding of the survey in HTML was completed by a colleague, Steve Bayer. All data operations, data analysis and statistical analysis were designed, managed and completed by the author. The chapter was written in its entirety by the author.

Chapter 5 (Structured interviews). This study was instigated, completed and written in its entirety by the author.

Chapter 6 (Literature Review). This was written in its entirety by the author. Approximately 40% was based on material arising from the REGIONAL project, which was completed by the author and a number of colleagues (predominantly Tracy Ross and Gary Burnett).

Chapter 7 (Requirements study). This study was devised in conjunction with colleagues (predominantly Tracy Ross and Gary Burnett). The original participant transcripts of navigation instructions were generated by a colleague (Steve Bayer). The coding scheme for analysing the data was devised by the author. Although the original data was coded by a colleague (Steve Bayer), data was subsequently recoded by the author in order to focus on the location of objects. All ensuing analysis of data was completed by the author and the chapter was written in its entirety by the author.

Chapters 8 and 9 (Empirical studies). Data for Chapters 8 and 9 was collected as part of one large study, which was devised in conjunction with colleagues (predominantly Tracy Ross and Gary Burnett). Considerable effort was spent by a large number of individuals (including the author) in order to set up and run this study. Jason Duffield and Sebastian Paszkowicz investigated potential routes. Derek Brutnell (Advanced Driving Instructor)

acted as expert driving assessor. Nick Smith provided some guidance on statistical analysis. The dependent variables, metrics and data collection materials were devised by the author, and Tracy Ross. All data analysis (design and completion), generation of results and statistical analysis was undertaken by the author. The chapter was written in its entirety by the author.

Chapters 10 (Overview and Synthesis) and 11 (Conclusions and Further Work). These were written in their entirety by the author for this thesis.

2 LITERATURE REVIEW: MULTIDISCIPLINARY PERSPECTIVES

	Research questions addressed in this chapter:
1	**Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?**
2	**How are mobile location services fairing in the current consumer marketplace?**
3	**What is user 'value' in the context of mobile location services?**
4	How can a specific mobile location service (driver navigation) be enhanced using a value perspective?
5	What general recommendations can be made for mobile location services research and design?

2.1 Introduction

The aim of this thesis is to address the user-centred design of mobile location services (MLS), with an emphasis on those that offer information, rather than communication-based services to a user. Rather than focussing on interface design, this thesis attempts to focus more on the opportunities and potential benefits that can be derived from these services. Although 'value' is quoted frequently within the literature, it is an elusive and often poorly defined concept. At the outset of this research, it was assumed that 'value' motivates an individual to interact with a service (adoption and choice), and also describes the benefit derived from actually using a MLS at an interaction level within a context of use. These are roughly equivalent to the motivational and action levels described by Kankainen (2002). Due to the potentially broad nature of 'value', a multidisciplinary approach was attempted within this thesis, guided by a human factors perspective. This multidisciplinary perspective contributed to: (1) the choice of application domain later in the thesis; (2) approach taken with empirical work; (3) specific measures and metrics used within following studies; and (4) the synthesis and interpretation of results.

The review of literature in this chapter is based on the following assumptions:

- A human factors perspective (i.e. focussed on the end user) can contribute to effective service design.
- Other theoretical disciplines can help explain or predict how users interact with new technology.

- The design of services that provide mobile access to information must be based on how that information adds value within a task context.
- Location and context provide specific opportunities and challenges for service development.

The literature review therefore contains five sections which explore value from a variety of different theoretical perspectives and highlight the implications for this thesis:

2.2: Marketing/retailing based definitions of value

2.3: User centred design and human factors perspectives on designing effective systems

2.4: Theoretical perspectives which attempt to predict technology adoption

2.5: Information and information value

2.6: Mobile location services from a theoretical and practical perspective

The literature review chapter concludes with a summary of the main design and methodological implications for the remainder of the thesis.

2.2 A marketing / retailing perspective

This short section presents views on value from a general marketing/retailing perspective. There is considerable literature within this field which provides definitions of value in relation to products and service, and links this to consumer behaviour, and in particular, purchase decisions.

Zeithaml (1988) highlights how value is an indistinct and elusive construct. She undertook an extensive review, and an explorative study of consumers in the product category of beverages, to propose a conceptual model that defines and relates price, perceived quality and perceived value. Based on a range of conceptually different descriptions from participants, Zeithaml (1988) defines perceived value as 'the consumer's overall assessment of the utility of a product (or service) based on perceptions of what is received and what is given' and how value represents a tradeoff of the salient give and get components'. She underlines how both the desired 'get' components (e.g. volume, quality, convenience) and the 'give' components that are important (e.g. money, time and effort) vary across consumers.

Fornell et al. (1996) define value as a factor influencing overall customer satisfaction, leading to either customer loyalty or customer complaints. Value is described in terms of the perceived level of product quality relative to the price paid. Quality depends on the degree to which the firm's offering meets individual needs, plus the extent to which the firms offering is stable, standardised and free from defects. This definition therefore describes how value is contingent on a match with user needs, but is also influenced by the sum paid by the consumer.

Sheth et al. (1991) propose that consumers' decisions are influenced by five consumption values (shown in Table 2.1 below), operating on decisions regarding whether to buy, what product to buy, and what brand to buy. Within this framework, functional value was seen as the key influence on consumer choice.

Functional value	The *perceived* utility acquired from an alternative's capacity for functional, utilitarian, or physical performance
Social value	The *perceived* utility acquired from an alternative's association with one or more specific social groups
Emotional value	The *perceived* utility acquired from an alternative's capacity to arouse feelings or affective states
Epistemic value	The *perceived* utility acquired from an alternative's capacity to arouse curiosity, provide novelty, and/or satisfy a desire for knowledge
Conditional value	The *perceived* utility acquired by an alternative as the result of the specific situation or set of circumstances facing the choice maker

Table 2.1 Consumers' consumption values (Sheth et al. 1991)

Consumer choice is influenced by any or all of the above consumption values, which are independent, and make differential contribution in any given choice situation. Sheth et al. (1991) are confident that the theory may be applied to any consumer choice situation of interest, with the limitation that the context of decision making is individual (rather than group), systematic (rather than random) and voluntary (as opposed to mandatory).

Based in part on Sheth et al. (1991), Sweeney and Soutar (2001) developed a multidimensional model that can be used to assess customers' perceptions of the value of a durable good at a brand level. Their model contained four basic dimensions as shown below:

Emotional value	The utility derived from the feelings or affective states that a product generates
Social value (enhancement of social self-concept)	The utility derived from the product's ability to enhance social self-concept
Functional value (price/value for money)	The utility derived from the product due to the reduction of its perceived short term and longer term costs
Functional value (performance/ quality)	The utility derived from the perceived quality and expected performance of the product

Table 2.2 Consumers' consumption values (Sweeney and Soutar 2001)

Although developed in the context of durable goods they believe that their findings are applicable to other product contexts, 'with only quality items likely to need adaptation for nondurable products'. In contrast to Sheth et al. (1991), they believe that the *conditional value* component is not of the same order as the other dimensions; rather it is 'derived from the moderating effect of a situation on perceptions of functional and social value on outcomes'. In this respect, conditional value is more consistent with the *context* label within HCI (see Section 2.6.3).

Lin et al. (2005) review different conceptions of value, and conclude that 'perceived value should be defined as a second-order multidimensional formative construct'. In their view, value comprises multiple 'give-get' components – and is measured in terms of those components - rather than being a construct which can be measured directly.

Turel et al. (2007) undertook a questionnaire survey to investigate perceived value in the context of pay-per-use services, and particularly SMS. They used the multidimensional 'perceived value' construct developed by Sweeney and Soutar (2001) and examined (1) whether overall assessments of value were a key determinant of the behavioural intention to use SMS, and (2) what the key value components are that drive the adoption of SMS. Their research model is shown below.

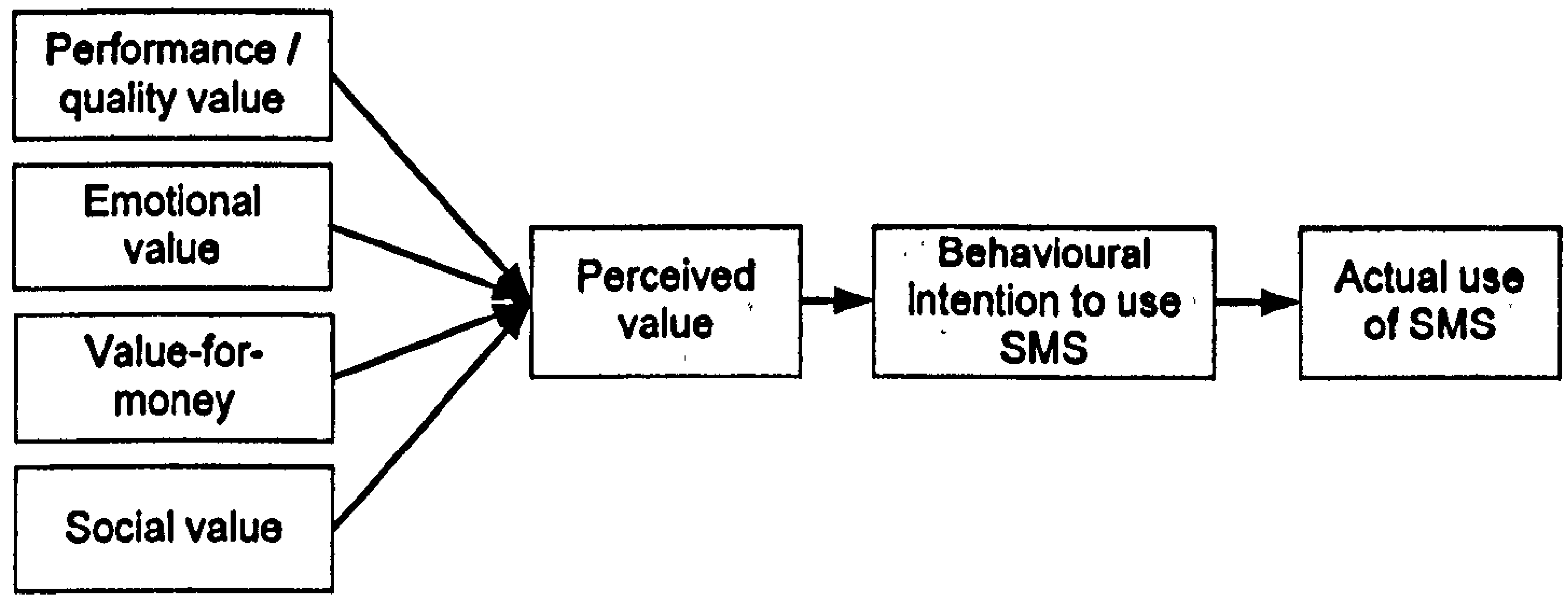


Figure 2.1 Model of user acceptance of SMS (Turel et al. 2007)

Perceived value was not measured directly, but was modelled as an aggregated function of the four first order constructs shown on the left. Their findings were that whilst individual value constructs had minor influence on users' behavioural intentions, an aggregated perceived value construct strongly affected behavioural intentions. This is in line with the improved performance of models that consider perceived value as a second order factor, as described by Lin et al. (2005). Perceived social value was found to have no impact on users' overall value assessment. A key argument of Turel et al. (2007) was that existing models do not account for the per-use payment of services. However, it was not made clear in their study whether the participants recruited actually held pay-per-use or monthly contracts. In addition, they offered no explanation for the apparent lack of social value, despite texting becoming a widespread social phenomena (Taylor and Vincent 2005). A possible explanation for this anomaly is that when a service becomes an integral component of life, the capability being offered ceases to be an influence that is readily articulated by individuals.

2.2.1 Summary of contribution to thesis

The focus of this thesis is not on consumer purchase decisions (and the cognitive processes involved), rather on providing benefit or utility to end users of MLS (which will of course influence ensuing consumption or purchase decisions). However, the literature reviewed briefly above shows how utility (or more accurately, *perceived* utility) is a key factor in consumer purchase decisions. In line with the summary above, the majority of researchers define customer value in terms of a get (benefit) and give (sacrifice) components (Lapierre 2000), and some also highlight the influence of the situation or context of use. The particular relevance of the above literature is that it highlights the need to (1) provide utility to the end user in order for MLS to be successful in the marketplace, and to (2) consider both the benefits and costs to the individual within a specific context of use.

2.3 User centred design

2.3.1 User centred design

The basic philosophy underlying this thesis is that of user-centred design, in as much as there is a focus on design of services from a user's perspective. User centred design is an iterative design process involving a multidisciplinary design team, and end users, with the objective of developing well specified and usable products or services. There is a wide range of techniques and tools that can be used (for example, see Preece et al. (2002) and Dix et al. (1993)), plus many texts specifically focusing on the design of mobile products or service, examples being: (Jones and Marsden 2006; Lindholm et al. 2003; Weiss 2002). In addition there is a range of standards for specifically supporting a user focus on the design of computer-based systems, including definitions and measurement of usability (ISO 1996) and human centred design processes for interactive systems (ISO 1999).

Preece et al. (2002) recognise that effective user-focused design is concerned with a broader set of issues than has traditionally been the scope of human-computer interaction (HCI), and use the term 'interaction design', defined thus:

> 'designing interactive products to support people in the everyday and working lives'.

Due to the multidisciplinary scope of user-focused design, and a huge diversity of products (e.g. single/multi-user, fixed/mobile ICT, work/consumer focused, functional/fun, explicit/embedded etc) there is a wide range of overlapping perspectives and terminology used by academics and practitioners. Irrespective of which perspectives, methods or tools are being used to accomplish user centred design, whether it is fixed or mobile ICT that is being designed, or the particular application domain, there are some common underlying principles to system design. Gould and Lewis (1985) set out some early principles to lead to the design of usable computer systems:

1. An early focus of users and tasks, including the characteristics of those users and the nature of the tasks being undertaken.
2. Empirical measurement, including their reaction and performance with task-based scenarios and prototypes.

3. Iterative design, with cycles of 'design, test, measure, redesign'.

Preece et al. (2002) develop the first principle (early focus on users and task) further, and these are used as general guiding principles throughout this thesis:

1. User's tasks and goals are the driving force behind the development.
2. Users' behaviour and context of use are studied and the system is designed to support them.
3. Users' characteristics are captured and designed for.
4. Users are consulted throughout development from earliest phases to the latest and their input is seriously taken into account.
5. All design decisions are taken within the context of the users, their work, and their environment.

2.3.2 Ecological approaches to interface design

The above section is concerned with *user* centred design. Flach et al. (1998) describe an ecological or *use* centred approach to interface design. They quote Hollnagel (1988) who states that within a complex work environment, the objective is to 'provide the right information at the right time and in the right way'. Ecological or use-centred design aims to understand what 'right' means in the context of a specific work system. It takes a broad perspective of a support system and defines the system relative to its function within a larger problem space. The term *ecological* emphasises the inclusion of the work domain, and the enablers and constraints arising from this work domain. It is based on the notion of possibilities or affordances (Gibson 1979; Norman 1988). Gibson coined the term, describing the affordances of the environment as 'what it offers the animal, what it provides or furnishes, either for good or ill'. He makes the key point that affordances are not physical properties - they have to be measured in relation to an individual or a situation. Affordances describe a relationship between people and objects/the environment, when an individual is attempting a specified task. A key point is that the work constraints, and the associated costs and values are related to a situated context, consistent with the notion of situated action (Dourish 2001b). Norman then used the concept of affordances to help show how a designed object provides the meanings necessary to explain the range of activities that can be undertaken with it.

An example of an ecological perspective is given in relation to the provision of altitude information to a pilot. This information by itself is not enough; rather the pilot must know 'the significance of that altitude relative to their flight objectives (e.g. landing, evading detection from enemy radar etc, etc.) and relative to the dynamic capabilities of the aircraft ..... they must know if they are flying too low or too high' (Flach et al. 1998).

The ecological or user-centred perspective is contrasted with three other approaches to the design of human-machine systems by Flach et al. (1998); The key differences are outlined in Table 2.3.

Technology-centred approach	Focuses on the capabilities and limitations of the technologies Interface design reflects the technological capabilities (there may a display for every sensor, a control for every control parameter)
User-centred approach	Focuses on the limitations and capabilities of the human operators Interface design reflects the capacity and expectations of the users (mental models, stereotypes, information chunking, stimulus-response, proximity compatibility etc are used to guide interface design).
Control-centred approach	Focuses on the coupling between humans and technologies, the user is a controller or supervisor of the technology. System design focuses on the dynamics and stability of the human-machine control loops.
Ecological or use-centred approach	A broader perspective that defines the system relative to its function within a larger problem space.

Table 2.3 Different perspectives on human-machine design, based on Flach et al. (1998)

A key message from Flach et al. (1998) is that 'it is the ability to represent meaning, not information that is the test of an interface'. They underline the importance of constructing interfaces that are intelligent, in so much as they take into account the possibilities afforded by a work domain, the constraints imposed and the criticality of information within that context. Ecological approaches also highlight the need to support all three levels of skill, rule and knowledge-based behaviour (Rasmussen 1983): workers should be able to act directly on the interface (skill-based behaviour); there should be a consistent one-to-one mapping between the work domain constraints and the perceptual information of the interface (rule-based behaviour); the interface should represent the work domain in the form of an abstraction hierarchy to serve as an externalised mental model for problem solving (knowledge-based behaviour) (Vicente 2002).

The ecological or use-centred perspective can help understand how to deliver value to an end-user within a dynamic and contextually varying usage situation. It is particularly relevant within a mobile context due to the multitasking nature of mobile activities, which are often embedded within, and influenced by, a series of wider influences. The ecological perspective contributes to this thesis by highlighting how:

- End users operate within a context of use which influences their behaviour and varies dynamically.
- It is information, not data that is important to user. This information must have *meaning*, and this need for meaning also varies dynamically.
- Interactions with the use environment guide the actions of user, by contributing to information environments, and providing users with opportunities for action and constraints on future behaviour.

2.3.3 Usability engineering

Usability engineering seeks to apply a formalised and structured approach to specifying and testing user requirements for systems. It seeks to maximise the usability of systems, in terms of their effectiveness, efficiency and satisfaction (Bevan 2001; ISO-9241 1998). In contrast to the model-based approaches of MIS as discussed in Section 2.4, usability engineering supports directly the design and development of products and services.

There are many strengths to the usability engineering approach (see Dillon and Morris (1999) for an interesting summary):

1. Performance targets are explicitly set, and operationalised in quantitative terms. These therefore allow absolute (e.g. 70% of users must be able to do ...) or relative (this design must result in xx % fewer input errors) performance statements to be made.
2. These performance targets are defined within the specific context of the users and tasks that are relevant, and therefore can take into account the variability between different user groups, and the contextual nature of the interaction between these users and technology.
3. Usability engineering focuses on *what* the user is trying to achieve, and the direct link between these tasks/goals and the usability metrics embodied within the usability engineering approach. If the IT is properly specified (it has a good functional fit with

the task of the user) then the utility of the IT can be clearly demonstrated via the usability engineering approach.

4. Usability engineering directly supports an iterative design process by providing user performance data that can demonstrate to the development stakeholders the extent to which a current design is an improvement over previous versions or competitors' products. Usability engineering emphasises the tasks/goals of the user, rather than the simple conformance with style guides and design principles. Usability engineering therefore goes further than creating a usable interface, and focuses on the information and functionality needed to support the activities of the user.

Although usability engineering has many strengths, it also has associated weaknesses (Dillon and Morris 1999), many of which stem from the contextual nature of human performance:

1. Usability is very context dependent - there is no universal usable design - and so the design solution that works well in one context of use may not be optimum for a different set of users, variations on the tasks or activities they are completing, or a different location of use.
2. Due to the context dependent nature of usability, it is difficult to make generalisations about good or poor solutions; this then limits the extent to which design principles can developed.
3. Determining suitable usability criteria and numerical performance targets (such as 90% first time accuracy) also requires considerable experience in order to ensure that they meaningful and achievable within the usage context and constraints imposed. Depending on the user, the activities they are undertaking, the motivations for these activities and the context of use, one or more of the usability constructs will be most appropriate for quantifying user interaction with a product or service.
4. Although the usability engineering approach allows the quantification of user performance with a system, it does not directly inform the design of a 'better' system. Results of usability testing need interpretation

There is also another limitation, not directly discussed by Dillon and Morris (1999). By focusing on discrete and measurable aspects of user interaction with a product, it is easy to miss the underlying motivation(s) and subtleties of system use. Usability engineering generally implies a highly functional perspective on users and systems, which may be appropriate within a work or organisational context. However, there has much recent recognition of the importance of a wider range of 'usability' criteria to take into account the diverse and subtle motivations for using services. Abraham Maslow (1943) developed a general hierarchy of human needs that can help identify a wider range of user needs and motivational influences. The lowest order needs are (1) biological and physiological needs, progressing upwards through: (2) safety and security; (3) social (belongingness and love); (4) ego and esteem; and (5) self-actualization and fulfilment needs. The basic characteristics of this model are that lower order needs are generally more important to the individual that higher order ones, and that as soon as lower order needs become satisfied, an individual seeks fulfilment at higher levels of need.

Several human factors authors have developed similar models based on a hierarchy of needs. Jordan (1999) suggests hierarchical needs based on functionality; usability; and then pleasure. Bonapace (2002) (user needs when interacting with products) proposes: safety and well-being; functionality; usability; pleasure. Ching (2001) (in-vehicle telematics systems from a telecoms perspective) suggests needs based on being: connected; protected; productive; and entertained.

Menou (1995a) identifies a general weakness in these models - in the context of the mapping of information needs onto Maslow's hierarchy by Horton (1983). The hierarchical models assume that as lower order needs are increasingly satisfied, higher level needs come into operation. Maslow (1943) did actually discuss the 'degree of fixity' of the hierarchy of basic needs, and identifies a number of exceptions, including self-esteem taking precedence over love, self-actualization driving creative people, and the deadening of aspirations within the chronic unemployed. Rather than describing a hierarchy of needs, Menou suggests categories of a non-hierarchical nature (i.e. of equal importance) and also identifies the potential contribution that could be made 'if someone could ever identify and define the attributes of 'basic information needs'.

A user-centred approach within HCI has traditionally aimed to maximise the usability of interactive systems. Cockton (2004a; 2004b) states that concepts such as tasks, needs, quality and costs are meaningless unless they are defined relative to usage, i.e. that they are inherently *situated* concepts. He is critical of traditional usability by highlighting that 'fit' is more important than quality in use (i.e. usability), fit being the match between the needs of the stakeholder and the capabilities offered by a computing system, similar to that described by Goodhue and Thompson (1995). However, the main argument of Cockton

(2004a; 2004b) is that HCI must go further than 'fit' and focus on delivering value, where value is the proposition which is truly important for the various stakeholders that a product impacts on. Value can be described in various forms, including monetary, organisational, cultural, experiential or spiritual. The specific example given by Cockton (2004a) is a heating controller for a domestic hot water system. He makes the distinction between it being easy to programme (usability), there being a good match between the heating needs of individuals and the program capabilities, such as flexibility in programme settings (fit), and it being able to conserve fuel resources or minimise spend on heating bills (value propositions). He argues that the role of HCI is to deliver value through design, and that ultimately 'innovation, quality and fit are worthless if they do not deliver value'. Interestingly, although Cockton later (2006) describes 'value' as a 'unifying concept for design' he also recognises the problems of definition associated with the term. Instead of using the term '*value-centred*' design, he prefers the term '*worth-centred*' to describe the need to focus on what is worthwhile, driven by individual and collective human motivation.

2.3.4 Summary of contribution to thesis

The literature within the section above highlights how user-centred design (or more strictly, a *focus on users*) provides an effective means of service development. A wider view of the situated nature of use is needed, particularly for mobile service design, and it is the meaning provided to the end user within this context that is important and provides value to the end user. Usability engineering (and its quantifications of effectiveness, efficiency and satisfaction) is useful, but insufficient: a broader perspective is necessary to understand user interactions with technology and ensure that technology delivers *value*, rather than just *usability*, to a user.

2.4 Theoretical perspectives on interaction with technology

2.4.1 Attitude-based models of technology adoption

There is a range of models centred on the formation of attitudes, as would be generated by consumers when exposed to new (mobile) products or services. Fishbein and Ajzen (1975) describe a general consensus that attitude is a 'learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object'. Peter and Olson (1999), in the context of consumer behaviour, define attitude as 'a person's overall evaluation of a concept'. When measuring attitude (e.g. via a survey), Oppenheim (1992) defines an attitude statement as 'a single statement that expresses a point of view, a belief, a preference, an emotional feeling, a position *for or against* something'.

Attitudes have been described as comprising three components, e.g. Spooncer (1989): cognitive, affective and conative. The *cognitive* component relates to the knowledge / beliefs that an individual has about the object – it concerns knowing about something, or believing something. An example would be a consumer knowing or believing (perhaps erroneously) that an online information source was more current than a paper-based equivalent. The *affective* component relates to the consumer's emotions or feelings about the product. These are based on an evaluation of the product itself, but also a wider consideration of aspects such as the brand (and these could even be in direct conflict with each other). An example of an affective response would be 'it is fun using this online information service'. The *conative* aspect of attitudes refers to the behavioural tendencies towards the object (or idea, person or group). These are attitudes to do with *doing something* with the object, for example an attitude that reflects wishing to enrol with a mobile information service. However, as highlighted by Spooncer (1989), a statement of behavioural intention may, or may not, produce actual behaviour. Attitudes are often the focus of consumer behaviour research because they are learnt, but can also be changed (e.g. by marketing). In addition, given the existence of a certain set of contextual criteria, attitudes can relatively accurately predict the actual behaviour of consumers.

Despite this distinction, most recent researchers agree that the early and simpler concepts of attitudes are most useful – 'that attitudes represent a person's favourable or unfavourable feelings toward the object in question' (Peter and Olson 1999). This assumes that beliefs (cognition) and intentions to behave (conation) are related to attitudes, but are separate concepts, and not part of attitude itself.

The Technology Acceptance Model (TAM) is one of the most widely used attitude-based models for describing and predicting the end user acceptance of computer systems. It was initially developed in a doctoral dissertation (Davis 1986) and subsequently published widely (e.g.: (Davis 1993; Davis et al. 1989; Davis and Venkatesh 1996). TAM is based on the Theory of Reasoned Action TRA (Ajzen and Fishbein 1980), shown in Appendix 2A. The key feature of TRA is that any factors (i.e. all external variables such as system characteristics, user characteristics, task characteristics, political or organisational influences etc) influence behaviour only indirectly by influencing attitude, subjective norm, or their relative weights (Davis et al. 1989).

The goal of TAM (shown below) is to provide a parsimonious explanation of the determinants of computer acceptance, applicable to a broad range of end-user computing technologies. TAM suggests that two particular beliefs, perceived usefulness, and perceived ease, are of most relevance to end user acceptance. Perceived usefulness is defined as 'the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context'. Perceived ease of use is 'the degree to which the prospective user expects the target system to be free of effort' (Davis et al. 1989).

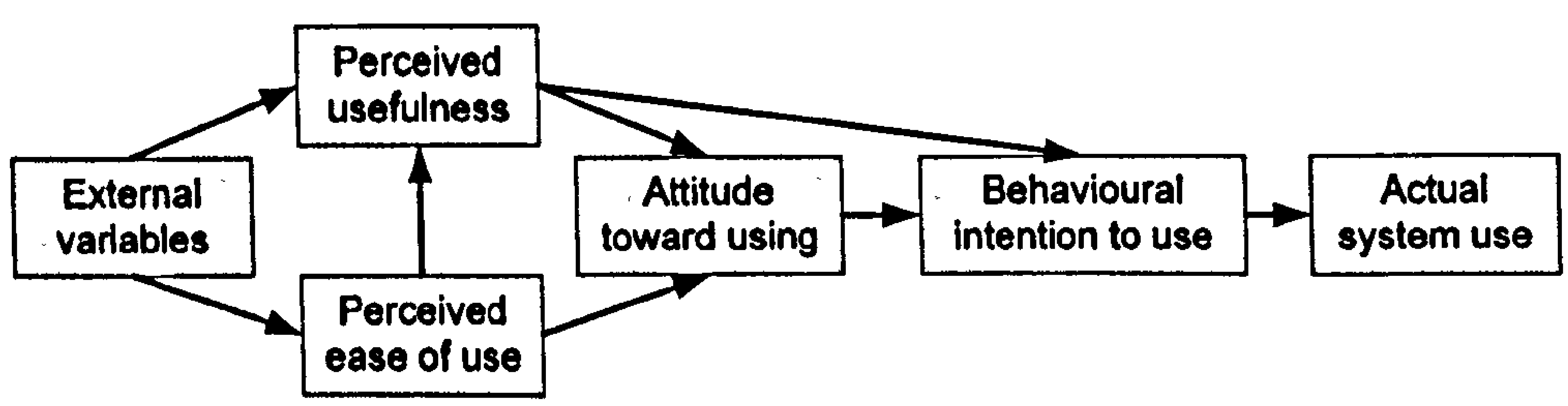


Figure 2.2 Technology Acceptance Model (Davis et al. 1989)

Consistent with TRA, TAM suggests that computer usage is determined by behavioural intentions and that those intentions are determined by a person's attitude towards the system. However, unlike TRA, TAM also shows a direct link between the perceived usefulness of a computer system and behavioural intentions (i.e. independent of attitudes). This reflects the work context, where an individual may intend to use a system irrespective of their attitudes towards it, if for example they believe it will increase their job performance. In addition, TAM did not include the subjective norm construct of TRA, largely due to its 'uncertain theoretical and psychometric status' (Davis et al. 1989), and stated, based on original work, that subjective norm had no impact on usage intentions.

TAM is based on user reporting on multiple items representing the different constructs, typically via a survey approach. It has been widely applied to a range of differing computing contexts, and has repeatably demonstrated a R^2 (explanation of variance in usage) in the region of 40% for a range of office software applications (Legris et al. 2003).

More recent developments of TAM have generally decomposed the *external variables* of TAM, and included constructs that recognise the importance of social influence (including subjective norm and image) and the influence of factors that enable usage behaviour to actually take place. Venkatesh and Davis (2000) developed TAM2, which provides a more detailed decomposition of the factors influencing perceived usefulness and intention to use. They undertook a longitudinal study of four computing systems in four different organisations to show that social influences (subjective norm, voluntariness, and image) and job/task factors (job relevance, output quality, result demonstrability, and perceived ease of use) significantly influenced user acceptance, accounting for 34%-52% of the variance in usage intentions.

Mathieson et al. (2001) extended TAM by suggesting that *perceived resources* acted in addition to perceived usefulness and perceived ease of use to influence behavioural intentions to use information systems. A comparison with the original TAM demonstrated a greater explanation of the variance in usage intentions. They suggested that where resource constraints exist (e.g. relating to hardware, software, expertise, time etc), it is beneficial to include a construct that takes into account these factors.

In a further extension of TAM, Venkatesh et al. (2003a) reviewed and empirically compared eight prominent IT acceptance models, and developed the Unified Theory of Acceptance and Use of Technology (UTAUT). This model is designed to explain and predict the success of new technology within organisations, and help understand the drivers of acceptance (Appendix 2B). *Performance expectancy* replaces the perceived usefulness of the original TAM. *Effort expectancy* replaces the original perceived ease of use. *Social influence* is added as an influence on behavioural intention, and *facilitating conditions* is added as a construct directly influencing usage. In addition, gender, age, experience and voluntariness of use are added as factors mediating the impact of the four key determinants of intention and usage. This model was shown to outperform each of the individual models, and to explain approximately 70% of the variance in IT usage intentions. The authors also identified the need for a deeper understanding of the dynamic influences on usage of IT.

Legris et al. (2003) undertook a critical review of TAM, and while concluding that later versions of TAM (e.g. TAM2) were an improvement on the original, they also highlighted that the model 'hardly explains more than 40% of the variance in use' (i.e. *actual* use rather than *intended* use). They specifically identify three limitations of much of TAM research: (1) use of students (and therefore a lack of contextual validity); (2) a narrow set of applications being studied; and (3) relying on self-reported usage. The following example was given to highlight the problem with self-reported use:

> 'Observers in public washrooms in New Orleans, New York, Atlanta, Chicago and San Francisco noted that only 67% of the persons washed their hands after visiting the toilet cabinet. When 1201 Americans, in a telephone survey were asked if they washed their hands after going to the bathroom, 95% answered yes.' (La Presse Montréal, Tuesday 17 October 2000).

Legris et al. (2003) also highlight the need to take into account a wider range of influencing variables, including human and social factors, and those relevant to the adoption of innovations.

A variant of TRA (on which the original TAM was based) is the Theory of Planned Behaviour (TPB) (Ajzen 1991), shown in Appendix 2C. This was proposed to account for conditions where individuals do not have complete control over their behaviour. TPB adds an additional construct, *perceived behavioural control* that influences behavioural intentions. This refers to peoples' perceptions of the ease or difficulty of performing the behaviour of interest, reflecting the perceptions of internal and external constraints on behaviour. Varying influence has been found for the effect. Although some early studies, e.g. Davis et al. (1989), found little influence of a behavioural control construct on intention to use, the lack of this relationship has been attributed to little social pressure to use these systems (Pedersen 2001). More research studies within both organisational and electronic commerce settings have found support for a direct link between subjective norm and intention to use (Pedersen 2001).

Venkatesh and Brown (2001) undertook a longitudinal, phone-based survey of US households to investigate the drivers of adoption and non-adoption of PCs in the home. Initial respondents were contacted again six months later. The TPB was used due to the inclusion of a social norm influence. A relatively unique feature of this study (and a shortcoming of much of the research based on these attitudinal models) was the ability to determine what participants *actually did*, rather than what they *said* they were going to do. In addition, this study used a guiding theoretical framework, with factors and subfactors refined and re-defined based on preliminary analysis of data (i.e. an inductive element, with the data influencing the development of theory). The three main TPB belief structures of attitude, subject norm and perceived behavioural control were operationalised into factors and subfactors. For example, attitude was operationalised wrt. utilitarian, hedonic and social outcomes, with a range of questions relating to each of these.

The study found evidence for differing influences on the decision to adopt versus that to *not* adopt. Key in influencing decisions to adopt were attitudes regarding utilitarian, hedonic and social outcomes, and social influences. The top reported factors were: status impact from possessing current technology, applications for fun, influence of friends and family members, applications for personal use. However the factors influential in the decision to adopt were not so salient in the decision to not adopt. For non-adopters, the social influences and barriers were the most influential, and specifically, the normative influence of information from secondary sources (e.g. newspaper or TV) and critical barriers such as high cost, rapid change and lack of knowledge are influential

Another key finding was the mixed power, and asymmetry, of the link between intentions and behaviour. Based on the follow up survey, less than half intenders (i.e. those who said that they intended to buy a PC) actually did so, while 'nearly all' non-intenders did indeed not buy a PC. A key recommendation was to 'carefully consider factors that are salient to non-adopters, especially if the ultimate goal is to increase technology adoption.' Gollwitzer (1999) also highlights how the strength of the intention-behaviour relation varies drastically with the type of behaviour that is specified.

As a development of TPB the decomposed theory of planned behaviour (Taylor and Todd 1995) was developed to operationalised the components (i.e. determinants) of behavioural attitudes, subjective norm and behavioural control. This decomposed model is shown in Appendix 2D, and includes compatibility as a determinant of attitude towards use, consistent with Rogers (1995a).

The original TAM and related models were designed to explain technology adoption with fixed ICT within a work setting. More recent work has started to apply and develop TAM and its related models specifically to e-commerce and mobile contexts, with a range of different services that are largely volitional in their use.

The decomposed TPB was slightly adapted by Teo and Pok (2003) to investigate the adoption intentions for WAP-enabled mobile phones. They identified *relative advantage*, *ease of use*, *image*, *compatibility* and *risk* as beliefs influencing attitude towards WAP, *significant others* as influencing subjective norm, and *self efficacy*, *government* and *mobile operator* as influencing perceived behavioural control. They found that intentions to adopt a WAP-enabled mobile phone were associated with attitudinal factors and subjective norms, but not perceived behavioural control. They highlight the importance of the relative advantage, social image and perceived risk attitudinal factors, but also suggest that 'the ability to access the Internet anywhere, anyplace and anytime will only be useful if doing so serves a purpose', and that the convenience offered by time sensitivity is important. However, the model displayed poor overall power, explaining only 10.6% and 17.2% of the variance in behavioural intention within a newsgroup and email sample respectively.

Similarly, Hung and Chang (2005) tested the acceptance of WAP services using a survey based on TAM, TPB and a decomposed TPB. Although the TPB and decomposed TPB slightly outperformed TAM in explaining user acceptance of WAP services, all three models were poor in explaining the variance in actual use (R^2= 0.12, 0.11 and 0.08 for decomposed TPB, TPB and TAM respectively). The models were more effective in explaining intentions to use (R^2= 0.38, 0.38 and 0.33 respectively). The authors do not discuss the possibility of these models being inappropriate for understanding and modelling this type of behaviour.

Lu et al. (2003) proposed (but did not test) a model for Wireless Internet via Mobile Devices (WIMD). This distinguished between near term consequences (e.g. improvements in productivity, job performance, satisfaction) and long term consequences (e.g. impact on career prospects or social status). Long term consequences reflect the 'image' concept within innovation adoption (Moore and Benbasat 1991). The original construct of perceived usefulness was therefore divided into long-term and short term usefulness. The 'external variables' (acting on long or short term usefulness, and/or ease of use) were decomposed into: technology complexity, individual differences, facilitating conditions, social influences, wireless trust environment.

Nysveen et al. (2005) developed a model based on the TPB and tested this using individual surveys across four different categories of mobile services: text messaging, gaming, contacts, and payment. This model incorporated expressiveness and enjoyment constructs, along with usefulness, ease of use, normative pressures and behavioural control. The first five constructs were modelled as acting directly on intention to use, or via the generation of attitudes. Normative pressures and behavioural control were modelled as acting directly on intention to use. The model explained 72% of the variance in intention to use. They demonstrated that the intention to use mobile services is significantly affected by expressiveness, enjoyment, usefulness and ease of use (i.e. motivational factors), as well as by attitudes, normative pressure and perceived control. Their conclusions are that: services must be perceived to be enjoyable, useful (which the authors recognise as a 'hardly groundbreaking' finding), and enable expression of their personal and social identity. In addition, perceived ease of use is important, as are the limited influence of normative pressures, and a moderate influence of perceived control. As is typical of this literature, there is no reference to any usability or human factors literature.

Kaasinen (2005) adapted the Technology Acceptance Model for Mobile Services, as shown in Figure 2.3 below.

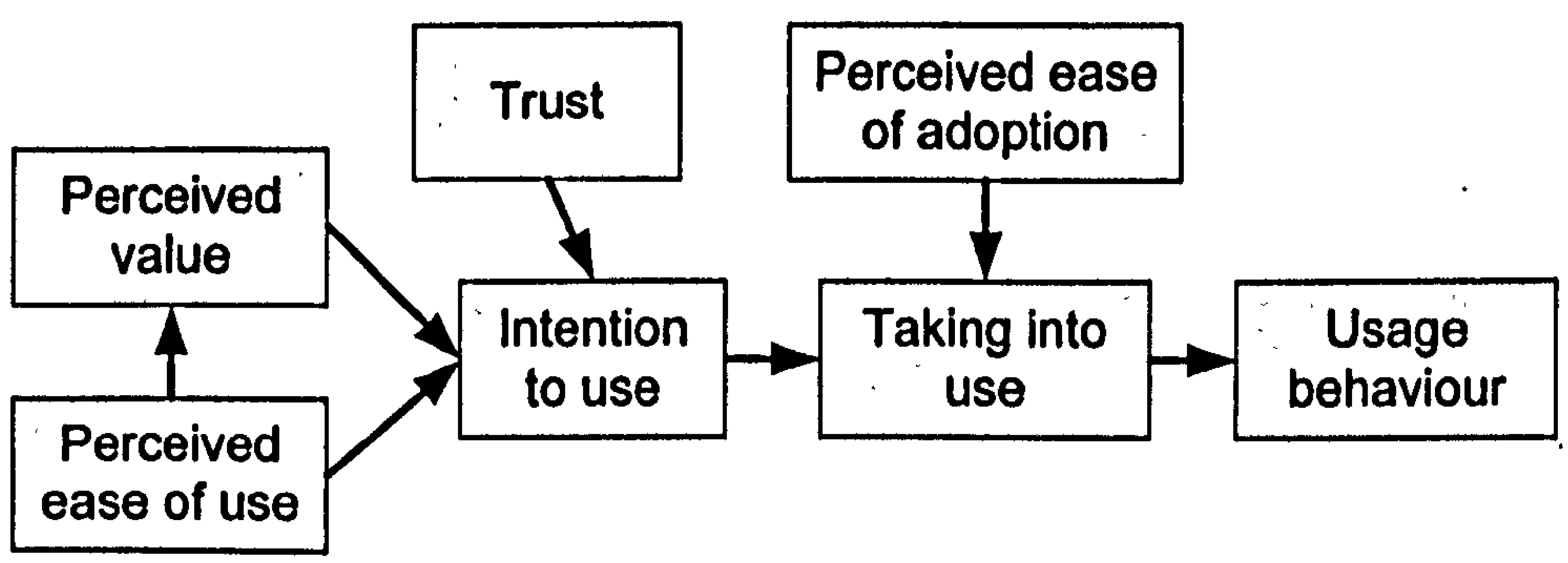


Figure 2.3 The Technology Acceptance Model for Mobile Services (Kaasinen 2005)

Perceived ease of use is retained as in the original TAM. *Perceived value* replaces perceived usefulness, recognising that perceived usefulness may not indicate adequate motivation to adopt a mobile service. By *value*, Kaasinen (2005) refers to the comment by Jarvenpaa et al. (2003) that 'consumers may lack a compelling motivation to adopt new pay-for service offerings unless they create new choices where mobility really matters'. She underlines the need to focus on the fundamental objectives that users are trying to achieve, rather than being tempted by featurism where products become a collection of useful features without addressing the needs of the end user.

Trust is added as a new element, recognising that the original TAM was developed in the context of work-related information systems where the information provided was perceived as reliable, and there was trust in how personal data was used, and relatively few concerns over privacy. Kaasinen uses the definition of trust offered by Fogg and Tseng (1999) - trust includes perceived reliability of the technology and service provider, ability to rely on the service in planned usage conditions, and confidence that the service can be controlled and will not misuse personal data. *Taking into use* is added since Kaasinen

(2005) identified that there may be a major gap between intending to use a service, and actually being able to use it. *Taking into use* is influenced by the *perceived ease of adoption* – it refers to the ability of the user to become aware of a service, being able to acquire, install and configure it and actually starting to use the service. Within the original TAM work setting, this gap between intentions and usage behaviour is not so relevant, since software will typically be installed by the IT department, and appropriate training provided.

2.4.2 Task-related models of technology use

It can be seen in the section above that there is a wide range of models based on user attitudes and the link to usage intentions. In contrast, task technology fit (TTF) models are based on a match of the capabilities of the technology to the demands of the task. Goodhue (1995) proposed TTF as a specific user evaluation construct that can be used to measure the success of management information systems. Consistent with usability approaches, he views technology as a means by which a goal-directed individual performs tasks. With tasks defined as the actions carried out in turning inputs into outputs, the TTF perspective 'suggests that a better fit between technology functionalities, task requirements and individual capabilities will lead to better performance' and that 'individuals can evaluate fit and choose technologies on that basis'.

Goodhue (1995) makes the distinction between mandatory and non-mandatory usage situations. In the latter case, individuals 'will not always utilize technologies with the highest TTF'. However he makes the key point that where usage occurs, a technology with higher TTF will give better performance; user performance is therefore both a function of degree of usage *and* the TTF that occurs.

Goodhue (1995) does recognise that the evaluation of a system will differ according to different users, as they may have different task needs and different abilities, and that objective measures of system success are extremely difficult to achieve – the reason for many MIS researchers relying on subjective user evaluations of systems in order to assess system success. He also underlines the need to better understand the link between subjective evaluation of the fit between (1) the task and the technology (i.e. the degree to which the IT is perceived to support the tasks in question), and (2) the actual performance of the user, and highlights the fact that with many MIS studies, there has been a 'neglect of the impact of the fit between technology and task needs'.

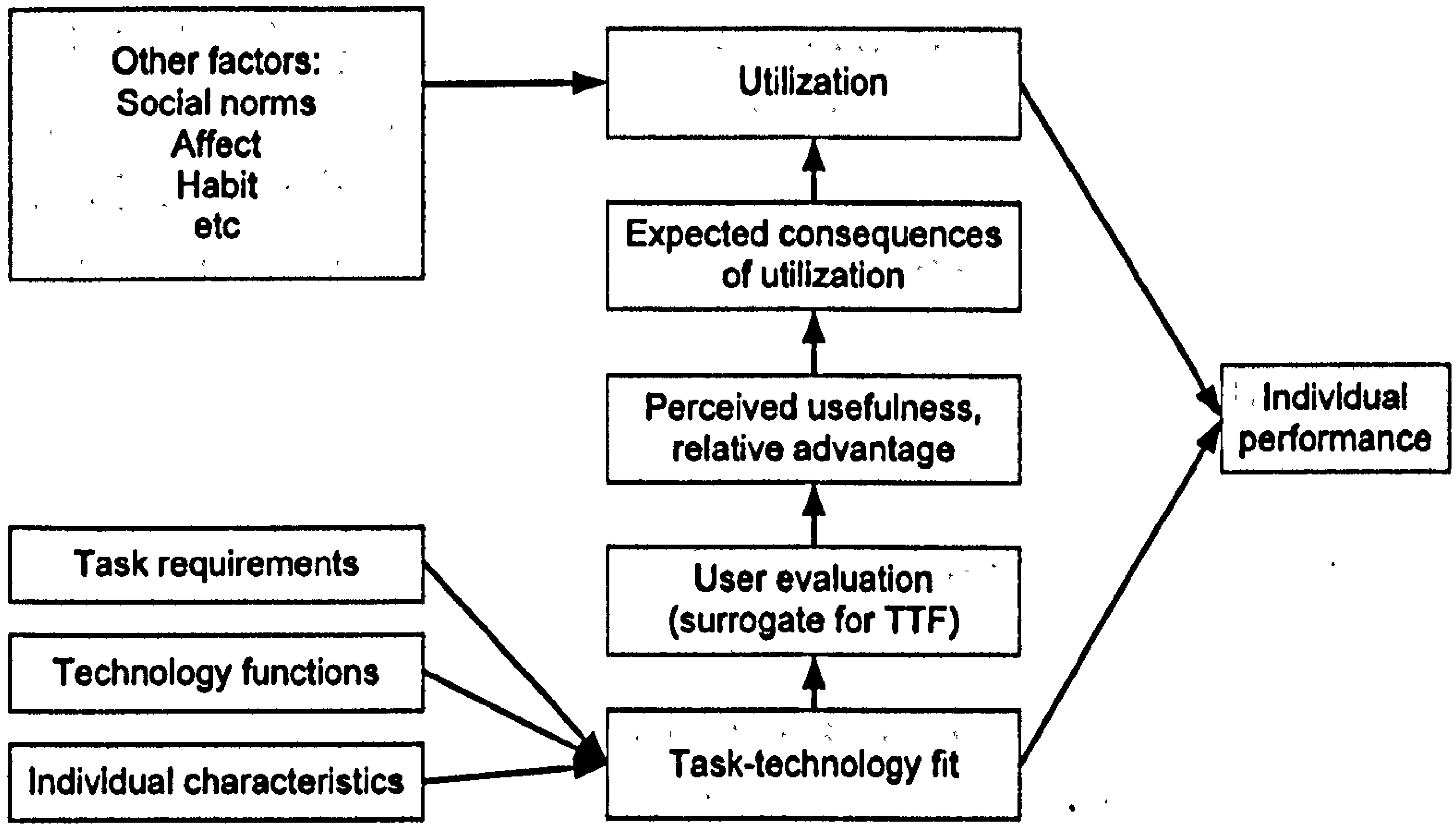


Figure 2.4 The Task Technology Fit Model Goodhue (1995)

Dishaw and Strong (1998) used a TTF model based on a functional description of the software maintenance activities (the basic user tasks) and a description of the basic functions available in design support software. Questionnaires were used to determine the extent to which particular activities were carried out, the existence of particular tool functionality (relevant to those tasks), and the extent to which the software tools were used (i.e. self-reported actual usage). TTF fit was calculated as the interaction between task and functionality variables. The model demonstrated that task-technology fit was associated with increased tool usage. Mathieson and Keil (1998) demonstrated that TTF affects perceived ease of use independent of system interface design – i.e. that the underlying way in which a system is designed (as well as user interface design) influences perceived ease of use.

Sarker and Wells (2003) undertook an exploratory study to identify the key factors affecting the use and adoption of mobile devices offering voice and data services. Rather than testing existing models using typical surveys or experimentation, data collection was based on interpretive interviews, to identify 'unique issues associated with mobile devices' and to offer (but not test) 'a framework providing an integrative view of the key issues related to mobile device use and adoption by individuals'. This framework consisted of: (1) Inputs (e.g. user characteristics, message/task characteristics, mode of mobility, technology characteristics and surrounding context); (2) Process (consisting of two interacting subprocesses of exploration and experimentation); and (3) output (the outcome of the use process – adoption decision and behaviour). There were several limitations with the study. It was limited in scale, consisting of a three-week field trial with 21 users. It identified a range influencing factors, but did not test any relationships between them. Finally, there appeared to be no explicit incorporation of a task aspect (i.e. what the user was doing) and the relative advantage of using a mobile device in this context.

2.4.3 Models based on characteristics of innovations

Although there is a range of models that aim to understand the *adoption process* for new innovations, the most widely recognised is the work done by Everett Rogers, now published in its 5th edition (Rogers 2003). He discusses the *adoption* and *diffusion* of a wide range of innovations - being distinct concepts in as much as *adoption* is the decision taken by members within that community to use a particular innovation, whereas *diffusion* refers to the spread of a particular innovation throughout a community. Rogers (2003) identifies five key variables that determine an innovation's rate of adoption:

- Perceived attributes of innovations
- Type of innovation decision (i.e. optional/individual, collective, or authority)
- Communication channels (e.g. mass media or interpersonal)
- Nature of the social system (e.g. its norms, degree of network interconnectedness)
- Extent of change agents' promotional efforts

Relative advantage	'The degree to which an innovation is perceived as better than the idea it supersedes'
Compatibility	'The degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs, of potential adopters'
Complexity	'The degree to which an innovation is perceived as difficult to understand and use'
Trialability	'The degree to which an innovation may be experimented with on a limited basis'
Observability	'The degree to which the results of an innovation are visible to others'

Table 2.4 Perceived attributes of innovations shown to help explain their rate of adoption, from Rogers (2003)

Of most relevance to this thesis is the identification by Rogers of the perceived attributes of an innovation which have a significant influence on individual adoption and the rate of diffusion of that innovation within a community. These factors are shown in Table 2.4. It is important to note that these are *perceived* attributes; therefore it is the *perception* of these factors which influences consumer adoption behaviour.

Rogers states that the first two attributes, relative advantage, and compatibility, are particularly important in explaining the rate of adoption (i.e. uptake or rejection) of an innovation. In addition, he identifies five categories of *adopters* of innovations based on their propensity to undertake adoption behaviour, and the time frame within a consumer product context. By taking the mean time of adoption (X), and the standard deviation (sd) based on a normal distribution, the adopter categories are defined thus: Innovators comprise 2.5%, falling to the left of X-2sd; Early Adopters comprise 13.5%, falling between X-2sd and X-sd; the Early Majority comprise 34%, falling between X-sd and X; the Late Majority comprise 34%, falling between X and X+sd; the Laggards comprise 16%, falling to the right of X+sd. Rogers acknowledges that the term 'Laggards' is unfortunate as it implies a degree of fault in not taking up an innovation. These categories of individuals differ in terms of their age, socio-economic grouping, income and occupation.

The attributes shown in Table 2.4 are useful predictors of successful services. However it must be remembered that they alone do not explain or predict the overall level of uptake of an innovation. Newell et al. (2001) also underline how the diffusion of an innovation throughout a community is not explained sufficiently by models based on benefits to the end user. Although of vital importance to marketers, innovation diffusion lies outside the scope of this thesis.

Moore and Benbasat (1991) adapted the characteristics of innovations originally presented by Rogers to refine a set of eight constructs that could be used to study individual technology acceptance. Rogers' diffusion of innovations perspective incorporates five innovation characteristics as antecedents to any adoption decision: relative advantage, compatibility, complexity, trialability, and observability, as outlined above. The Perceived Characteristics of Innovating (PCI) inventory incorporates three of these constructs as proposed by Rogers: (1) *relative advantage* (the degree to which an innovation is perceived to be superior to current offerings), (2) *compatibility* (the degree to which an innovation meshes with the adopter's current habits and practices), and (3) *trialability* (the extent to which a potential adopter believes that the innovation can be adequately tried prior to the adoption decision). The complexity construct of Rogers was renamed as (4) *ease of use* (the degree to which an innovation is perceived to be easy to use) for consistency with other models of adoption (e.g. TAM).

While Rogers proposed the construct of observability, Moore and Benbasat (1991) argued that this was not specific enough, and introduced two alternative constructs: (5) *visibility* (the degree to which an innovation is visible during its diffusion through a user community) and (6) *results demonstrability* (the degree to which the benefits and utility of an innovation are readily apparent to the potential adopter). *Image* (7) (the degree to which an individual believes that the adoption of an innovation will bestow them with added prestige in their relevant community) was included as a separate construct – not included within the relative advantage construct as proposed by Rogers. Finally, (8) *voluntariness of use* indicates the degree to which use of the innovation is perceived as being voluntary, or of free will.

Plouffe et al. (2001) compared the Perceived Characteristics of Innovating (PCI) inventory with TAM in the context of a large-scale market trial of a smart card- based electronic payment system being evaluated by a group of retailers and merchants. They demonstrated that the PCI antecedents explained substantially more variance (approximately 12% more) than does TAM in the intention to adopt construct, and also provided more detailed information regarding the technology adoption antecedents. They concluded that the PCI constructs outperformed TAM, and provided greater richness of data, although TAM was also effective, more parsimonious, and required less effort from respondents.

Karahanna et al. (1999) highlight the review findings of Tornatzky and Klein (1982) in that only three innovation characteristics, *compatibility*, *relative advantage* and *complexity* have been related consistently to adoption. Agarwal and Prasad (1998) make the key point that all three of these perceptions are relative (and personal) concepts and not inherent attributes of an innovation – they can therefore be perceived differently by different individuals, and also in different contexts of use (a point not made explicitly by the authors).

2.4.4 Integrated models of technology adoption

Much recent work on technology adoption has integrated concepts or constructs from different models to attempt to increase the power of models to explain and predict adoption behaviour. Karahanna et al. (1999) combined aspects of the theory of reasoned action (Ajzen and Fishbein 1980), and innovation diffusion, e.g. Rogers (1995a), to develop a general theory of technology acceptance. This theory includes *image* and *trust* as factors that influence attitudes towards an innovation. It also includes subjective norms as influences on behavioural intentions to adopt or use technology. This model is shown below.

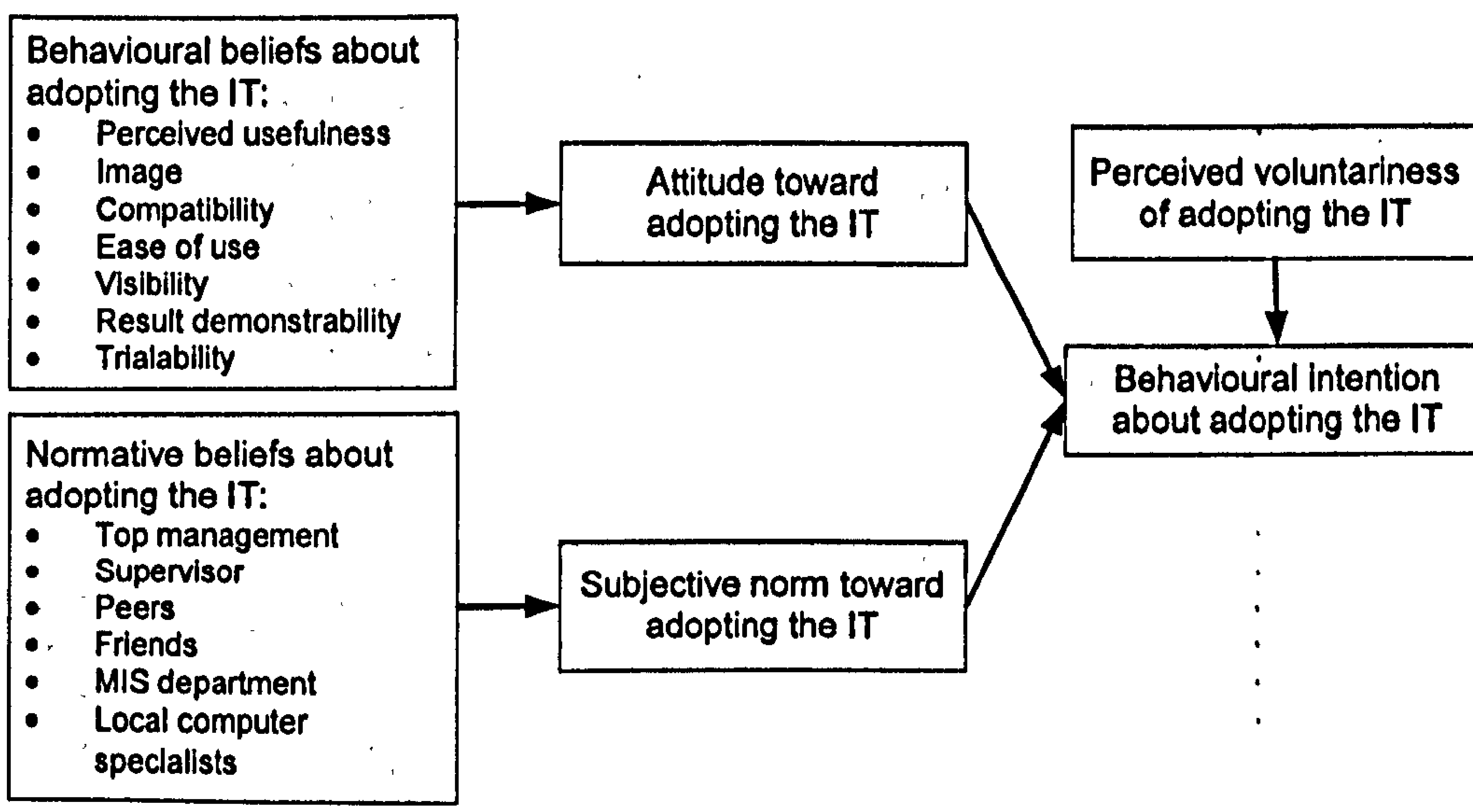


Figure 2.5 Integrated Model (Karahanna et al. 1999)

Barnes and Huff (2003) used the general theory of technology acceptance (Karahanna et al. 1999) to help understand the adoption dynamics and success of i-mode in Japan. They describe the success of i-Mode in Japan based on: its *relative advantage* due to a high level of unmet Internet demand (including access to email); its lack of *complexity* due to access via a single button press; *compatibility* with previous experience and Japanese cultural values; high *trialability* due to its pay-as-you-use nature; *observability* of use in public and propagation of sites via email signatures; a high level of *trust* due to the established NTT DoCoMo brand; and the role of *image* within a fashion conscious society. They also highlight the Japanese tendency for group conformity and hence the role of *subjective norms* in influencing technology adoption.

Dishaw and Strong (1999) integrated TAM and TTF. They highlighted that TAM usually focuses on the *intention to use*, or *actual use*, whereas TTF applications focus later in the outcome chain on actual use or individual performance attributable to actual use. In addition, TAM has no direct task focus (although the usefulness construct will reflect the extent to which the system is perceived to support the users' activities), and TTF does not explicitly include attitudes towards IT. They state that while TAM provides 'excellent explanation of intention to use, it is much weaker for actual use.' The authors suggested that a model that integrates constructs from the two perspectives may offer more explanatory power than either model alone. The study empirically compared three models: TAM, TTF and an integrated TAM/TTF model, using the same set of data collected from programmer analysts in three Fortune 50 firms. The TAM and TTF variables were collected using questionnaire items validated via previous studies.

The integrated model explained 51% variance in actual use (cf. 36% for TAM), this variance being explained by perceived usefulness, perceived ease of use, task-technology fit, task characteristics and tool experience. Task characteristics had the strongest total effect. They state that 'TAM's weaknesses for understanding IT utilization may be primarily attributable to its lack of explicit inclusion of task characteristics and how well the IT meets the requirements of that task'.

Dishaw and Strong (1999) did not find a direct link between TTF and perceived usefulness (i.e. did not show that a higher match of tool functionality and task requirements led to a greater perceived usefulness), concluding that perceived ease of use seemed to mediate (i.e. act between these functions) in some way. 'Apparently the relationships among these three variables [TTF, perceived usefulness, perceived ease of use] are more complex than originally thought.' This integrated (and less parsimonious model) highlights the importance of understanding the user task and matching technological capabilities to that task while maximising ease of use. However, the study still provides little prescriptive advice on the user-centred design of systems.

A rare cross-disciplinary approach to technology acceptance is the P^3 (Power, Performance, Perception) model proposed by Dillon and Morris (1999) as a means of integrating the approaches of usability within human-computer interaction, and TAM (stemming from management information systems research). They highlight that whilst usability typically addresses the question '*can* users use the system?', it does not tackle the question of '*will* users use a system?'. Usability engineering (as outlined in Section 2.3.3) may ensure a *usable* system, but not necessarily one that is *used* – Dillon and Morris (1999) describe usability as a 'necessary but insufficient determinant of use.' They propose that by integrating acceptance models into usability, it may be possible to incorporate acceptance features into the development phase of new computer systems, and hence reduce the risk of rejection of systems, and increase the quality of the early versions of software.

Dillon (2001) is of the view that Davis' TAM model is really a satisfaction scoring system, with performance being independent and thus necessarily measured via behaviour. This distinction between user performance and user attitudes is a basic argument of the P^3 model.

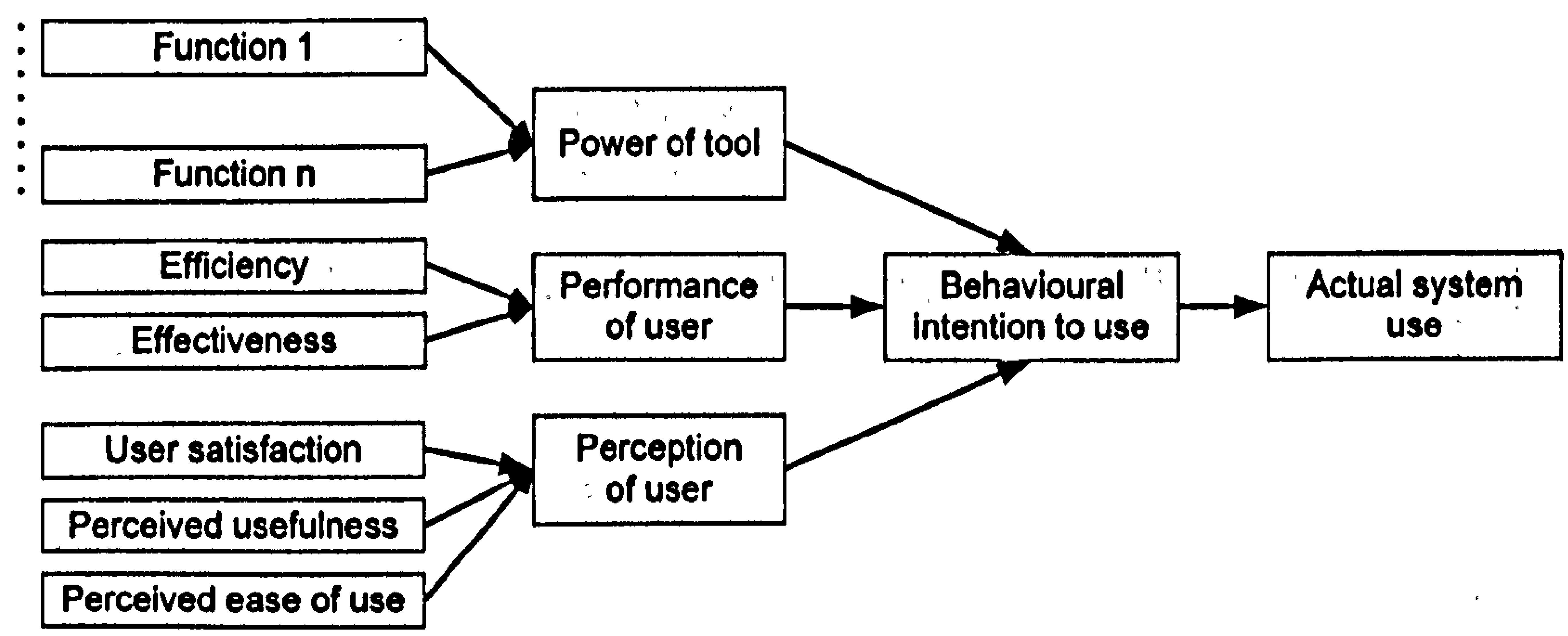


Figure 2.6 The Power, Performance, and Perception (P^3) Model (Dillon and Morris 1999)

The P^3 was tested formally by Fiorello (1999) using speech and conventional keyboard entry to perform word processing operations within an experimental setup. The *power* construct was decomposed into the functionality needed to perform the word processing, text generation and text editing tasks, and held constant across the tasks. *Performance* (effectiveness and efficiency) was measured with usability metrics relating to the quantifiable assessment of usability goals – accuracy rate, text input count and formatting error rate, accurate words per minute count. *Perception* was measured using subjective measures from TAM and usability engineering, with ease of use and perceived usefulness from TAM (Davis 1989) and user satisfaction based standard usability questionnaires. Intention to use was also determined.

Their main conclusions were that performance measures were poor predictors of behavioural intentions, and that 'a subject's perception of the ease of use and usefulness of the target technology adequately explains a subject's behavioural intention to use that technology'. They state that the advantage of incorporating the usability questionnaires is that they at least contain some insight into the aspects of interfaces that are key determinants to successful adoption (whereas the TAM *perceived usefulness* and *perceived ease of use* do not provide any prescriptive guidance). The main limitation in this study was that the power construct was kept constant (the same functionality was made available using convention and speech input). Although this enabled a more controlled comparison of the two input technologies (SRS and manual), it removed the potential predictive contribution of one of the constructs of the P3 model.

2.4.5 Summary of contribution to thesis

The literature within Section 2.4 demonstrates that there is a wide range of theoretical models which describe user interaction with technology. There is very little cross-disciplinary integration of theories, and attempts to understand user interaction with technology are usually grounded in a single discipline. Although attitude-based models can be effective indicators of behaviour within certain usage contexts, they may be poor explanatory tools within more complex and context-dependent situations. Studies typically focus on the influence of stable or underlying personal or system constructs, rather than more dynamic influences. An example of this is Kwon et al. (2007), who investigate the static (rather than situational) influence of the sensitivity to contextual pressure on user acceptance of context-aware services.

These theoretical models provide an understanding of the influences on adoption (for example the need to provide relative benefit, ease of use and compatibility) but provide little support for service design within dynamic usage environments. Research into successful MLS can usefully incorporate concepts from differing disciplines, including whether users will *want to* use a service *and* whether they will be *able to do so.*

2.5 Information and information value

Within this thesis, the end user of a MLS is considered to be an information processor. A MLS provides information to the end user who undertakes goal-directed behaviour within a certain context of use. The basic information processing perspective within this thesis is that shown below:

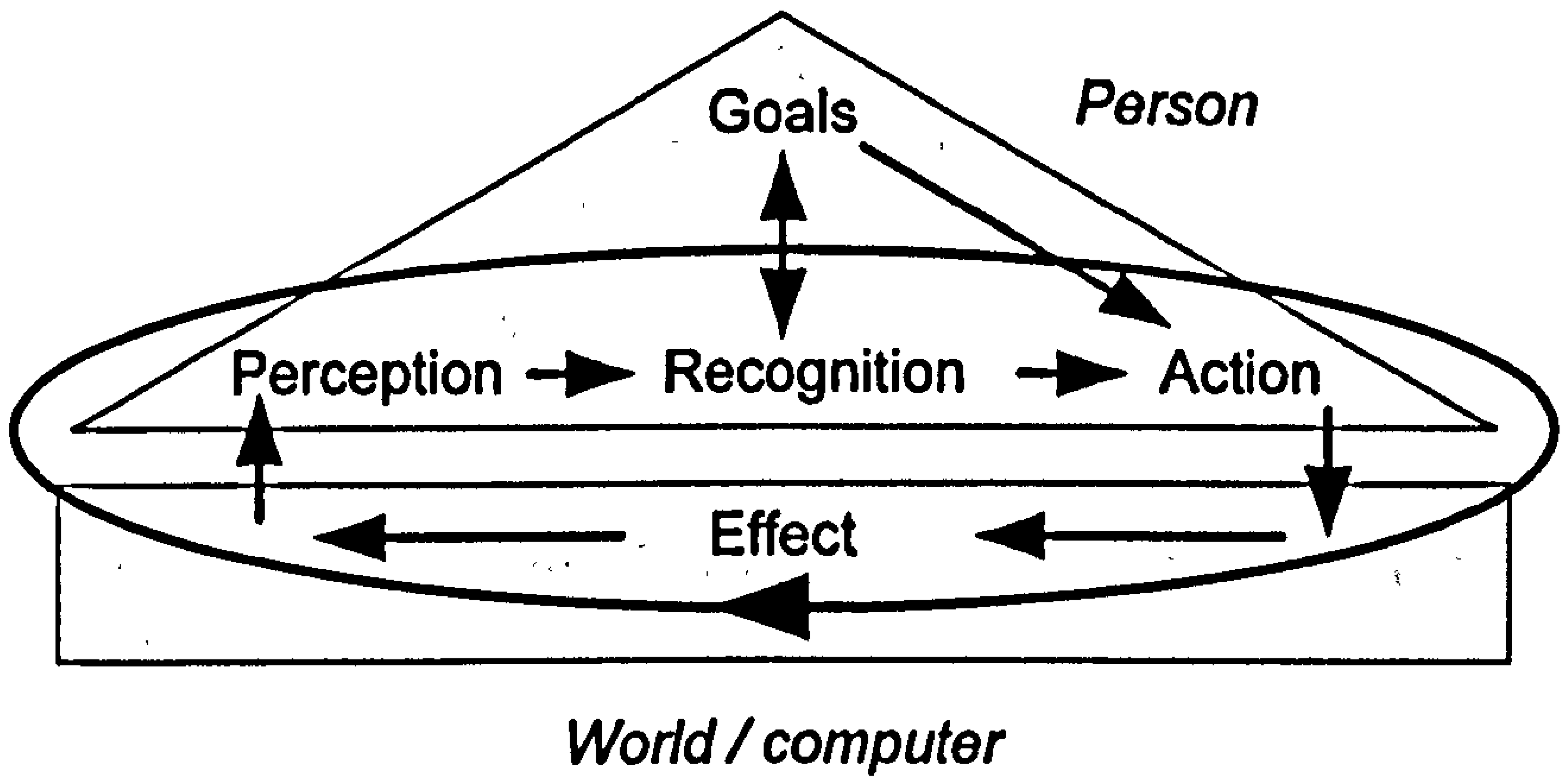


Figure 2.7 Cyclic and goal-driven interaction (Monk 1998)

This model has several key features. It describes the [external stimulus (from the environment, including computer)] > [perception] > [recognition] > [action] sequence of traditional cognitive psychology, but also demonstrates the importance of user goals in influencing behaviour. Action arises directly from goals, but also from recognition that has occurred as a result of perception. Goals influence recognition, but recognition of cues from the world and/or computer can also influence goals. In addition, the model explicitly describes a cyclic process where action leads to changes in the environment (including the computer), with these changes in turn being perceived by a user in relation to their current goals, and in a manner influenced by those goals.

The remainder of this section discusses 'information', its impact on the individual, and how the value of information may be determined from a user's perspective.

2.5.1 Information and human activity

Information plays a fundamental role within human tasks or activity. Wood (1986), in discussing and defining human tasks, describes all tasks as containing three essential elements: products, required acts and information cues. Products are described as 'entities created or produced by behaviours which can be observed and described independently of the behaviours or acts that produce them'. These will include an object (e.g. a report), and event (e.g. to serve a customer), and will have 'defining attributes such as quantity, timeliness and cost'. 'Acts' are required to create a defined product, these can be described at specific or general levels of abstraction, and can include physical (e.g. lifting) and cognitive component (i.e. judgment and inferential acts which require that information cues are consciously attended to and processed). These information cues are the third component comprising tasks, defined as 'pieces of information about the attributes of stimulus objects upon which an individual can base the judgments he or she is required to make during the performance of a task'. Wood (1986) makes the distinction between stimuli, cues and information, describing how 'stimuli that are used to make discrimination during the performance of a task are cues, and when these cues are presented in the form of facts that can be processed to make conscious discrimination i.e. judgments, then they are .... information cues.'

Information is therefore fundamental to human activity. It continuously revises the knowledge that an individual has, and uses, to make decisions, and therefore directly influences the actions that individuals perform (Ahituv et al. 1994). Information is key to both the formation of attitudes of consumers towards products and services, and the ability of services to support human behaviour by providing consumers with necessary meaning.

This section discusses information without reference to any specific application domain. Later chapters in this thesis focus on a specific task – driver navigation – and Chapter 6 describes information and decision making within this specific context.

2.5.2 Descriptions of information

Buckland (1991) identifies three principal uses of the word 'information': *information-as-process*, or the act of informing; *information-as-knowledge*, that which is perceived during the process of being informed; *information-as-thing*, or those things which are informative, such as data or documents. In a similar fashion, information is described by Menou (1995b) as having various states:

- As a product (or thing, object, resource or commodity) - i.e. something that exists, may be configured by humans and can be bought and sold.
- As a process - e.g. the acquisition, processing and assimilation of information, consistent with information processing perspectives.
- As what is conveyed in a channel – as implied by phrases such as 'electronic information', or 'the media'.
- Information as contents – that which conveys sense or meaning to the recipient.

The states above are not mutually exclusive, rather they can be used to characterise the communication of information within a given context. Menou (1995b) argues that it is information as *contents*, influencing a state of knowing that is the most important, and this is the perspective taken in this thesis.

The contents state of information is made up of layers at the semantic, syntactic and paradigmatic levels, these representing meaning, the physical arrangement of the words or graphics such that they are recognised and make sense, and the perspective or set of values of the individual and their community. For information-as-contents to be effective, it must be recognised and understood, but must also be believable, and consistent with an individual's ways of thinking. The example given by Menou (1995b) is information giving precautions against HIV. This information is 'known' by West African males, but is inconsistent with their deeper paradigms – being seen as a surrogate of castration – and therefore not used.

Source	Definition of information	Relationship between information and knowledge
Badenoch et al. (1994) quoting Blumenthal, 1969	Data recorded, classified, organized, related or interpreted within context to convey meaning	Information is the link between knowledge and observed phenomena
Badenoch et al. (1994) quoting Bell, 1979	A pattern or design that rearranges data for instrumental purposes	Information is the link between knowledge
Badenoch et al. (1994) quoting Burch, 1974	The result of modelling, formatting, organizing or converting data in a way that increases the level of knowledge for its recipient	Information supplies and supports knowledge
Badenoch et al. (1994) quoting Arrow, 1984	The reduction in uncertainty	Knowledge is manifest in terms of uncertainty about outcomes in the real world; information is a change in this probabilistic state; implies that information is 'useful knowledge'
Badenoch et al. (1994) quoting Stonier, 1990	Information is a function of complexity	Knowledge is 'organised information in peoples' heads'
Badenoch et al. (1994) quoting Farradane, 1976	Representation of knowledge or of thought	Information is an expression of knowledge
Menou (1995b) quoting Machlup, 1980 and Brookes, 1980a	Is designed to produce a state of knowing	Information affects knowledge by adding something to it or restructuring it

Table 2.5 Distinctions between information and knowledge (Badenoch et al. 1994)

The table above provides a summary of definitions of information, and its link with knowledge, quoted by Badenoch et al. (1994) and Menou (1995b).

Reinmoeller (2002) describes information as a commodity because it is pervasive and accessible to everybody, whereas knowledge is context-specific, relational, dynamic and personal. Badenoch et al. (1994) describe three main groupings of information classification:

1. That which develops knowledge – i.e. the process of learning.
2. That which is created by knowledge – the expression of knowledge.
3. A function of probability – i.e. addressing uncertainty.

A commonly used definition for information relates to its use in the reduction of uncertainty. Sheridan (1995) highlights this perspective: 'information, as explicated by Shannon (1949) refers to the reduction in uncertainty about the state of an event after a message has been sent relative to the uncertainty about the state of the event before the message was sent.' Rouse (1986) describes the reduction of uncertainty as occurring if an individual 'gains knowledge of a previously unknown or forgotten fact'.

However, although in many cases information will reduce uncertainty about an event, it may also *increase* uncertainty (Buckland 1991). If information is ambiguous or contradictory, the accessing and assimilation of this information by a user may increase the uncertainty they experience with regard to a particular event and any decisions that need to be taken. In addition, information is not the only thing that may reduce uncertainty (Badenoch et al. 1994): emotional support is cited as being able to reduce (subjective) uncertainty. Clearly then, the qualities of information are important in the context of mobile service design, and these are discussed briefly in Section 2.5.6.

In addition to the impact on uncertainty, the provision of meaning is also critical. Lindgren et al. (2002) - in specific reference to mobile products - makes this point: 'the biologist and systems theorist Gregory Bateson (1980) defined information as a 'difference that makes a difference'. By this he meant that we could appreciate something as information if it could be placed in a context that was useful to us. On the basis of this, we could interpret, gain understanding and draw conclusions'. The role of existing knowledge in determining whether something is information is highlighted by Harter (1992) in summarising Sperber and Wilson: (1986) 'a fact is manifest to a person at a given time only if he can understand it, at that time, and accept its representation as true or probably true'. The point being made by Menou (1995b) in relation to information relevance is that although potential cues may exist, information operates only when it makes sense to the recipient – it is therefore highly dependent on the individual and the context of use.

Two key points are made by Badenoch et al. (1994), which are themes throughout this thesis. Firstly, that 'information that isn't used is not information' – information only exists when considered in the context of an individual (or group) actually doing something with it. Secondly, that 'it is essential to find out the views of those who use information' – highlighting the need for a user-centred approach to determine the design of services that supply information to a user. For purposes of this thesis, a human-centred view of information is adopted – it is considered in the context of human understanding of events in the real world, and the impact this has on human behaviour.

2.5.3 Information value

With a user focus on design of services that deliver information to an individual, it is *information value*, rather than *information*, that determines the user outcomes resulting from using a MLS. Sheridan (1995) makes the distinction between information and information value, and concludes that the two concepts are quite independent, and characterise different aspects of information seeking and using. Information value is that which arises from using information – in terms of 'what one pays to acquire information together with what one earns by taking action based on it'. The importance (and complex context) of information value is demonstrated by Hollnagel (1988) when he describes the need to provide the right information at the right time for users, and the observation by Flach et al. (1998) that the challenge is to determine what 'right' means. This is consistent with Menou (1995b) that in terms of information, it is merely a means to an end, where 'the impact is to be seen in the improvement of a new state of knowledge over the previous one as a result of information-as-contents' (Menou 1995b). Menou continues to argue that the most promising avenue for research is the study of how information changes an individual's knowledge structures, which is outside the scope of this thesis.

There is a range of different views on information value, many of which are used within an organisational, information systems perspective e.g. Badenoch et al. (1994). Iyengar (1996) - also from the perspective of information systems within organisations - offers three basis for putting a value on information as shown below:

Economics approach	The value of information is derived from its use, rather than having inherent value. Users and decisions results or expected results are included.
Information economics approach	An emphasis is placed on the actions of the decision maker, the information value is determined by the worth of the decision; includes probability estimates for different decisions, estimated payoffs etc.
Information utility approach	Information contains inherent characteristics or attributes and the value of information can be assessed against these attributes.

Table 2.6 Perspectives on information value, from Iyengar (1996)

Ahituv et al. (1994) discuss information value in terms of normative, realistic or subjective determinants, as shown below; this distinction being appropriate within human factors:

Normative value of information (also called information economics)	A quantitative calculation of the value of information based on objective or subjective probabilities of occurrences of events and expected costs and payoffs
Realistic or revealed value of information	An outcome measure, the measured difference in *actual* (not *possible*) performance due to informational factors Information processing/decision making is considered a black box, there is no attempt to understand or model these processes
Subjective value of information	Reflects people's comprehensive impression of information, a personal judgement of the worth of information

Table 2.7 Perspectives on information value, based on (Ahituv et al. 1994)

The advantages of the normative perspective in Table 2.7 are that it compels a systematic and structured assessment of the decision environment, and enables an *ex ante* (i.e. before the event) evaluation of the impact of information. This perspective can therefore be applied before a system is implemented or used. The disadvantages of the normative perspective are that it requires exact measurability of all the factors: (1) the *a priori* (i.e. assumed rather than based on fact) probabilities of outcomes (with and without information); (2) the conditional probabilities of outcomes (i.e. taking into account those that have occurred previously); (3) the payoffs; (4) the costs involved. In addition, comparable units of measurement are needed to enable the various payoffs and costs to be aggregated and compared. The normative perspective is particularly difficult to apply within a volitional, individual user-centred perspective, due to the difficulty in determining individual behavioural probabilities, and the multi-dimensional nature of the user outcomes.

The advantages of the *realistic*, or *revealed value* perspective are several: (1) it is not necessary to consider information processing, decision making strategies, event probabilities and outcome payoffs; (2) it is possible to take into account human factors related to perception and preferences without having to measure them; (3) this approach takes into account the characteristics of the system and its impact on the individual; (4) the output can be directly measured, in appropriate units. The disadvantages of the realistic or revealed value perspective are that confounding factors (i.e. non-informational factors such as the environment) that would influence performance must be controlled, and that it is an ex-post measure, so there is a need for an actual system or a prototype in order that behaviour can be measured.

Finally, the *subjective* perspective has associated advantages and disadvantages. It is easy to perform this analysis, and units can be chosen to enable cross-comparisons between different systems or contexts of use. The subjective perspective takes into account personal factors that influence information value, and this analysis can be performed before system development using simulations or scenario building or post development using an actual system within a certain context of use. However, there are several disadvantages associated with this perspective: (1) it is a subjective measure that may be entirely dependent on the individual undertaking the evaluation, hence inter-personnel reliability may be poor; (2) it may be difficult to translate subjective to monetary units to enable a monetary comparison; and (3) the value variable is ex-post if based on the assessment of a real system (i.e. does not allow *prediction* of user behaviour and outcomes).

Within the empirical work described later in this thesis, a combination of the above three perspectives is used to understand interaction with information by a user of a MLS.

Several authors have highlighted the need to focus on the practical impact of information within a specified context of use. Badenoch et al. (1994) states that 'we should be looking at the utility of information, rather than trying to put a cash value on it. Do we know how decisions are made? Does information change decisions?' Sheridan (1995) also highlights this utility role, by describing how 'information value, as explicated by Howard (1966) and others refers to the difference in what one can gain by action taken knowing the state of the event relative to what one can gain by action taken without such knowledge'.

Karim (1997) discusses how the value of decision support systems can be influenced by considering the information captured, its level and detail, its intrinsic value to the decision maker and the impact this information has within the wider context of the decision environment. The concept of *the expected value of information* (EVOI) is defined as the 'expected increase in the value (or decrease in the loss) associated with obtaining more information about quantities relevant to the decision process'. The expected value of information is therefore a measure of the importance of the uncertainty about a quantity in terms of the expected improvement in the decision that might be obtained from having additional information about it. Although Karim (1997) discusses EVOI in the context of specific decision support systems, it can also be applied to interfaces more generally, given that many can be considered as decision support systems, even if they are not explicitly labelled as such.

Ahituv et al. (1998) also highlight the pragmatic context within which information value should be determined when they describe how the real value of information is derived from measuring differences in a decision maker's behaviour when he or she is provided with different information sets. Ahituv et al. (1994) make the key point that no matter how information value is defined, 'it is a relative value, based on comparisons between payoffs gained under different sets of information'. Koops (2004) describe how 'the value of correct information ..... is the difference in payoff obtained when informed versus uninformed'.

Koops (2004), from a biological context, also describes how the value of information 'is not affected by variance in the possible states of the environment, but rather by variance in the available actions'. The key point here is that value is derived from the potential to undertake difference forms of behaviour – if there is no possibility of an individual undertaking a different set of actions if supplied with information, then the value of that information is zero. This mirrors Bateson (1980), when he defines information as being 'any difference that makes a difference'.

It is only within a situated context of use that the real value of information can be determined. Karim (1997), quoting Ahituv and Neumann (1986) highlights the importance of this user context within an information value analysis, by describing how 'information value is not uniquely defined but instead depends on the type of decision supported by the information'. Sheridan (1995) highlights how in many contexts, the timeliness of information is crucial, and will impact directly on its value. In many cases, the delivery or non-delivery of information will be so time critical that there will be a step change in potential user outcomes based on when information can be used to enable decisions and influence actions. An obvious example is the delivery of congestion information in time to allow a driver to undertake a potential route diversion. As highlighted by May (2001), windows of opportunity open and then close again, and information delivery must take these windows into account.

Rouse (1986) undertook an interesting study in order to develop a framework for understanding the value of information to designers. He considered a general view of computer-based information systems and the identification of information that is likely to be of value to system users. The value of information was recognised as an 'elusive concept', and although this may be defined simply as 'what one is willing to pay in money and/or effort', Rouse underlines that in order to be able to define information requirements, it is necessary to understand 'value' in terms of why an individual would be willing to pay (in monetary or effort terms) for it. The three key information value attributes put forward by Rouse are that information must (1) reduce uncertainty, (2) be relevant to the tasks of interest and (3) be in an appropriate form. If information does not satisfy all of these criteria, then it will be of little or no use to an individual.

According to Rouse (1986), the reduction of uncertainty can arise in four different ways: gaining knowledge of a previously unknown fact, being reminded of something previously forgotten, decreasing the variance in the estimate by a user of a variable (e.g. a narrower range of estimates for the time to complete a journey), or being provided with 'information about information' i.e. a means of enabling an individual to find the specific information of interest.

It is generally accepted that relevance is a situational, dynamic judgement (Anderson 1999), i.e. that the relevance of information to a user can only be assessed at a single point in time, and is often highly time-varying, and context dependent. Rouse makes the distinction between relevant and necessary, and relevant and discretionary. Although the discussion is in the context of designers' use of information, this distinction can apply to any situation where information is being used to accomplish a task. If information is necessary or primary, it is required in order to solve the problem or accomplish the task; if discretionary, it will help an individual accomplish that task, but is not necessarily required. This distinction is important since it enables a prioritising of the provision of information to a user, and is incorporated in Chapter 7 of this thesis.

The final criterion for information value discussed by Rouse (1986) is that of appropriateness of form. Information that is not accessible, or is inappropriately presented is of limited value to a user since it cannot actually be used. Rouse underlines the need to understand the tasks being supported or enabled by information, and how these tasks are performed, and states that 'the value of information is not intrinsic to the information itself, but depends totally on the recipient's intentions and perceptions.'

Burns and Vicente (1996) undertook a questionnaire study of professional designers of nuclear power plant control rooms. Based on the framework developed by Rouse, they investigated whether information accessing behaviour could be predicted based on the perceived relevance, perceived importance and perceived cost of information. They developed Rouse's claim that information would only be accessed if its perceived value was greater that its perceived costs into the following:

Accessing behaviour = *f* (perceived value, perceived cost)

Perceived value was defined as a function of importance and relevance:

Perceived value = *f* (importance, relevance)

Due to the natural context of this study, Burns and Vicente (1996) did not force the designers to search for information; rather the designers gave ratings of *effort* which they would be willing to spend to obtain the information. These effort ratings were grounded on participants' ratings of the effort of accessing information from various sources. Effort was used as a surrogate for accessing behaviour, consistent with Rouse's notion that value is what an individual would be willing to spend for information in terms of money or effort. Accessing behaviour (as indicated by willingness to spend effort) therefore depended on the perceived value and perceived costs of information, and incorporating above, became:

Accessing behaviour, reflected by effort = *f* (importance, relevance, cost)

A series of hypothetical design questions were presented to the designers, each of which was scored on the following semantic differential scales: (1) *cost to obtain* - the time and effort needed to find the answer - (no cost-high cost), (2) *importance* – the extent to which that information was necessary to complete a project - (not important-indispensable), (3) *relevance* – the number of times the particular issue arises during the problem - (irrelevant-highly relevant), (4) *effort you would spend* – (no effort-high effort).

The results indicated that in general, a linear additive model with either relevance or importance or both provided the best fit for the ratings of most of the participants. On an individual basis, in addition to importance and relevance, cost was often found to be a significant predictor of stated accessing behaviour.

Another study of information searching behaviour was that by Wang and Soergel (1998). They used the five consumption values of Sheth et al. (1991), outlined in Section 2.2, to propose a model of document selection by actual users of a bibliographic retrieval system. They identify the analogy between purchasing goods and reading documents, with both: being need-driven; involving decision making based on value-judgements; and considering the costs (money or time) of acquisition.

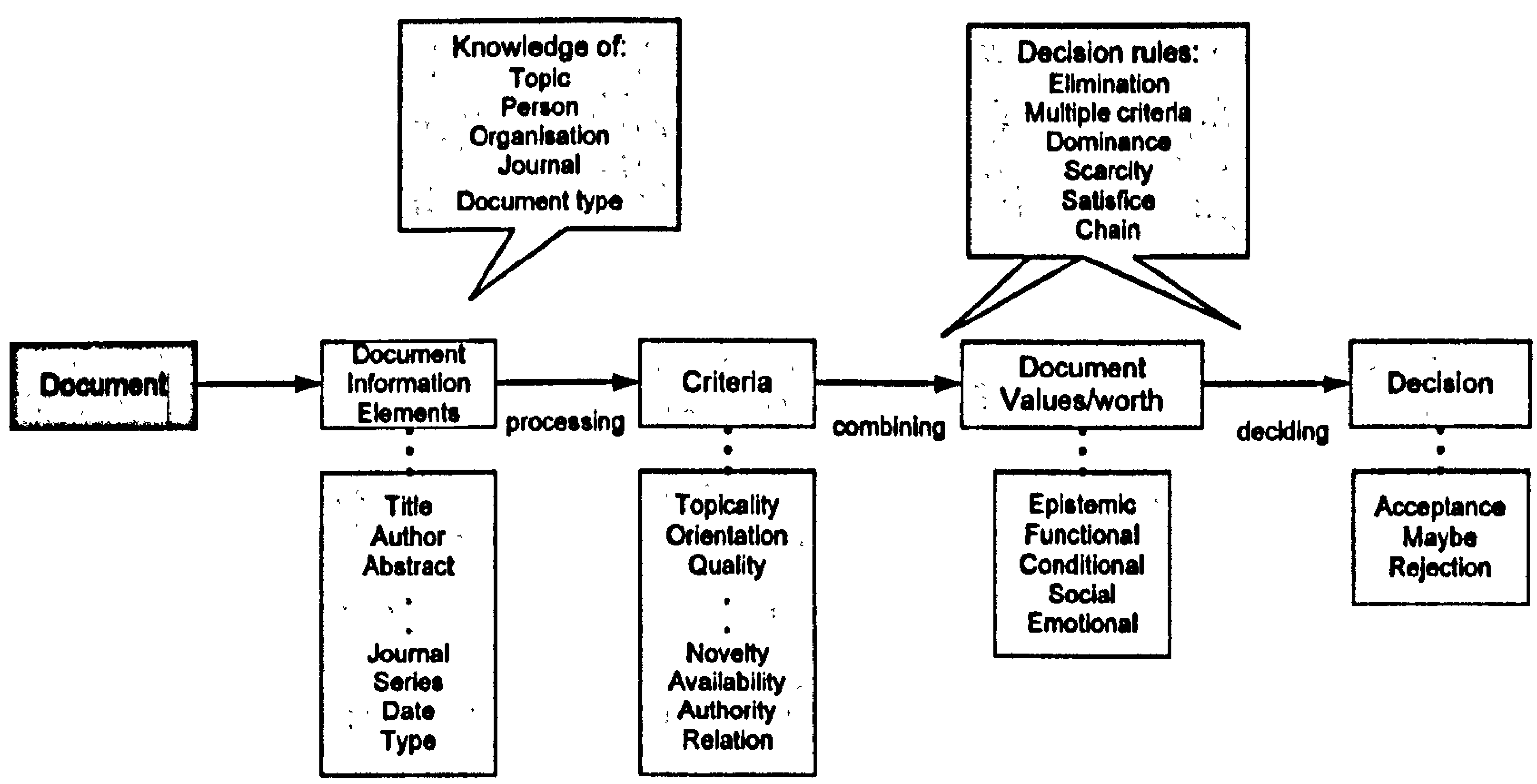


Figure 2.8 Document selection model (Wang and Soergel 1998)

Their model above shows how document information elements (e.g. title, author, abstract etc) are used to form judgements on user-based criterion (e.g. topicality, quality), leading to value judgements (e.g. how useful the document is perceived to be) and then a decision regarding document selection. Document value was defined as the user's perception of the desirability or potential utility of a document. Wang and Soergel (1998) underline the role that user knowledge and decision making rules play in the final decision to actually select a document.

Badenoch et al. (1994) sums up both the impact of a user's context, and the measures that are appropriate for determining information value when he states that 'fundamentally, [information] value is attributed by a person'.

2.5.4 Information costs

The 'cost' of information is usually defined as the resources or effort expended to acquire and use that information. These costs can include all or some of the following: monetary costs (what an individual is willing to pay); cognitive costs associated with acquiring and processing information (e.g. the multiple dimensions encapsulated within mental workload measures); and physical costs in terms of effort expended. Koops (2004) - in the context of general behaviour - uses a broader perspective to describe how information acquisition costs can be incurred through use of resources (e.g. effort), increased risk, or lost opportunity.

The costs of information access are generally recognised as influencing the value of information, with value being diminished as the costs of acquisition increase (Koops 2004). Sheridan (1995) highlights the role of information costs by stating 'in application, the cost of [information] subtracts from [information value], and/or diminishes [information value] in relation to information access time'.

Information costs (or perceived costs) directly influence access behaviour. Goodhue (1995) describes how 'humans do respond (though imperfectly) to cost and benefit differences in information sources and they learn and improve their choices over time'. Kerstholt (1996) (in the context of simulated judgement of an athlete) also highlighted the difficulties that individuals have in trading off the costs of information and its diagnostic value.

In the work context described by Rouse (1986) the judgements made by designers at the beginning of information acquisition were: 'will this information be valuable to me?', 'will it require resources (e.g. cost/effort) to obtain it?', 'how many resources am i willing to expend trying to obtain this information? Rouse therefore explicitly included information costs in his framework, and claimed that information will only be accessed if its perceived value is greater than its perceived costs, i.e. that the accessing or using of information depends on the perceived value (a function of importance and relevance) *and* the associated user costs. Karim (1997) also identified the impact of accessing costs on behaviour, by identifying how using more information to support a decision may prove to be of only marginal benefit and may just add to the acquisition costs.

The context in which the costs are incurred is important as highlighted by Burns and Vicente (1996). In two different scenarios, the potential value of information may not change, and the absolute costs (effort) may not change, but the impact of undertaking that effort may differ enormously. The example given was that of a designer looking for information during a slow day compared with the same activity just before a major design meeting. This demonstrates: (1) the need to consider the wider context within which cost and benefits are accrued, and (2) the potential variations due to user context.

From an information economics or normative viewpoint, the fixed and variable costs associated with information access can be subtracted from the expected benefits in order to derive a net financial value to information. However, from a human factors perspective, it is difficult to offset information costs from the benefit derived, since the costs and benefits are measured using different metrics, and either or both of these may not include financial aspects. Within this thesis, benefits derived from information are discussed in relation to accrued costs, without attempting to specify these such that they can be offset against each other. It is assumed throughout that the value derived from an information-based MLS is a function of both user benefits and costs (in the widest sense of the word) incurred. To highlight the direct relevance of the benefit/cost tradeoff to the design of mobile service Helyar (2001) describes how the early mobile phone WAP services provided insufficient benefit to the user to warrant overcoming the usability barriers present.

2.5.5 Measuring information value

A fundamental problem in measuring information value is that it is a relatively ill-defined term: 'it is well nigh impossible to establish an agreed definition of what we mean by the terms' (Badenoch et al. 1994). As an example, Burns and Vicente (1996) describe accessing behaviour in terms of value and cost (i.e. value and cost being separate constructs) whereas other authors describe value being a function of benefit and costs (i.e. value being *reduced* by costs). Despite these semantic inconsistencies, at a broad level it can be assumed that information value is a function of benefits to the individual and costs incurred (Ahituv et al. 1994).

A prerequisite to developing mobile services that successfully deliver information to the user, is being able to measure, or predict, the value of information to that user. Based on the previous discussion of information and information value, it is clear that there are multiple approaches that can be employed to measure the value of information to a user. These are shown Table 2.8 below.

Perspective on information value	**Means of measuring information value**
Monetary or economic value (from the demand side)	The monetary sum that a user is willing to pay
Monetary or economic value (from the supply side)	The monetary sum that a supplier is willing to sell information for
Realistic, actual or revealed value	The behaviour (or change in behaviour) that the information results in
Perceived or subjective value	The individuals perceptions, in terms such as perceived usefulness, perceived emotional support

Table 2.8 Approaches to measuring information value

The approaches above are not mutually exclusive. For example a monetary perspective on 'value' could be taken. This could be assessed by either asking an individual how much they would be willing to pay for information (monetary value from the demand side, based on perceived value), or by placing the individual in a situation where they must obtain information, and observing how much (or whether) they actually pay for information (monetary value from the demand side, based on realistic value). Where dynamic choice is modelled within an economic context, the 'information value' is the highest price an individual is willing to pay for information; individuals choose to buy information when the variance of payoffs (i.e. outcomes) is sufficiently high, and there is a greater willingness to pay for more detailed information (Denant-Boemont and Petiot 2003).

In terms of the perceived or subjective value of information, an expressed willingness to pay can be considered a measure of attitude or intention (Ajzen et al. 1996). In this respect, the *perceived* value of information is consistent with the attitudinal models (and influences thereon) described in Section 2.4.1.

The basic viewpoint being taken in this thesis is that of the realistic, actual or revealed value of information, due to the advantages outlined in Table 2.8. This is consistent with the views of Ahituv et al. (1998) who state that 'the real value of information is derived from measuring differences in a decision maker's behaviour when he or she is provided with different information sets', and Bateson (1980) – information is 'any difference that makes a difference' – implying a need to be able to determine this 'difference' within a particular context of use.

Dakins (1999) highlights how information value is not absolute, and has to be measured against a comparison. Karim (1997) presents various options for making information value comparisons, based on the assumption that value is a function of the resulting user behaviour with that information (i.e. a realistic, actual or revealed perspective is being taken). These are: (1) the optimal decision having all the information that is needed, or (2) a decision based on random use of information. In the context of assessing the value of traffic congestion information to a driver, there will be an optimum decision and course of action, resulting in an earliest arrival time. A decision based on poorer information (or no information) is likely to result in a later arrival time. The difference between these arrival times is an indication of the value of the information to the driver. However, this example also highlights the complexity involved in assessing differences in behavioural outcomes, the importance of context in determining value, and the limitations of focussing on superficial quantifications of user outcomes. It may make no practical difference to an individual if they are 10 minutes later than originally planned (for example if a meeting has a 30 minutes 'coffee' period to allow for late arrivals). However, in other contexts, being 10 minutes late may result in a missed flight. Although in both cases, information may save an individual 10 minutes, the value of information is clearly much greater in the second example. It is only by determining the real impact on an individual that the value of information (which will depend on that user and the context of use) can be determined.

If an information service does not provide any additional value over and above making a random decision (e.g. guessing the departure time of a train) then from a utility perspective, that information service has no value to the user. This does not necessarily mean it will be will not be used, or *perceived* as useful, since non-utilitarian judgments will influence the user's perception of the service. This is particularly the case with novice users, where an ease of use assessment may initially be more influential that a usefulness judgment.

The measurement of information value as described in *realistic* terms is clearly at odds with the use of the term 'value' when used in a marketing perspective, which often focuses on attributes of information and its delivery to the user, rather than user outcomes. An example of this is where Lindgren et al. (2002) state that 'clearly, what adds value is quality' and describes value as a function of *freshness, accessibility, customization* and *exclusivity*. Similarly Couzens (2001) describes value as being a function of convenience, reliability, ease of use, relevance, reach, immediacy, quality and consistency. Neither of these two definitions takes into account the real impact on the user of information.

To conclude this section, a cautionary note is sounded by Menou (1995a) when he states that 'people do not use information, they just take care of their business'. By this he means that people are able to talk about *what they do* (which will be influenced by what they know), but are less able to talk about *what they know*, and even less able to describe how they *were informed.* In practical terms, when people are asked about which information is most useful to them, 'they hardly understand what the question is about'.

2.5.6 Information quality and relevance

The realistic or revealed approach implies it is not necessary to measure value by considering the intrinsic qualities of information, since it is the behavioural outcomes that are important. However, design of information-based MLS needs to be based on the presentation of information of 'quality', in addition to the wider implications for adding value (e.g. the potential for variance in outcomes). As Lindgren et al. (2002) state: 'the consumer places higher demands on information quality'.

The human-centred value of information is closely related to their personal experience of that information - relevance within context as described by Badenoch et al. (1994). 'Relevance' is typically described as the judgement of the quality of the relationship between information and a user's information needs (Anderson 1999). Information-based MLS clearly need to maximise the relevance of the information they present to a user. Information relevance helps determine what 'right' is, when Hollnagel (1988) states the need for the right information at the right time in the right format.

Early work to define relevance was narrow in focus (e.g. management accounting systems), with studies often lacking contextual validity. More recent work has underlined the importance of relevance within a context of use. Relevance is described by Sperber and Wilson (1995) as being a factor of contextual effects and the processing effort expended, and hence the more processing effort is expended for the same contextual effects, the less relevance the individual experiences. Similarly for equal processing effort, the more the contextual effect, the greater the relevance the user experiences. Sperber and Wilson (1995) describe several key features of relevance, including that it is: personal; contextual; depends on what has been communicated before; varies with the intellectual alertness of the addressee; is a function of effort and effect; a relative, not an absolute term; and a matter of degree.

Barry and Chamber (1998) undertook a comparison of data from two studies, based on interview data from participants undertaking information search. They attempted to bring some consensus to definitions of 'relevance' and made five assumptions regarding relevance, i.e. that it is:

- Cognitive and subjective, depending on the users;' knowledge and perceptions
- Situational, relating to users' information problems
- Complex and multidimensional, influenced by many factors
- Dynamic, changing constantly over time
- A systematic phenomenon, observable and measurable at a single point of time

They derived the following set of common criteria for relevance evaluation, and conclude that 'there is evidence for the existence of a finite range of criteria that are applied across types of users, information problem situations, and information sources:

Depth, scope, specificity	The extent to which information is in-depth or focussed, is specific to the user's needs; has sufficient detail or depth; provides a summary, interpretation, or explanation; provides a sufficient variety or volume
Accuracy, validity	The extent to which information is accurate, correct or valid
Clarity	Presented in a clear and well organized manner
Currency	Current, recent, timely, up-to-data
Tangibility	Relates to real, tangible issues; definite, proven information is provided; hard data or actual numbers are provided
Quality of sources	General standards of quality or specific qualities can be assumed based on the source providing the information; source is reputable, trusted, expert
Accessibility	Some effort is required to obtain information; some cost is required to obtain information
Availability of information, sources of information	Information or sources of information are available
Verification	Information is consistent with or supported by other information within the field, the extent to which the user agrees with information presented or the information presented supports the user's point of view
Affectiveness	The user exhibits an affective or emotional response to information or sources of information; information or sources of information provide the user with pleasure, enjoyment or entertainment

Table 2.9 Information relevance criteria (Barry and Schamber 1998)

Another interesting result from the work by Barry and Schamber (1998) was that a redundancy of criterion mentions was achieved through interviews with fewer than 10 respondents.

Although falling outside the scope of this thesis, there is a lack of conceptual consensus regarding terms such as information *relevance* and *quality*. As an example, Danielsson and Ohlsson (1999) describe information quality as a function of: (1) reliability (is it a true statement of facts?); (2) availability (can you access it, is it available for use?); and (3) relevance (can you use it, does it help you achieve your goals?). This is not entirely consistent with Barry and Schamber (1998) since it describes relevance as a separate construct to reliability and availability, as opposed to a construct that subsumes factors such as reliability (i.e. accuracy) and availability.

2.5.7 Summary of contribution to thesis

The literature within Section 2.5 highlights the need to identify what 'right' means when Hollnagel (1988) describes providing the right information to an end user at the right time and in the right format. User-centred research needs to investigate the provision of *information value*, i.e. the measurable impacts on end-user outcomes, whilst also considering the costs or resources involved in acquisition and use. Research also needs to explicitly consider the impact of context on these user outcomes, and how the qualities of information cues impact on these costs and benefits. The dynamic influence of context is particularly important for mobile location services, due to the variance in the context of use encountered by end users, and hence the impact on added value.

2.6 Mobile location services – theory and practice

The literature summarised in this chapter so far has had broad relevance to the user-focused design of effective information-based services, without focusing specifically on the *mobile* or *location* aspect. This section describes two different perspectives on MLS – a marketing view on mobile commerce, and an HCI perspective on interaction with location aware services.

2.6.1 Adding value with mobile services

It can be assumed that MLS fall under the umbrella of *mobile commerce*, since there is likely to be 'the exchange of goods or services for value [i.e. payment]' (Emery 2000).

Keen and Mackintosh (2001), against the backdrop of the 'boom and bust' technology bubble at the end of the twentieth century, underline the need for value:

> '.. the challenge for m-commerce is to create appealing distinctive new value for customers. The main value of m-commerce will come from what it creates in terms of changing the limits of the possible in the structures of everyday life'.

Keen and Mackintosh (2001) discuss how new technologies (such as mobile ICT) potentially offer new freedoms to the individual, and that these freedoms become value when they change 'the limits of the possible in the structures of everyday life'. They term this the Braudel rule, after the historian Fernand Braudel who demonstrated that the economic, social and technological shifts that we label as progress come from changing the limits of the possible in the structures of everyday life. Drawing on this analogy, Keen and Mackintosh (2001) describe how mobile services must create new freedoms for consumers, which if taken away would affect a basic component of everyday life. They specifically draw comparisons with mobile services that merely provide *conveniences* (which if taken away would by a nuisance or irritant) and those which are just *features* (functions provided because of technological capability). Mobile services which enable new freedoms are potential winners, those which are conveniences are less likely to succeed, and those which are features are almost certainly doomed to failure. Keen and Mackintosh (2001) are very sceptical of the 'day in the life of the future' scenarios, where a vision of the future is described in terms of ease of use, convenience and immediacy, i.e. a series of 'conveniences' with nothing that fundamentally provides new freedoms to the individual.

Drivers of value are described by Keen and Mackintosh (2001) as being defensive or proactive. In a defensive context, a mobile service can provide a freedom from something negative (e.g. fear or hunger), or can be a loosening of limits imposed on the individual. In contrast, a proactive driver of value enables something positive and/or expands possibilities. The work by Keen and Mackintosh (2001) presents some powerful arguments for how mobile services such as MLS may be commercially successful, and suggest that the safety-related services are the almost sure-fire winners. By reference to the taxonomy of MLS given in Table 1.2, it can be seen that many MLS offer 'conveniences' rather than potential 'new freedoms' since in most cases, the service merely makes it easier to do something which can be achieved via other means. Some potential exceptions are the safety-related locating services for children (particularly *young* children), provision of navigation directions where there are no alternative sources of information (e.g. bystanders or relevant road signs) and safety camera information.

Other marketers such as Lindgren et al. (2002) have identified how consumers place demands on information quality, and state that it is this quality that adds value. Lindgren et al. (2002) describe value using the FACE acronym, with value being a function of Freshness, Accessibility, Customization and Exclusivity. However this view of value is limited as it focuses purely on the attributes of the content being provided - it omits: (1) descriptions of what they user is trying to do, (2) the dynamic and contextual nature of content relevance, (3) the extent to which a service enables them to achieve any goals (stated or implied), and (4) whether there are other lower cost or lower effort alternatives that can be used instead.

Value is better described by Couzens (2001) who highlights the need to 'sell value not price, product or technology'. He describes value as a 'set of desirable user-centric attributes, such as convenience, reliability, ease of use, relevance, reach, immediacy, quality and consistency'. Implied within these terms is the need for timely delivery of value-adding information. However, what is lacking is an unpacking of the term 'relevance' and how it actually impacts on the value provided to a consumer. The relevance of information has been discussed briefly in Section 2.5.6. The statement by Couzens (2001) is similar to that made by Hollnagel (1988) when he talks about interfaces delivering the right information at the right time and in the right way. As Flach et al. (1998) state, the challenge is to determine what 'right' means in this context, and similarly with the statement by Couzens above, the challenge is to understand what terms like 'relevance' and 'quality' mean.

2.6.2 Location and time responsiveness

Lindgren et al. (2002) underline the important role that time and location play in mobile services when they state that 'services that are both time and position critical are using the potential of the mobile marketplace to the full'. Keen and Mackintosh (2001), in a discussion of success factors for mobile commerce, similarly highlight the need for mobile services to satisfy a 'moment of value' and 'location responsiveness'. The importance of the 'here' aspect in being a key component of the value that mobile services generate is highlighted by pointing out that many mobile shopping, information or new services are location-irrelevant, and that it does not matter where you are when accessing these services. In addition to location-relevance, Keen and Mackintosh (2001) describe how mobile services can capitalise on time relevance, where the service provider can do something for the user regardless of where they are :'unless customers can connect with a moment of value [established via location and/or time relevance], they soon stop wasting time'. From a practical viewpoint, a test of this 'moment of value' concept is to ask if the value provided information from a service changes if it were to have a delay imposed on it, or if the location of the user changes.

Time sensitive	High	Online games Share trading & monitoring Sports news Email Chat	Road maps, directions Local weather information Booking restaurants Video communication Electronic wallet Positioning service to locate children
	Low	Price comparisons Browsing E-commerce Information retrieval	Local telephone directories Local entertainment guides
		Low	High
		Location sensitive	

Table 2.10 The mobile marketplace: time and position-critical services (Lindgren et al. 2002)

Table 2.10 shows the time and location sensitivity of a range of mobile services, and therefore highlights those services typically described as mobile location services. However, this treatment by Lindgren et al. (2002) is an over-simplistic categorisation of many services as being unrelated to location. The relationship of many services with location becomes clear when the wider context of the activity of the mobile user is considered, for example:

- The need to access location telephone numbers may be highly time sensitive depending on the immediate needs of user.
- Chat *is* location sensitive if it is in the context of friends physically meeting up, or constrained or promoted as a communication channel due to the location of the individuals involved.

- Price comparisons may be very time *and* location sensitive if the end-user is undertaking price comparisons in a particular store.
- Information retrieval may be critically sensitive to time *and/or* location depending on the usage context.

A similar model is used by May (2001) to characterise mobile commerce services as a 3D space to represent *location, time* and *mission. Mission* is described as the criticality or importance of the particular user activity. By including mission, May (2001) recognises the need to add value to a user, i.e. that making a service time and location aware will not in itself mean that a service is useful to that user. A mobile location service that enables a driver to find a parking slot can be characterised thus:

- **Mission:** high since the user is chasing a scarce resource, parking is a necessary activity that cannot be abandoned as a means of terminating a journey, and failure to acquire a spot blocks her from embarking on the next mission
- **Location** – vital, since parking spots are specifically linked to particular locations
- **Time** - vital as parking availability and traffic conditions change over time

As described by May (2001): 'parking is a service that cannot be put off to another time, done in another place, or abandoned as a means of terminating a journey'. May (2001) identifies two key roles for *time* within the user experience with mobile devices. The first is the influence of urgency on the user interaction with a mobile device, where 'an opportunity to achieve or avoid some outcome presents itself to the user'. The second role is that related to the scheduling of activities, or taking into account 'the patterning of life according to obligations and habits'. The potential importance of time is summarised by May (2001) when he describes how, within an event-driven world, 'windows of opportunity open and close and are consumed by time', and how the link between events in the world triggering actions by the user is the transmission of information to that user.

Location clearly plays a critical role in some of these services described by Lindgren et al. (2002), particularly the 'direction services' shown Table 2.10 . The provision of turn-by-turn instructions to a driver requires knowledge of the location of the driver in relation to the road infrastructure in order to specify the content and timing of these instructions. In the parking example given above, the knowledge of the location of the driver enables the identification of nearby available parking spaces. What is not highlighted by Lindgren et al. (2002) is how in many cases location can be used as an enabler for a more effective service, with the location aspect merely serving to increase the relevance of the information presented or made available to the user. This is particularly true of services such as 'where's my nearest'. The parking service described by May (2001) is essentially a temporally sensitive 'where's my nearest' service, and knowing where the driver is merely reduces the number of potential parking spaces that are presented to the driver.

May (2001) highlights the need to look past the limitations of mobile devices (e.g. relatively small screens and awkward data input), and to 'look at where the mobile platform clearly wins out over the fixed Internet'. He highlights three key features of the mobile platform:

1. Mobile devices are carried into different locations.
2. Uses personal devices that tend to be carried as essential pocket equipment.
3. Significance of a user's situation.

May (2001) describes how mobile commerce is integrated with people's lifestyles, while fixed Web-based e-commerce is a distinct task inside people's lifestyles, and also the general change in nature of task-driven applications: 'when applications migrate from fixed to mobile channels, the emphasis switches from consideration to action.' The 'significance of a user's situation' above is one of the most important enabling or constraining influences on the use of a mobile device by an individual, and is discussed in Section 2.6.3 below.

2.6.3 Context of use

MLS are those services that use location to influence the provision of a service to a user – location changes at least one aspect of the way in which a service operates. The location of a user may be defined from different perspectives and at different levels of granularity. Rankin (2001) defines different location scales, ranging from 'body space' through to 'cultural space'.

Dix et al. (2000) discuss the role that location plays in mobile systems, highlighting that location places devices within a 'space', and that context aware devices are made aware of that 'space'. They highlight how, in order to adapt to location, a mobile device needs to be able to ask:

(1) 'Where am I?'

(2) 'What else is nearby?'

(3) 'How should I behave in the light of (1) and (2)?

MLS form a subset of the area of computing known as context-aware computing. Although location is a fundamental component of context (as discussed below), it is widely accepted that 'there is more to context than location' (Schmidt et al. 1999b). Similarly, Kolari et al. (2004) highlight how 'location is not the actual user context, it is a means to [help] identify the context'. Discussion of user context helps understand the relative lack of success of location-aware services which are impacted by other, non-location aspects of context.

An understanding of the potential offered by context-aware computing highlights some of the possibilities for MLS, and as they become more sophisticated, they will increasingly use knowledge of the wider context of use (rather than just location) to provide an enhanced level of service to a user. Tangis (2001) – from a developer's perspective state that 'context awareness is the keystone technology that will transform wireless/mobile computing and help it become the predominant paradigm for the future'. Köhne et al. (2003) described how for LBS providers, the contexts in which services are used and evaluated are of major importance.

By way of example, whilst a navigation service on a Smartphone or PDA is clearly a location-aware service, the way it operates could be influenced by a wider range of factors than just the location of the user. Information presentation (including content and format) could be dependent on time of day, the speed of travel, level of familiarity of the driver, traffic levels, the presence of a passenger etc, as well as where the driver is within the geographical environment.

At a general level, context is important because it helps determine the way in which a mobile service should operate when interacting with a user. Services delivered to a user over a mobile device have the capability of adapting to the context of use (including location of the user) in order to add value to that user.

Within general computing systems development, identifying the intended context of use is a starting point for a human-centred design process as defined by ISO 13407 (1999), with context being defined as the characteristics of the user, tasks and environment in which the systems is being used. Similarly ISO 9241 (1998) describes context as the users, tasks, equipment and the physical and social environments in which a product is used.

Within *mobile* computing, it is widely stated that context-aware computing was first discussed by Schilit and Theimer (1994). Since then, a wide range of definitions and models of context have been developed within the personal computing literature, including at least two different general perspectives (Dourish 2001a). The first is 'physically based interaction and augmented environments' (and is expanded on below). The second attempts to understand the 'generally operative social processes surrounding everyday interactions'. Dourish (2001a) argues that they are two different strands of the same program of investigation, since they mutually depend on the concept of embodiment, described as 'a presence and participation in the world, real-time and real-space, here and now'.

Schilit et al. (1994) define context as the constantly changing execution environment, made up of: (1) computing environment; (2) user environment: location, collection of nearby people and social situation; (3) physical environment: lighting and noise level. They claim that the important aspects of context are where the user is, who the user is with, and what resources are nearby. This early definition of context therefore does not incorporate any aspect of what the user is *doing*.

Schmidt et al. (1999a) define context as 'knowledge about the user's and IT device's state, including surroundings, situations, and to a lesser extent, location', explicitly recognising the role that location plays.

Some descriptions of context are very broad. Dey et al. (2001) define context as 'any information that can be used to characterize the situation of entities (i.e. person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.' A similarly broad definition is provided by Dix et al. (2000) who provide a taxonomy of context comprising: (1) infrastructure (determining a relationship with bandwidth, reliability and display resolution); (2) system (relationship with other devices, applications and users); (3) domain (relationship with domain of application, style of use, identification of user); (4) physical (relationship with the physical nature of device, environment and location).

In contrast, Norros et al. (2003) use the term *intentional context* to describe what the user has been doing and what they are planning on doing next, thus allowing for proactive services that behave in such a way as to support the user task(s).

Buchholz et al. (2003) discuss quality of context, and describe the five most important quality of context parameters as: precision; probability of correctness; trust-worthiness; resolution; and up-to-dateness. They make the point that quality of context is different but overlapping with quality of service parameters. However, their paper does not discuss how the value provided by a context aware service (and the potential changes in desirable levels of quality of context) alters as the situated use changes – i.e. what 'right' means when they describe information being provided 'at the right time, in the right quality, and at the right place'.

Other definitions explicitly focus on the relevance to the behaviour of an application, and the user interaction with that device. Chen and Kotz (2000) define context as 'the set of environmental states and settings that either determines an application's behaviour or in which an application event occurs and is interesting to the user'. Rankin (2001) describes the negotiation process between user-initiated actions (pull) and environmentally-triggered opportunities (push), hinging on external context (the setting of the user) and internal context (their internal agenda). Both the external and internal context revolve around three major poles: time, topic (or content) and location, with the negotiation concept being key to the success of services such as location-aware reminders or offers to the user.

With specific reference to mobile access to the internet, Kim et al. (2002) define mobile context as 'any personal and environmental information that may influence the person when he/she is using [the] mobile internet.' They outline two key characteristics of context: the focus on contextual information from the user's perspective, and the inclusion of personal and environmental contexts as shown below:

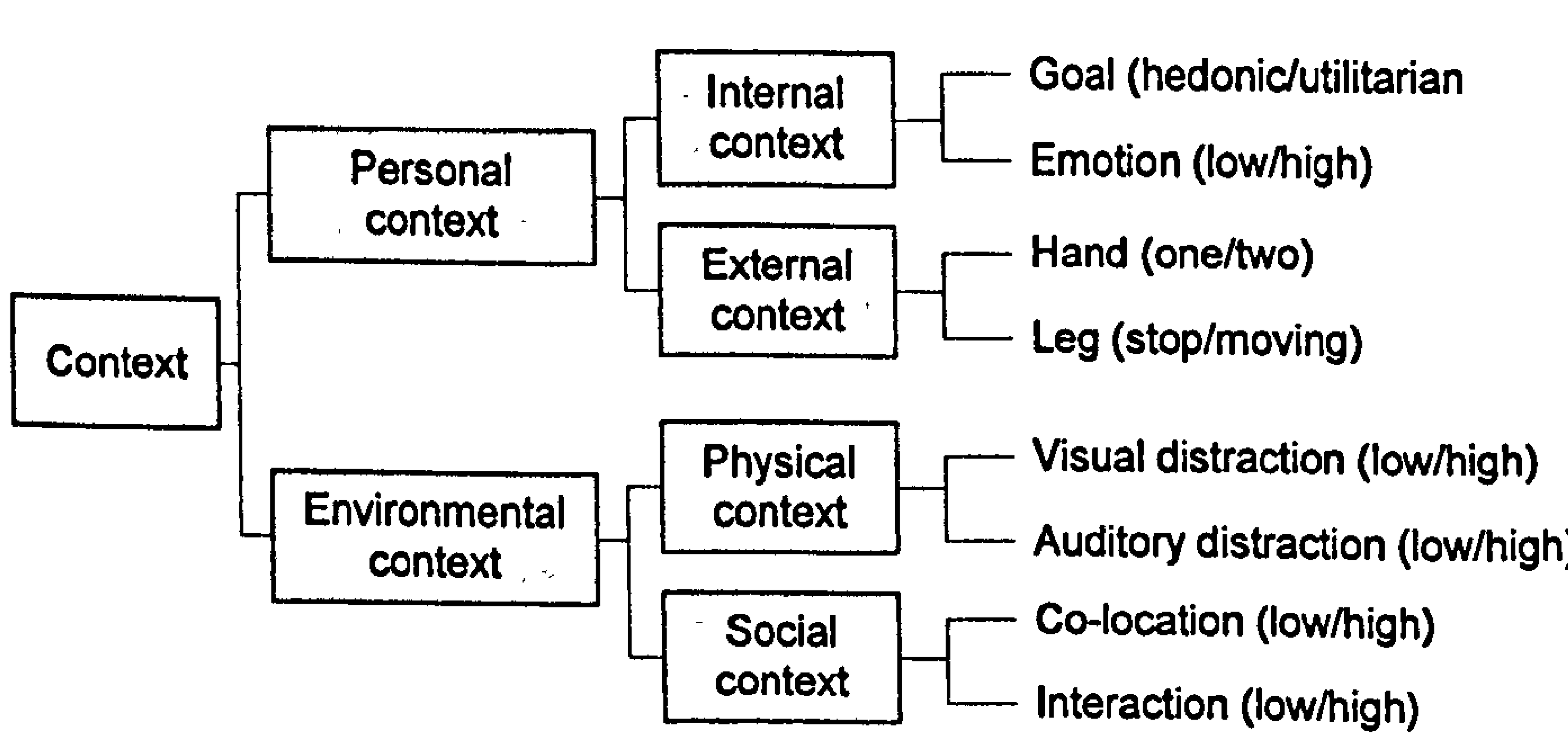


Figure 2.9 Model of context (Kim et al. 2002)

Relatively few studies have attempted to empirically quantify the context of use, or link contextual factors with aspects of user performance with a mobile device. An exception was Kim et al. (2002) who undertook a diary and web log study of access to the mobile internet. Participants were issued with new mobiles and asked to keep a log of use of the mobile internet, together with an assessment of context for each use, using a bipolar scale that described each of the above facets of context, plus a description of any usability problems. The study therefore identified the frequency of use of the mobile internet, and usability problems, associated with different contextual dimensions as shown in Figure 2.9. The main findings were that usage was clustered around a few context combinations as differentiated above, the most frequent being when participants had a hedonic goal, a joyful emotional state, one hand was used, legs were not moving, visual and auditory distractions were low, few people were around them, and interaction was low. Most usability problems were to do with content (as opposed to navigation, representation or structure) and that usability problems were typically impacted by availability of hands, movement (of legs) and the presence of people.

Tamminen et al. (2004) highlight how much research into context has been concerned with the static (and indoor) contexts such as offices and meeting rooms. They specifically sought to understand mobile outdoor contexts using the principles of ethnographic participant observation, and an emphasis on the 'social processes' perspective described by Dourish (2001a). They identified five key characteristics of mobile contexts: (1) situational acts within planned ones (unplanned changes during the course of a journey); (2) claiming personal space (a sphere of privacy); (3) social solutions to navigation problems (e.g. phoning having missed a bus); (4) temporal tensions (fluctuations in the importance of time); and (5) multitasking.

There are clearly a wide range of perspectives on context, e.g. a computing, personal, physical or social emphasis, or combinations thereof. The elements of context discussed within context aware computing are consistent with the information use environments described by Menou (1995a). These are defined by: (1) people, (2) the settings, (3) culture, (4) the problems, (5) the expected solutions, (6) the process of problem solving and decision making, and (7) the available information sources.

The most apparent aspects of context are described by Dey et al. (2001):

Identity – the ability to assign a unique identifier to an entity.

Location is used to describe much more than the user's position in 2D space. It also includes 'orientation and elevation, as well as all information that can be used to deduce spatial relationships between entities, such as co-location, proximity, or containment....' 'Location also applies to places' as they can be 'located in a frame of reference such as geographical coordinates or relative spatial relationships, and thus have a location.'

Activity (or status) defines 'intrinsic characteristics of the entity that can be sensed'. In the context of people, it can 'refer to physiological factors such as vital signs or tiredness, or the activity the person the person is involved in such as reading or talking. Activity can also relate to groups of people, by describing the characteristics of the group such as their enthusiasm or global mood, or a description of their activity such as attending a lecture or having a meeting.

Time is used either as a 'timestamp', or 'time span', by 'indicating an instant or period during which some other contextual information is known or relevant'.

The importance of context is highlighted by Dey et al. (2001) who describe how 'a goal of context acquisition is to determine what a user is trying to accomplish. Because the user's objective is difficult to determine directly, context cues can be used to help infer this information and to inform an application on how to best support the user.'

Bradley and Dunlop (2002) highlight the need to understand contextual interactions in order to maximise usability of systems. Rankin (2001) proposes that 'a new class of highly localized and targeted services which rely on more precise positioning will be greatly valued for their currency and relevance, both by users and service providers'.

Cockton (2004b) underlines the benefits of context-centred HCI, but also that it is difficult to determine which aspects of context are most important, and that as designs improve, incorporation of context results in diminishing returns. He makes the interesting observation that luck can also play a substantial role in the design of context-centred HCI – 'you must see the right bit of context at the right time and associate this with the right aspect of design'.

2.6.4 The use of context by applications

At a general level, Dey (2001) describes how 'adaptation to context can be used to simplify a user's understanding of, and interaction with, interactive systems by migrating complexity away from the user to some form of intelligent user'. There are various ways in which applications can specifically use context (including location) to configure their interaction with the user. Dey et al. (1999) - based on Pascoe (1998) - describe four context aware capabilities that applications can support:

1. Contextual sensing, where a system detects contextual information (e.g. location, other people, and data related to other people nearby), and presents this to the user, augmenting their sensory system.
2. Contextual adaptation, where a system uses context to adapt its behaviour instead of providing a uniform interface in all situations.
3. Contextual resource discovery, where a system locates and uses resources that share its context (e.g. linking to a local server based on location).
4. Contextual augmentation, where a system augments the environment, associating additional data with the current context. The example given by Dey et al. (1999) is automatic attaching of speaker information to notes that a conference attendee may make.

In contrast, Chen and Kotz (2000) describe two basic ways to use context, based on whether the context is used to automatically determine how an application functions, or whether it is used as a means of *enabling* a user. According to Chen and Kotz (2000), *active* context awareness describes where 'an application automatically adapts to discovered context, by changing the application's behaviour'. *Passive* context awareness refers to an application that 'presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later'.

Dey et al. (2001) propose three categories of context-aware functions that a context-aware application may implement:

1. The presentation of information and services. Applications either 'present context information to the user, or use context to propose appropriate selections of actions to the user'. Examples are navigation services that locate the user on a map or indicate the location of nearest petrol stations that lie within a certain radius.
2. The automatic execution of a service – these are applications that 'trigger a command or reconfigure the system on behalf of the user according to context changes'. Using a similar navigation system example, examples of this function are the generation of turn instructions on approach to manoeuvres, and the disabling of destination entry while the vehicle is moving.

3. The tagging of context information for later retrieval, where 'applications tag captured data with relevant context information'. Examples of these functions would be applications that tag notes taken by the user with the location and time of the observation.

2.6.5 User-centred design of location and context aware applications

A wide range of requirements and evaluation studies have been undertaken with services that use location (and additional contextual factors) to enable or enhance a service. A representative list is given below:

Application	Use of location/context
Context-aware tour guides Cheverst et al. (2000); (2002)	Location, personalisation and activity to tailor information pull or push
Location-based gaming Wu et al. (2004)	The incorporation of contextual information (e.g. player location and orientation) into a mobile game setting
Location-based learning Benford (2005)	Location-based services used to enhance the learning experience
Outdoor recreation guides Krug et al. (2003)	Location and personalisation to provide access to relevant information
Personal navigation tool Chincholle et al. (2002)	Retrieval of location relevant information, maps, and route guidance
Conference assistant Dey et al (1999)	Personalised schedules, context based information display and augmentation
Mobile internet services Kolari et al. (2004)	A range of context aware mobile internet services that are based on location, time-based and user activated context sensing
Wireless advertising Yunos et al. (2003)	The use of wireless devices to deliver personal adverts
Personal reminders Dey and Abowd (2000)	The specification of user defined contextual variables (e.g. time, place) to deliver reminders
Driver navigation Phillips (1999)	Simulated location-relevant presentation of landmarks within route directions
Mobile information system Kjeldskov and Paay (2005)	Access to location-relevant information on places, POIs and nearby friends
Location relevant photo collections Pauty et al. (2005)	Navigation through multi - contributed photos which were taken near to the user

Application	Use of location/context
Mobile applications for museums Raptis et al. (2005)	Review, arguing that effective interaction needs to take into account multiple dimensions of context
In-situ authoring Weal et al. (2006)	Location-based authoring and playback of electronic tour guides for visitors
Photo-enhanced pedestrian navigation Beeharee and Steed (2006)	Location-based presentation of photos to enhance pedestrian navigation instructions
Personal training aids Buttussi et al. (2006)	Location-based mobile guide and virtual fitness demonstrator
Tracking and sharing of user location via a contacts list Oulasvirta et al. (2005)	Location, phone status, time in current location, no. of contact and non-contact phones nearby displayed to friends

Figure 2.10 A sample of location/context aware applications

Even those applications that use location as the major determinant of application behaviour are usually more widely context aware to some extent. For example, although navigation applications use location to trigger information presentation, they often allow the setting of personal preferences, and hence can take into account aspects of a user's personal, internal context as described by Kim et al. (2002), even though this is not a dynamic, realtime input.

Other applications are truly 'context aware' as they explicitly take into account more than just location in order to provided a service to the user – for example the guides described by Cheverst et al. (2000) and Krug et al. (2003) both take into account personal context (and in particular user interests) in order to increase the relevance of the information they access or presented with.

In most cases, prototype development and evaluation have shown services to be relatively easy to use and effective (as might be expected if a user-centred design process has been followed). However, the validity of the evaluation process undertaken varies considerably, with some studies focusing superficially on usability evaluation with a very limited number of participants (Chincholle et al. 2002). Other studies, e.g. Cheverest et al. (2000), have had much greater ecological validity, incorporating users with real needs, and recognition of the need to provide value by providing benefits over and above the 'alternatives' out there (Lindgren et al. 2002).

Some key messages emerge from this sample of context-aware applications:

- The potential for adaptation to location, and physical, personal and social aspects of context.
- General user acceptance based on user trials (although longitudinal studies - which are lacking - may produce different results).
- The need for simplicity and speed of interaction and information delivery, echoing the view of Ahmed and Hurst (2000) when they state that 'instant response is crucial to a good wireless customer experience'.
- The potential impact of technical limitations such as positioning accuracy and response latency
- The importance of user orientation (and direction of gaze), and the challenges of determining this.
- The difficulty in determining user relevance where there is not a single, discrete task focus.
- The variation in granularity of location context needed to support effective applications
- The need for flexibility of interaction to match the flexibility of human activities.
- The need for systems to be considered within a wider context of use, and for interaction to be based on windows of opportunity to make a difference within a wider task context.
- Maintenance issues to ensure information remains current and relevant.
- Service design that supplements the real experience, rather than detracts from it – in the same way that Keen and Mackintosh (2001) highlight the need for an enhancing rather than distracting experience.
- Balance between the adaptation of information presentation and the need for 'consistency' of operation.

2.6.6 Challenges for context aware applications

Designing to take into account context (which may be incomplete and varying) is identified as one of the key challenges for designers of mobile devices and services (Dunlop and Brewster 2002; Tarasewich 2003). Greenberg (2001) describes how context is a highly dynamic construct, being in many cases indiscernible, and unpredictable. Similar looking categorisations of context may differ due to prior use, social factors, changing internal goals and subtleties. Greenberg (2001) describes three difficulties for a context aware designer: (1) describing the set of contextual states that may exist, (2) knowing what information accurately determines a particular contextual state, and (3) knowing what action is appropriate within that state. Bellotti and Edwards (2001) make a related point: even if a contextual state can be defined, and the descriptors of that state identified, they highlight that there are human aspects of context that cannot be sensed or inferred by technological means. They state: 'only the basic non-human aspects of context, with constrained conditions and well-defined responsive behaviours, can be handled by devices on their own'. Brown and Randell (2004) are of the view that due to the highly multidimensional nature of context, even simple examples such as a context sensitive mobile phone (which 'knows' when not to ring) are likely to fail as they will make mistakes. Such a 'context sensitive' phone will ring when inappropriate, and also result in unnecessary missed calls due to the inability of capturing and using the relevant aspects of context. As they state with regard to prescribing the behaviour of a mobile phone: 'for every situation [in which a desired behaviour can be predicted], there is an exception'.

Bellotti and Edwards (2001) set out some principles for context-aware systems, highlighting that although they are not hard and fast rules, they must at least be considered by designers. They can be subsequently ruled out as unnecessary, or requiring too great a trade off against another desired design requirement (e.g. response time) – but the following must at least be considered:

1. *Informing the user of current contextual capabilities and understanding.* Bellotti and Edwards (2001) argue that since individuals must have knowledge of the type of situation they are in, in order to behave properly, the understanding of that situation by the system must be made available to the individual so that the individual can modify their behaviour accordingly. An example given is enabling the individual to opt out of being a 'participant' when a context-aware system identifies them as having 'arrived'.
2. *Providing feedback to the user, including: feed-forward* (what will happen if I do this?) *and confirmation* (what have I done and what am I doing?). Bellotti and Edwards (2001) argue that many context-aware systems pay little attention to the need for feedback. They identify the need for feedback on: whether and how a system has

3. *Enforcing identity and action disclosure, particularly when sharing non-public, i.e. restricted information* (who is that, what are they doing, what have they done?). The particular human details necessary for this enforcement by designers include: identity, arrival, departures, status, availability, activity etc.
4. *Providing control to the user, and deferring control to the user, over system and other user actions that impact them.* This is especially important in the case of conflicts of interest. Since Bellotti and Edwards (2001) argue that 'systems cannot be entrusted with the role of taking action on behalf of users, because there are too many contextual contingent considerations [i.e. contextual 'it depends'] that shape human behaviour' they propose three strategies for control. (1) If there is slight doubt about what the desired outcome might be, automatic configuration can take place (since in most cases the system will do the right thing), but the user must be offered an effective way of correcting the system action. (2) If there is significant doubt about what the desired outcome should be, the system should propose an intended outcome, but require that the user confirm that action. (3) If there is little basis for a system inferring a desired outcome, the user should be able to select an action, based on choices offered to them by the system.

Similarly, since Brown and Randell (2004) are sceptical of the success of context-aware applications, they identify three main implications for context-aware technology:

1. *Provide simple structures for users to allow them to appropriate, adopt and dwell with technology.* This implies designing technology so their behaviour (and the way in which they react to context) is simple, predictable and observable. This enables users to 'incorporate [technology] into their practice and develop behaviours and understandings around them'. The example given is a phone where the number of rings a caller experiences indicates whether the call has been 'rejected' (i.e. switched to voice mail). Although not explicitly intended in this way, the behaviour of the call receiver is 'seen through the behaviour of the technology', and forms part of a social understanding. 'The technology [through its behaviour] is put into context by its users, rather than the device itself attempting to understand the context'.

2. *Use context defensively as building computers which understand even simple context will be hard.* They state that 'we should not ignore context in building systems, but rather that we should be careful only to do this in cases where mistakes can be easily tolerated and repaired'. Therefore, context information is used to prescribe what a device does, but 'only in a way which would not be likely to cause bother or irritation to the user if the inferences made from context are incorrect'.
3. *Communicating context to users is helpful.* An argument of Brown and Randell (2004) is that context is of great value when it is presented to users such that they can interpret it. Therefore they 'argue for technology which gives users access to context, even if that context might seem unimportant'. The key point here is that it is the users themselves who interpret context and decide what appropriate action is.

In practice, those services that can use context successfully may be those which operate where all aspects of context are tightly bounded, bar those whose variance directly influences the behaviour of an application. In addition, the variance in that influencing aspect of context must be reliably measurable or computable, with a direct link between the measured or computed context and the changes in the desired application behaviour. A user must also expect changes in context to alter the way the service works. This implies that those changes in context must be highly visible, in order for a user to be able to link changes in context with changes in system behaviour. In general, it may be that the more task-focused an application is within a discernable application domain, the more context can by used successfully to enhance that application.

The implications for MLS are that they may only be successful where it is only location (plus perhaps only one or two simple and easily determinable contextual factors) that determines how a system should ideally interact with a user. Services which use location directly are more likely to be successful than those that use location to infer a contextual state. An example of the former is the tourist or museum guide; a latter being the context aware phone, described by Brown and Randell (2004). However, even where location is seemingly the determinant of how an application should interact with a user, it may not be sufficient. As described by Long et al. (1996) it is not the exact physical position of someone using a context aware tour guide that is important, or even their orientation, what is more useful is knowing what they are looking at.

One reason why navigation applications are relatively successful is that they use one component of context (location) to trigger simple changes in information presentation –

their behaviour in relation to changes in the user context (i.e. chiefly user location, and environmental attributes) is simple, predictable and observable. There is therefore the 'contextual understanding' and 'feedback' recommended by Bellotti and Edwards (2001), and the 'simple structures' and 'communication of context' of Brown and Randell (2004). It could also be argued that context is also being used 'defensively' (Brown and Randell 2004), since a navigation system only presents context-dependent information to the user. However, the user actions based on acting on that information (i.e. taking a particular turning) may not be easily 'repaired', and in this sense violates the 'defensive' guideline.

Driver navigation can be compared to pedestrian navigation. Although pedestrian navigation may be a more 'defensive' application of context (the consequences of 'getting it wrong' are less), a context-aware pedestrian navigation application may be more likely to 'get it wrong'. A driver is generally focusing on only two activities – driving and navigating – and not multitasking in a relatively unpredictable manner in the way that Tamminen et al. (2004) describe pedestrian behaviour.

2.6.7 Summary of contribution to thesis

The literature within Section 2.6 highlights the need for MLS to create meaningful new possibilities for users, and to capitalize on their time and location responsiveness, and knowledge of other entities in order to deliver value to the end user. It is necessary to understand the context of use in order to what aspects should act to change the behaviour of systems, and how that behaviour should change as a result. MLS that require complex interpretation of context are unlikely to be successful; those that act more directly on discrete elements such as location are more likely to 'get it right'. Similarly, there has to be a compelling reason for using a MLS: some MLS appear to offer little more than mobile conveniences and it is questionable whether users will adopt these kinds of services.

2.7 Conclusions

The aim of the literature review in this chapter was to explore the contributions of multiple disciplines in terms of developing value-adding MLS. Several authors have identified the benefits of a multidisciplinary approach, for example Stay (2001) identifies the benefit of a multidisciplinary approach to investigating the value of information for consumer products within the automotive market. However, others - e.g. Rasmussen (2000) - have underlined the reasons why multidisciplinary approaches are seldom seen in the research literature, and why 'interdisciplinary, problem-focussed activity is dangerous territory for untenured faculty members'. There appeared to be very few genuinely multidisciplinary attempts at understanding how users interact with new technology. An exception was the P^3 (Power, Performance, Perception) model proposed by Dillon and Morris (1999), where they integrate the 'can they use it?' from usability, and the 'will they use it?' from management information systems.

Based on the literature reviewed in this thesis, the following are the main messages relating to value and service design which inform the remainder of the thesis.

- Consumers have a choice, and the decision to use a mobile service will depend on the degree to which services meet their needs over and above alternatives available. The volitional nature of most consumer services limits the potential application of theories derived within organisational settings with less voluntary usage.
- Value can comprise functional, social and emotional components (the emphasis within this thesis being the *functional* component).
- Value comprises 'give' and 'get' aspects, i.e. costs and benefits to the individual. The benefits and costs are not absolute terms, but are personal, dynamic and relative.
- Usability alone is an insufficient determinant of success. For a new technology such as MLS, they must provide relative advantage to an individual and compatibility with lifestyles and cultures, as well as being easy to use.
- Services that offer 'new freedoms' within existing life or work constraints are more likely to be successful than those that offer technological features.
- MLS must specifically capitalise on temporal and location attributes of the individual and their relationship with their activities and environment.
- Those that use location directly to adapt information access or presentation are likely to be more successful than those that use location to infer context. The use of location within MLS design should take into account the design principles of Brown and Randell (2004) and Bellotti and Edwards (2001) – in particular to enable system behaviour to be understood, and to minimise the impact of it 'getting it wrong'.

- The nature of the environment (e.g. the affordances offered) plays a key role in the potential impact of a MLS.
- Information-based MLS must add relative advantage in relation to other mobile and non-mobile (IT and other) information sources, taking advantage of opening and closing moments of value.
- Value is highly context dependent, and ultimately depends on the ability to take alternative courses of action, and the impact that those courses of action have on the individual.

In addition, there are several key methodological points which can be used to guide the approach taken in this thesis:

- Empirical studies need to focus on validity and generation of insights, rather than highly numerical treatment of data. Objective data, based on *what people do*, needs to be coupled with data based on *attitudes* and *explanations*.
- Attitudinal responses, determined solely by questionnaire, are relatively poor indicators of what individuals actually do within a complex task environment.
- Clearly defined and operationalised performance measures are needed for evaluating user interaction with technology. These can be relative, absolute, or both.
- Research needs to explicitly account for the relationship between the user tasks, their information needs, and the physical and information environment.
- Technological capabilities of MLS must be mapped onto user tasks (although it may be difficult to identify what these 'tasks' are).
- The real value of a service is demonstrated by the extent to which it is used, and results in a differing set of behaviours or outcomes than those which would have occurred without using the service.

As a final point, value can operate at both macro (impact) and micro (interaction) levels, similar to the motivational and action levels described by Kankainen (2002). At a *macro* level, value is delivered to a user by providing them with the new freedoms described by Keen & Mackintosh (2001). Consideration of the macro level can help determine the kinds of services that may be successful for individuals. At a *micro* level, an MLS provides value by providing specific benefit within a particular context of use or more appropriately, the *context of impact* (Cockton 2006). It will provide location and temporal relevance to an end user, without relying on clumsy interpretations of context. As well as impacting directly on outcomes, an MLS that adds value will take into account an end-users' existing knowledge, and information already available, and will ensure that there is a positive cost-benefit ratio in terms of the benefits realisable and the resources needed to use a service.

3 RESEARCH METHODS

3.1 Introduction and aims

The overall aim of this thesis was to use 'value' concepts with the user-centred design of mobile location services. This chapter discusses the different approaches that may be used within a research design, and their applicability to this thesis. In particular, the objectives of this chapter are to:

- Outline the different methodological approaches that may be taken when undertaking applied research
- Identify generally accepted principles or 'good practice' for research design
- Describe the research methods to be employed within this thesis
- Identify potential methodological concerns or limitations with those methods chosen

This chapter assumes that the basic requirements for 'good' research with mobile users are no different to other user-centred applications (or indeed research in other scientific domains). Therefore, rather than reviewing *methods* for mobile research, this chapter highlights the basic tenets of scientific enquiry, and how these can be applied to the research questions identified in Chapter 1. However, it is recognised that the mobile arena does pose specific challenges, and these are highlighted in Section 3.5. In addition, each of the five studies within this thesis (described in Chapters 4, 5, 7, 8 and 9) discusses methodological issues and potential limitations in more detail.

3.2 The research arena

Robson (2002) offers a useful framework for research design, shown below in Figure 3.1. This highlights the central role that the formulation of research questions takes in determining the strategies and methods used in a research study. In addition, the research process is clearly driven by the motivations for the particular study, in conjunction with theory that helps frame the research questions.

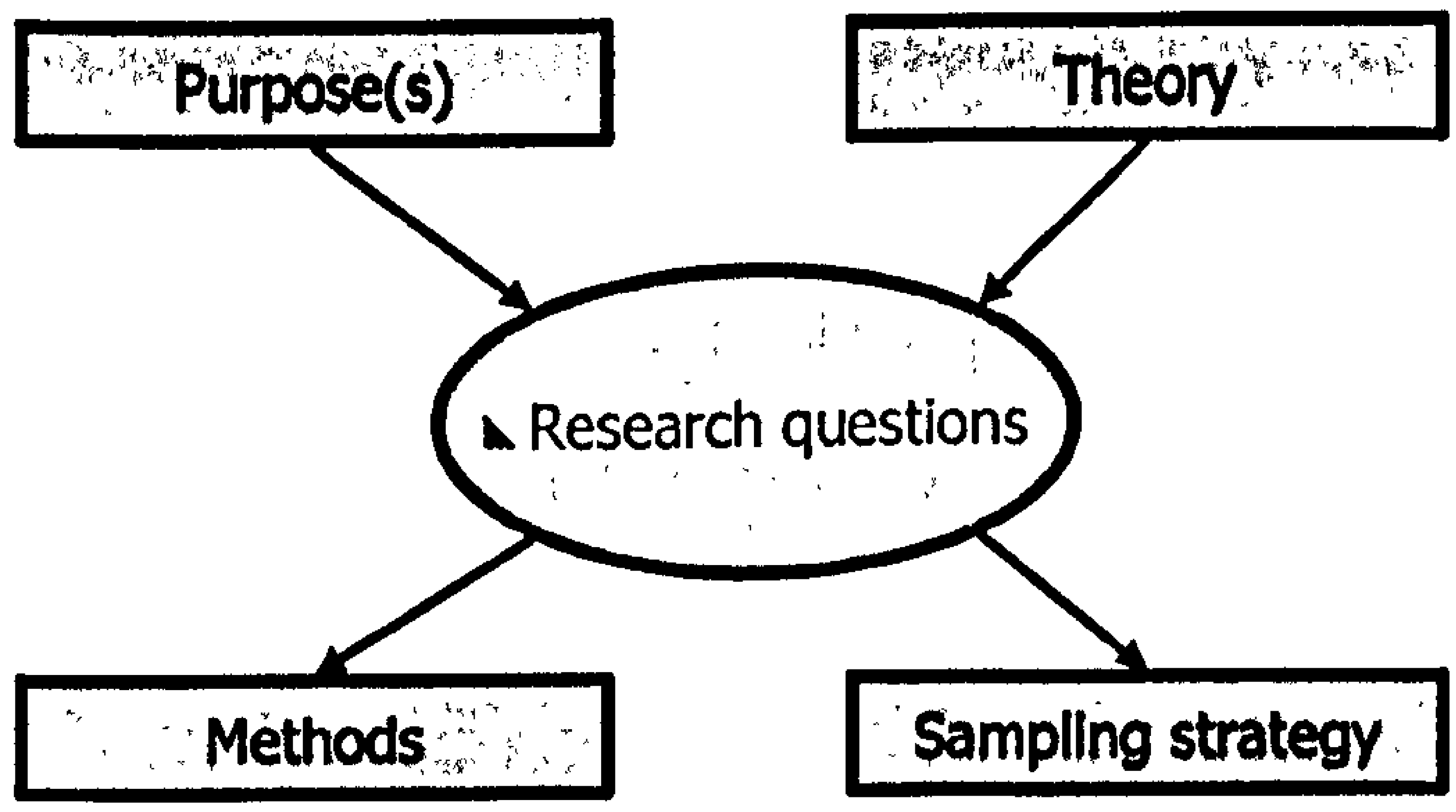


Figure 3.1. Framework for research design (Robson 2002)

Many authors have described the different dimensions or facets of research design. The research 'onion' (Saunders et al. 2000) shown below outlines the different layers involved in the research process, i.e. the main distinctions that may be made in terms of how research may be undertaken, and knowledge developed.

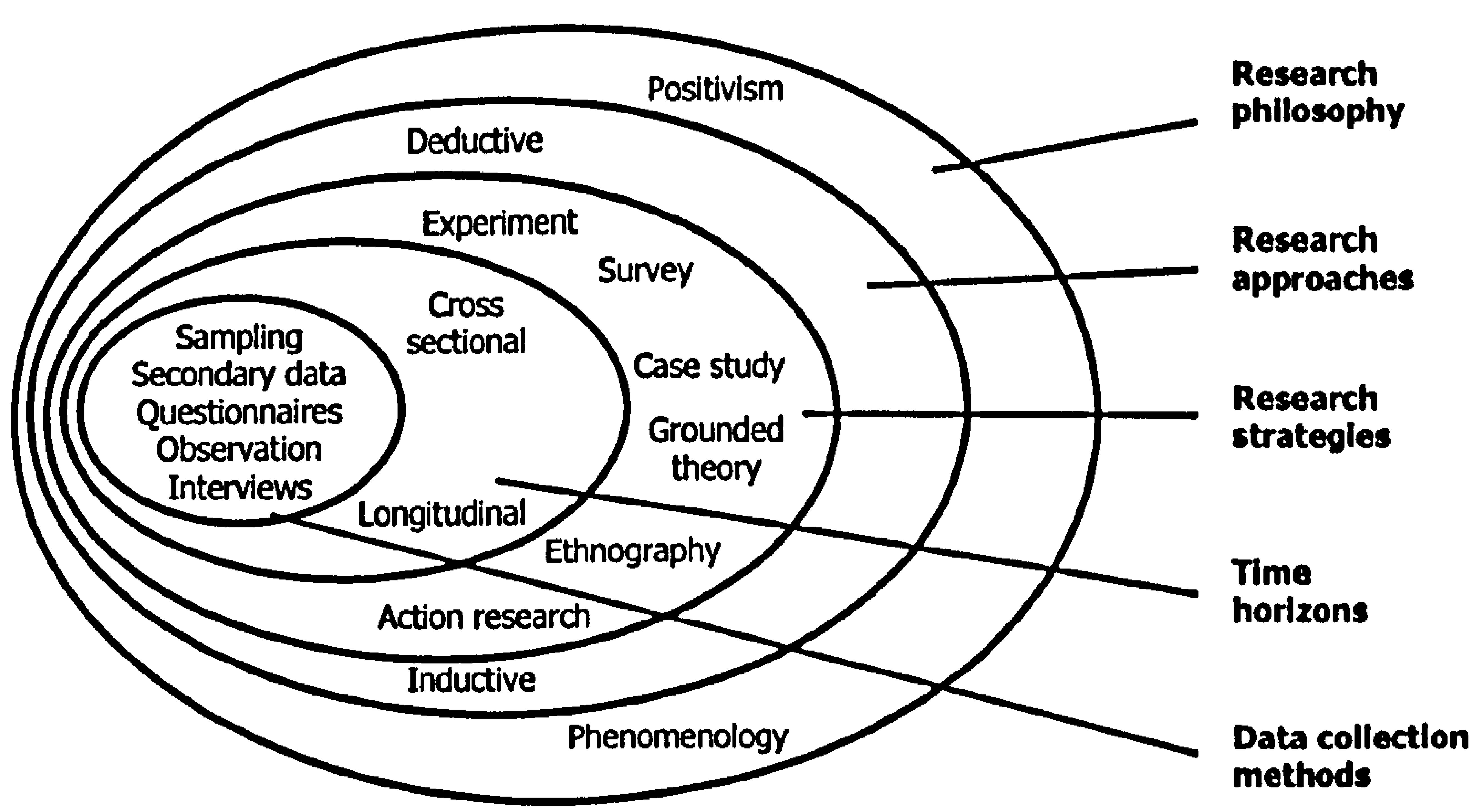


Figure 3.2 The research process 'onion' (© Saunders et al. 2000)

The figure makes the following main distinctions:

- A *positivist* ('quantitative' in the traditional view of science) or *phenomenological* (sometime more widely described as 'qualitative', and labelled as interpretivist, constructivist or naturalist) view of the world.

(Note for the purposes of this thesis, the finer distinctions between non-positivist research philosophies are not further elaborated – e.g. Saunders et al. (2003) in a later edition revised this figure to replace Phenomenology with Interpretivism and Realism.)

- A *deductive* or *inductive* approach to developing or testing hypothesis
- The *strategy*, or means of operationalising the research process
- The *timescales* and *data collection* methods used

Gable (1994) offers a similar distinction between different aspects of the research process, shown below Table 3.1 below:

1	Exploratory vs. Explanatory
2	Case vs. Statistical
3	Field vs. Laboratory vs. Simulation
4	Cross-sectional vs. Longitudinal
5	Observational vs. Survey
6	Experimental vs. *Ex post facto*
7	Descriptive vs. Causal

Table 3.1. Dimensions of research designs, from Gable (1994)

The distinctions made above are useful; however as noted by Saunders et al. (2000), there are overlaps within factors, and there may not be clear distinctions (e.g. between different research strategies). In addition, there are clear associations *between* factors - surveys will tend to use questionnaires, experiments will be based on participant samples, and will tend to focus on quantitative data generation, and so on. Sections 3.2.1 to 3.2.3 discuss the main distinctions in more detail.

3.2.1 Research philosophies

A basic distinction is often made between positivist and non-positivist (termed interpretivist within this thesis) approaches to research. Positivism and interpretivism are considered paradigms, i.e. ways of looking at the world, or viewpoints that are taken with regard to the research process. Positivism is the belief that the social world exists externally, and that its properties should be measured through objective measures (Gill and Johnson 2002). In contrast, an interpretivist approach recognises the need to discover 'the details of the situation to understand the reality or perhaps a reality working behind them' (Remenyi et al. 1998).

The positivist approach reflects the philosophical stance of the physical or natural scientist, with an emphasis on a highly structured methodology to facilitate replication (Gill and Johnson 2002). Positivist research is characterised by quantifiable independent and dependent variables, statement and tests of hypothesis, and the generalisation of results to a stated population by the drawing of inferences from the representative sample that is being tested.

Interpretivist research does not predefine dependent and independent variables, but is undertaken in order to allow the important phenomena, and the meanings attached to these phenomena, to emerge naturally from the research process. Interpretivist research focuses on the complexity of human processes within a given context. Klein & Myers (1999) underline how 'interpretive research...... has the potential to produce deep insights into information systems phenomena'. They describe how [information science] research can be classified as interpretivist 'if it is assumed that our knowledge of reality if gained only through social constructions such as language, consciousness, shared meanings, documents, tools, and other artefacts.'

A summary of the positivist and interpretivist research approaches is given below.

		Positivist paradigm	**Interpretivist paradigm**
Basic beliefs are that:	The world is:	external and objective	internal and subjective
	The observer:	is independent	brings their own perspective
	Science is driven by:	testing hypothesis and theories (science is neutral, about getting to the truth)	human interests
The researcher should:	Focus on:	facts	views, perspectives, phenomena, meanings
	Try to understand:	why it is happening, establish cause/effect relationships	what is happening (not interested in cause/effect relationships)
	Deal with phenomena by	reducing it to the simplest elements	obtaining a rich picture, look at complexity and totality
The basic process	Is one of	Formulating hypothesis and then testing them	Observing the real world, understanding the problem, being inductive
Preferred methods include		Operationalising concepts so that they can be measured	Using multiple methods to establish different views of phenomena
		Taking large samples	Taking small samples and studying them in greater depth

Table 3.2. A summary of the key features of positivist and phenomenological paradigms, based on Cohen (2001)

Lee (1991) makes the observation that the positivist and interpretivist approaches would appear to be in opposition, but can be used together. He developed an integrated model of the positivist and interpretivist approaches, in which three levels of understanding are identified: (1) subjective understanding, which consists of the 'everyday common sense and everyday meanings' of the human subjects, giving rise to their behaviours within a social setting, (2) interpretivist understanding, which is the 'researcher's reading or interpretation' of the subject meanings, and (3) positivist understanding, which is 'one that the researcher creates and tests in order to explain the empirical reality they he or she is investigating'. A key point that Lee (1991) makes is that good research can combine interpretivist and positivist approaches, in order to understand a phenomena, and develop theoretical propositions which can be tested.

The terms *qualitative* and *quantitative* are often used to describe an interpretivist and positivist viewpoint respectively. However, Klein & Myers (1999) underline how qualitative research (such as that based on interview data) may be interpretivist, but can equally well be undertaken from a positivist viewpoint. Equally, quantitative research can be undertaken from a variety of research perspectives. Additionally, the term 'qualitative research' is sometimes used to describe generating data in order to develop theory, whereas 'quantitative research' may be used to describe starting with a theory and then testing it with data. In this respect, it represents the dichotomy between an inductive or deductive approach respectively, outlined below in Section 3.2.2.

Within research concerning humans acting in the real world, there is a trend towards the collecting of qualitative instead of quantitative data, an increasing recognition that human-centred research needs to take place in the real world rather than in the laboratory, and a wide range of philosophical viewpoints from a social science perspective (Robson 2002). Within a real world context, Robson (2002) advocates what he terms 'flexible' research designs, and uses this term in preference to the term 'qualitative'.

3.2.2 Research approaches (deductive vs. inductive)

A *deductive* research approach 'entails the development of a conceptual and theoretical structure prior to its testing through empirical observation.... it begins with abstract conceptualisation and then moves on to testing through the application of theory' (Gill and Johnson 2002). The basic process is one of conceptualisation of the problem > rules for observation > operationalisation through indicators and measures > and finally testing by corroboration.

In contrast, an *inductive* research method involves 'moving from the plane of observation of the empirical world to the construction of explanations and theories about what has been observed' (Gill and Johnson 2002). The outcome is theory and the basic process is one of stimulus > experience and interpretation > and response/action conceptualisation.

The key differences between an inductive or inductive approach are shown below in Table 3.3. In very basic terms, they represent the act of 'understanding' or the act of 'testing' respectively.

Induction emphasises:	Deduction emphasises:
Gaining an understanding of the meanings humans attach to events	Scientific principles
A close understanding of the research context	Moving from theory to data
The collection of qualitative data	The need to explain causal relationships between variables
A more flexible structure to permit changes of research emphasis as the research progresses	The collection of quantitative data
A realisation that the researcher is part of the research process	The application of controls to ensure validity of data
Less concern with the need to generalise	The operationalisation of concepts to ensure clarity of definition
	A highly structured approach
	Researcher independence of what is being researched
	The necessity to select samples of sufficient size in order to generalise conclusions

Table 3.3. The major differences between deductive and inductive approaches to research, from Saunders et al. (2000)

Saunders et al. (2000) underline how rather than there being mutually exclusive divisions between the different approaches (deductive vs. inductive) you can take to research design, it is often advantageous to combine approaches within the same piece of work. This multiplicity is discussed in Section 3.2.4.

3.2.3 Research strategies

Saunders et al. (2000) describe the basic means of operationalising research as comprising the following: experiment; survey; case study; grounded theory; ethnography; and action research. Robson (2002) makes a similar distinction, but differentiates between fixed designs (often called a quantitative strategy) and flexible designs (typically labelled as a qualitative approach). Fixed designs are differentiated according to whether they are experimental or non-experimental strategies. Case studies, ethnographic studies and grounded theory are three typical flexible design research strategies.

A summary of different strategies is given below, based in part on Boudreau et al. (2001), followed by recommendations (Robson 2002) for choosing a specific strategy.

Laboratory experiments take place in a setting created by the researcher in order to investigate the phenomenon. The researcher has control over the independent variables and can assign (randomly or otherwise) the research participants to various treatment or non-treatment conditions.

Field experiments involve the experimental manipulation of one or more variables within a naturally occurring system and the subsequent measurement of the impact of this manipulation on one or more dependent variables.

Field studies are non-experimental investigations occurring in natural systems, where independent variables cannot be manipulated and influencing confounding variables cannot be controlled. Field studies can collect data using questionnaires (in person, mail, email, web), interview transcripts (coded for quantitative data analysis), plus other techniques. Where multiple case studies are carried out, these can be considered as field studies.

Note that with reference to the above Robson (2002) makes the distinction between experimental and non-experimental *fixed* designs, the former occurring where the experimenter 'actively and deliberately introduces some form of change in the situation, circumstances or experience of participants with a view to producing a resultant change in their behaviour'.

Case studies involve the intense examination of a small number of entities by the researcher where no independent variables are manipulated and confounding variables are not controlled. They involve empirical investigation of a 'phenomenon within its real life context using multiple sources of evidence' (Robson 2002). Case studies usually involve questionnaires, coded interviews or systematic observation, but unlike field studies, the main aim of the case study is to generate knowledge of the particular from which theory development is possible (Stake 1995). Case studies allow the development of deep insights of a phenomena from which hypothesis may be generated (Yin 1994). As emphasised by

Benbasat et al. (1987), during case study research, there will be less a priori knowledge of what the variables of interest will be and how they will be measured.

Ethnographic research involves (and is predicated on) immersing oneself in the places, cultures and practices of the group being studied, typically over an extended period of time. The typical data collection method is observation, although there are several different observation roles that the researcher may take (Robson 2002), and a wide range of data collection techniques that may be appropriate.

The final two distinctions in terms of research strategies are those which are specifically undertaken for a particular reason: *evaluation research* and *action research.*

Evaluation research is undertaken in order to establish the worth of something such as an intervention, innovation, policy, practice or service. As highlighted by Robson (2002) it is a 'study which has a distinctive purpose; it is not a new or different research strategy', and can encompass any kind of research strategy, including those outlined above. It may seek to be *formative* (to help in the development of the intervention, innovation, policy, practice or service that is the focus of the evaluation), or *summative* (to assess the effects and effectiveness of the innovation etc that is the focus). In practice, even those studies with a summative focus tend to have at least some formative value.

Action research is primarily undertaken to influence or change an aspect of the intervention, innovation, policy, practice or service etc that is the focus of the research. In addition to the traditional research purposes of description, understanding and explanation, 'improvement and understanding are central to action research' (Robson 2002). The individuals who are the focus of the research collaborate closely with the researcher, and participate in the research process. Like evaluation research, it can incorporate a wide range of research strategies.

Attewell and Rule (1991) highlight the relative strengths and weaknesses of different research methodologies, including surveys, field work/observational studies, simulations and experimental methods. Rather than each method being suited to both discovery and verification, they view the different methodologies as 'lying along a spectrum, those at one extreme being concerned primarily with discovery (with limited capacity to prove, verify, or replicate), those at the other, well suited to objective verification of hypothesis but singularly clumsy for generating new discoveries.'

Gable (1994) discusses the relative strengths and weaknesses of case studies, surveys and experimentation, shown below:

	Case study	Survey	Experimentation
Controllability	Low	Medium	High
Deductibility	Low	Medium	High
Repeatability	Low	Medium	High
Generalisability	Low	High	Medium
Discoverability (ability to explore phenomena)	High	Medium	Low
Representability (potential model complexity)	High	Medium	Low

Table 3.4. Relative strengths of case study, survey and experimentation, from Gable (1994)

3.2.4 Multiplicity and situated research

Within the disciplines that are concerned with human interaction with technology - including human factors (ergonomics), information science and consumer research - there have been various calls for multidisciplinarity within research programmes or studies.

Rasmussen (2000), from a human factors perspective, argues that as society becomes more dynamic and integrated with technology, there is a need for greater multidisciplinarity in tackling human factors problems, and also a need to study the context within which human activity is occurring. Mick (2003), in an editorial, pleas for more relevance, and greater multidisciplinarity within consumer research. Graham (2003b), in a review of methods used specifically within mobile HCI research, highlights the predominance of the 'build and laboratory test' approach , and the relative lack of application of action research, case studies, field studies and basic research. He argues that the lack of situated research limits the development of understanding how humans actually interact with mobile technology. As a specific example (within online shopping), Limayem et al. (2003) conclude that 'even after several years of research in this important area, we still don't have a very good understanding of the real drivers of online shopping'.

The growing call for more situated research that has relevance in the 'real world' is reflected in the shift towards flexible (qualitative) approaches underlined by Robson

(2002). However, as pointed out by Rasmussen (2000), 'interdisciplinary, problem-focussed activity is dangerous territory for untenured faculty members', which may explain the overall lack of published human-centred research undertaken in this way.

In terms of multiplicity, McGrath (1982) states that: 'No strategy, design or method used alone is worth a damn. Multiple approaches are required – at the method level, within study for every construct; at the design and strategy levels, between studies.' Attewell and Rule (1991) are not quite so vociferous, but do 'suggest that a carefully chosen mix of methods be combined for a single research project. The combination should be designed to meet the needs of discovery and verification, plus the need to understand actors' meanings and intentions while measuring objective quantitative distributions of outcomes.'

3.2.5 Reliability and validity

A fundamental requirement of research which attempts to understand phenomena, derive theories, or test those theories, is the requirement for reliability and validity, or as summarised by Saunders et al. (2003) in relation to the credibility of research findings 'reducing the possibility of getting the answer wrong'. Although validity and reliability are often used synonymously; they are quite different concepts. *Reliability* is 'the extent to which an instrument [i.e. data collection 'tool'] produces consistent or error-free results' Rogers (1995b) quoted by Boudreau et al. (2001); it is a statement about measurement accuracy. 'The most fundamental test of reliability is repeatability – the ability to get the same data values from several measurements made in the same way' (Alreck and Settle 1995). Establishing reliability without establishing validity simply demonstrates that you 'are measuring something' (Robson 2002).

In its most basic form, reliability can be assessed by asking:

- Will the measures yield the same results on other occasions?
- Will similar observations be reached by other observers?
- Is there transparency in how sense was made from the raw data?

Easterby-Smith et al. (2002) quoted in Saunders et al. (2003)

Threats to reliability can stem from various sources Robson (2002), e.g. participant error (where participant behaviour might fluctuate widely from occasion to occasion irrespective of the conditions of the study), participant bias (resulting from the participant being aware of the nature of the study), observer error (due to inconsistent measurement), or observer bias (e.g. influenced by raters' beliefs concerning the efficacy of a particular intervention).

Reliability of measures can be assessed in various ways. These are often described in relation to quantitative surveys, but can be equally as applicable to non-survey approaches: (1) internal or inter-item consistency – work out the correlations between different items within a dimension or construct; (2) split halves – divide the sample into two and test that the same results are achieved with each subset; (3) test-retest, where the same assessment is made at two points in time; (4) alternative, equivalent or parallel forms, where you look for the same results being generated by a different set of measures; (5) inter-rater reliability, where the same results (e.g. observations or interview transcripts) are rated or coded by different people, and the results compared.

The main attempts to ensure reliability of results within this thesis were to eliminate as far as possible confounding influences within experimental designs, hide the nature of the studies from participants where appropriate, use data collection protocols to maximise consistency of measurement and employ and compare multiple measures. Reliability was assessed by analyzing variability in measures, and by informal inter-rater comparison. Formal measurements of reliability within the thesis were not undertaken, and this is recognised as a potential limitation.

In contrast to reliability discussed above, *validity*, in its most general terms, is the extent to which you are measuring what you mean or set out to measure. 'A measurement of any kind is valid to the degree it measures *all* of that and *only* that which it's supposed to measure (Alreck and Settle 1995). The degree of validity is *limited by* the degree of reliability, even though they are quite different concepts. If a measure isn't reliable, it can't be valid, since it is not measuring all of, and only that required.

There are various distinctions between aspects of validity as follows. Although typically described from a positivist, deductive viewpoint (such as using a survey to test causal relationships), validity (and its subforms) is critical to all scientific enquiry.

Content validity refers to the degree to which items in an instrument (e.g. questionnaire) reflects the contents of the universe to which the instrument will be generalised – is the instrument relevant to the real world within the bounds of the generalisation that will occur? Content validity is usually established by understanding the problem domain through reviews of the literature and judgements of experts.

Construct validity is the extent to which an operationalisation of an instrument measures the concepts that it purports to measure (Boudreau et al. 2001), or stated in simpler terms by Robson (2002): 'does it measure what you think it measures?. The simplest method for assessing construct validity is to establish *face validity* – described by Robson (2002) as 'what seems reasonable' to those involved. Other methods are to investigate what are considered sub-elements of construct validity (Boudreau et al. 2001): *convergent validity* – do two instruments measuring the concept correlate well; *discriminant validity* – does the measure have a low correlation with a variable that should be unrelated to this concept (does it discriminate between them); and *predictive criterion validity* – how well does the measure predict performance on the criterion in question (e.g. links between pupils test scores and actual educational achievement in later life) (Robson 2002).

If *construct validity* has been established, *internal validity* - the extent to which you can plausibly demonstrate a causal relationship between treatment and outcome must also be established. This requires eliminating as far as possible the threats to internal validity, summarised by Robson (2002, pp. 105-106). These are particular threats when randomisation cannot be employed within research design, such that the effect of unforeseen factors can be assumed to act equally on the measures being taken.

The final type of validity that needs considering for any study that involves studying the specific in order to generalise to a wider population, is *external validity* or generalisability. Robson (2002) makes the interesting observation that internal and external validity tend to be inversely related, since the controls that are placed on research (e.g. undertaking laboratory-based experiments) can result in questionable generalisability outside of those controls (e.g. the application of findings to real-world behaviour). Threats to external validity (generalisability) are summarised by Robson (2002, p. 107), comprising findings being unique due to the selection of: the group, the setting which the study took place, the history associated with the participants or the constructs themselves being unique to that group. Robson (2002) highlights that several studies have demonstrated a lack of generalisability from what people *say* they will do, to what they *actually* do.

A related issue is ecological validity – the extent to which the phenomena you are observing is representative of that which occurs in the 'real world'. Saunders et al. (2003) describe how ecological validity is high with participant observation, since it involves 'studying social phenomena in their natural contexts'. This is key consideration within this thesis, since a human factors perspective is by necessity concerned with human behaviour within an actual context. As a general comment, Menou (1995a) - in the context of studies involving use of information - criticises small scale experiments where context and objects are artificial, or overly simplified. He highlights the need to undertake experiments in information use where the problems are clearly stated and there is real context.

Validity can usually be enhanced by using established instruments, scales or measures, which have been tested and validated. This is a key recommendation of Boudreau et al. (2001) - in the context of positivist research - who recommend that 'for the sake of efficiency, quantitative, positivist researchers should use previously validated instruments wherever possible, being careful not to skirt previous validation controversies or to make significant alterations in validated instruments without revalidating instrument content, constructs, and reliability.' However they also highlight that creating new instruments (e.g. new designs of questionnaires) allows for the testing of the robustness of constructs and the theoretical links to method and measurement change.

Validity is equally as important in qualitative inquiry as it is in the fixed designs of quantitative research. Since qualitative research is largely about generating understanding, threats to validity can be identified in this context. These include (1) generating inaccurate or incomplete data, (2) incorrect interpretation (e.g. by imposing a framework or meaning on the data, rather than allowing this to emerge naturally, and be traceable via an audit trail), and (3) not considering alternative explanations or understandings of the phenomena being studied (Robson 2002). Lincoln and Guba (1985), quoted in Robson (2002), describe three broad threats to flexible (qualitative) research: (1) reactivity, where the researcher's presence may interfere with the setting or behaviour of those involved in the study; (2) respondent biases, where the researcher may be seen as a threat, or those involved may give the answers or impressions that they judge that the researcher wants; and (3) researcher bias, where the researcher brings with them assumptions and preconceptions which affect how they behave, how they choose participants, what questions are asked and how results are reported – instead of allowing the natural phenomena and meanings to emerge.

Validity within this thesis was tackled chiefly by understanding the problem domain, allowing interpretations to emerge without preconceptions concerning cause and effect, using established measures (and measurement instruments and incorporated scales) where appropriate, and employing multiplicity where possible. In addition, an emphasis was placed where possible on research within a real (rather than simulated) usage context in order to maximise the ecological validity of the research undertaken.

In addition to issues of reliability and validity outlined above, a universally accepted recommendation for undertaking good quality research is that a pre-test, or a pilot study, or both is employed (e.g. Boudreau et al. 2001; Robson 2002). This is particularly true for fixed (i.e. quantitative) studies, due to the need to precisely define the research methods at the beginning of the study. A *pre-test* is defined by Alreck and Settle (1995) as a preliminary trial of some or all aspects of the instrument to ensure there are no unanticipated difficulties. A *pilot study* is defined by Alreck and Settle (1995) as a brief preliminary survey, often using a small convenience sample. Moser (1958), quoted in Boudreau et al. (2001) describes how a pilot survey is a 'dress rehearsal', and will be 'preceded by a series of preliminary tests and trials [the pretests]'. Boudreau et al. (2001) state that every instrument should be pre-tested, and also underline the importance of pilot tests.

3.3 Choosing a research strategy

3.3.1 Research design

Saunders et al. (2000) underline the importance of careful consideration of a research design, including whether a deductive or inductive approach is being taken. It enables the researcher to make informed decisions about a research design which are 'more than simply the methods by which data are collected and analysed. It is the overall configuration of the piece of research: what kind of evidence is gathered and from where, and how such evidence is interpreted in order to provide good answers to the basic research questions.'

Perhaps most importantly, this consideration (rather than premature assumptions about the data collection methods to be used) enables adaptation of the research design according to any constraints imposed (including lack of access, lack of existing research knowledge, including literature) of the subject. If there is insufficient understanding of the phenomena, or contradictory findings, it may not be possible to state a hypothesis with the necessary confidence, and an inductive approach may be necessary.

Robson (2002) sets out a series of steps for choosing a research strategy. He portrays this from the point of view of a critical realist, with a possible leaning towards qualitative (termed 'flexible') methods, and suggests the following considerations:

- Choice between a fixed or flexible design strategy, based on whether it is possible to tightly pre-specify the data collection.
- Whether the proposed study is an evaluation – 'are you trying to establish the worth of something such as an intervention, innovation or service?' A fixed design is usually indicated if the focus is on *outcomes*; a flexible design is more appropriate for studying *processes*.
- Whether the study is based on action research, with direct participation in the research by stakeholders, coupled with agendas for action and intentions to initiate change. A flexible design is usually indicated.
- For a fixed design strategy, a choice between an experimental or non-experimental design. The central feature of an experimental design is that the researcher 'actively and deliberately introduces some form of change in the situation, circumstances or experience of participants with a view to producing a resultant change in their behaviour'. With a non-experimental strategy, there is no attempt by the researcher to manipulate the situation, circumstance or experience.
- For a flexible design strategy, the choice of designs includes, but is not limited to: case studies, ethnographic studies and grounded theory.

Attewell and Rule (1991) state that 'getting close to the phenomenon – gathering insights or discoveries about casual links, motivations, reasons why things happened – should precede verification by more objective techniques, such as surveys.' This is the approach advocated by Gable (1994), who describes how case studies and survey methods may be integrated in order to draw upon the strengths of both approaches. The approach within this thesis is outlined in Section 3.4 and demonstrates multiplicity in approach and method – it progresses from inductive, qualitative data collection with an emphasis on exploration, to a deductive phase focussing on testing and confirmation of relationships between variables.

3.4 Research design within this thesis

This section outlines the methods chosen for each of the five studies in this thesis, focussing on the approach taken from a general methodological viewpoint. The *details* of each study are covered in the relevant chapters.

Research Question 1:

Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?

This question was tackled by undertaking a wide-ranging literature review looking at the applicability of perspectives from a range of user-focussed disciplines. This review also benefited considerably from discussions with academics and practitioners at a range of meetings, conferences and exhibitions over a number of years. The majority of this review was undertaken at the beginning of this research process and directly informed the empirical work, including the choice of driver navigation as an application domain. Later literature helped inform the discussion of results from individual studies, and the interpretation and discussion of results at the end of the thesis.

The literature review looking at multidisciplinary perspectives on value is described in Chapter 2.

Research question 2:

How are mobile location services fairing in the current consumer marketplace?

Without potential for the development of successful MLS, this thesis has little relevance in the real world - a fundamental prerequisite of a human factors research perspective.

Two methods were used to tackle the research question above. A research review was undertaken to understand user perspectives on the MLS market. This is described in Chapter 2. In addition, a descriptive focus was necessary to address this research question, with an emphasis on the discovery of facts (Robson 2002) relating to population samples. This phase needed to identify the extent to which motivating or enabling factors are present that are compatible with the use by individuals of new mobile technology, as well as determining directly user awareness of services and attitudes to them. There was no experimental manipulation within this phase, purely a desire to discover facts relevant to the consumers or potential consumers of MLS.

There were three main research methods appropriate at this stage: ethnographic studies, multiple case studies or a survey. An ethnographic study would have enabled the understanding of the lifestyles and cultures of a population segment, but would have been restricted to a narrowly defined subgroup, and necessarily focused on *existing* practices (which may or may not have included interaction with mobile services). Multiple case studies into individual (or group) lifestyles, awareness and attitudes would have provided the deep insights into the lifestyle factors that would indicate the extent to which mobile services could add value to the user. However, as identified by Gable (1994), they have relatively low generalisability, since the numbers of individuals studied are low, and there is no guarantee that those studied are members of larger homogeneous samples.

For the reasons above, a non-experimental, cross-sectional study, with a survey methodology (Robson 2002) was used to address this first research question. This approach can generate results which are highly generalisable to the wider population, and is also relatively effective at enabling the discovery of facts. The main disadvantage of a survey is the inability to probe deeply into behaviour, motivations and attitudes. A survey is good at determining *what* people do, but not so good at finding out *why*. As highlighted by Gable (1994), it is often advantageous to supplement survey results with other approaches which enable the discover of insights. Note with Gable (1994), a survey was used for the purposes of verification in order to test a model; for this thesis, a survey was used purely to discover facts, without any previously developed model.

The use of a survey to address the above research question is described in Chapter 4.

Research question 3:

What is user 'value' in the context of mobile location services?

Since there was no clear consensus regarding 'value', an exploratory study was needed to understand the concept of value in relation to MLS. However, in contrast to the survey approach described above, this exploratory study needed to develop insights into what is meant by 'value' and the influence on potential use or non-use of services.

The original intention was to use a case study approach, in which knowledge of the particular is generated, from which it is possible to generalise in more theoretical terms -

i.e. analytical generalisation (Stake 1995). Case studies have high discoverability (explorative power) and are well suited to exploring poorly-understood phenomena. True case studies require investigation of a phenomenon within its natural setting, plus the collection of multiple sources of data. In discussing potential scenarios of interest with participants, it became clear that those most interesting (and potentially insightful) were a range of events that had happened in the past – as opposed to current behaviour that could be investigated in real time with a case study. A decision was made to use a post-event enquiry using structured interviews, described in more detail in Section 5.4.2. These had the advantage of being able to target the phenomena of interest, but a potential lack of validity compared to true case studies. This recognised limitation is discussed in Section 5.8. The additional inherent drawbacks of an explorative study can be mitigated to some extent by:

- Ensuring the careful selection of participants, such that they are representative of the wider population who are of interest
- Undertaking multiple studies – using a relatively large number of participants if the unit of measurement is the individual
- Ensuring a spread of coverage in terms of the situations or scenarios of interest
- Generalising and abstracting results such that they are applicable to a wider set of contexts and behaviours

The explorative approach to address the above research question is described in Chapter 5.

Research question 4:

How can a specific mobile location service (driver navigation) be enhanced using a value perspective?

Research questions (1) to (3) have addressed issues relevant to MLS in general. A desire within this thesis was to enhance the design of MLS using a 'value' perspective. An *application* focus was taken based on one specific service that can be delivered over a portable device – that of navigation services delivered to a driver within a vehicle. It is recognised that this selection of a service is relatively arbitrary; however the decision to focus on these services was made for three main reasons, described in Section 6.1:

- They can provide new freedoms to drivers (Keen and Mackintosh 2001) – they can be a truly value-adding service.
- They are a challenging service to design effectively, since they operate within a highly dynamic, information rich and safety critical environment.
- They are consistent with the principles/guidelines proposed by Bellotti and Edwards (2001) and Brown and Randell (2004) for incorporating context successfully within system design.

Having selected an application domain, the first step was to understand the phenomena, both in terms of the basic human behaviour involved, but also the human interaction with services designed to support this behaviour. This was undertaken with a review of existing research findings (Chapter 6).

Following this literature review (which helped establish content validity), an exploratory study (Chapter 7) was needed to understand the human behaviour of interest (driver navigation) within the limits of the assumptions made about use of a service. However, since there was literature to help define this study and validate findings, and specific constructs that are of interest (adding value), a non-experimental fixed design (Robson 2002) was appropriate. This approach does not experimentally manipulate variables or test hypothesis. However, it can control variables in order to promote the generalisability of the study, and can determine the *type* of data generated, without making assumptions regarding *what* this data is. To feed directly into potential service design, this experimental trial took the form of a requirements study, where participants generated data, defined only by the constraints specifically imposed. It therefore offered greater discoverability than a survey or 'true' experiment and more control and generalisability than a case study (Gable 1994).

The study above, plus the preceding literature review enabled the development of a proposal for how navigation systems may be improved. However, there was a lack of understanding of how the context of human behaviour influenced the value that might be provided by enhanced design of a service. It also lacked ecological validity, due to its lab-based nature. The study in Chapter 8 therefore set out to investigate the impact of context on driver performance and the potential to add value with a navigation system. It was felt that previous literature had failed to adequately describe context such that independent variables could be identified that would have high predictive power for added value. There was however greater confidence in the validity of the measures needed to assess value-add. For this reason, a single group, repeated measures design was used, where the repeated measures aspect was chosen to represent a range of situated contexts, and the impacts on the driver measured. This had the advantages of being highly ecologically valid due to its situated nature, and enabling exploration of a construct (context) that was not well defined. However the disadvantages were that it was not possible to rigorously *test* the impact of contextual constructs on value-add, merely generate potential causal explanations that link aspects of manoeuvre context and resulting value-add.

The final study used the findings from Chapter 7 in terms of potential enhancements, and by making assumptions regarding where added value may be provided (explored within Chapter 8), set out to test the design proposals. This final study did not set out to discover new facts or generate insights – it set out to test whether previously discovered facts or insights are correct within a given set of constraints. This final study was therefore an experimental study in the typical deductive sense, as shown in Table 3.3, and described as a 'true experiment' by Robson (2002). This experimental approach randomly allocated participants to experimental groups, controlled confounding variables, manipulated independent variables, and determined causal relationships between independent and dependent variables. This approach generated robust, generalisable conclusions. Since the manipulation of the independent variables, and the nature of the dependent variables, had been proposed, the main weakness of experimentation – the poor discoverability (inability to discover new insights) – was of less relevance than at earlier stages.

Research question 5:

What general recommendations can be made for mobile location services research and design?

The literature reviews and empirical studies undertaken in this thesis led to a number of recommendations for the design of successful MLS. This research question required moving away from a particular instantiation of MLS (driver navigation), and considering the insights gained in relation to MLS more widely. This is described in Section 10.7.

3.5 The challenges of doing 'mobile' computing research

So far this chapter has discussed research methodologies without specific reference to the 'mobile' aspect. This short section highlights some of the main methodological issues to do with mobile computing research.

Kjeldskov and Graham (2003a) highlight three main failings with much of the user-centred research into mobile computing:

- A lack of research to understand what is actually useful to individuals, and a predominance of evaluation focused on functionality and standard usability, rather than usefulness within a user context (i.e. value-add).
- Lack of consideration of context, treating mobile computer systems as generically applicable solutions that can be designed and tested within the laboratory using a 'trial and error' approach.
- Insufficient grounding of studies in methodological foundations, and a lack of methodological rigour employed throughout.

They specifically recommend a move away from a 'build and test' mentality, a greater emphasis on understanding mobile users within real contexts, and application and development of appropriate theories. Longoria (2001) similarly identifies 'that there is still a basic lack of understanding about what users want and need in mobile contexts'.

Clarke (2002) discuses e-business in general, but many of his points are highly relevant to research with mobile computing systems. He highlights the crucial aspect of e-business as its 'reach and borderlessness', and therefore a range of 'significant additional confounding variables'. Exactly the same can be said of mobile computing research. The over-riding message of Clarke (2002) is that the foremost requirement is to ensure the relevance of research, and then work within the constraints of rigour, not the other way round. Two particular criticisms he makes are that convenient reference theories are often used unquestioningly, and that great statistical emphasis is placed on survey results, without consideration of the validity or reliability of the data obtained. To some extent these observations are directly opposite to the criticism of the *build and test* approach by Kjeldskov and Graham (2003a). Although a gross generality, many mobile studies emanating from the MIS literature are consistent with the criticisms of Clarke (2002) - i.e. convenience reference theories, emphasis on statistical analysis, and lack of relevance - whilst many within HCI have a lack of reference theories and little methodological rigour.

Elaluf-Calderwood et al. (2005) present some practical difficulties in undertaking mobile research. They describe the difficulties in following the mobile device, following the user, and following the mobile space. They recommend: a multidisciplinary and multi-method approach; early emphasis on context of use; consideration of contextual variables investigated and/or controlled for when possible; and data collection methods used that allow a following of the contextual space or user.

In particular, the highly contextual nature of mobile computing (Section 2.6.3) presents some particular challenges for 'good' research:

- extracting aspects of context which are critical to understanding the use of mobile technologies
- controlling for context so that experimental effects due to independent variables can be measured
- ensuring that relevance of research is maintained, and that results can be generalised and applied to real work or life situations

By reference to Figure 3.1 (Robson 2002), it can be seen that there are some challenges associated with both developing research questions (*purpose* and *theory*) and the means of investigating research questions (i.e. *methods* and *sampling strategies*):

- A lack of useful *purpose* (i.e. relevance of the research).
- Lack of reference *theories*, inappropriate use of reference theories, and lack of interest in developing theory.
- Lack of *methodological* rigour (which may in part be due to underdevelopment of mobile methods)
- Issues with *sampling strategies*, e.g. difficulties in data mobile collection.

3.6 Conclusion

This chapter has outlined a range of different methodological approaches, and appropriate methods were identified for tackling each of the research questions within this thesis. The specific limitations and challenges associated with mobile computing research do not alter the basic requirements for research, nor the applicability of many traditional user centred design methodologies (Longoria 2001). Consistent with the views of Dourish (2001b), that all interaction is influenced by the setting within which it occurs, an emphasis was placed on situated research. A key feature of the studies undertaken in this thesis was multiplicity as follows:

- Literature from multiple disciplines was used to guide the research
- Multiple studies were undertaken within the thesis
- A combination of *discovery* and *verification* were used
- Qualitative and quantitative data collection were employed
- Multiple methods were used, including *survey* and *experimentation*
- Different forms of experimentation were employed, enabling both discovery and verification
- Where appropriate, studies collected data on multiple constructs, using a variety of different instruments

In addition, there were several methodological trends apparent throughout the thesis. In general terms, these are as follows:

Theme	Trend with thesis
Approach	An inductive (developing understanding) to a deductive (testing) approach
Data collection	Trend from qualitative to quantitative data collection (with the exception of the initial 'discovery of facts' via a survey)
Generalisability	The generic (i.e. mobile users of services) to the specific (drivers as navigators), followed by further generalisation

Figure 3.3 The trends occurring within the thesis

4 A SURVEY OF 'YOUNG SOCIAL' AND 'PROFESSIONAL' USERS OF LOCATION-BASED SERVICES IN THE UK

	Research questions addressed in this chapter:
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	**How are mobile location services fairing in the current consumer marketplace?**
3	What is user 'value' in the context of mobile location services?
4	How can a specific mobile location service (driver navigation) be enhanced using a value perspective?
5	What general recommendations can be made for mobile location services research and design?

4.1 Introduction

Mobile phones are continuing to offer increasing functionality to the user. The differentiation between phones and other portable personal devices is now relatively blurred, with mobile phones available with touchscreens, stylus character entry, handwriting recognition, qwerty keyboards, music players, radios, TV receivers and quality digital cameras. The emergence of 'smartphones' (together with a wide range of software that can be installed on devices) has resulted in top end phones being truly portable mobile and personal computing devices. The convergence of devices within a 'phone' continues with the emergence of increased connectivity (Bluetooth, WIFI and 3G), and increased locating capability through miniaturised GPS circuitry, and new developments such as Assisted GPS which can be built into handsets.

Although mobile location services (MLS) were portrayed as offering great potential (Mountain and Raper 2001), it is widely accepted that they have failed to live up to their initial hype (Schiller and Voisard 2004). Mobile location services, along with many other advanced features, have failed to become mass market products. This is despite the attempts by the mobile phone network operators to market these services in order to increase the revenues derived from non-voice services. It is now suggested that MLS are due for a comeback (Fasol 2004; Fearon 2004; Schiller and Voisard 2004). The literature on technology adoption, e.g. Rogers (2003), describes the need to understand the characteristics and behaviour of early adopter groups as an indication of the rate of uptake of innovations, including new technology. However, there is a lack of published data on the levels of awareness and use of different MLS. The study reported in this chapter was a survey, used to understand the characteristics of potential early adopters of MLS, including their use of ICT in general, their levels of awareness and/or use of a range of MLS, and their general attitudes to these services. This 'snapshot' of behaviour and attitudes was used to set the context for the thesis, and ensure both research and commercial relevance for the empirical work that follows in this thesis – the *meaningfulness* of survey research articulated by Lucas (1991), and the *relevance* described by Clarke (2002).

4.2 Aims and objectives

The overall aim of this study was to understand current early adopter consumer behaviour and attitudes in relation to existing and emerging mobile services, and particularly MLS. The specific study objectives were to determine:

- The typical demographic characteristics of three demographic groups who are typically early adopters, including living and working arrangements
- The typical travel that these groups undertake for work and leisure purposes
- The extent of mobile phone ownership, and use of other new technology
- Their use of mobile and static ICT and their overall attitudes to new technology
- Their level of awareness and/or use of a range of current and emerging MLS delivered over a mobile phone.
- Their overall attitudes to these services, and the implications for future service design.

The survey was specifically intended to be a 'snapshot' of consumers, rather than leading to theory development. Prior to the study, there was an expectation of high levels of mobile phone ownership, but no preconceptions regarding the levels of awareness or use of MLS.

4.3 Study rationale

4.3.1 Choice of methodology

Since the aims of this study were to determine broad patterns of relevant consumer behaviour and overall attitudes to services, a survey approach via a web-based questionnaire was used. This questionnaire was specifically designed to be a cross-sectional 'snapshot' of consumer behaviour and attitudes, and did not seek to develop or test any behavioural or attitudinal models. The survey was therefore of a 'descriptive' form (Robson 2002) with the imposition of a cross-sectional design (Oppenheim 1992) and there was no attempt to establish causal relationships between variables based on construct and item development (Newsted et al. 1997), as employed when developing or testing theory with survey data.

4.4 Method

4.4.1 Overview

This study comprised a web-based questionnaire that was targeted and analysed according to three demographic groups that are typically early adopters of mobile technology (Lindgren et al. 2002): a 'young social' and an 'older professional' group, the latter being split according to whether or not they had children. Data were analysed to give a snapshot of the typical demographics of these groups, their travelling behaviour, their use of static and mobile ICT, and their awareness/use of, and attitudes to a range of MLS that can be delivered over a mobile phone. The results are interpreted in terms of the potential for future provision of MLS over a mobile phone.

4.4.2 Target respondents

Telecom network operators segment customers in order to understand, target, develop and market services for relatively homogeneous user groups. A typical categorisation is as follows (note this is based in part on information supplied by a personal contact working in the telecoms industry who asked that this was not attributed to either him or his company). In addition, there are not necessarily clear distinctions between groups, as apparent from Table 4.1.

Group	Typical characteristics
Teenagers	Up to 18 years old, still at school, highly social, budget constrained, want fun, entertaining products, low ARPU value
Young social	Aged 18 – 30, students or young professionals, similar to above, but less budget-constrained
Older professionals	Employed, motivated to use time effectively and be productive, impacted by presence of dependent children
Company phone users	People given a company phone, need to be contactable, typically middle manager type, embrace new technology
Self employed	Self-employed business users - pay their own bill, need it for work, keep phone on all the time, use functional products, not interested in new technology per se.
Heavy business users	Travel extensively including abroad, keep phone on / in contact all the time, extremely high ARPU value
Older users	Typically aged 50+, want to be contactable, occasional use, low ARPU

Table 4.1 Typical customer segmentation

Consistent with the above categorisations, this study targeted key demographic groups that are typically early adopters (Lindgren et al. 2002). Two groups are consistent with the 'young social' and 'older professional' groups above:

'MOKLOFs' (mobile kids with lots of friends) are defined as:

> 'teenagers and young people up to the age of 30, constantly on the move and with extensive networks. They want to use their mobiles to keep in touch with friends, arrange meetings, chat, play games, listen to music, use picture telephony, send images, and so on'.

A 'YUPPLOT' (young urban professional parent with lack of time) is defined as:

> 'a professional, urban, well-educated parent of good income aged between 30 and 50. A typical YUPPLOT is a highly mobile individual, with his or her own laptop, mobile phone and possibly also PDA. His or her primary goal in life is to gain time, increase personal productivity, keep up-to-date and use time effectively.'

It is important to note that these groups are sub-groups of the age-defined population segments. 'MOKLOFs' and 'YUPPLOTs' respectively make up about 60% of the 16-30, and 40% of the 30 – 50 demographic group in Sweden. It is assumed that the proportions are roughly equivalent in the UK.

Although one key characteristic of a 'YUPPLOT' is that they have children (since this defines some of the competing lifestyle goals, and hence time pressures), this distinction excludes all older well educated professionals who do not have children but are still potentially motivated by the desire to use time effectively and increase personal productivity. Therefore an additional sample group was incorporated into the study to represent the well-educated professional *without* children.

Analysis of data was undertaken based on the definition of three mutually exclusive groups as follows:

1. Aged 18 to 29, with no children, educated to at least 5+ 'O level' standard or equivalent, and currently using a mobile phone and PC and the internet at home or work or study. This group approximates 'MOKLOFs' described above, but excludes younger teenagers as per Table 4.1.
2. Aged 30 to 50, without children, educated to at least 'A' level standard or equivalent, in full-time technical, professional or managerial employment, and currently using a mobile phone and PC and the internet at home or work (or study).
3. As (2) but with children. This group approximates 'YUPPLOTs' described above.

4.4.3 Sampling strategy

The target respondents were described above in Section 4.4.2. A non-probability sampling strategy was employed due to the impracticality of randomly selecting samples of the desired respondents from the general population. Although this limits the potential for statistical inference in relation to the wider population, non-probability samples are 'acceptable when there is no intention or need to make a statistical generalization to any population beyond the sample surveyed' (Robson 2002).

A mixed *convenience* (Robson 2002) and *quota* (Alreck and Settle 1995) sample approach was used. Potential respondents matching the three demographic groups were targeted as follows:

- Students at Loughborough University, via email distribution lists and online noticeboards.
- General staff at Loughborough University, also via email and online noticeboards

- Personal contacts of the above two categories.
- Employees of a large commercial organisation, via a link on the company intranet.
- Colleagues, friends and contacts and *their* friends and colleagues, via email.

The total set of responses received was differentiated and filtered according to the three demographic groups of interest; responses falling outside of these groups were not analysed. An attempt was also made to target respondents from a range of geographical locations, to reduce the bias arising from a predominance of local respondents.

In order to encourage participation, all completed responses were entered into a prize draw for £100. This prize draw was made approximately every 6 weeks, including all new respondents since the previous draw. It is recognised that the non-random nature of the sample employed limits the *external validity* or generalisability of the results; this is discussed in Section 4.7.

4.4.4 Design of the questionnaire

The items in the questionnaire were developed in order to meet the objectives outlined in Section 4.2, and to enable the segregation of respondents according to the 'MOKLOF' and 'YUPPLOT' distinction (Lindgren et al. 2002), including splitting the latter according to whether they had children. Demographic questions and response categories were based on those used by the Office For National Statistics (www.statistics.gov.uk), including occupation classifications (ONS 2000). Other questions were based on experience in developing and administering ICT-related questionnaires, and recommendations for questionnaire design (Oppenheim 1992).

The questionnaire was initially developed as a paper-based survey that was administered face-to-face to approximately 130 students. It was then developed in HTML using Dreamweaver™ as a web-based questionnaire in order to more easily target a larger number of (and more geographically-distributed) respondents. The web version was piloted before being finalised; screenshots are shown in Appendix 4A.

The questionnaire comprised a range of categorical responses based on radio buttons (where only one from a number of different items could be selected), check boxes (where more than one response to a question could be selected), and free text entry via text fields where alphanumerics could be entered. A decision was made not to incorporate field checking for incomplete responses, for the reasons stated in Section 4.7.

The questionnaire comprised the following sections:

- Participant demographics – gender, date of birth, qualifications held, whether in employment or studying, occupational category (if in employment), hours worked.
- Accommodation – living arrangements, location, length of residence.
- Travel behaviour for work and leisure purposes.
- Use of technology – mobile phone ownership, use of other new technology.
- Frequency of use of static and mobile ICT, for week days and the weekend.
- Awareness of different mobile services, as listed in Table 4.2 below.
- Attitudes - to technology in general, and to specific mobile services.
- Willingness to take part in follow-up research.

In addition there were other questions which are not reported in this chapter since they are not relevant to this thesis. These included: the details of mobile phone make(s), model(s), network(s) and contracts; the preferences for local Points of Interest (POIs) by participants; details of the respondent's job title and employer.

'Nearest Services'	'Safety Camera Information'
'Local Weather'	'Public Transport Information'
'City Guides'	'Friend Finder'
'Local Phone Numbers'	'Location-based Games'
'Walking Directions'	'Mobile Booking/paying'
'Driving Directions'	'Location-based Advertising'
'Traffic Information'	'Safety/Security Information'
'Roadside Assistance'	

Table 4.2 The mobile location services described in the questionnaire

4.4.5 Procedure

Where individuals (and groups) were targeted directly, an email was sent to them with a link to the web-based questionnaire. Where details were posted on online notice boards (i.e. individuals were not individually targeted), these also contained a web link.

Upon respondents clicking on a 'submit' button each questionnaire response was received via the university mailer as an emailed text file. These were imported into Excel and then SPSS to enable analysis. Blank entries were discarded, and duplicate responses were determined based on names and/or email addresses and discarded. It was stated that photographic ID was required in order for prize draw winners to claim their prize; this was to dissuade respondents from submitting multiple entries under different names. Entries were also discarded if the responded had only completed the first nine questions, or less.

Data cleaning was undertaken on the free text responses to convert any non-numeric text responses into numerics where appropriate. Typical examples were as follows:

Original entry (based on an expected single numeric value per day)	**Data cleaning operation**
'1x per *week*' (frequency requested per *day*)	Converted to give equivalent value in correct time frame
'3 – 4 times' (range given)	Mean value used based on upper and lower bounds
'None' (unambiguous textual response)	Converted to equivalent numeric value
'At least 3' or '3+' (semi-ambiguous textual response)	Recoded as the number included in response (i.e. '3')
'A lot' (ambiguous textual response)	Recoded as missing data

Table 4.3 Data cleaning operations used for questionnaire responses

Total replies (from October 2004 to July 2005), excluding completely blank returns	N = 1303
Discarded as duplicate responses from the same individual	N = 14
Discarded as incomplete responses (< 9 questions answered)	N = 13
Total valid responses	N = 1276
Total falling into Group 1: 'Young social'	**N = 737**
Total falling into Group 2 : 'Professional without children'	**N = 102**
Total falling into Group 3: 'Professional with children'	**N = 72**
Total valid responses not falling into Groups 1, 2 or 3, and not analysed	N = 365

Table 4.4 Summary of number of responses returned from the questionnaire

Categorical responses were recoded into numeric variables within SPSS (this enabled more reliable selection of data subsets within variables and calculation of additional variables). All analysis within SPSS was undertaking using the syntax facility; the full syntax coding that was developed is shown in Appendix 4B. A summary of data returned is shown above.

4.5 Analysis and results

The presentation of results was based on a three-way distinction between data returned from the survey:

1. The characteristics of the differentiated samples, including all variables used to differentiate the sample groups from the total (N=1276) returns.
2. The factors which described in more detail the demographics and lifestyle factors of the differentiated sample groups (N = 911).
3. The use of static and mobile ICT, and attitudes with respect to mobile services, according to the differentiated groups.

Bar charts plotting frequencies were used to display the nominal (i.e. categorical) data. Where comparisons were being made across different variables, percentage responses in categories were used instead of frequency counts. All response categories were mutually exclusive unless stated otherwise. Numerical data describing mobile or fixed-web information seeking and communication behaviour was non-normally distributed and positively skewed due to a relatively small number of high data values. In these cases, median values were plotted following the recommendations of Alreck and Settle (1995) for dealing with non-normal distributions. Chi-square statistics are given where appropriate to indicate significant differences ($p < 0.05$).

4.5.1 Summary of the differentiated sample

The variables used to differentiate between the three sample groups are shown in Table 4.5:

	Group 1: 'Young social'	Group 2 'Professional without children'	Group 3 'Professional with children'
Age	19 - 29	30 - 50	30 - 50
Children under 18	None	None	At least one
Education	At least 5 'O' levels or equivalent	At least two 'A' levels or equivalent	At least two 'A' levels or equivalent
Work / Study	No distinction	In full time professional, technical or managerial employment	In full time professional, technical or managerial employment
Use of mobile ICT	Uses at least one mobile phone	Uses at least one mobile phone	Uses at least one mobile phone
Use of static ICT	Uses a PC and the Internet at home or work or study	Uses a PC and the Internet at home or work or study	Uses a PC and the Internet at home or work or study
Number in sample	N = 737	N = 102	N = 72

Table 4.5 Characteristics used to differentiate between the sample groups

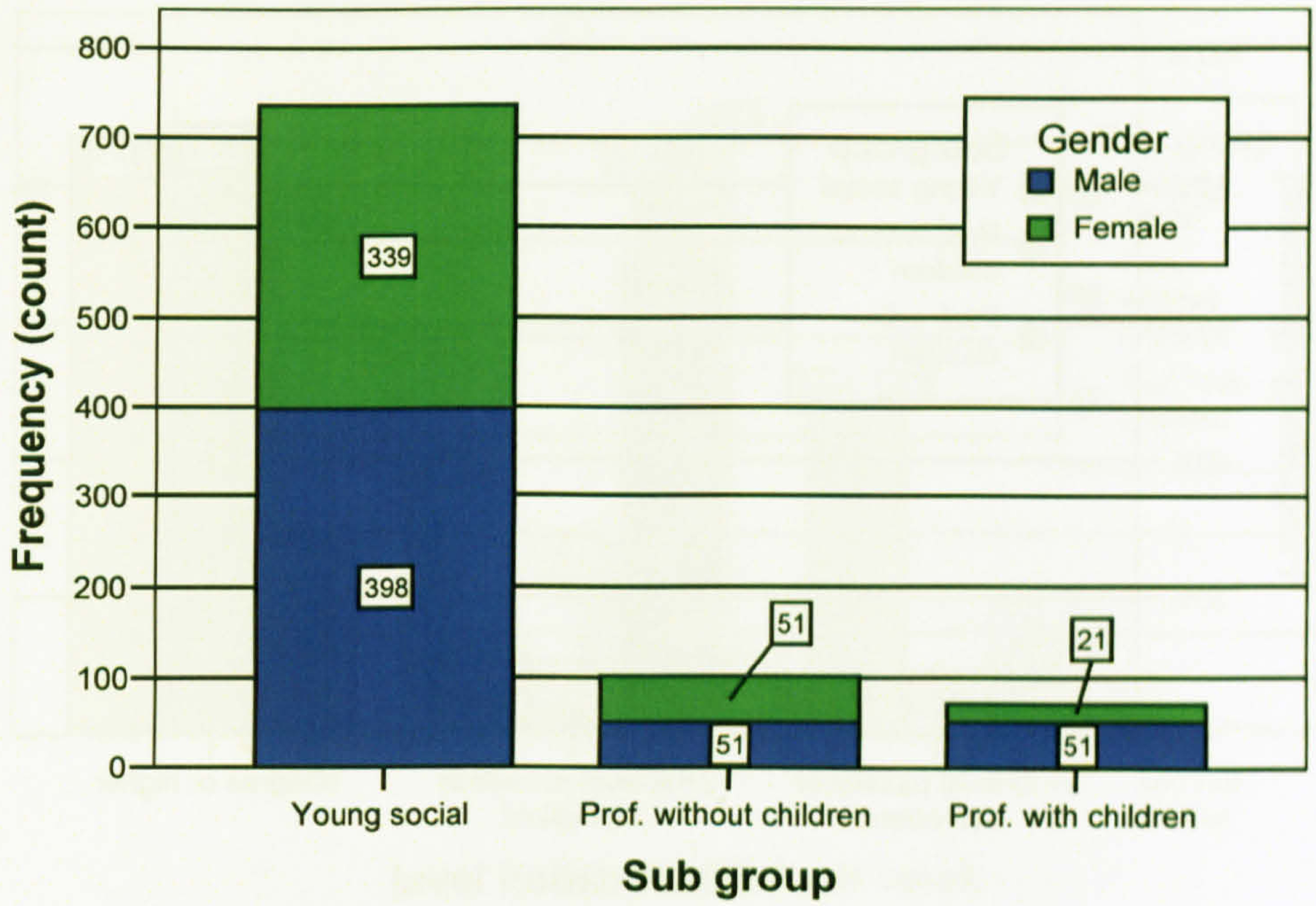


Figure 4.1 Sample frequency count and gender split, by Group (Q1.1)

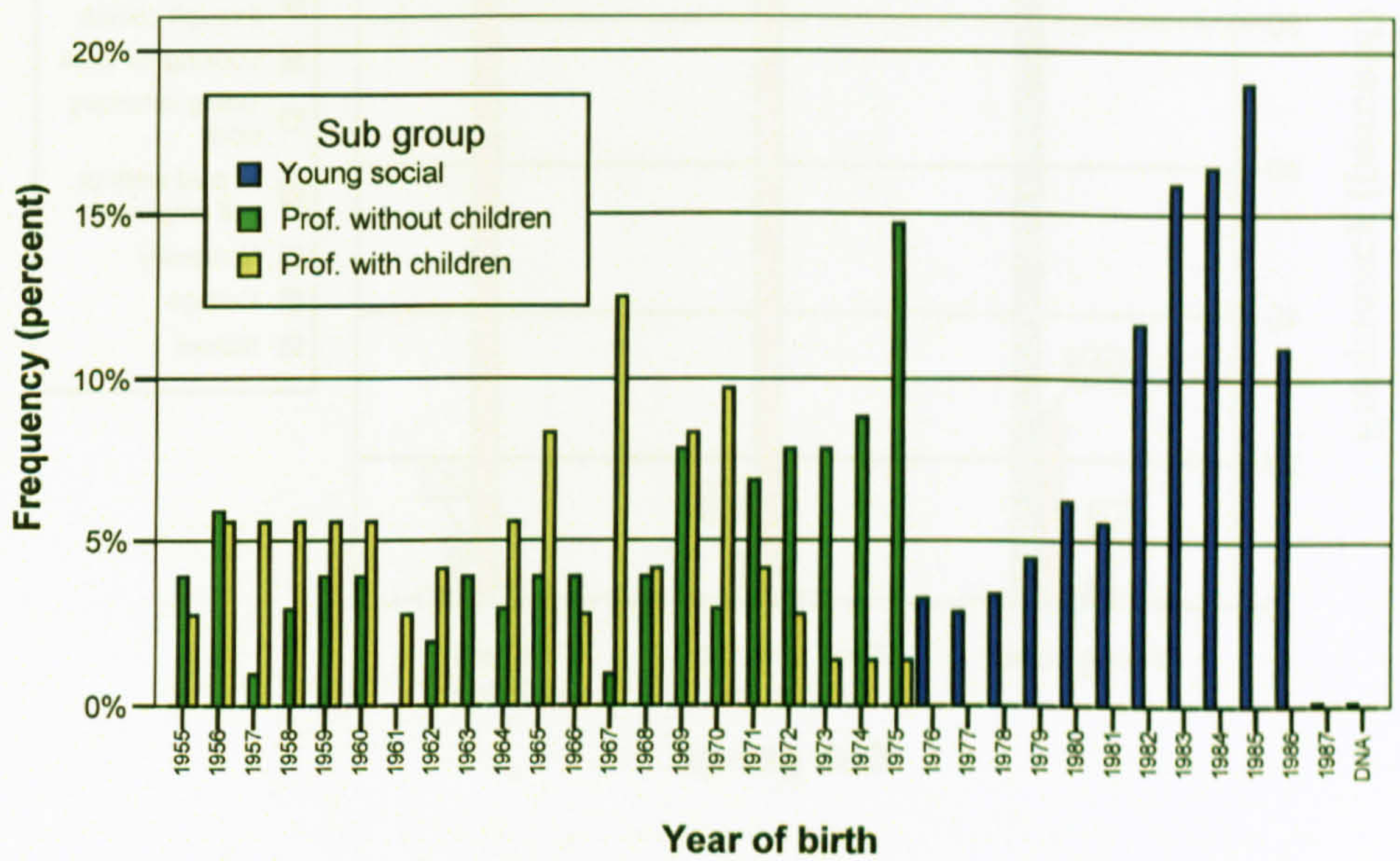


Figure 4.2 Date of birth, by Group (Q1.2)

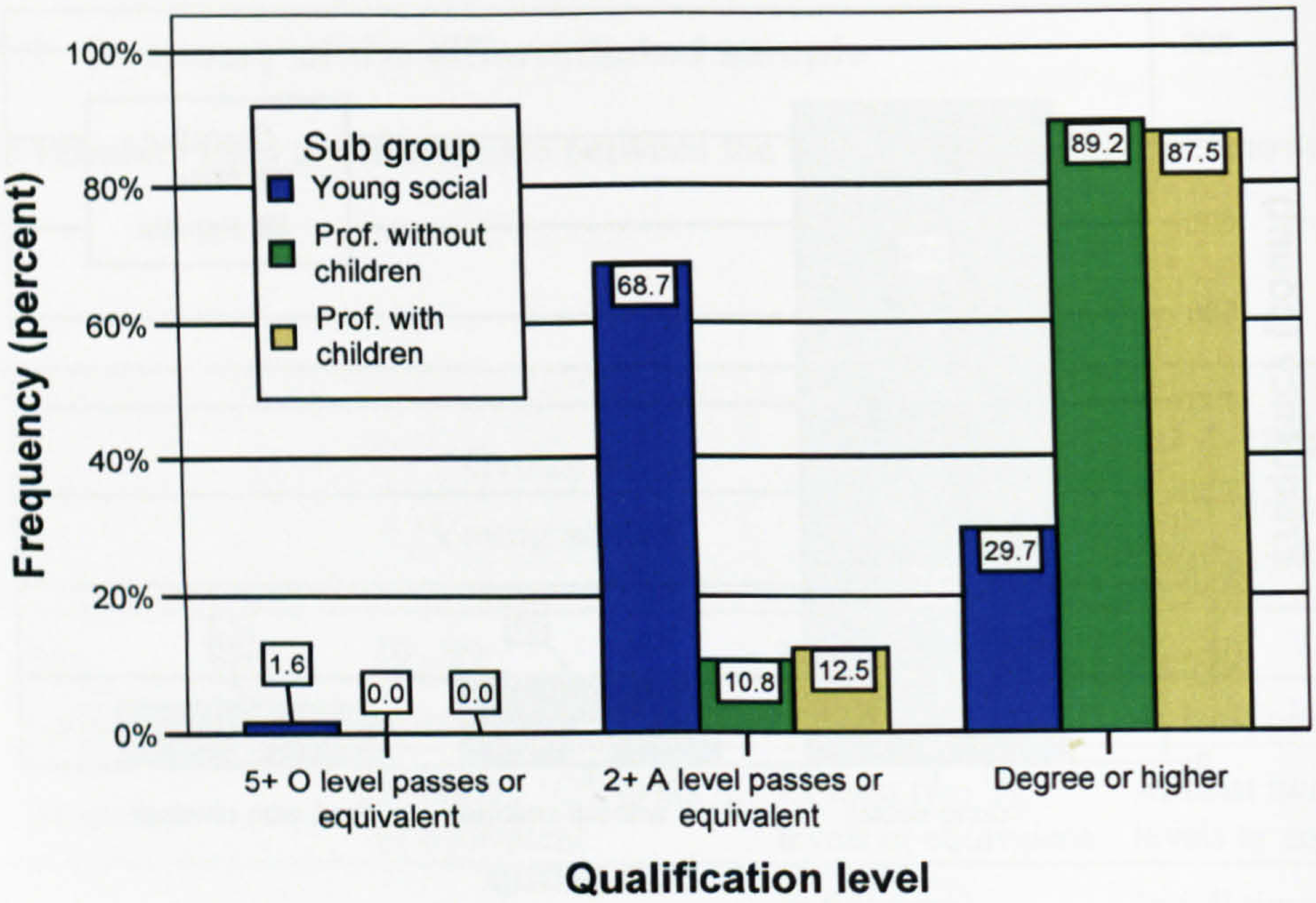


Figure 4.3 Qualification level, by Group (Q6.6)

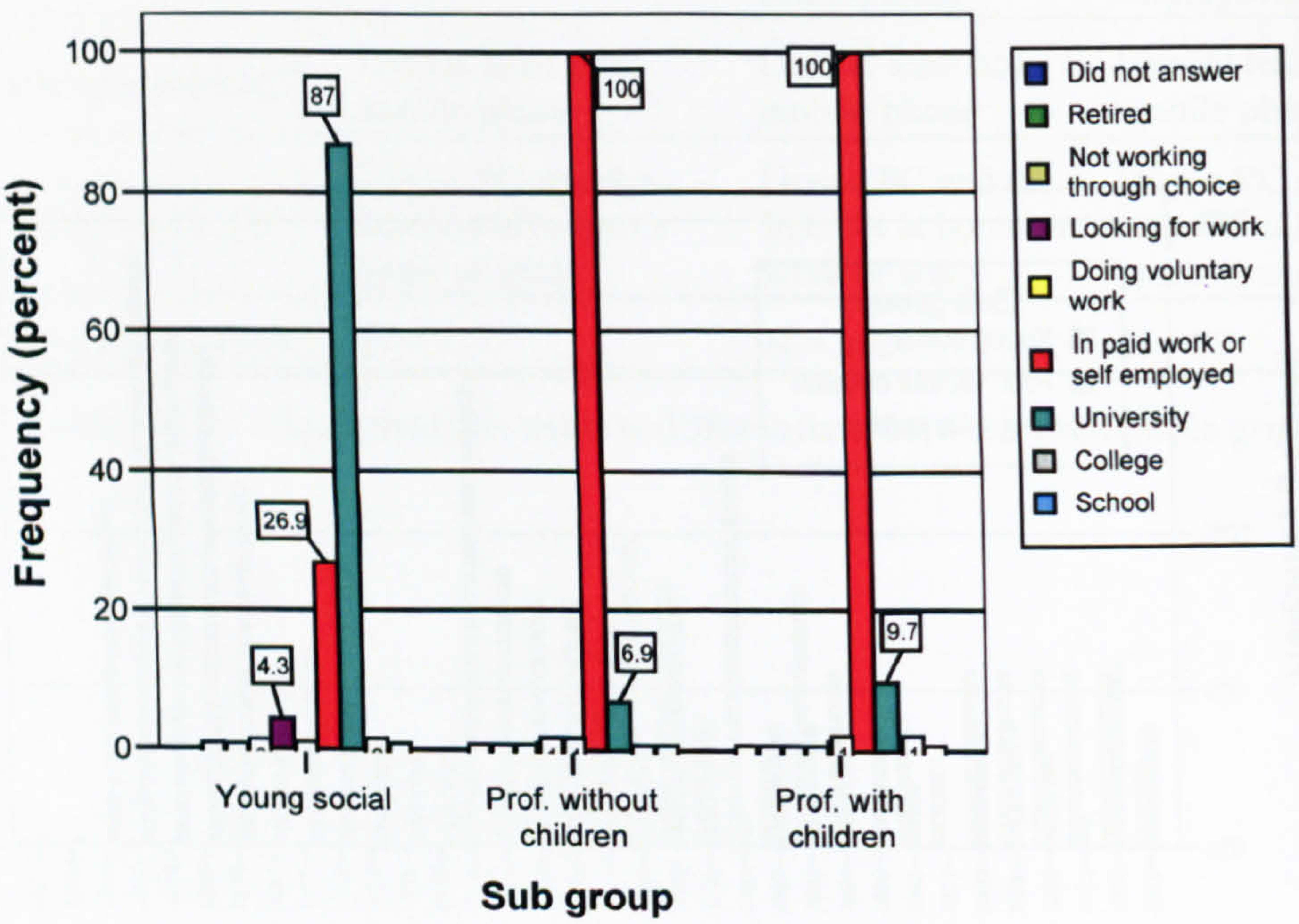


Figure 4.4 Work/study status, by Group (Q7.1)

Note: Respondents could answer in more than one category, e.g. they could be in paid work and also studying.

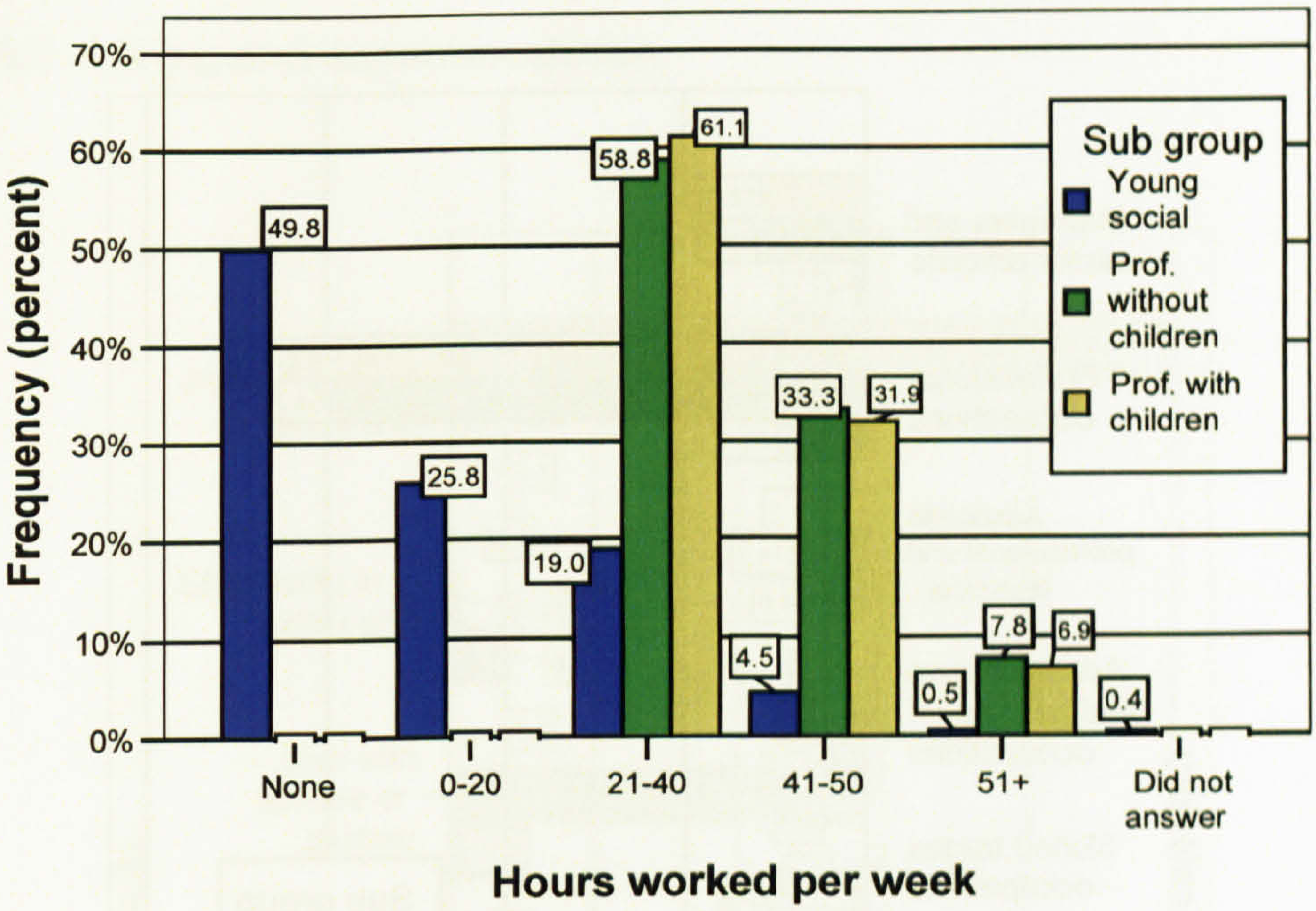


Figure 4.5 Hours worked (employment/study), by Group (Q7.2)

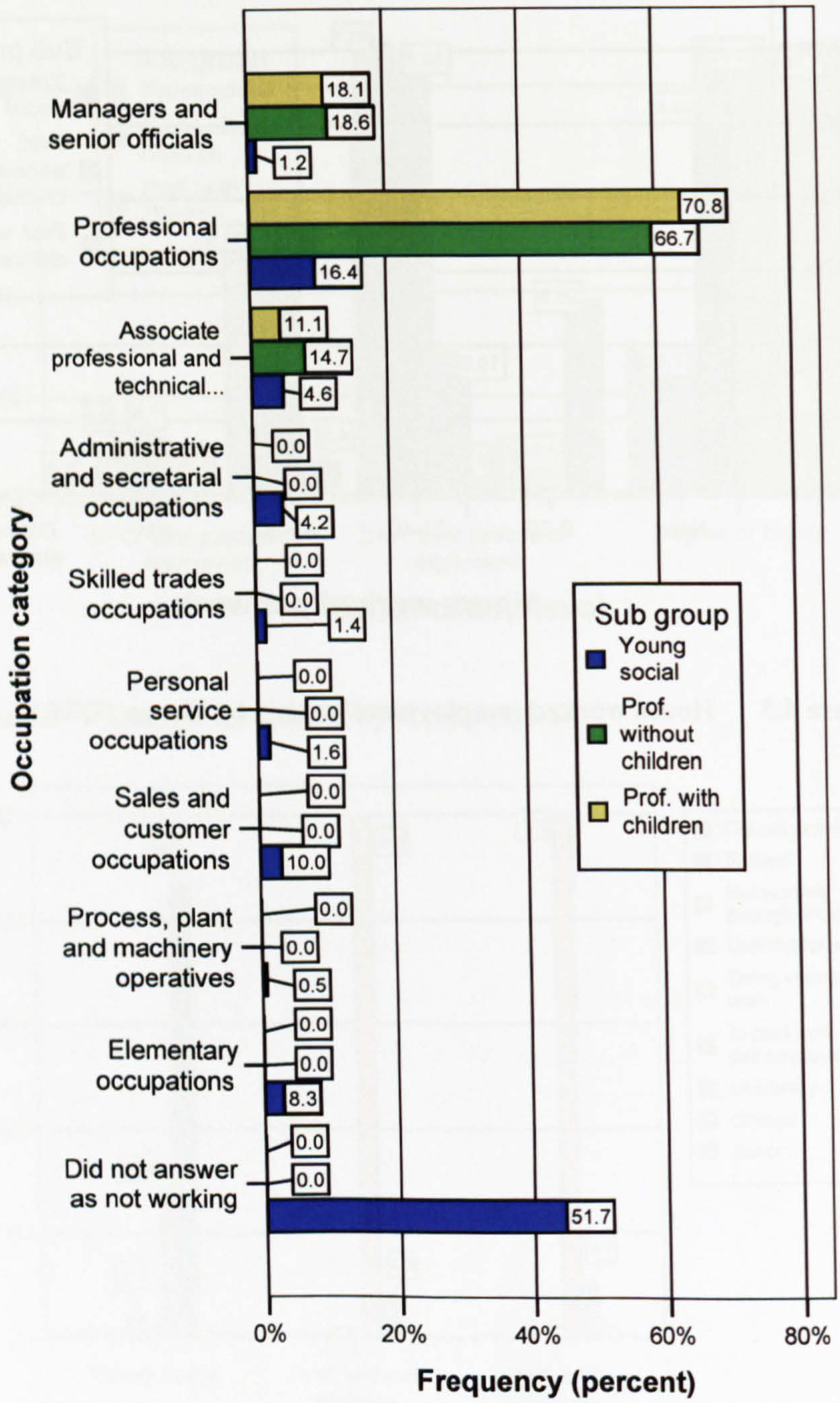


Figure 4.6 Employment category, by Group (Q7.7)

4.5.2 Living and accommodation

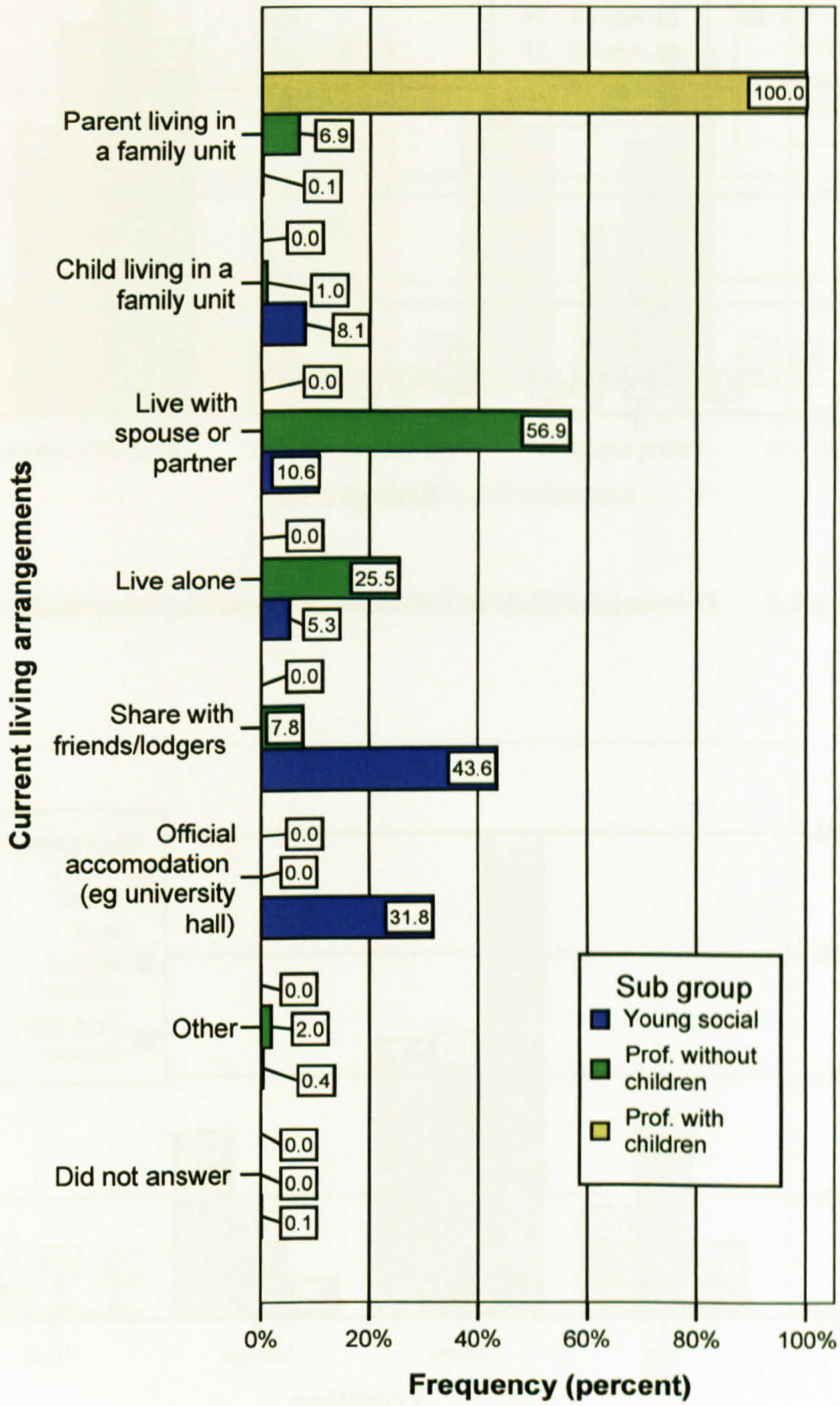


Figure 4.7 The living arrangements of respondents, by Group (Q6.1)

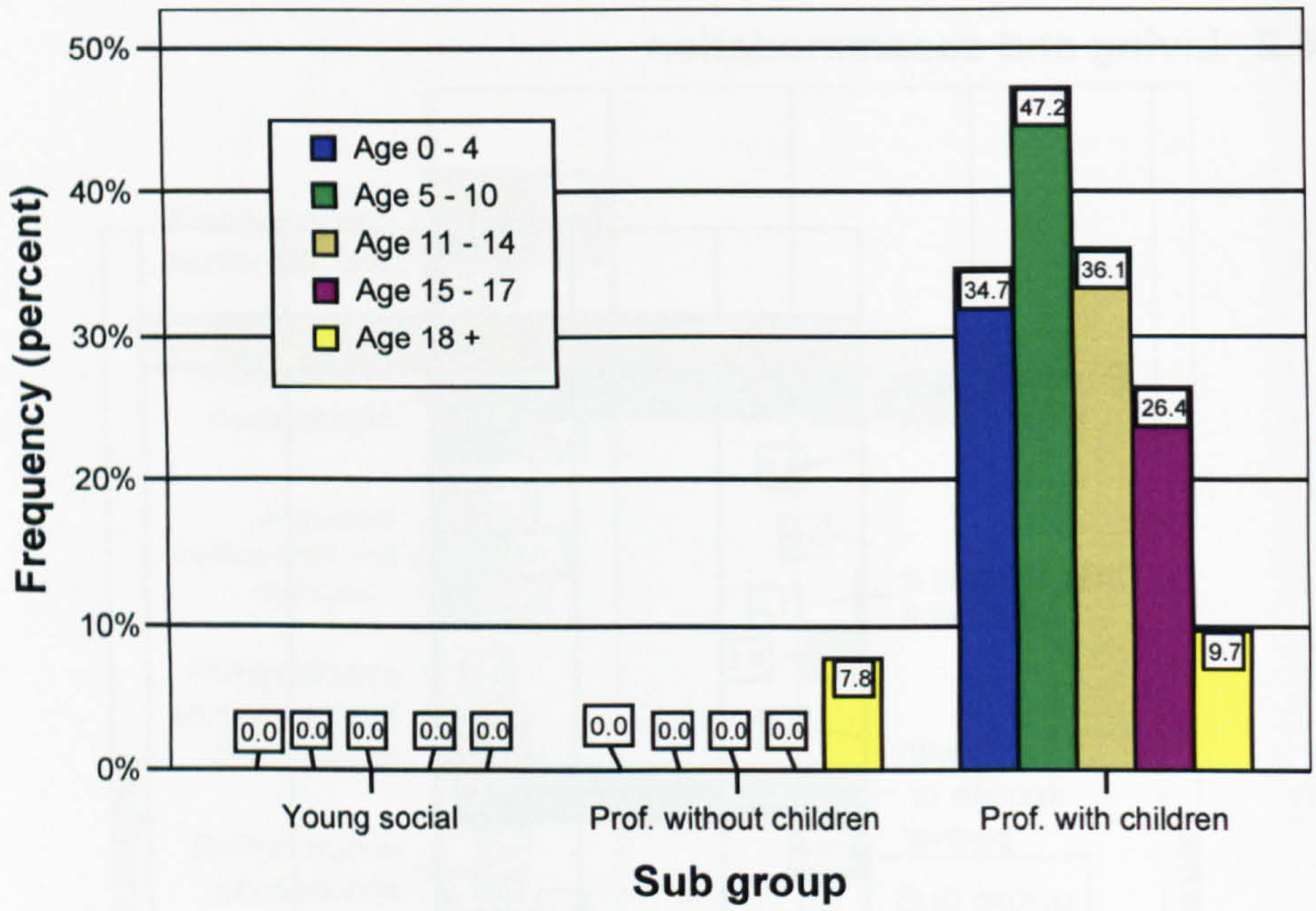


Figure 4.8 Existence of children of different ages, by Group (6.2)

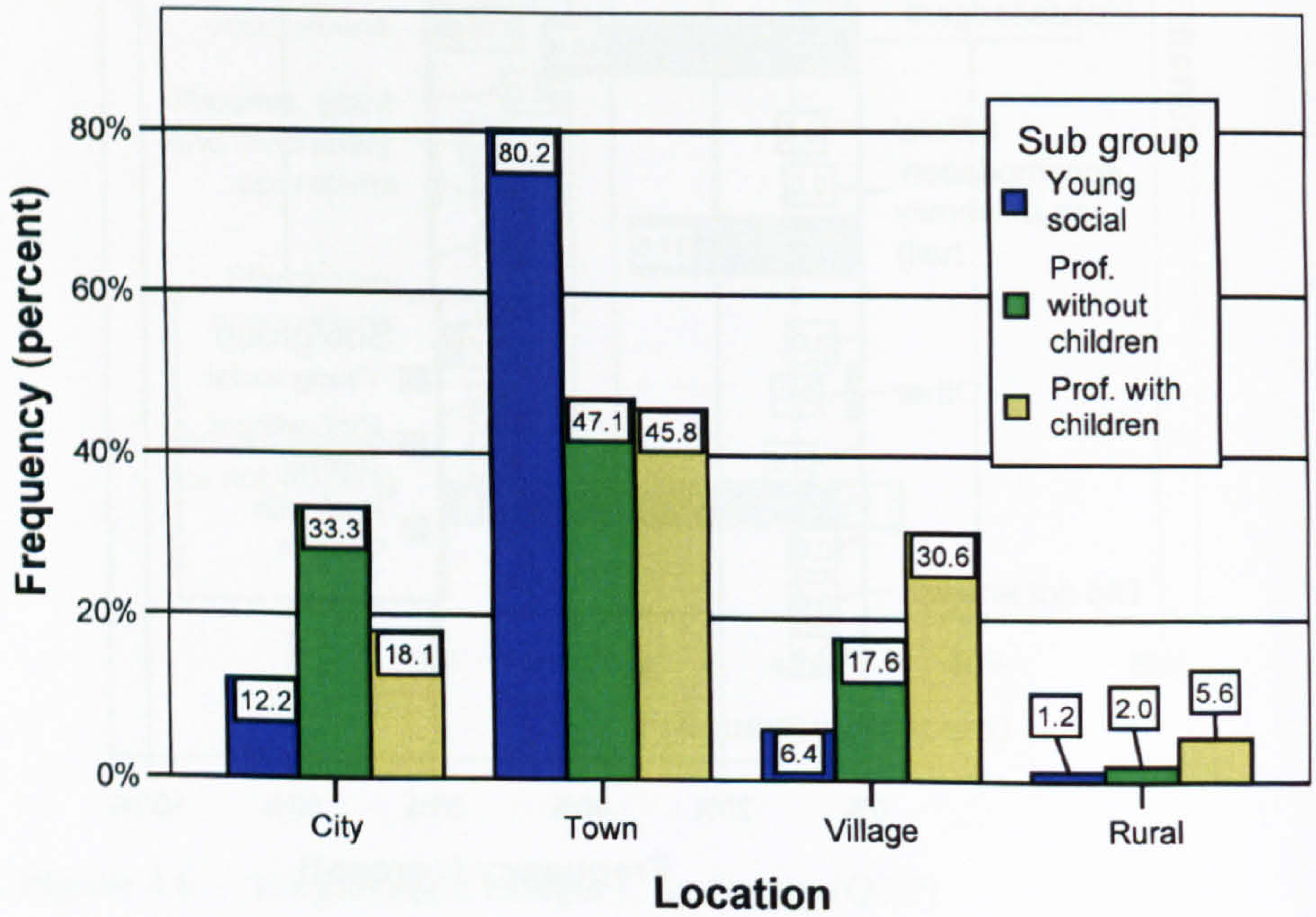


Figure 4.9 Location of respondents, by Group (Q6.3)

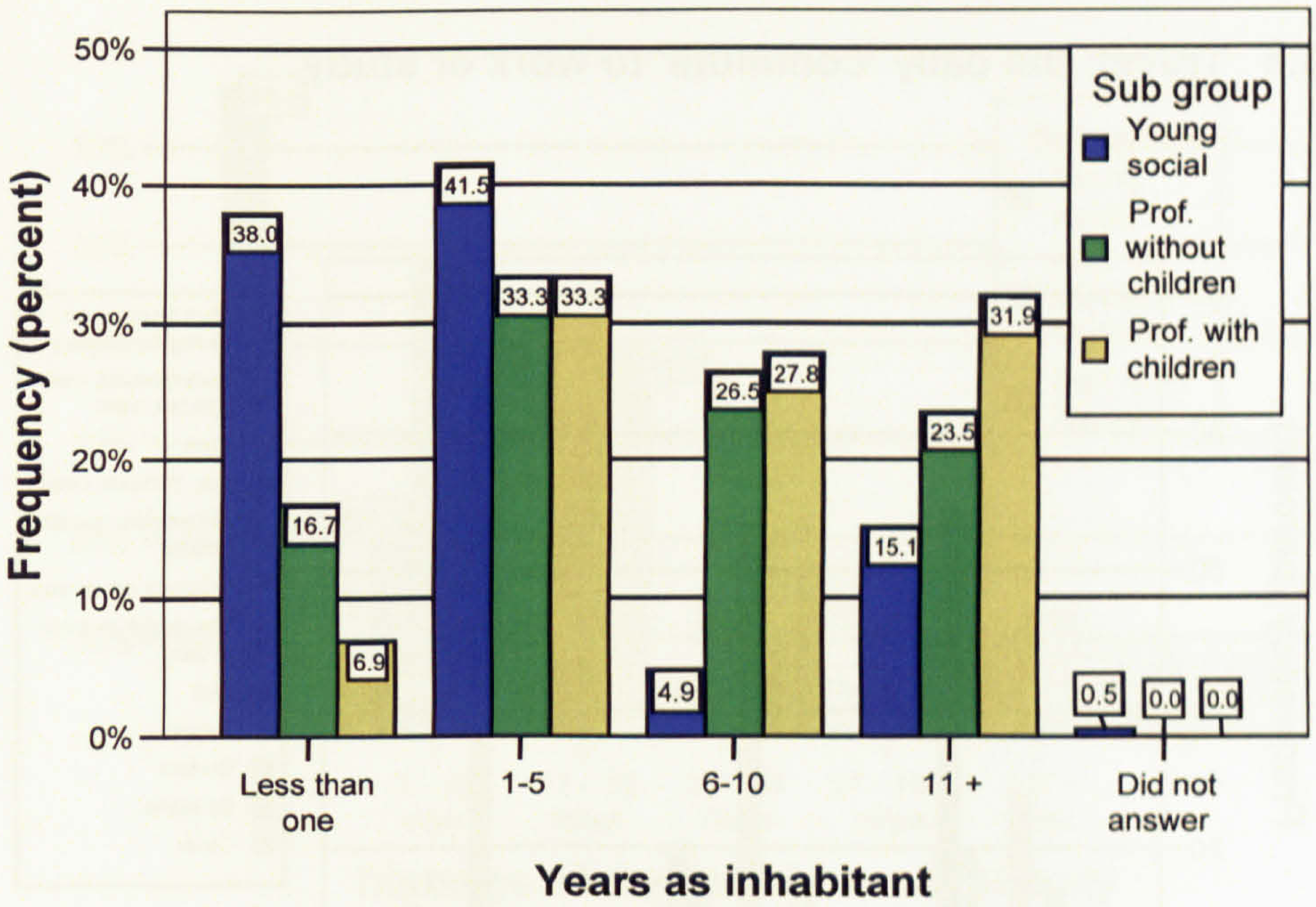


Figure 4.10 Length of residence, by Group (Q6.5)

4.5.3 Travel: the daily 'commute' to work or study

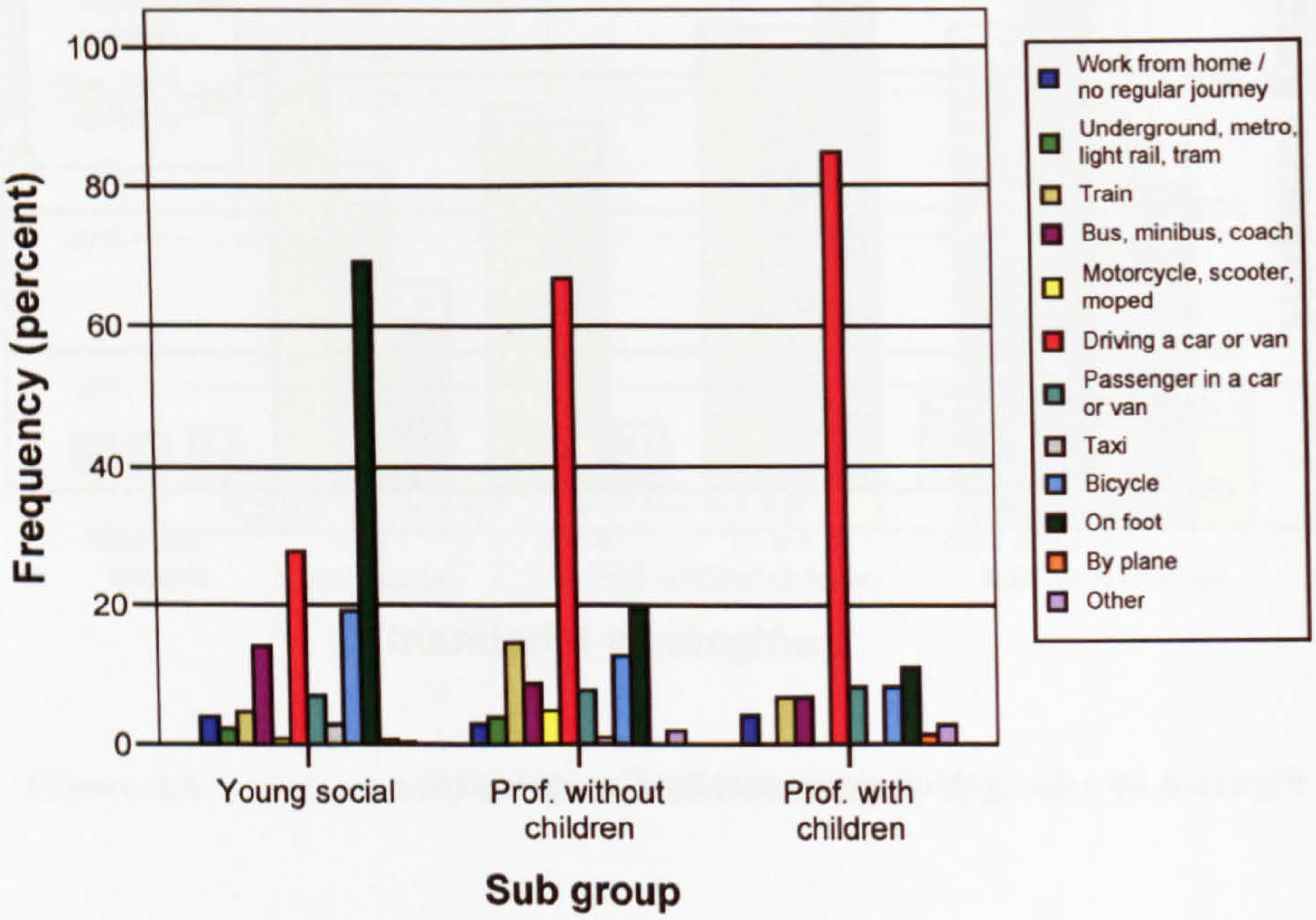


Figure 4.11 Mode(s) of transport used for the regular (i.e. at least once a week) journey *to work or study*, by Group (Q3.1)

Note: respondents could indicate they use more than one mode of transport for their regular 'commute'. The above figure plots usage of transport modes, irrespective of whether they were single journeys or elements within multimodal journeys.

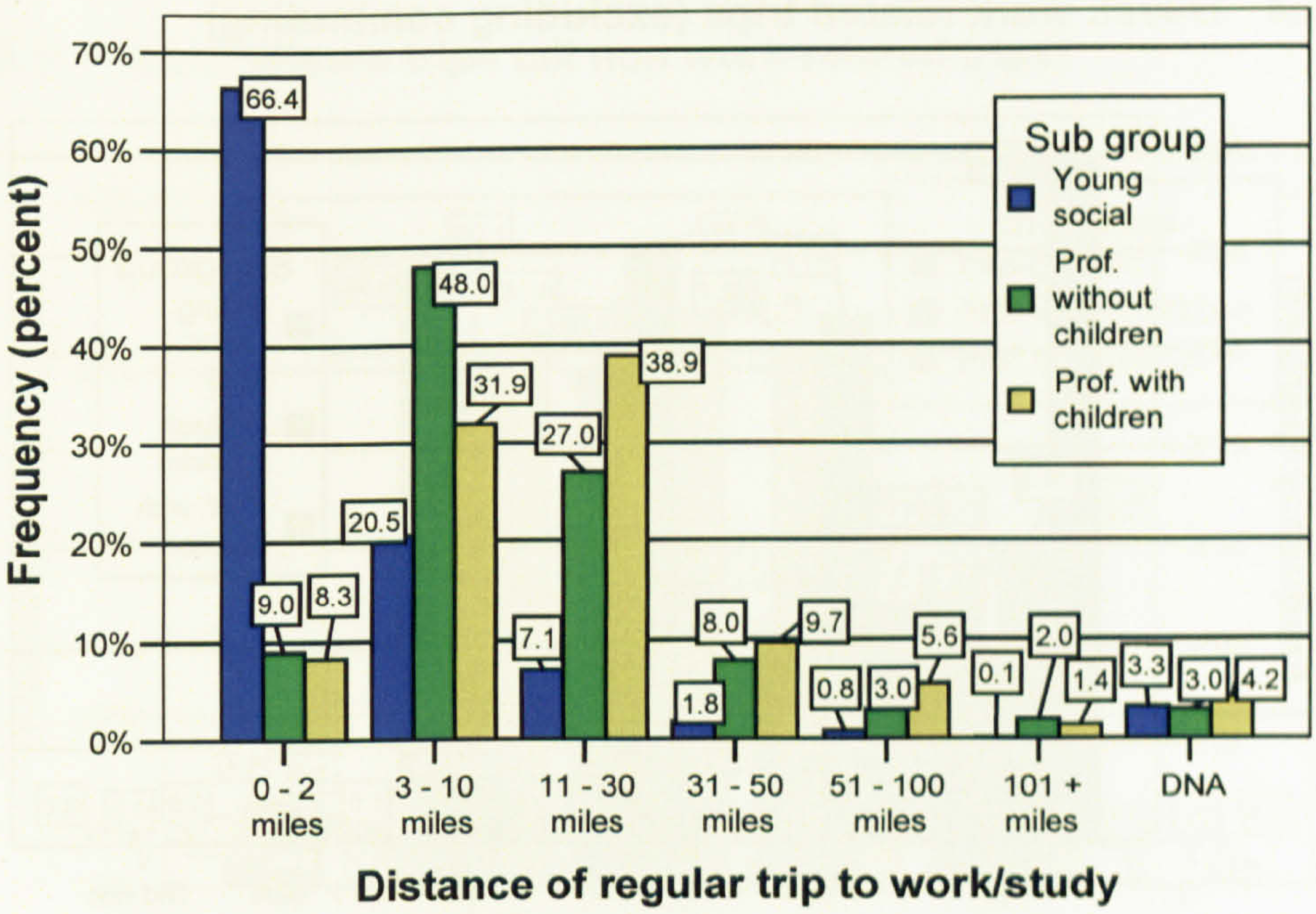


Figure 4.12 Total (one-way) ***distance*** **travelled during the regular journey to work or study (commute), by Group (Q3.2)**

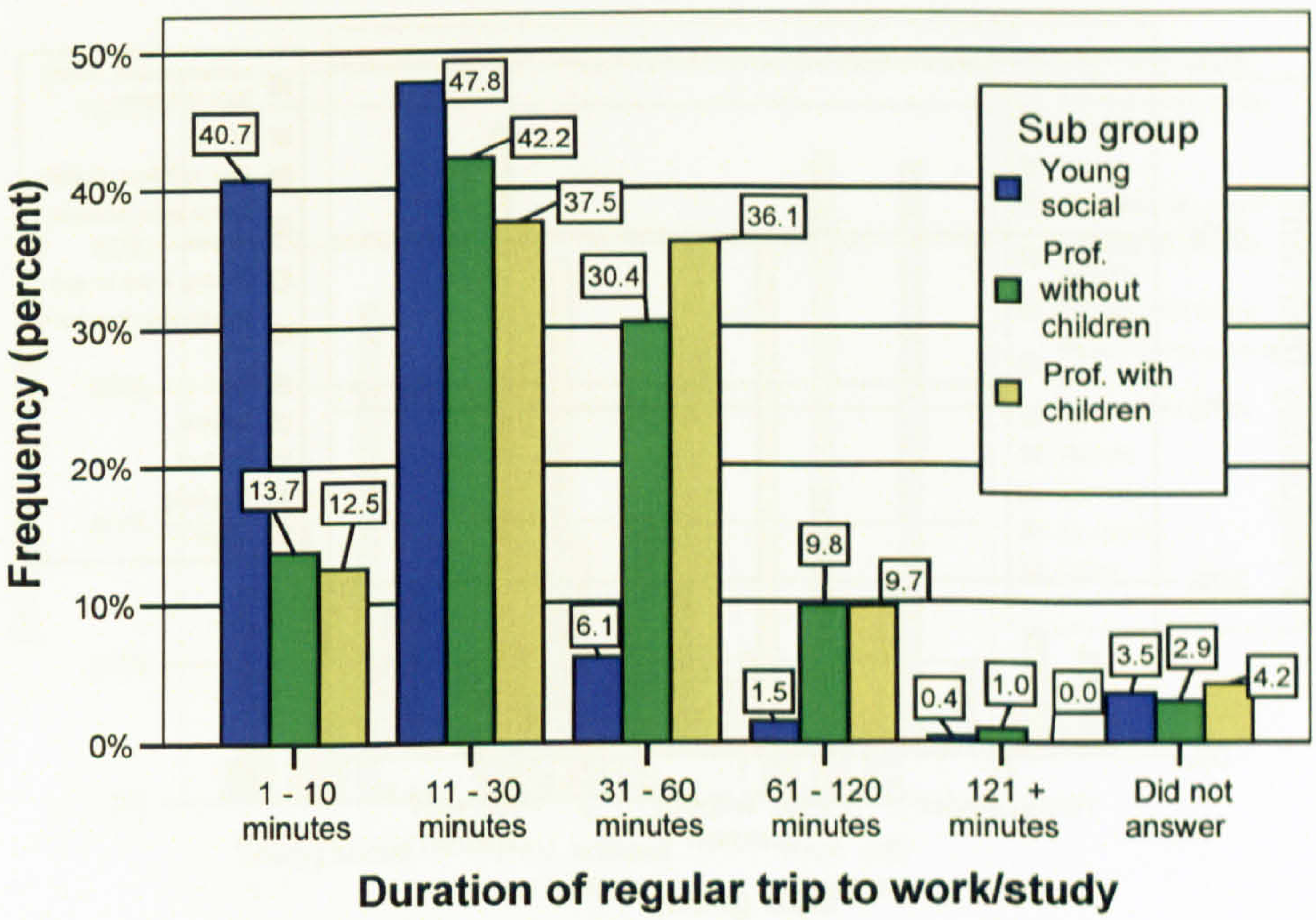


Figure 4.13 Total (one-way) ***time*** **spent travelling during the regular (at least once a week) journey to work or study, by Group (Q3.3)**

4.5.4 Travel: work related trips (excluding commuting)

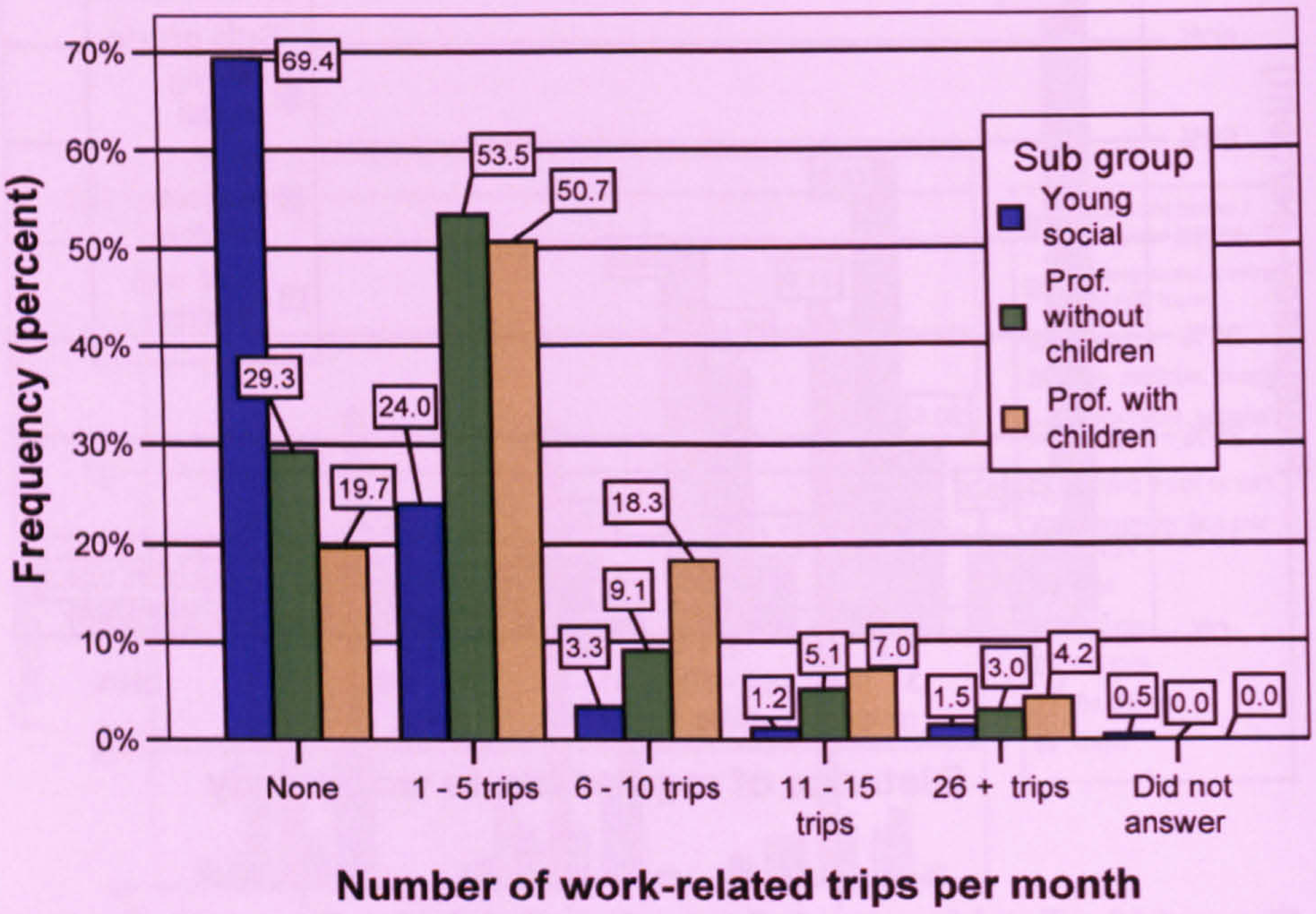


Figure 4.14 Number of work-related trips undertaken *per month* (excluding commuting), by Group (Q3.4)

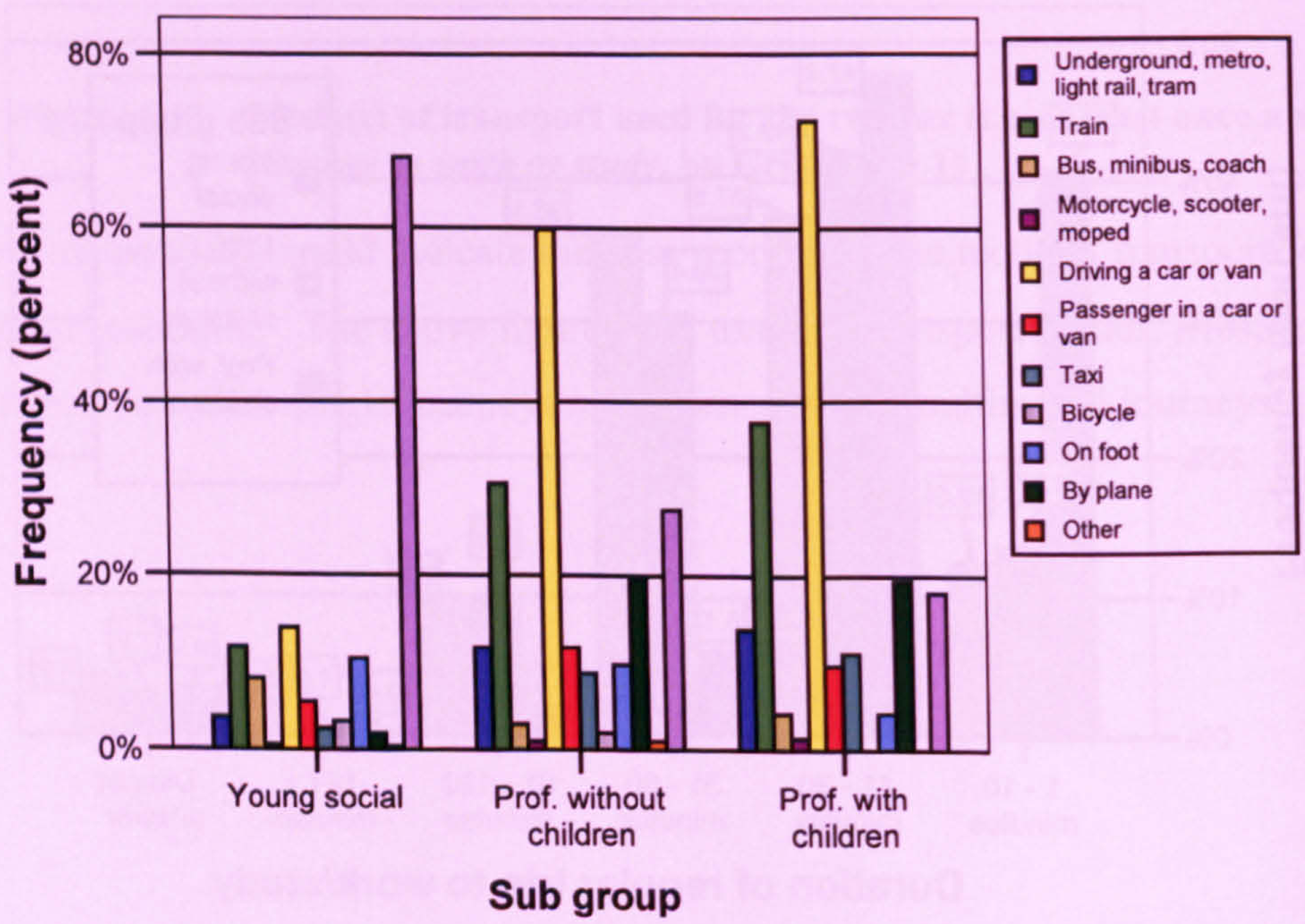


Figure 4.15 Mode(s) of transport used for work-related trips (excluding commuting), by Group (Q3.5)

4.5.5 Travel: leisure trips (all non work-related trips)

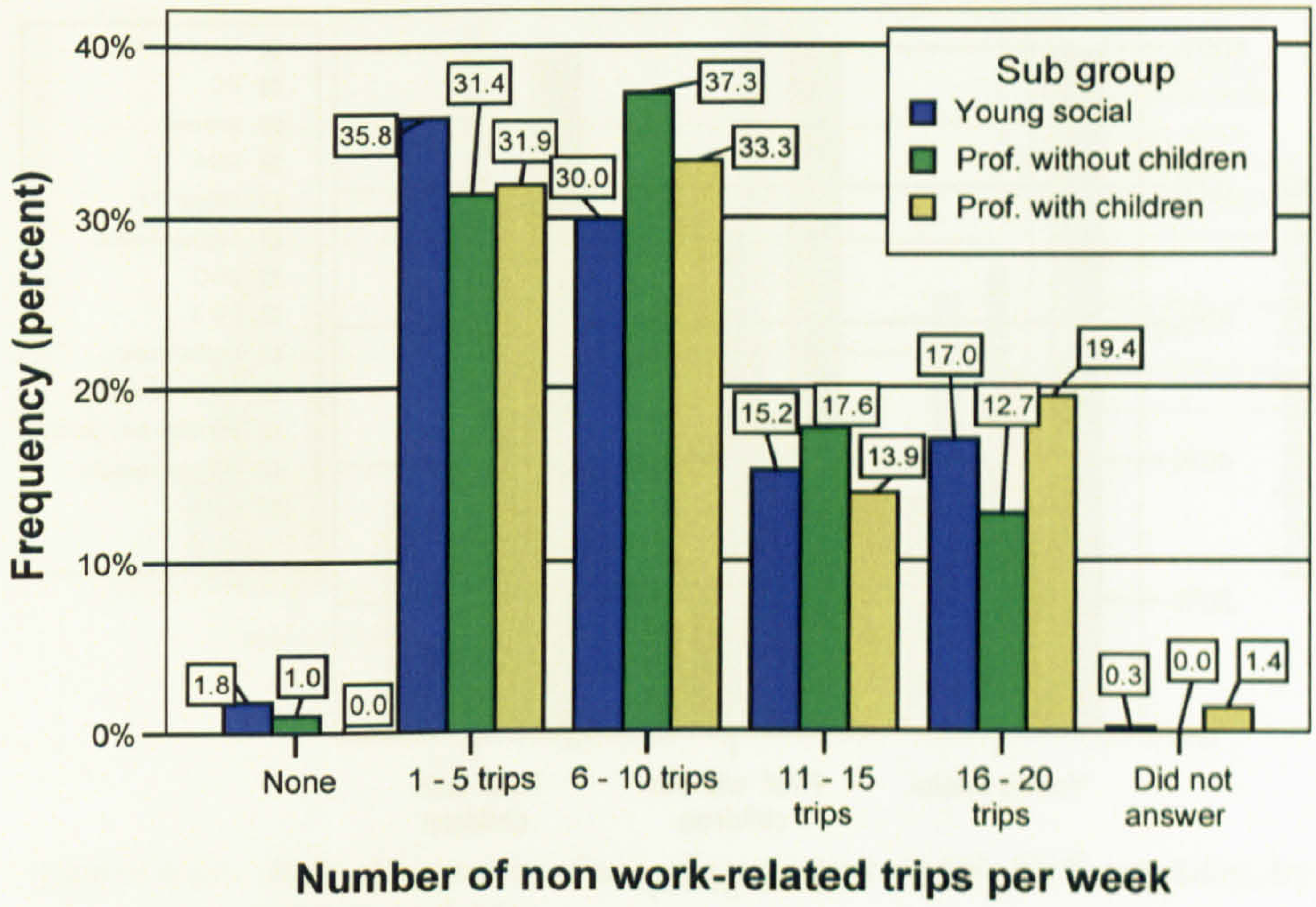


Figure 4.16 Number of non work-related trips undertaken *per week*, by Group (Q3.6)

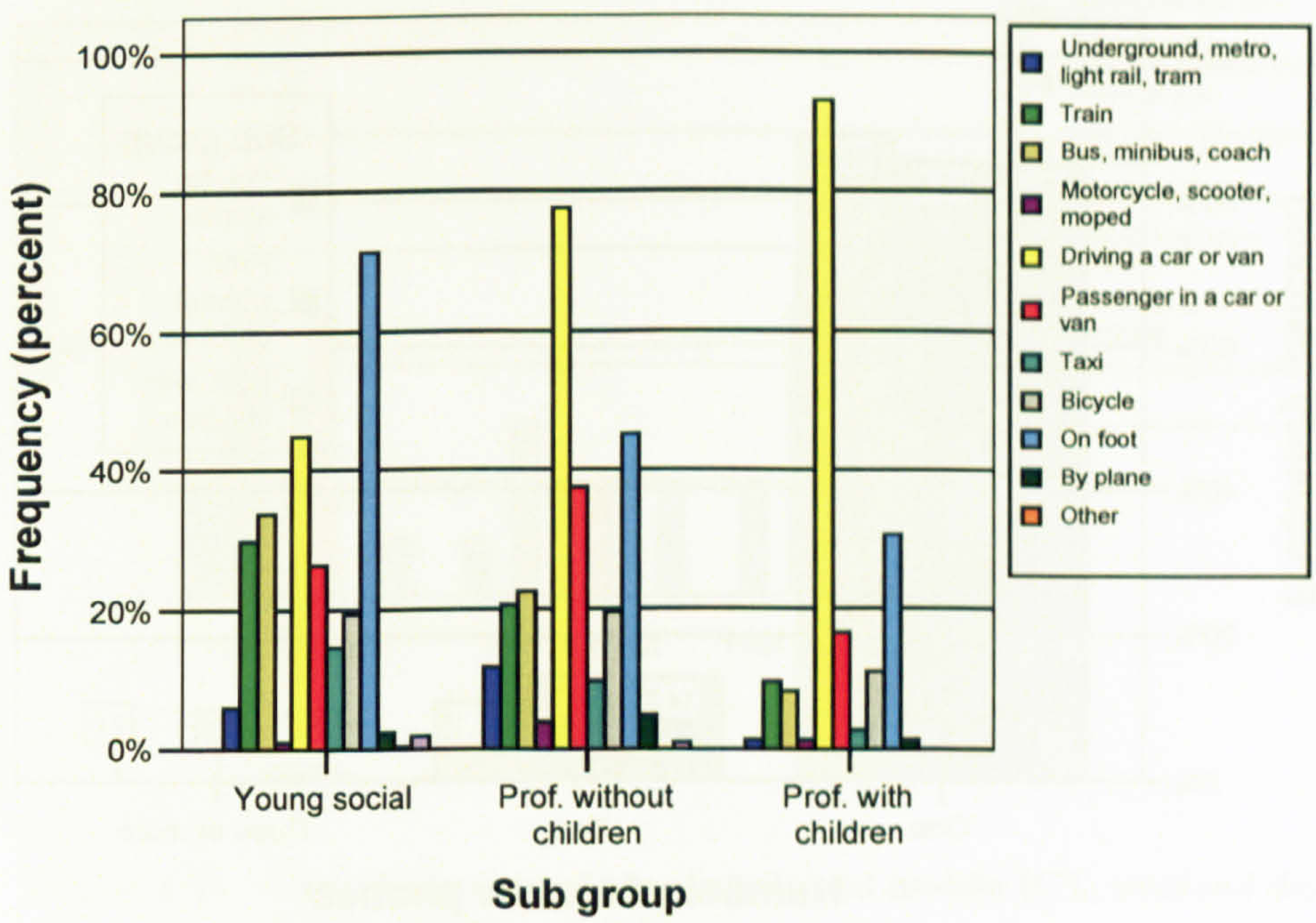


Figure 4.17 Mode(s) of transport used for non work-related trips, by Group (Q3.7)

4.5.6 Use of technology

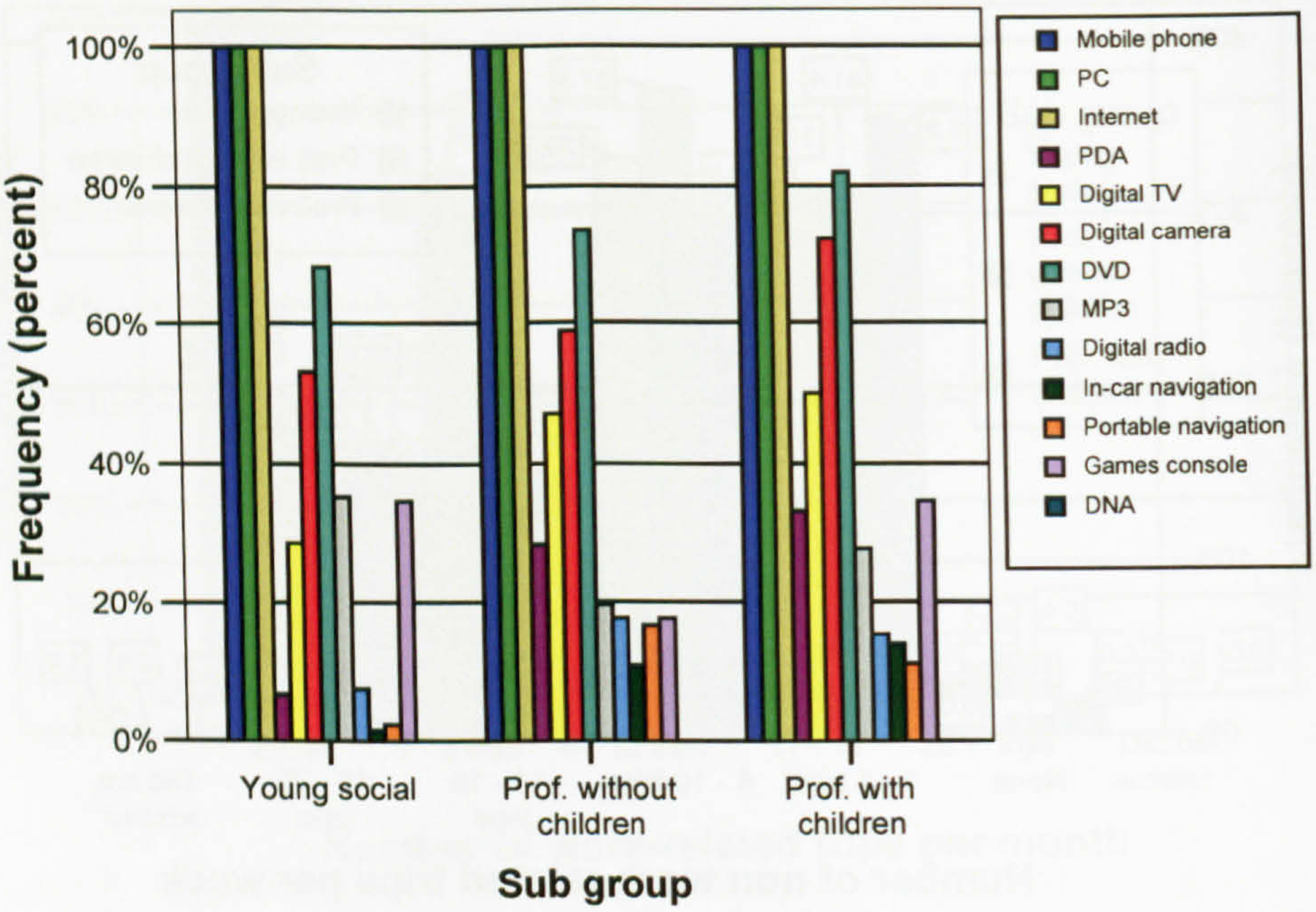


Figure 4.18 Consumer technology that is used regularly by respondents, by Group (Q4.1)

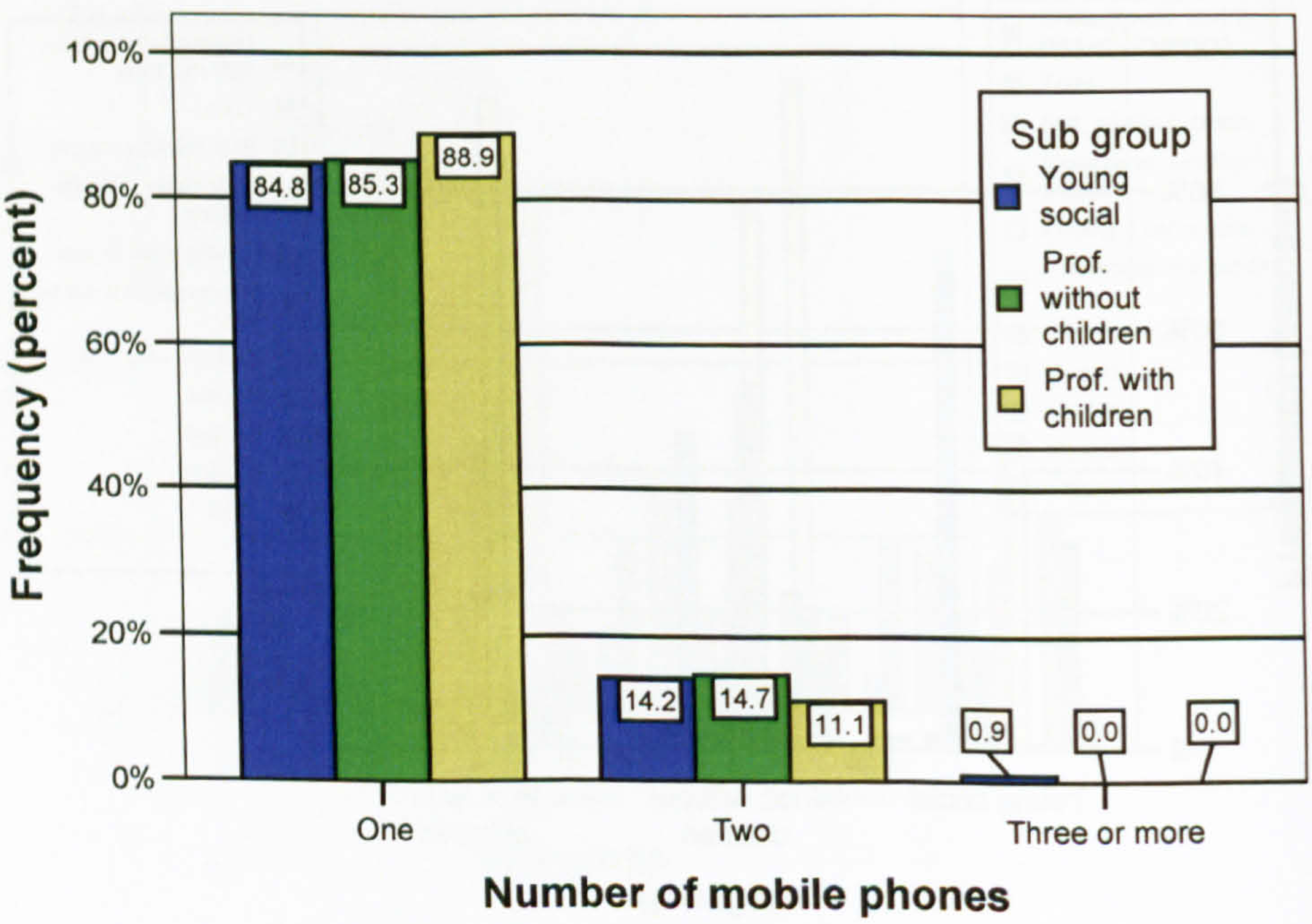


Figure 4.19 Number of mobile phones used by each participant, by Group (Q2.1)

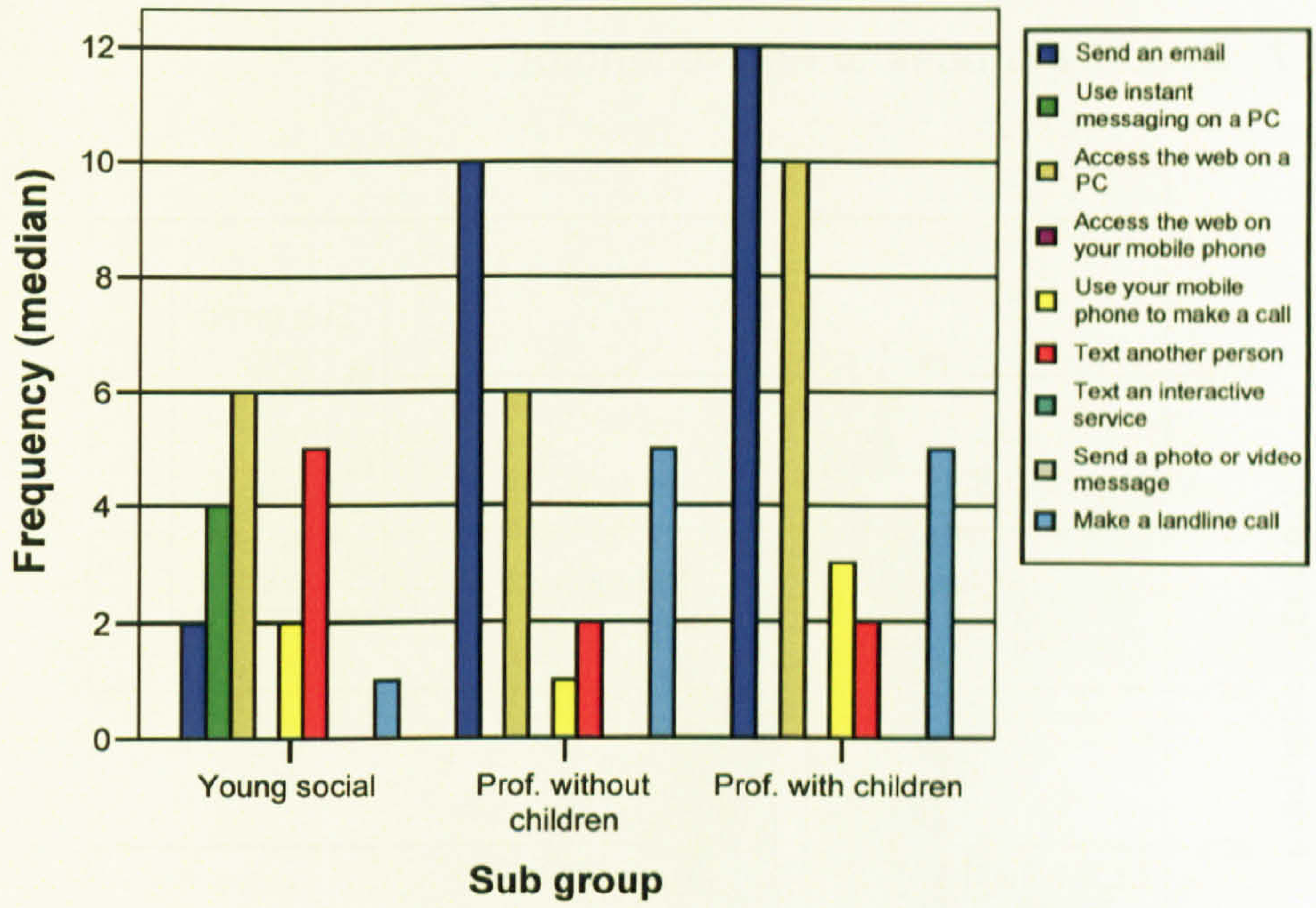


Figure 4.20 Daily frequency of use of static and mobile ICT, *weekday*, by Group (Q2.8a to 2.16a)

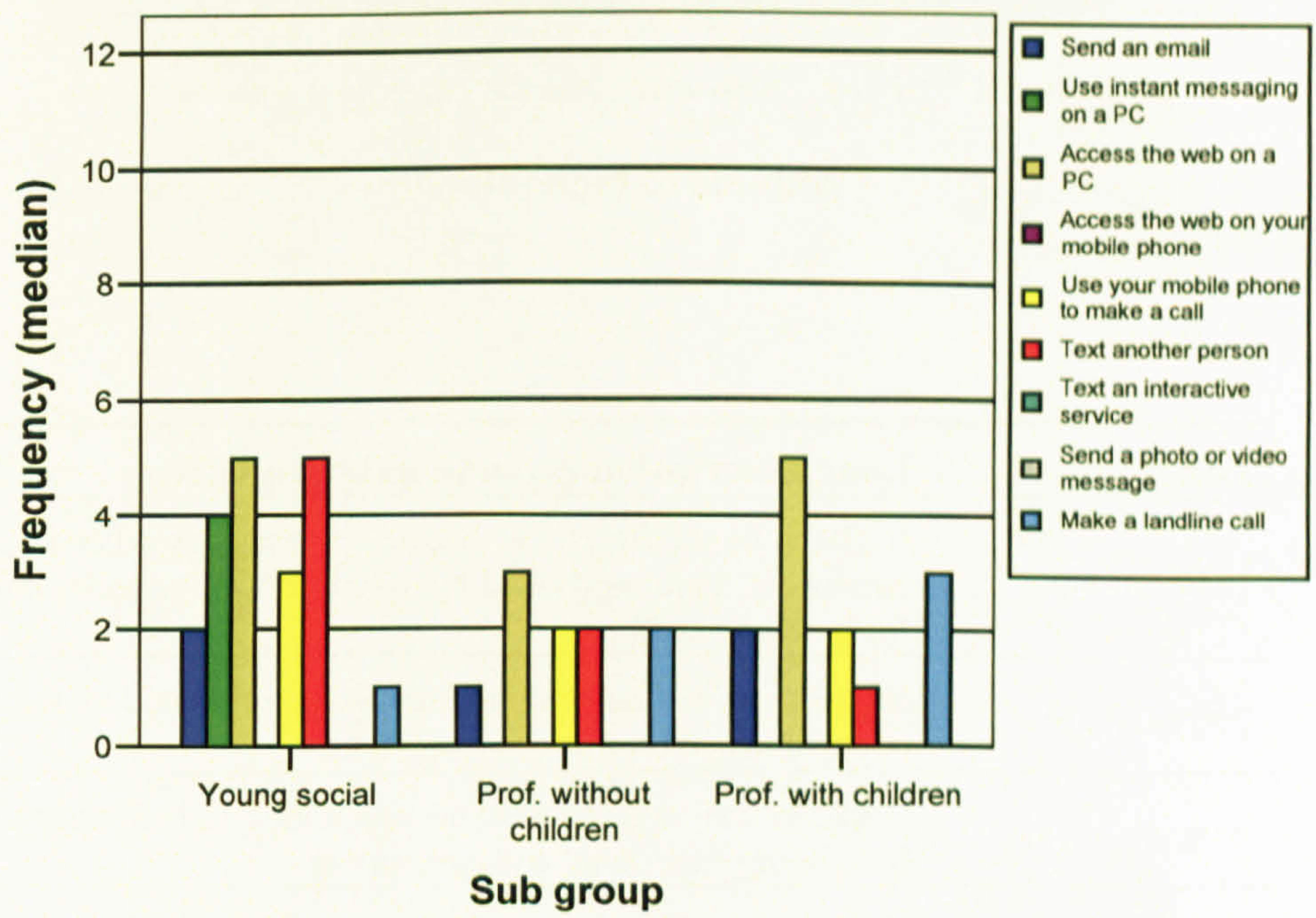
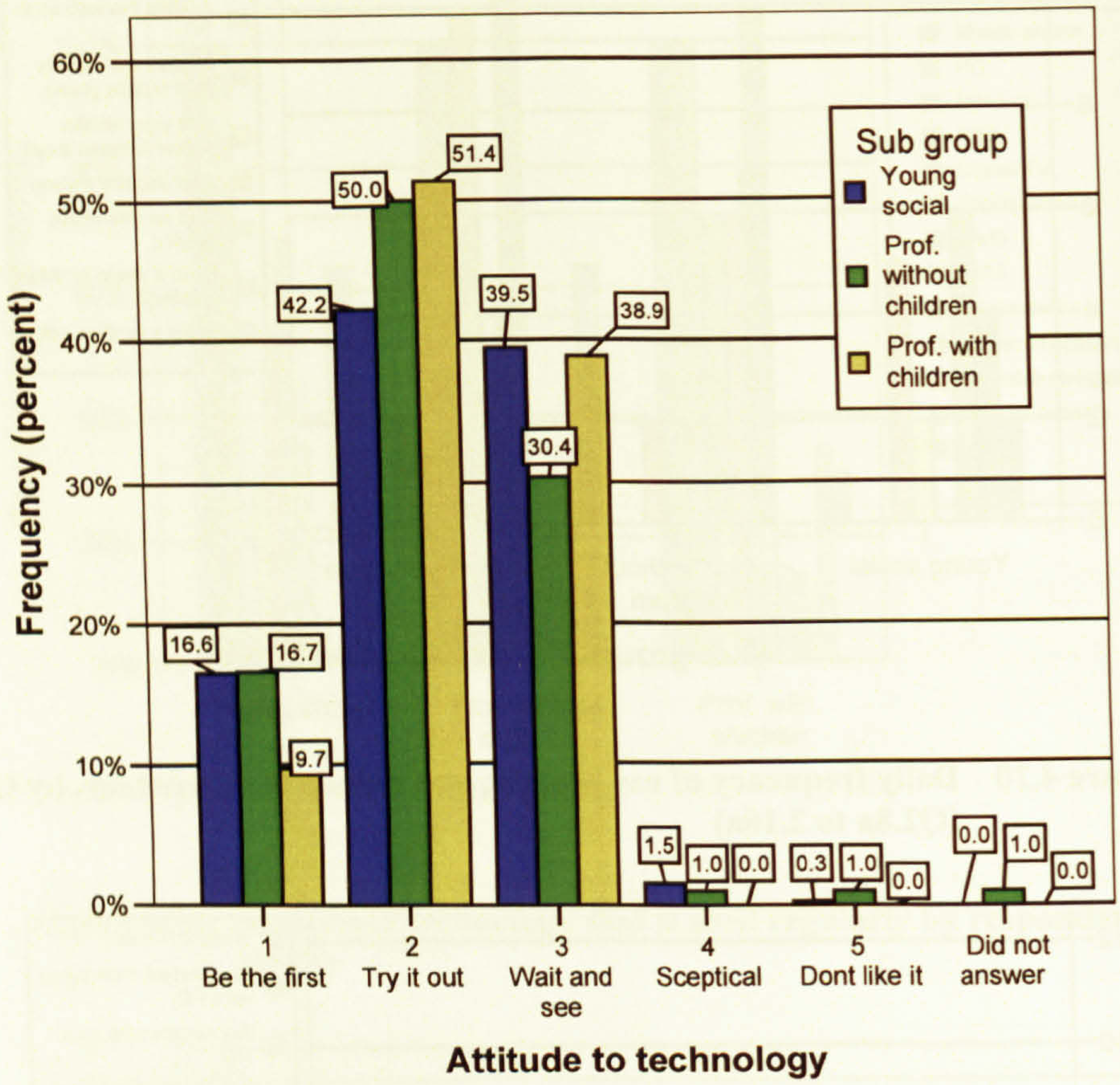


Figure 4.21 Daily frequency of use of static and mobile ICT, *weekend day*, by Group (Q2.8b to 2.16b)

4.5.7 Overall attitudes to new technology

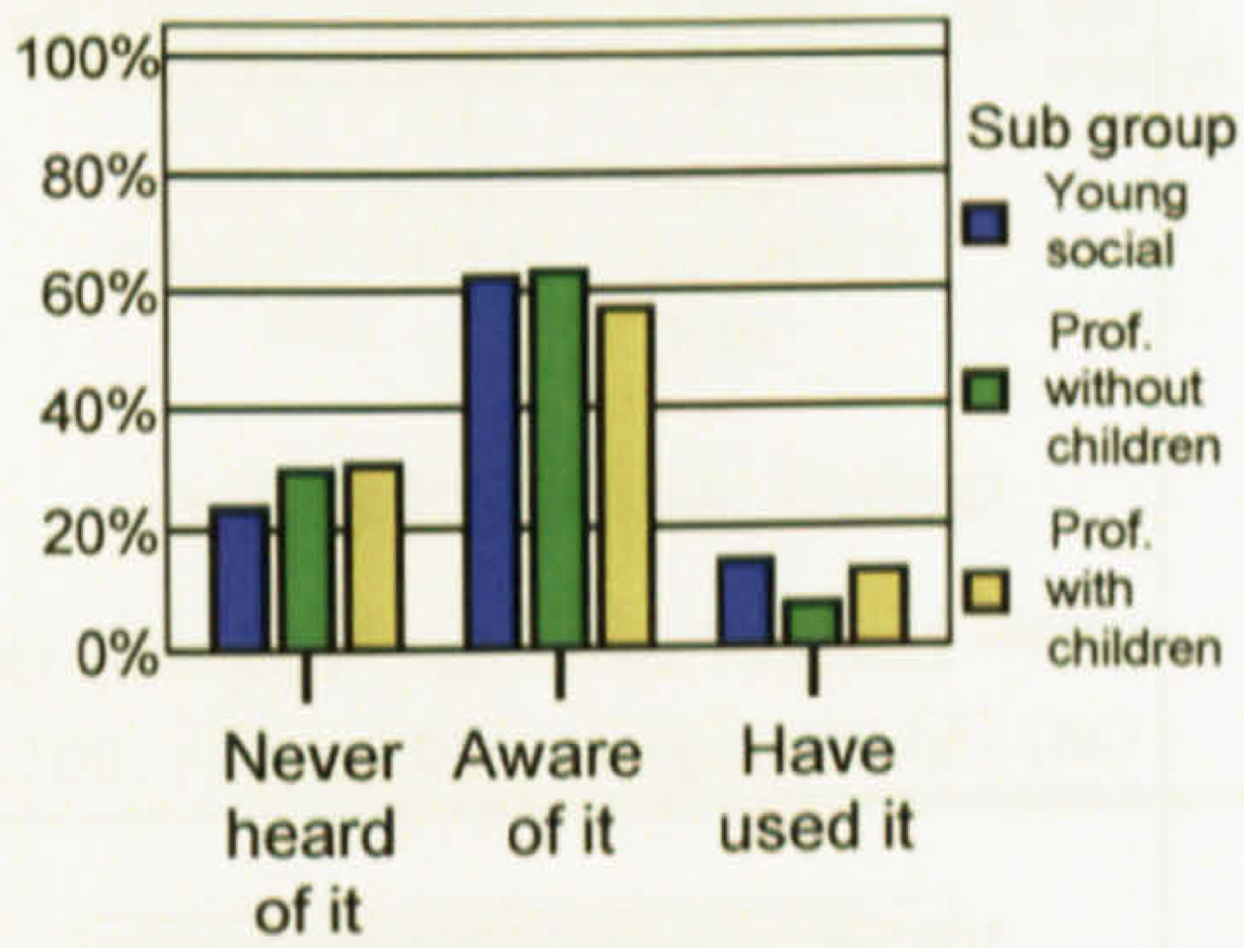


Label	Long description given in questionnaire
1 'Be the first'	'I like to be the first to try out new technology when it comes out. I am motivated by an interest in the technology for its own sake.'
2 'Try it out'	'I like to try out new technology. I am motivated by the opportunity to improve my lifestyle.'
3 'Wait and see'	'I like to wait and see with new technology. I am motivated by it being functional and easy to use.'
4 'Sceptical'	'I am sceptical about new technology. I am only motivated to use it when told to do so by others.'
5 'Don't like it'	'I don't like new technology. I am very resistant to using it.'

Figure 4.22 General reaction to new technology and motivation to use it, by Group (Q4.2)

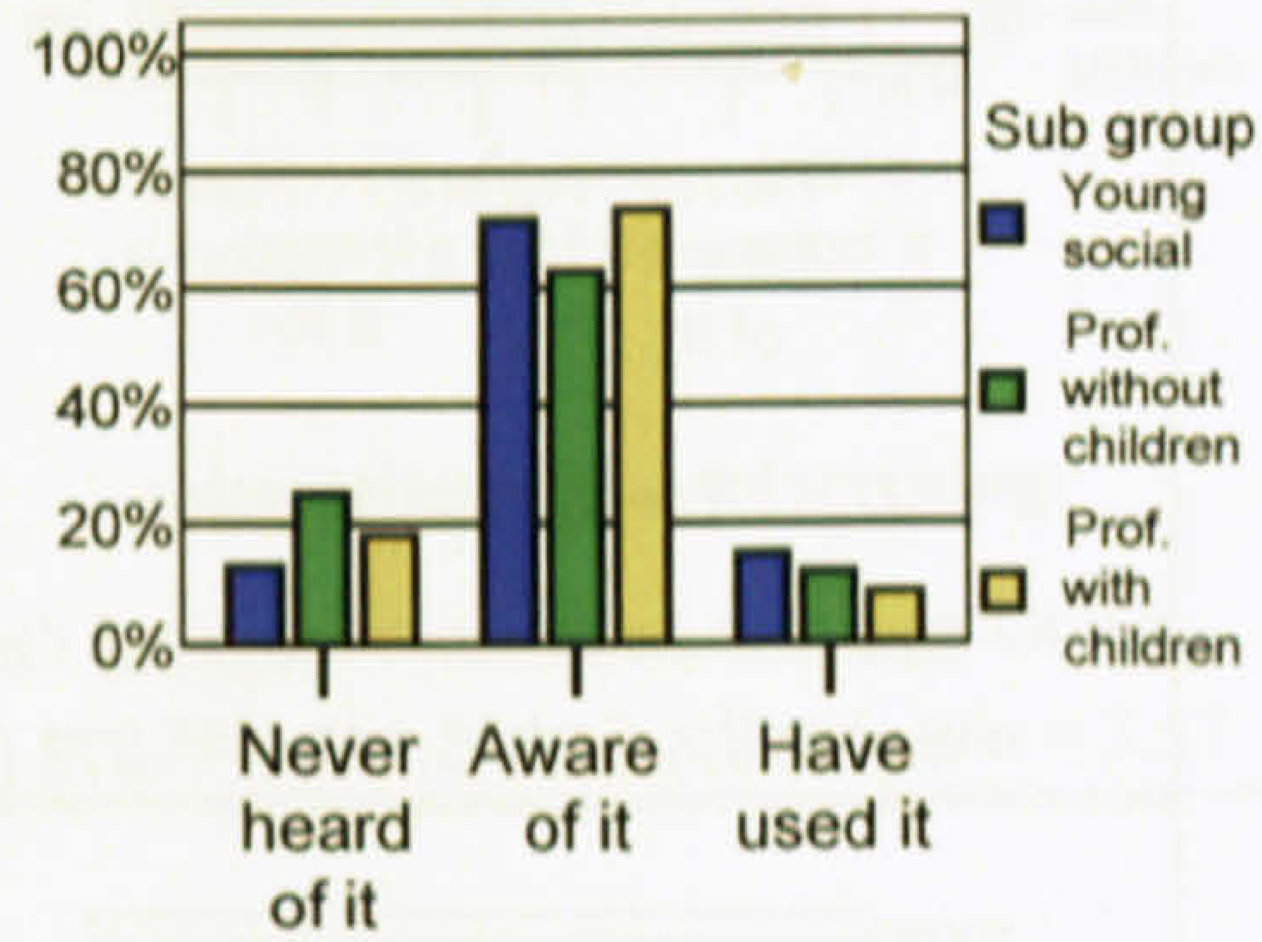
4.5.8 Awareness of services and/or use of mobile location services

The chi-square statistics for each graph show whether there were variations, according Group, of the proportions of levels of awareness and/or use of that service.



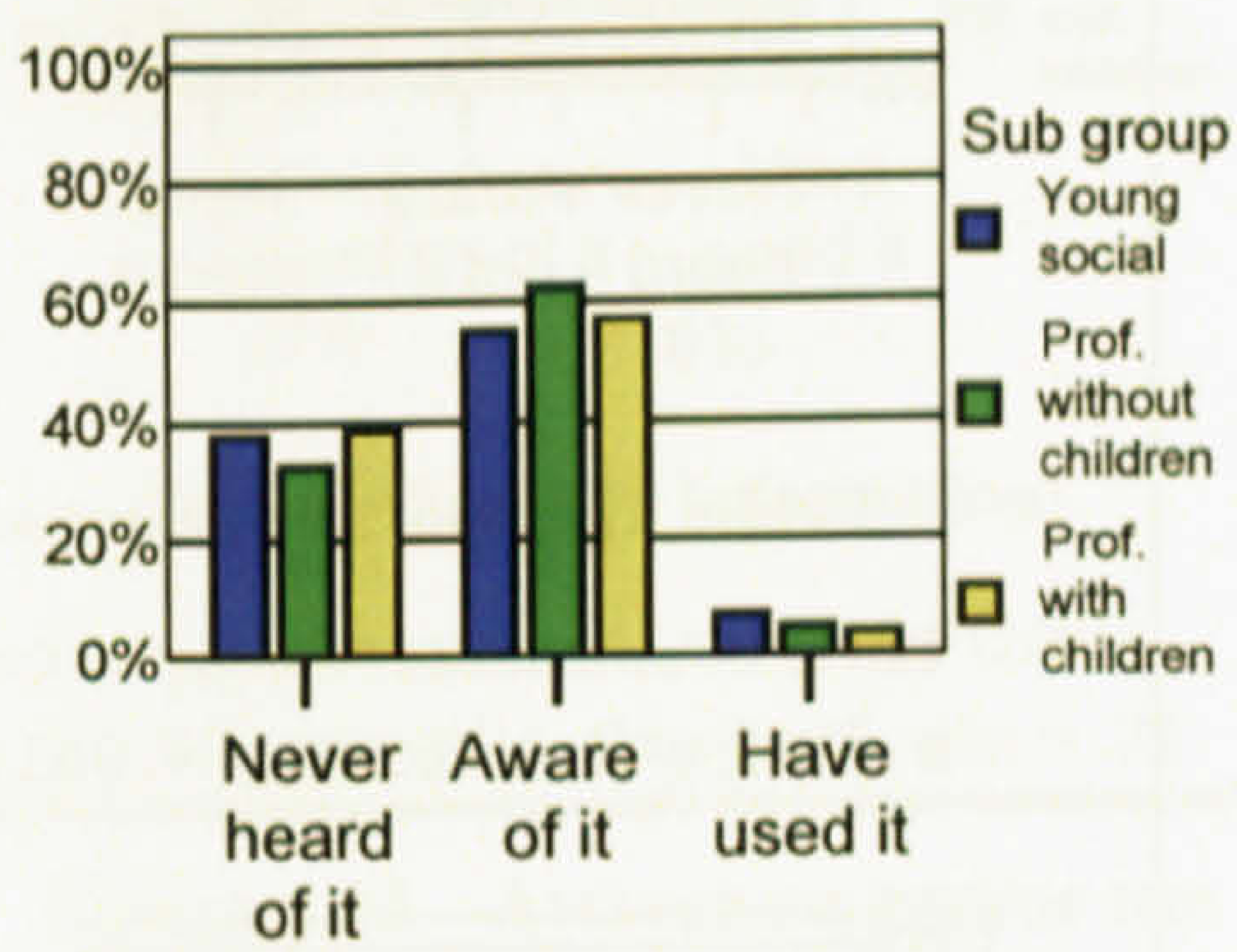
Nearest Services (e.g. nearest cashpoint):

Level of awareness / usage, by Group
n = 906, $\chi^2(4) = 6.605$, $p = .158$ (ns)



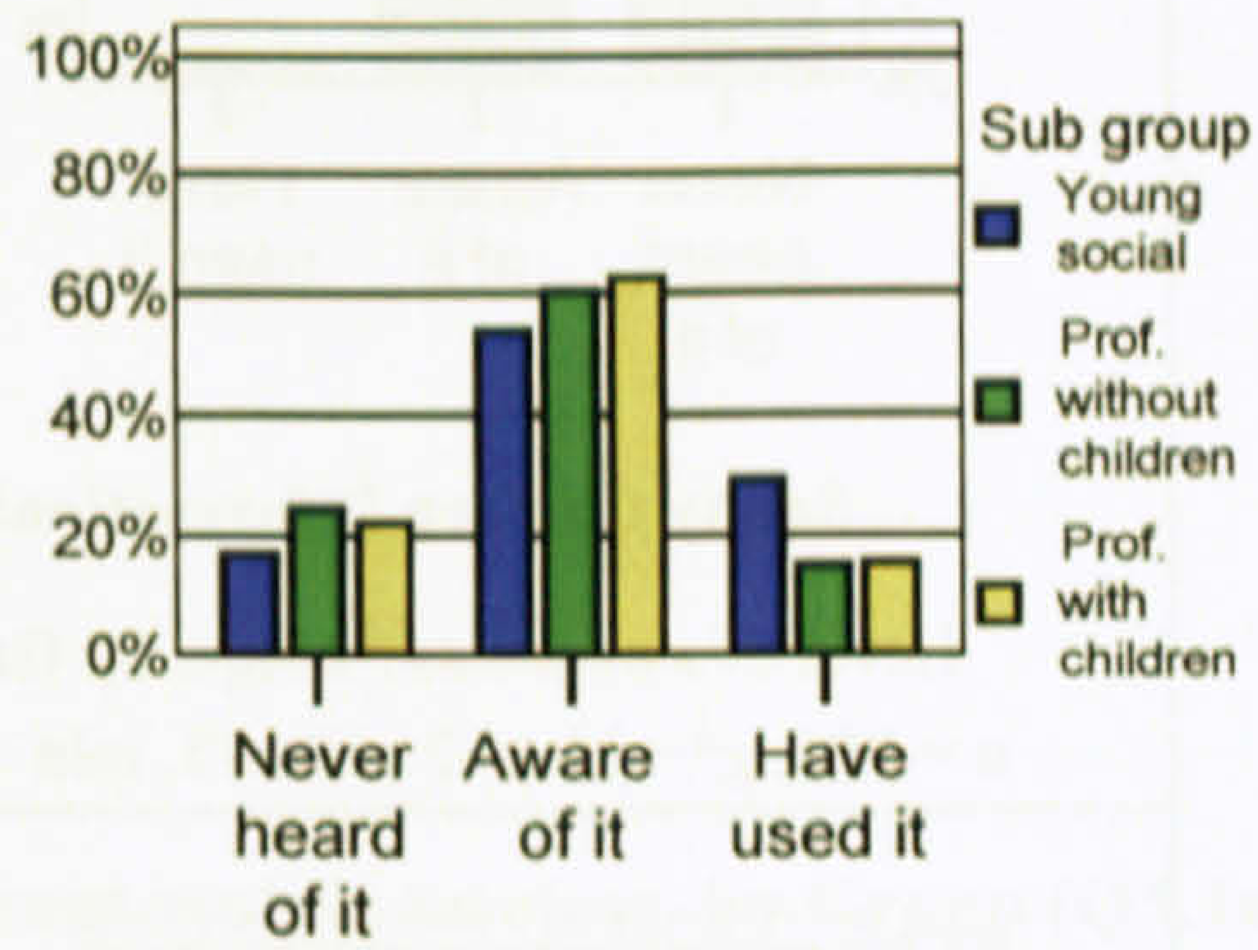
Local Weather:

Level of awareness / usage, by Group
n = 904, $\chi^2(4) = 12.427$, $p = .014$ (sig)



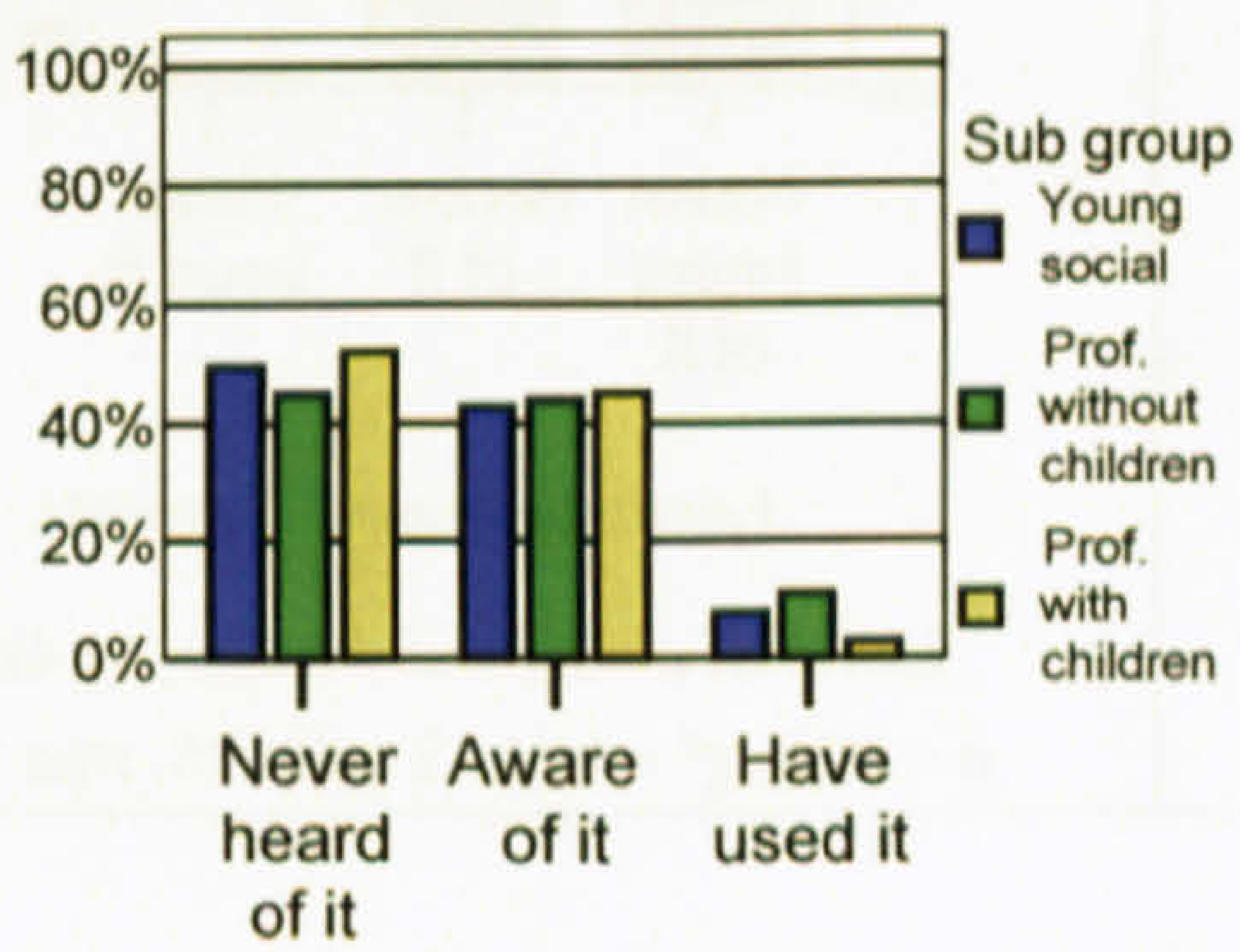
City Guides:

Level of awareness / usage, by Group
n = 906, $\chi^2(4) = 2.910$, $p = .573$ (ns)



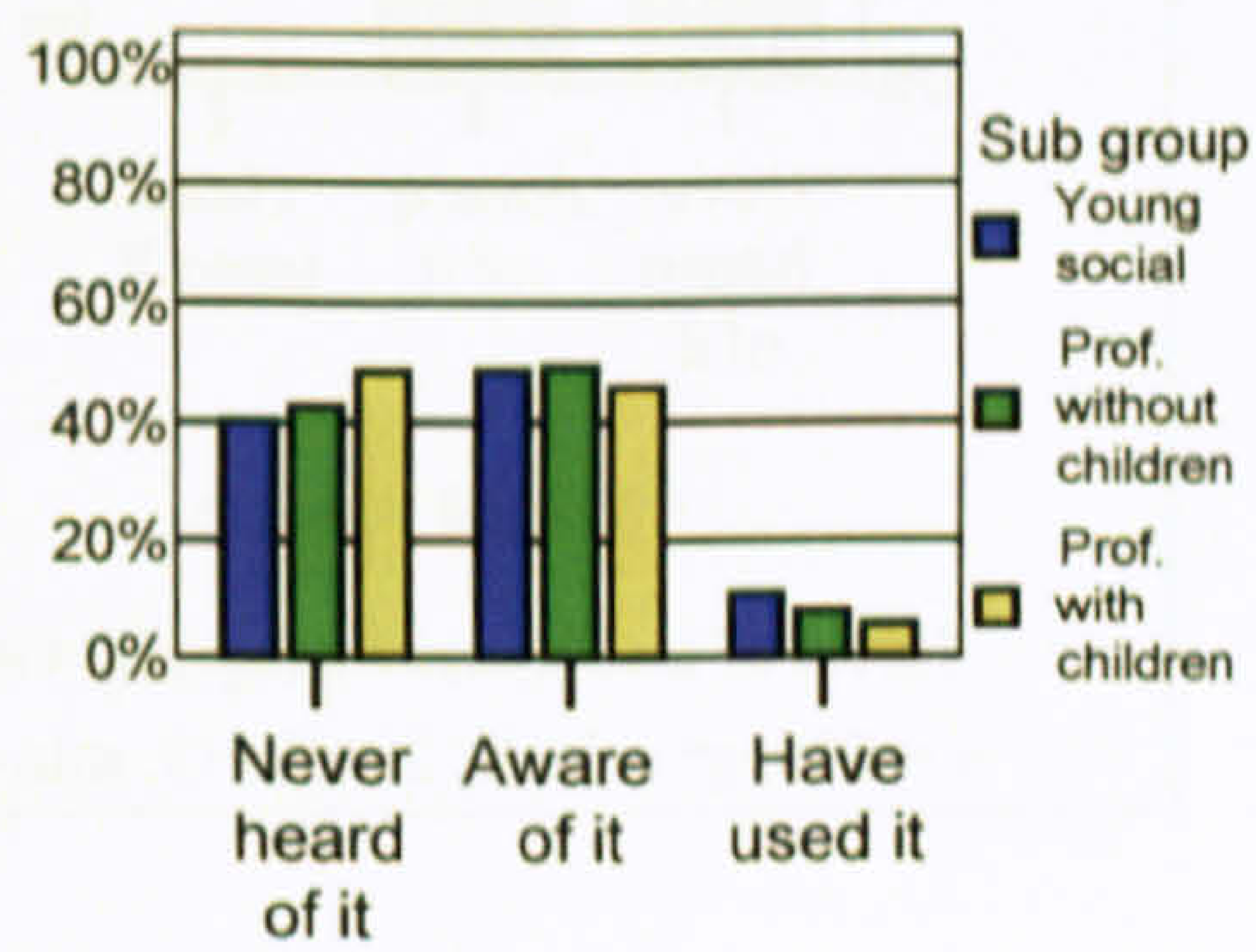
Local Phone Numbers:

Level of awareness / usage, by Group
n = 905, $\chi^2(4) = 16.071$, $p = .003$ (sig)



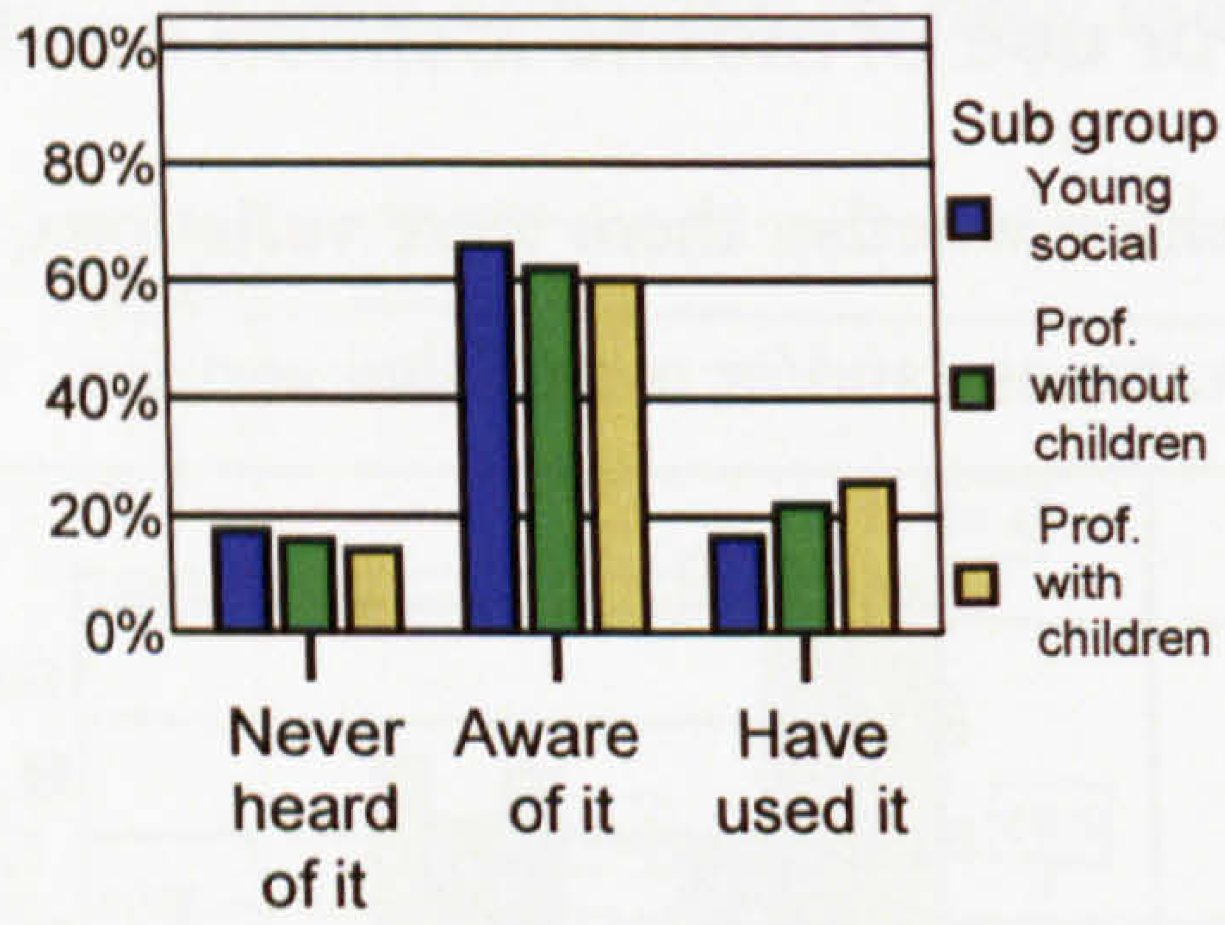
Walking Directions:

Level of awareness / usage, by Group
n = 901, $\chi^2(4) = 4.303$, $p = .367$ (ns)



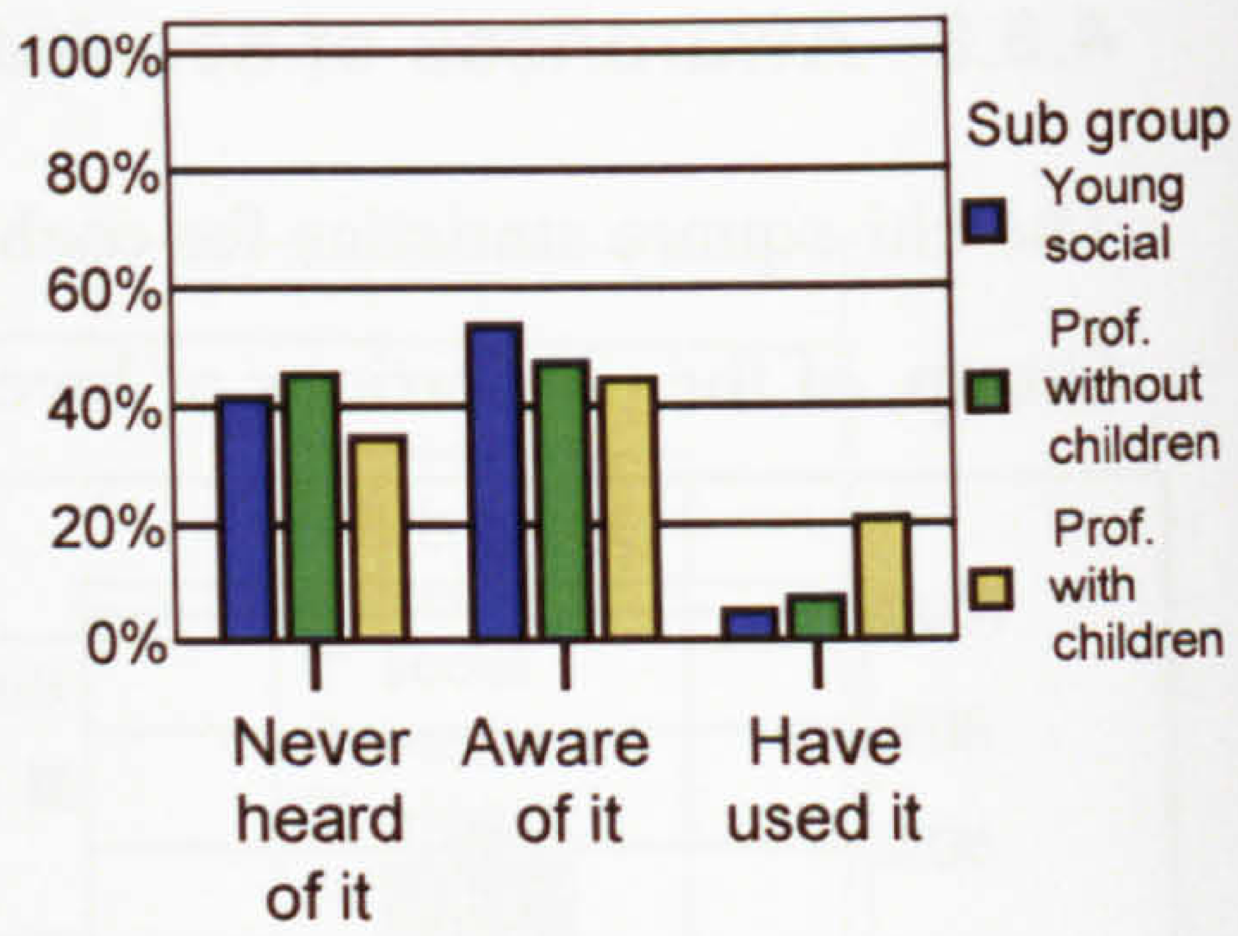
Driving Directions:

Level of awareness / usage, by Group
n = 900, $\chi^2(4) = 3.825$, $p = .430$ (ns)



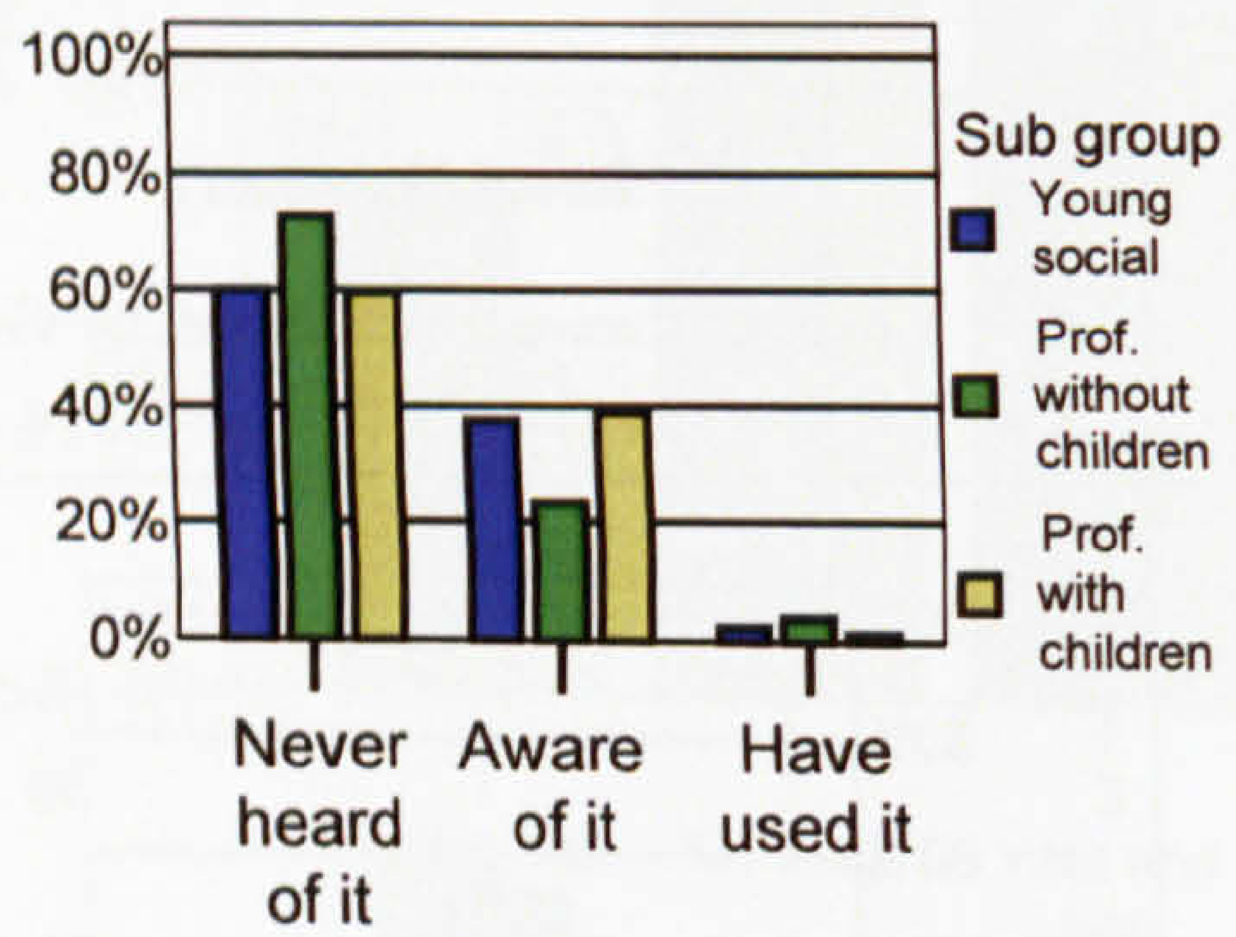
Traffic Information:

Level of awareness / usage, by Group
n = 898, $\chi^2(4) = 5.155$, $p = .272$ (ns)



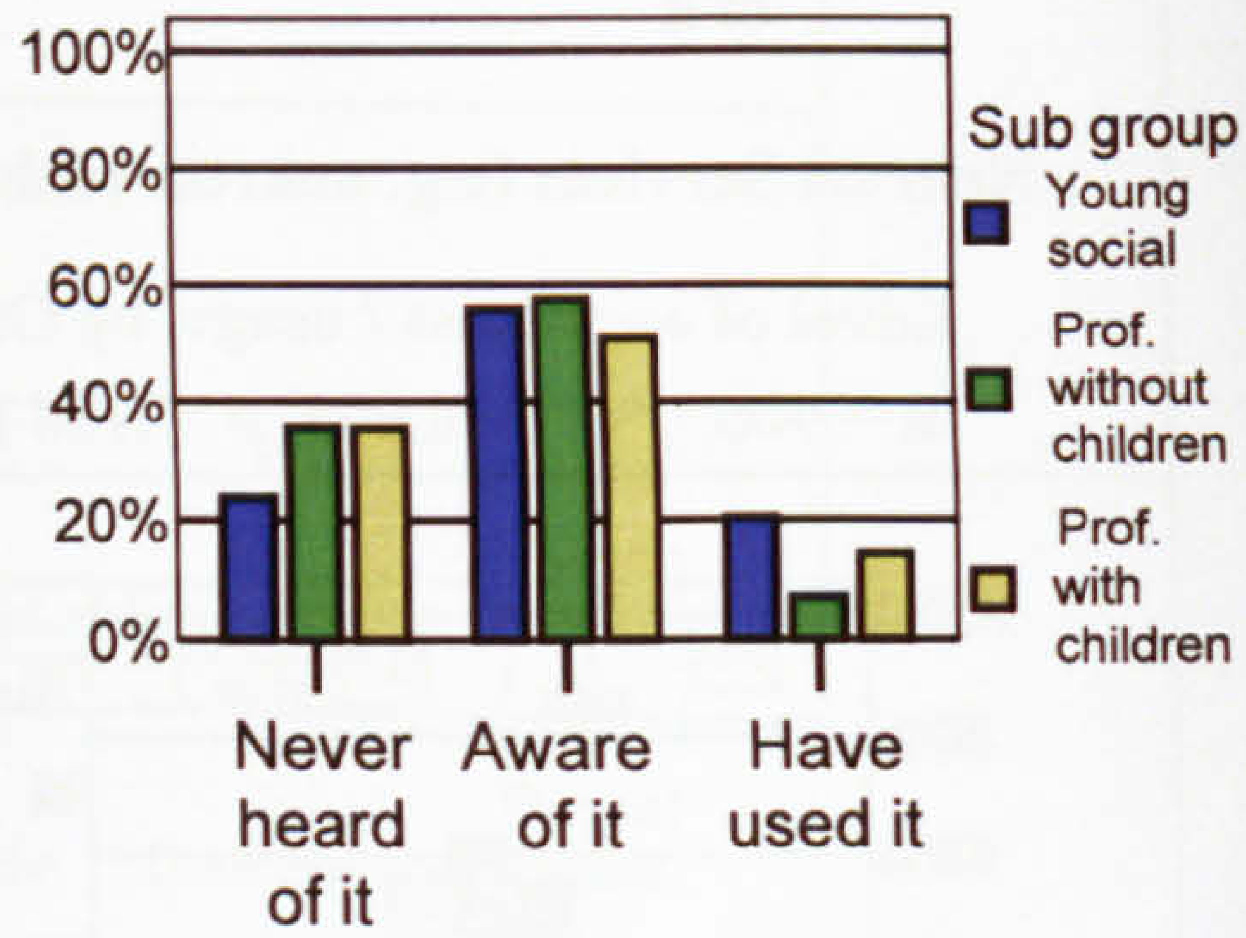
Roadside Assistance:

Level of awareness / usage, by Group
n = 897, $\chi^2(4) = 29.260$, $p < .001$ (sig)



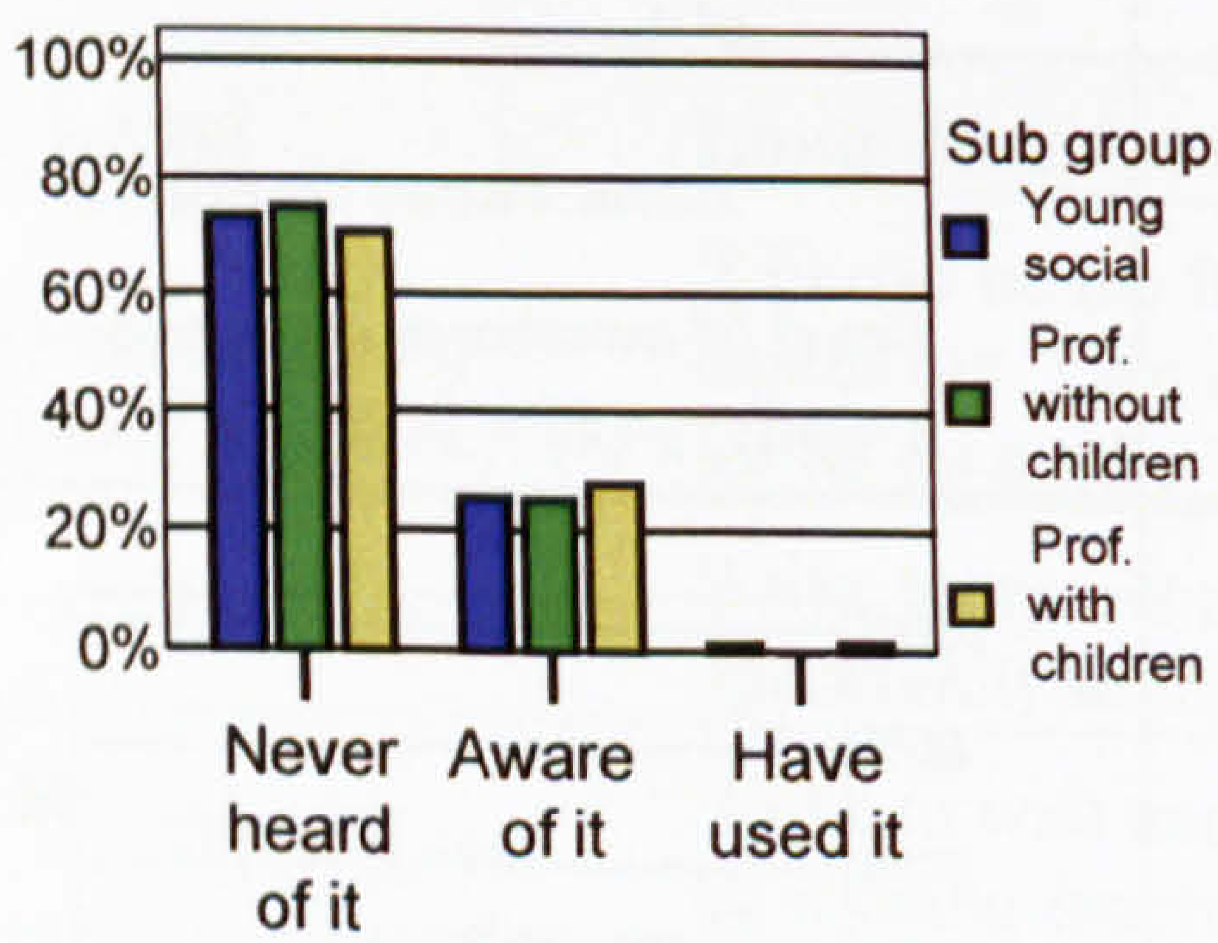
Safety Camera Information:

Level of awareness / usage, by Group
n = 901, χ^2 = N/A: 2 cells <5, min = 1.84



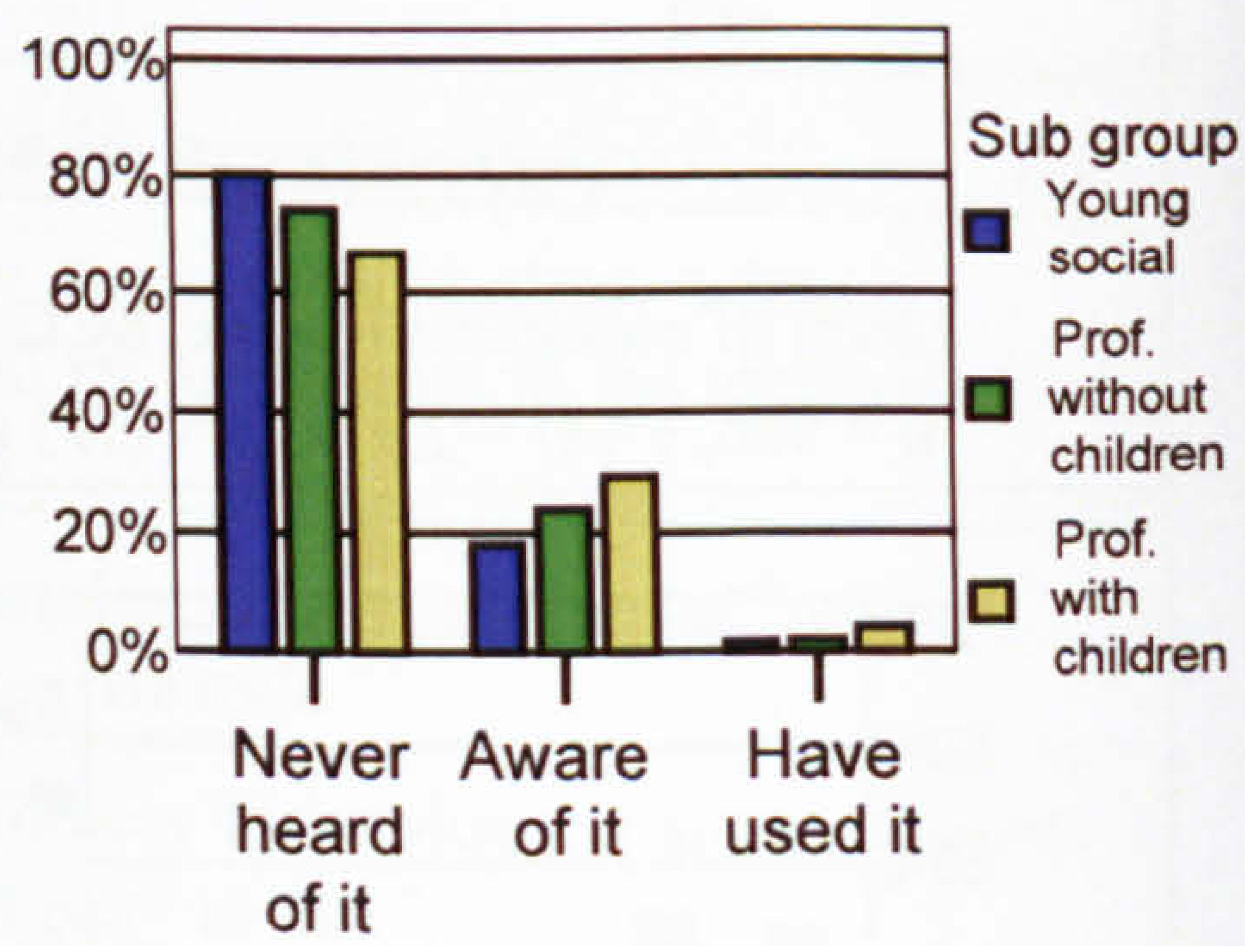
Public Transport Information:

Level of awareness / usage, by Group
n = 891, $\chi^2(4) = 16.668$, $p = .002$ (sig)



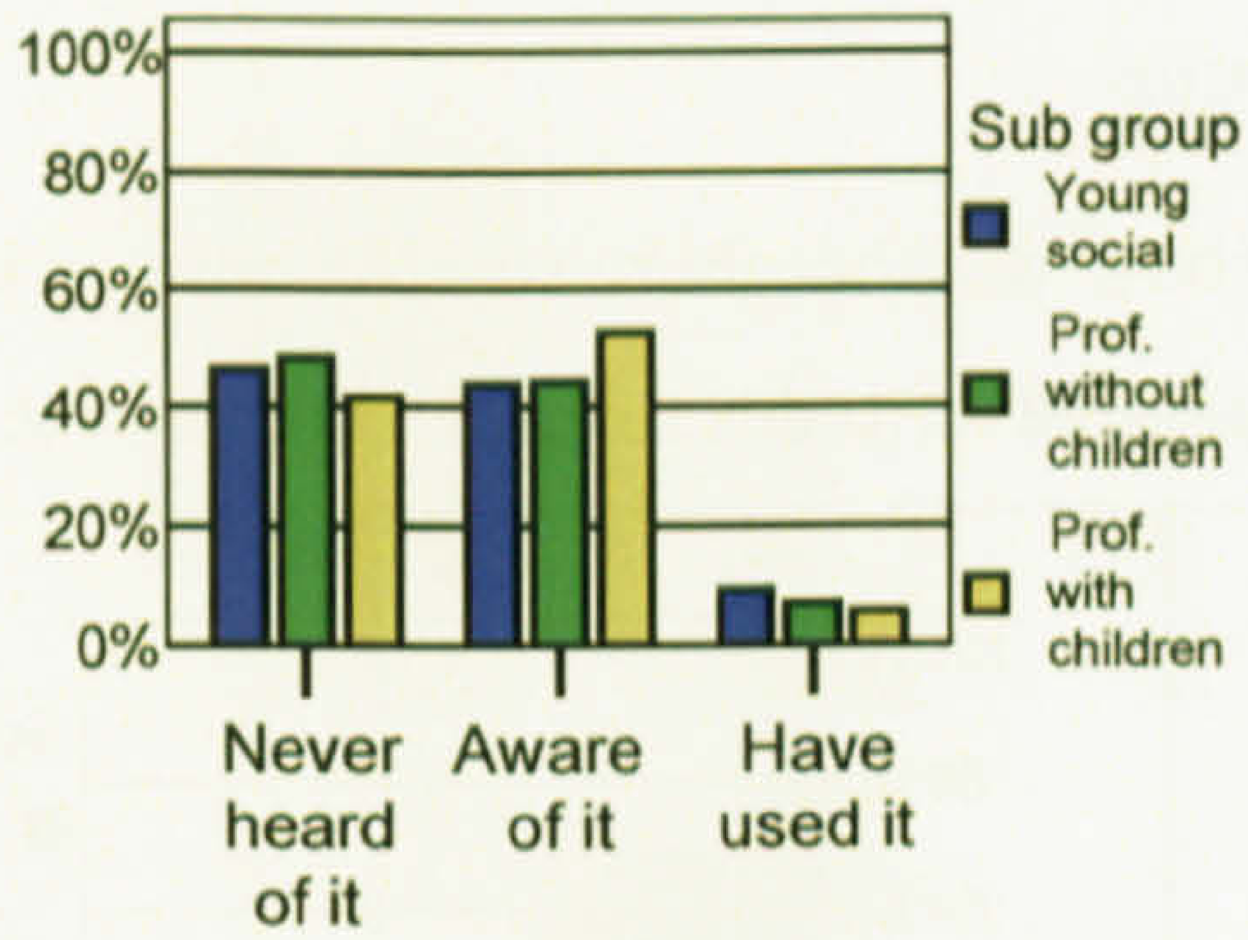
Friend Finder:

Level of awareness / usage, by Group
n = 899, χ^2 = N/A: 2 cells <5, min = .80



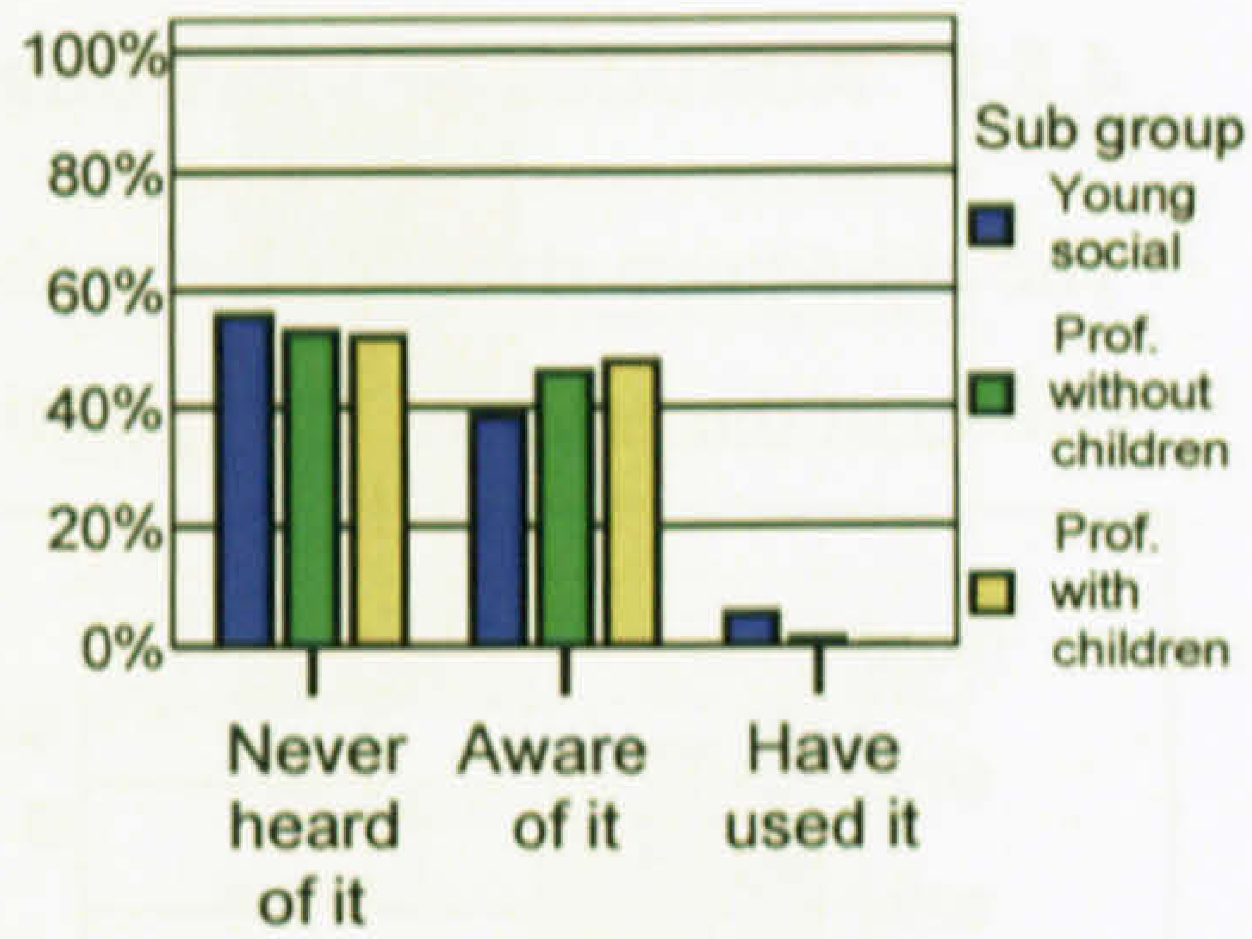
Location-based Games):

Level of awareness / usage, by Group
n = 902, χ^2 = N/A: 2 cells <5, min = 1.36



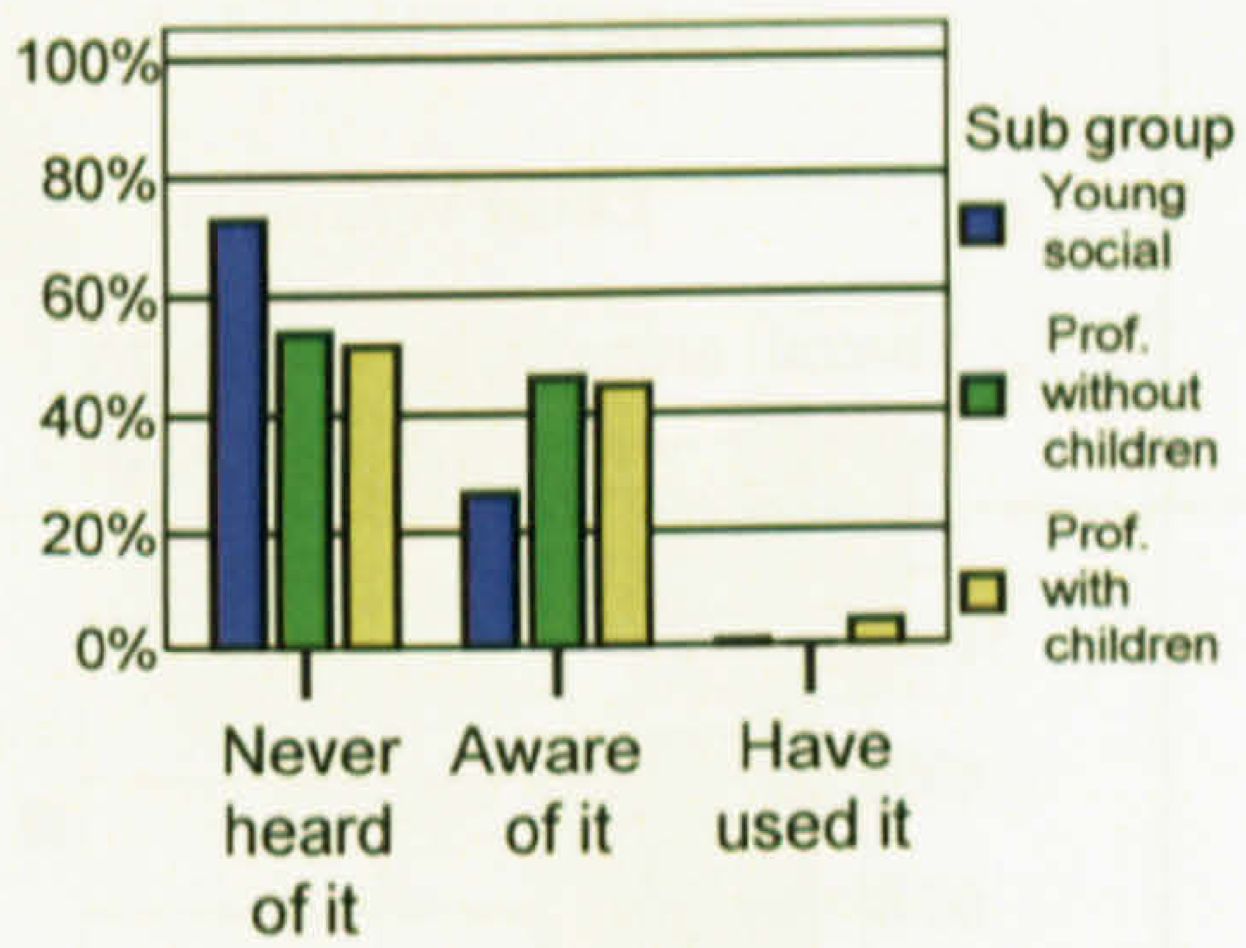
Mobile Booking / Paying:

Level of awareness / usage, by Group
n = 897, $\chi^2(4) = 3.162$, $p = .531$ (ns)



Location-based Advertising:

Level of awareness / usage, by Group
n = 895, χ^2 = N/A: 2 cells <5, min = 3.17



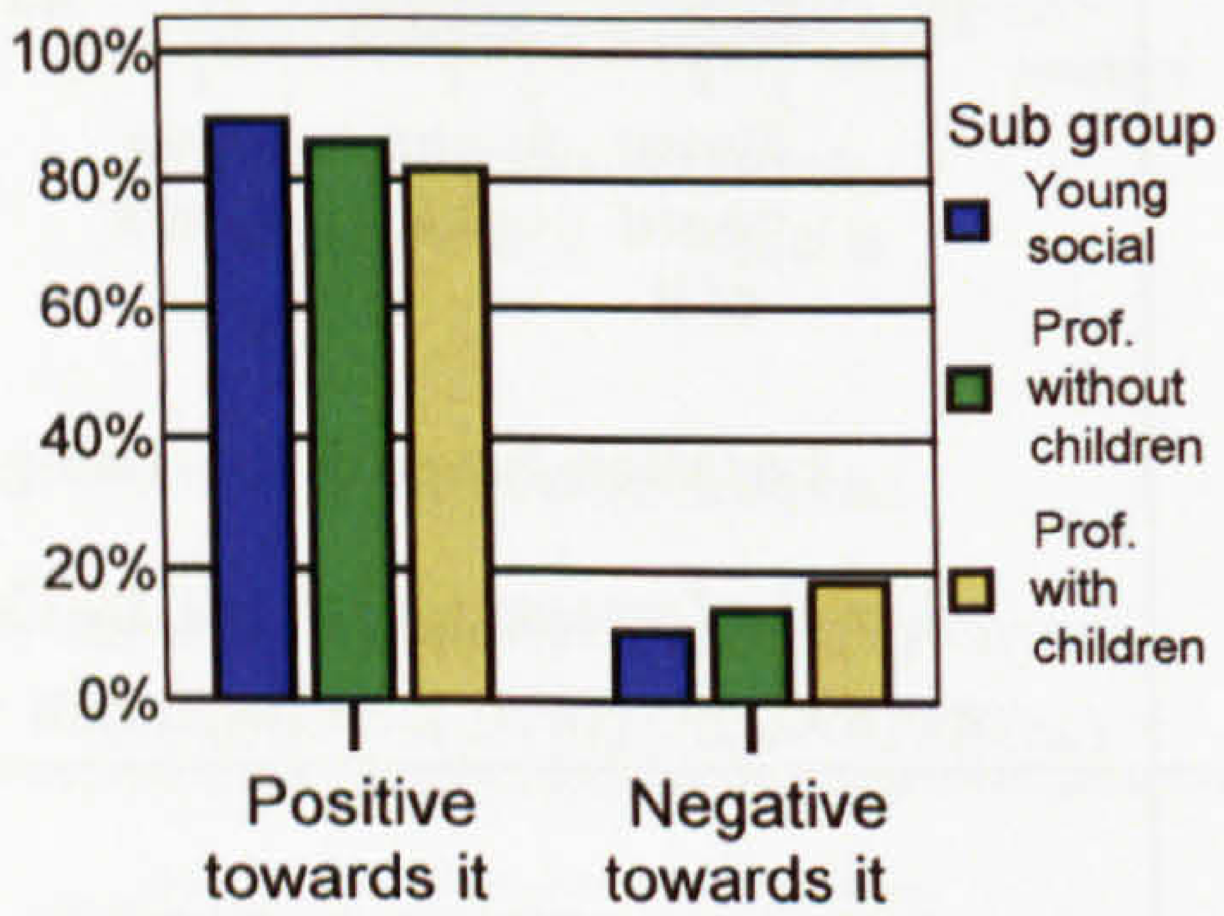
Safety / Security Information:

Level of awareness / usage, by Group
n = 901, χ^2 = N/A: 2 cells <5, min = .72

Figure 4.23 Awareness and/or use of different mobile services, by Group (Q5.1a - 5.15a)

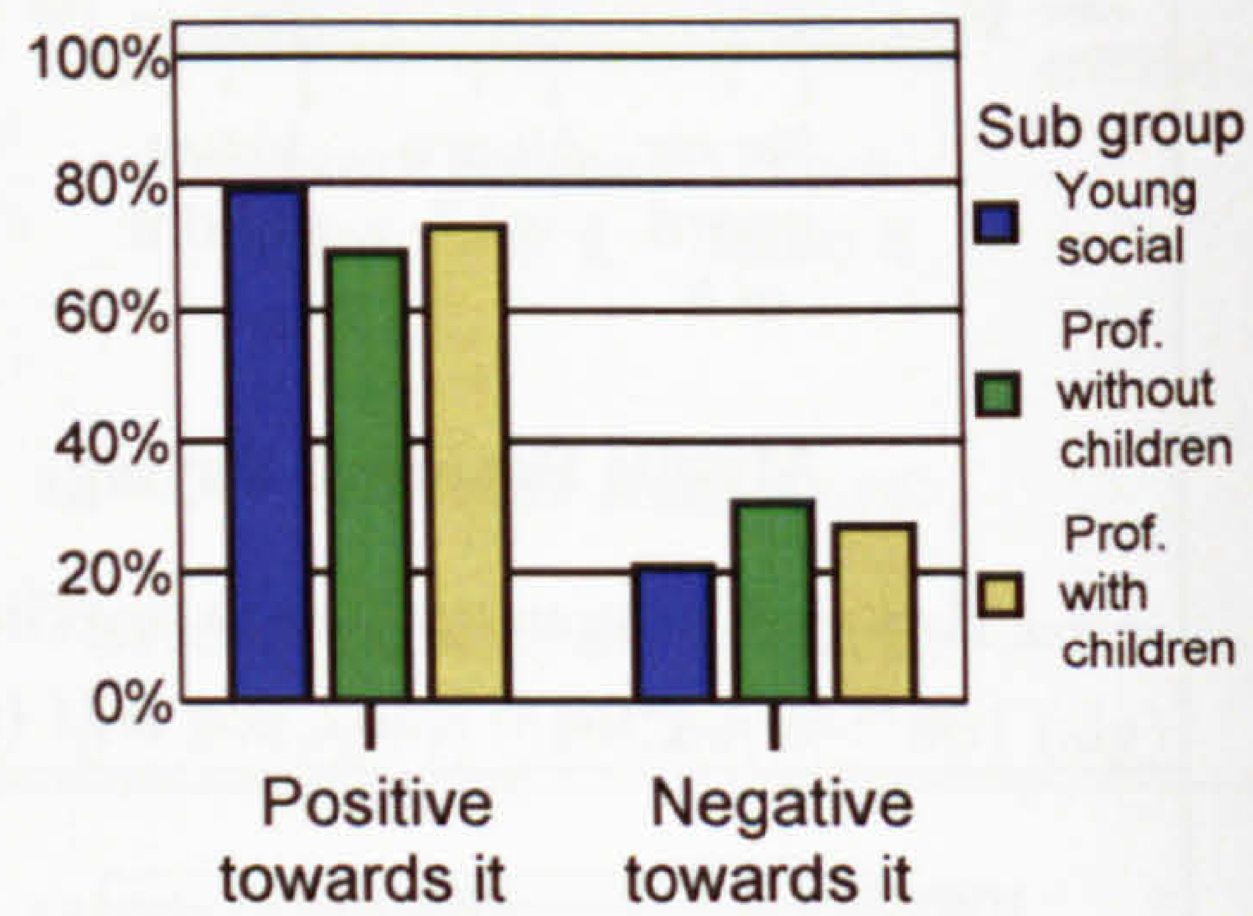
4.5.9 Attitudes to individual services

The chi-square statistics for each graph show whether there were variations according to Group of the proportion of positive or negative attitudes towards that service.



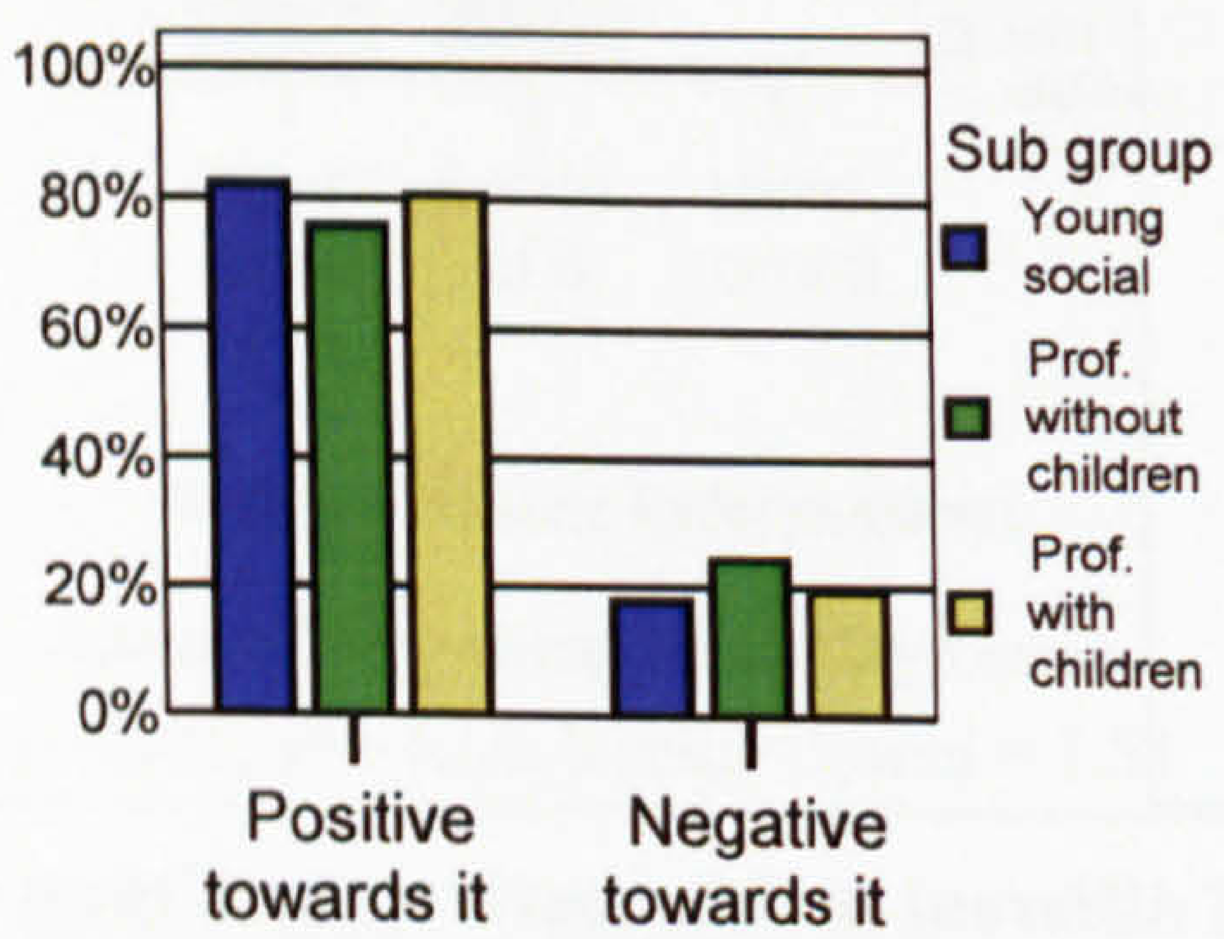
Nearest Services (e.g. nearest cashpoint):

Overall attitudes towards it, by Group
n = 885, $\chi^2(2) = 4.155$, $p = .125$ (ns)



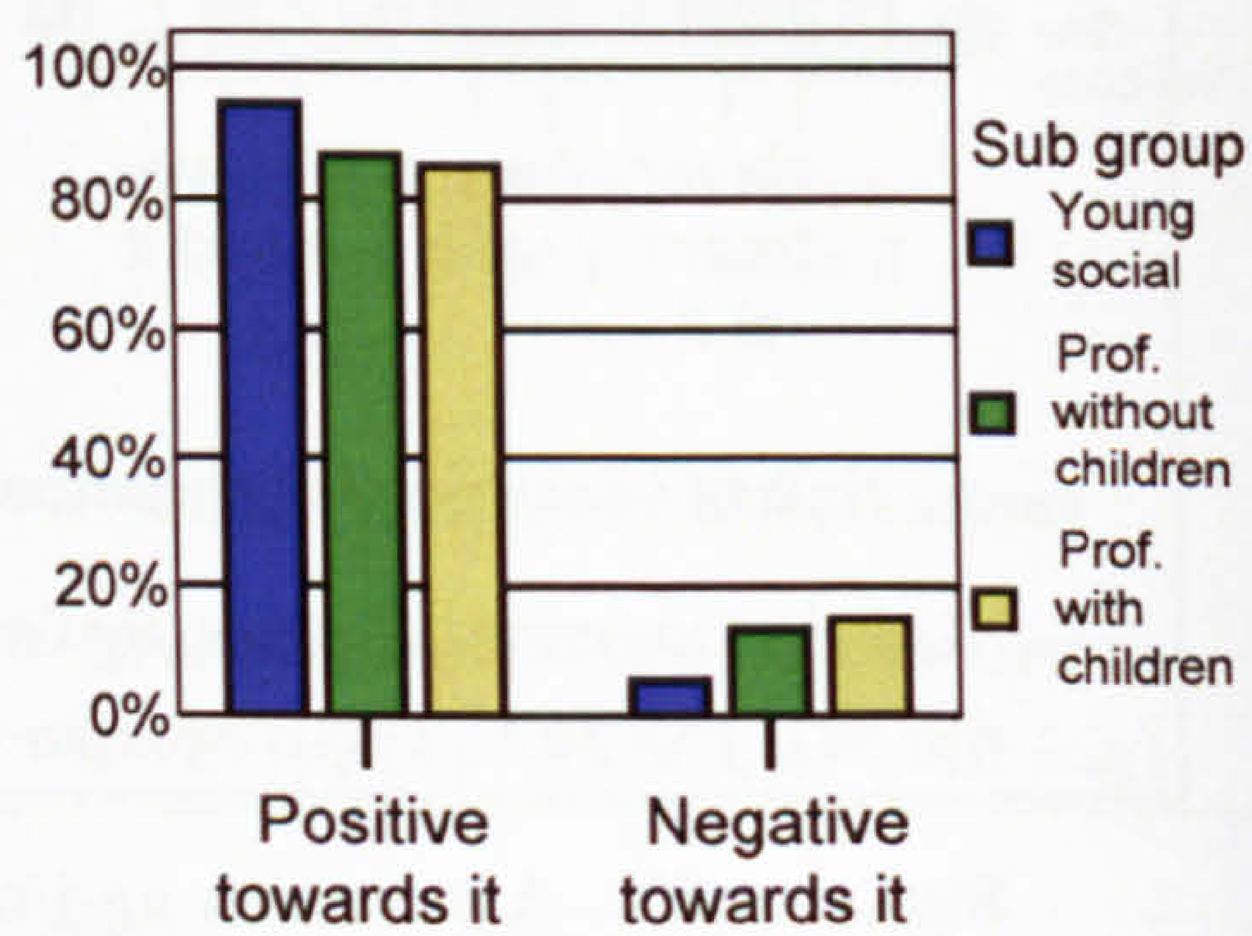
Local Weather:

Overall attitudes towards it, by Group
n = 891, $\chi^2(2) = 6.206$, $p = .045$ (sig)



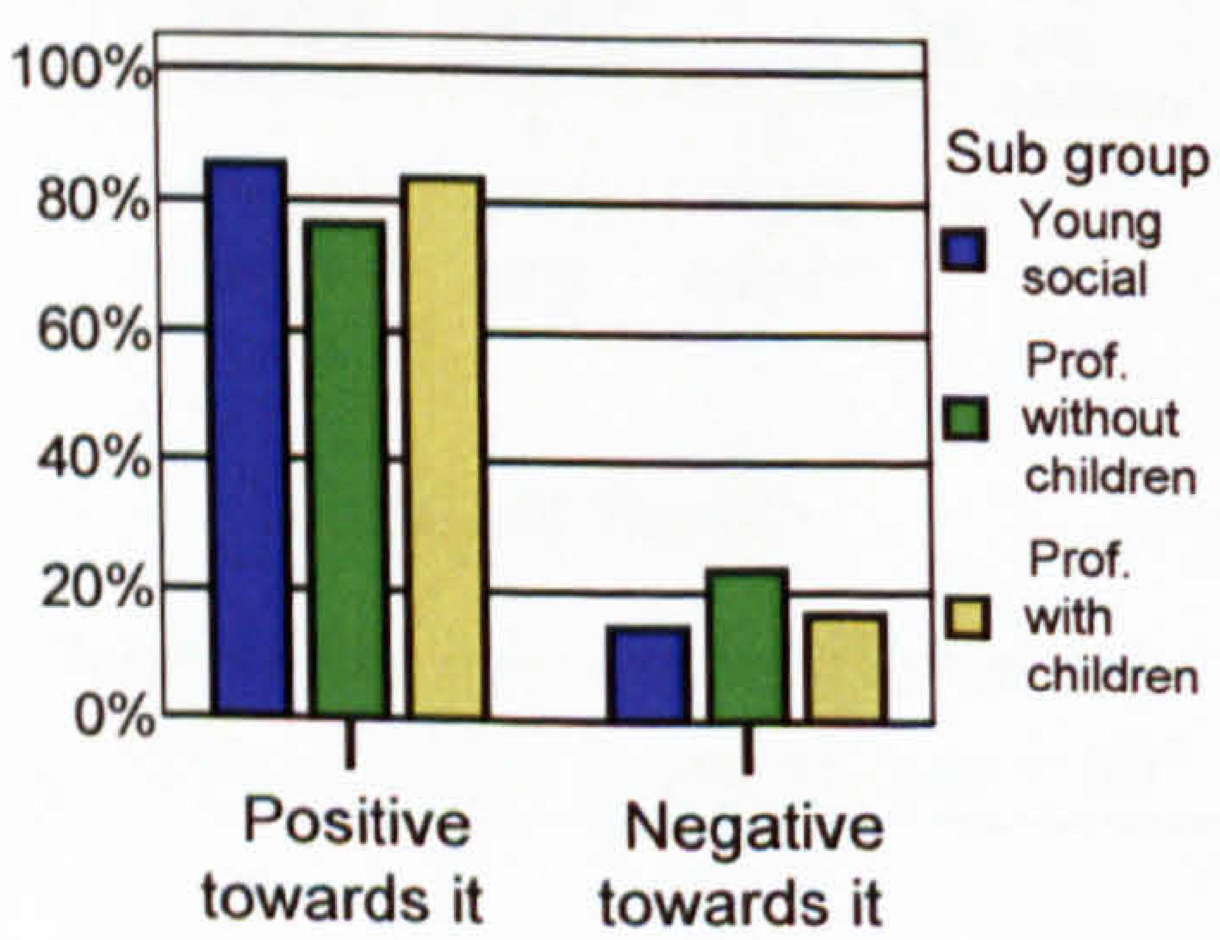
City Guides:

Overall attitudes towards it, by Group
n = 875, $\chi^2(2) = 2.428$, $p = .297$ (ns)



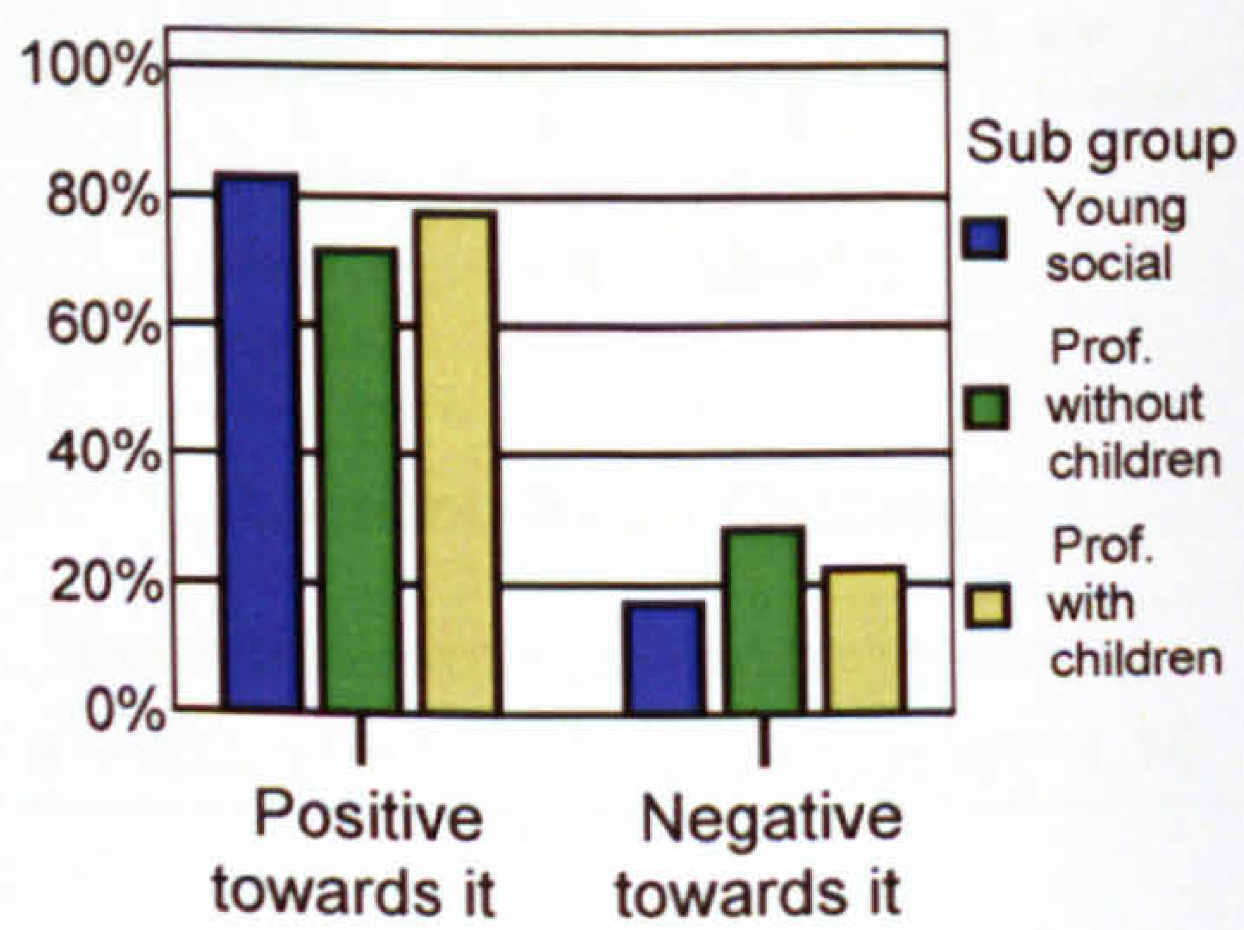
Local Phone Numbers:

Overall attitudes towards it, by Group
n = 871, $\chi^2(2) = 14.491$, $p = .001$ (sig)



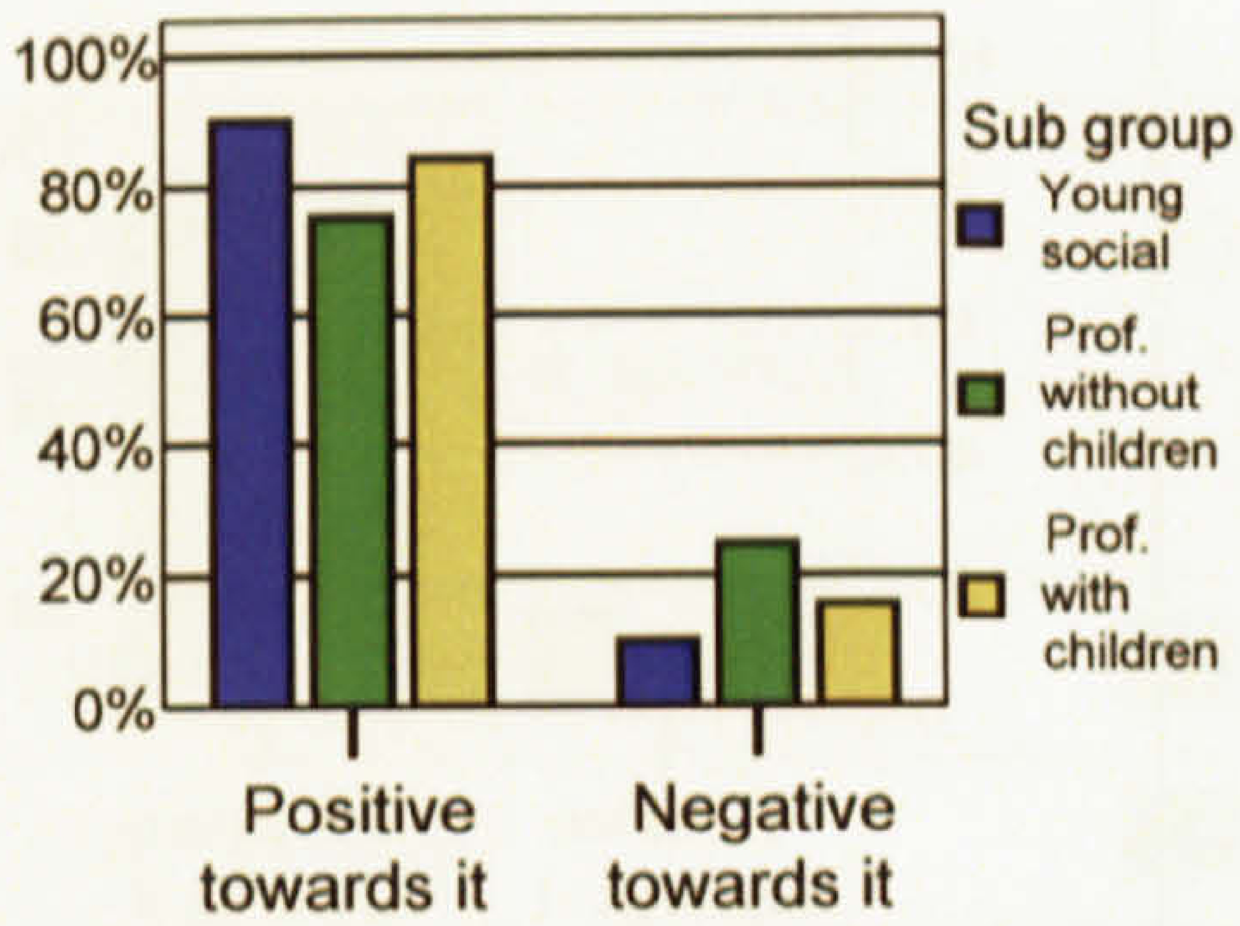
Walking Directions

Overall attitudes towards it, by Group
n = 870, $\chi^2(2) = 5.532$, $p = .063$ (ns)



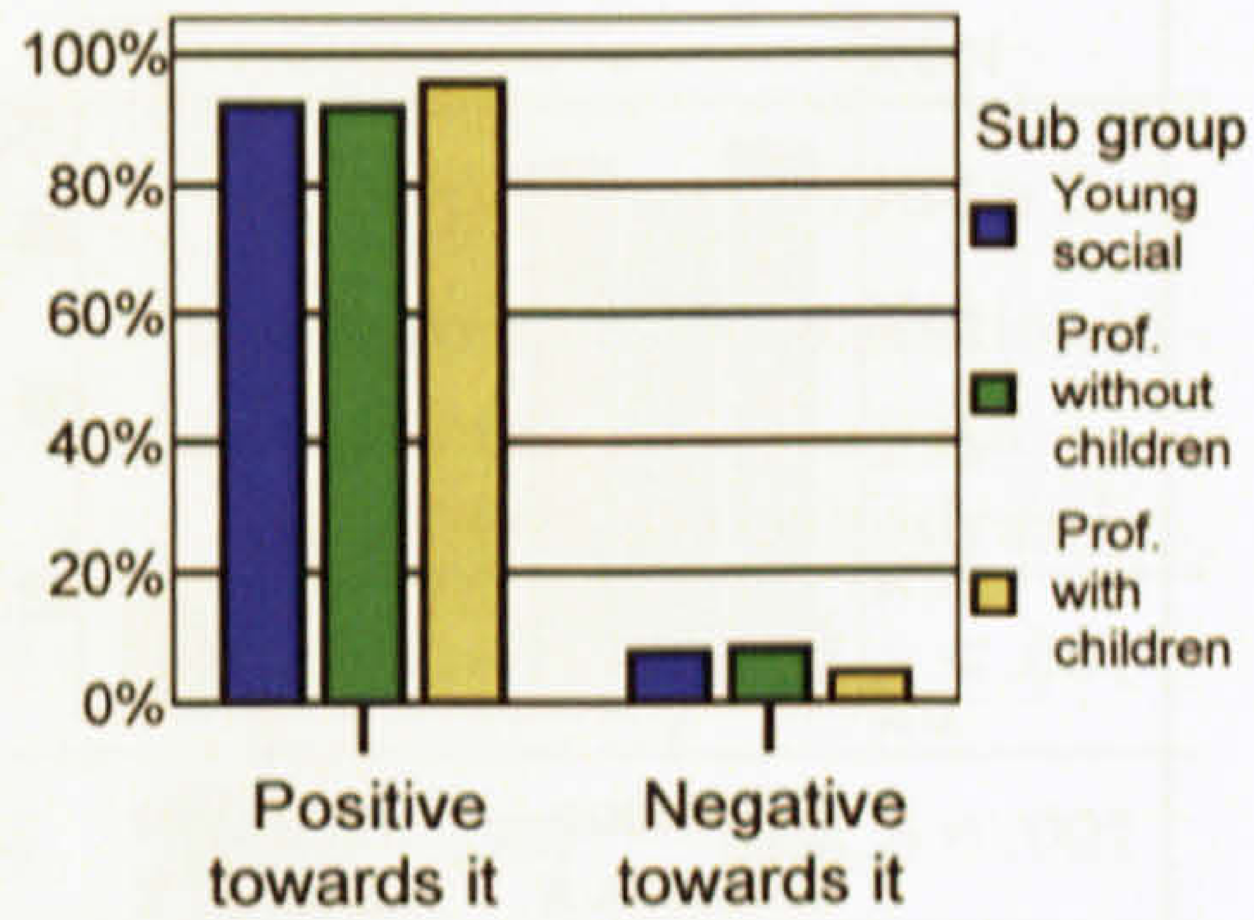
Driving Directions:

Overall attitudes towards it, by Group
n = 871, $\chi^2(2) = 7.961$, $p = .019$ (sig)



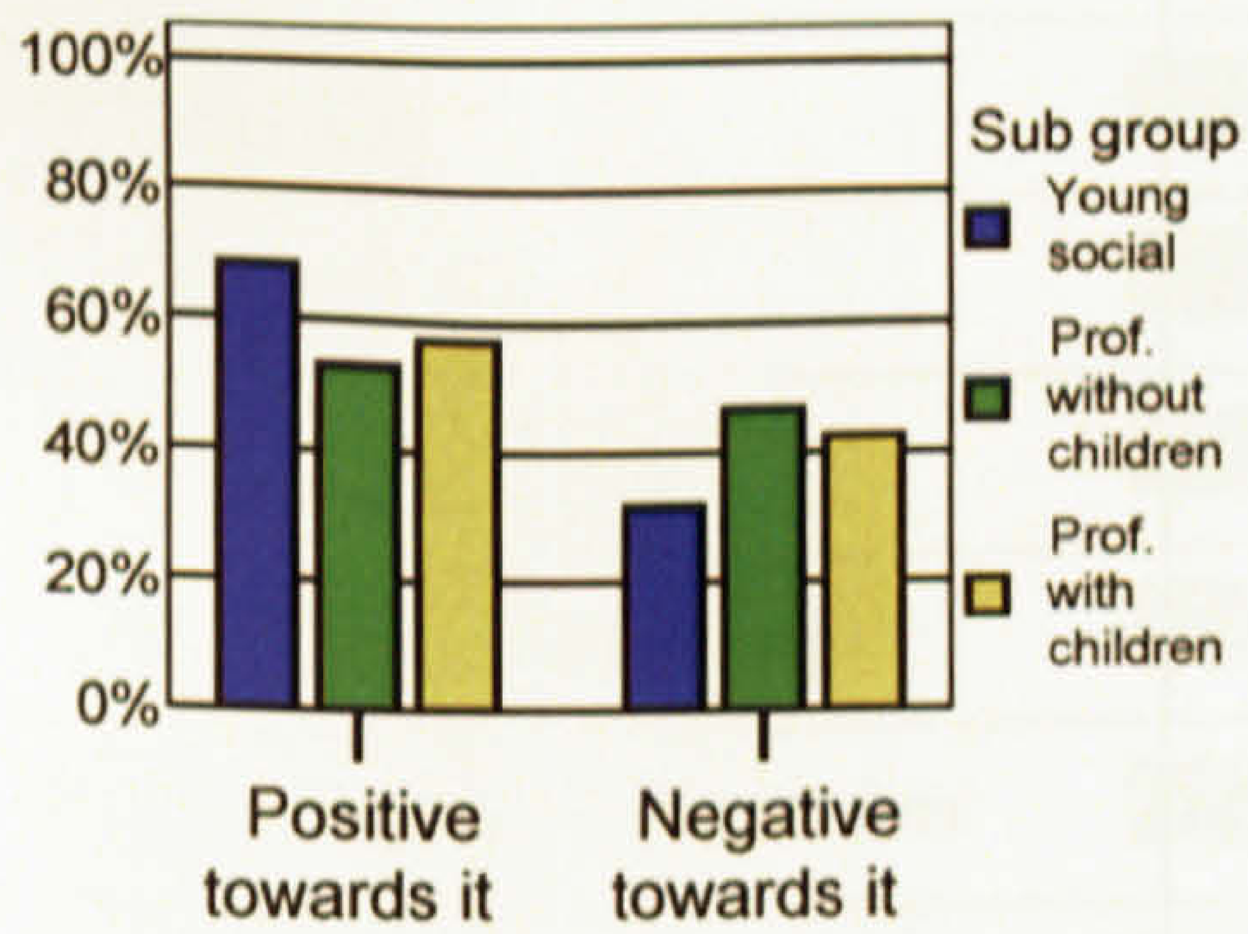
Traffic Information:

Overall attitudes towards it, by Group
n = 872, $\chi^2(2) = 19.242$, $p < .001$ (sig)



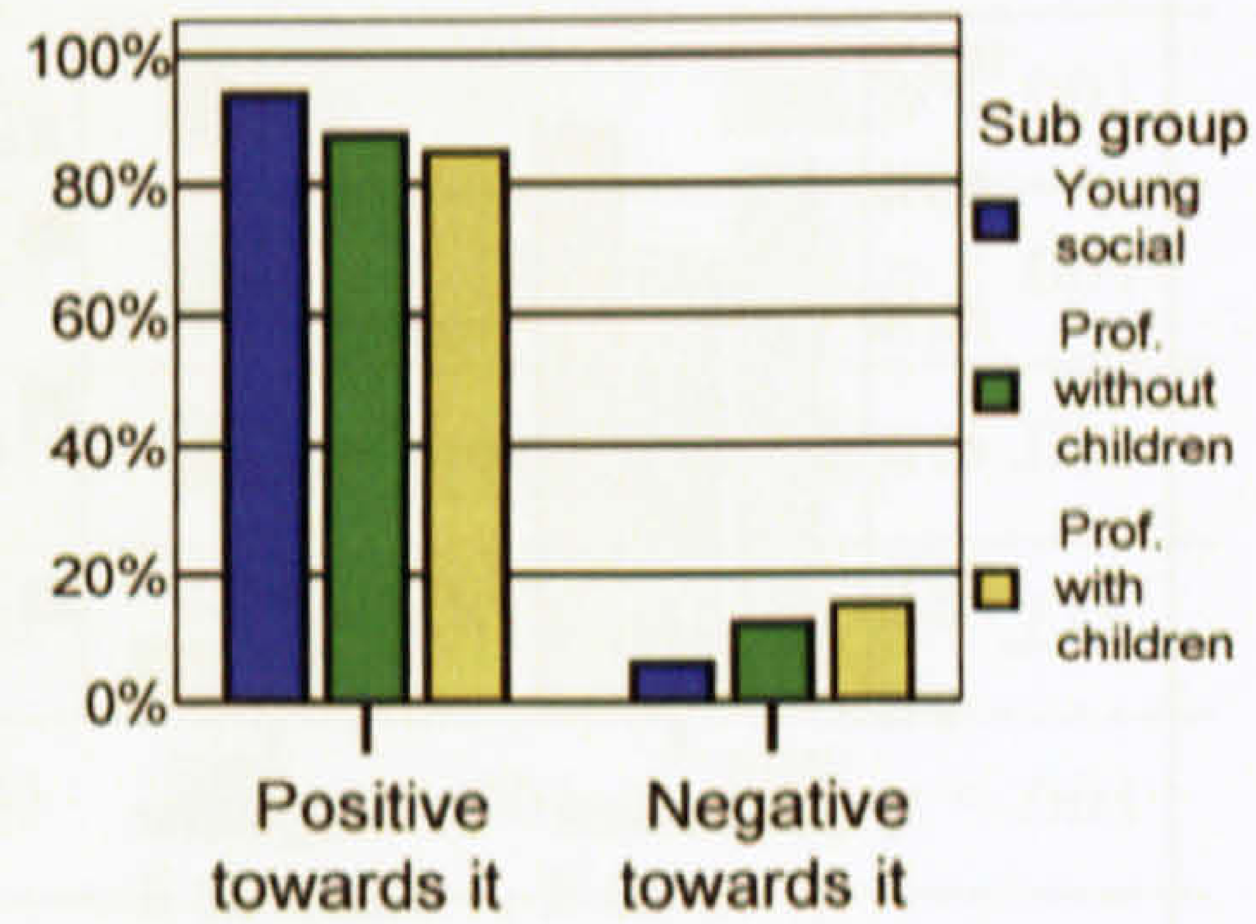
Roadside Assistance:

Overall attitudes towards it, by Group
n = 865, $\chi^2(2) = .989$, $p = .610$ (ns)



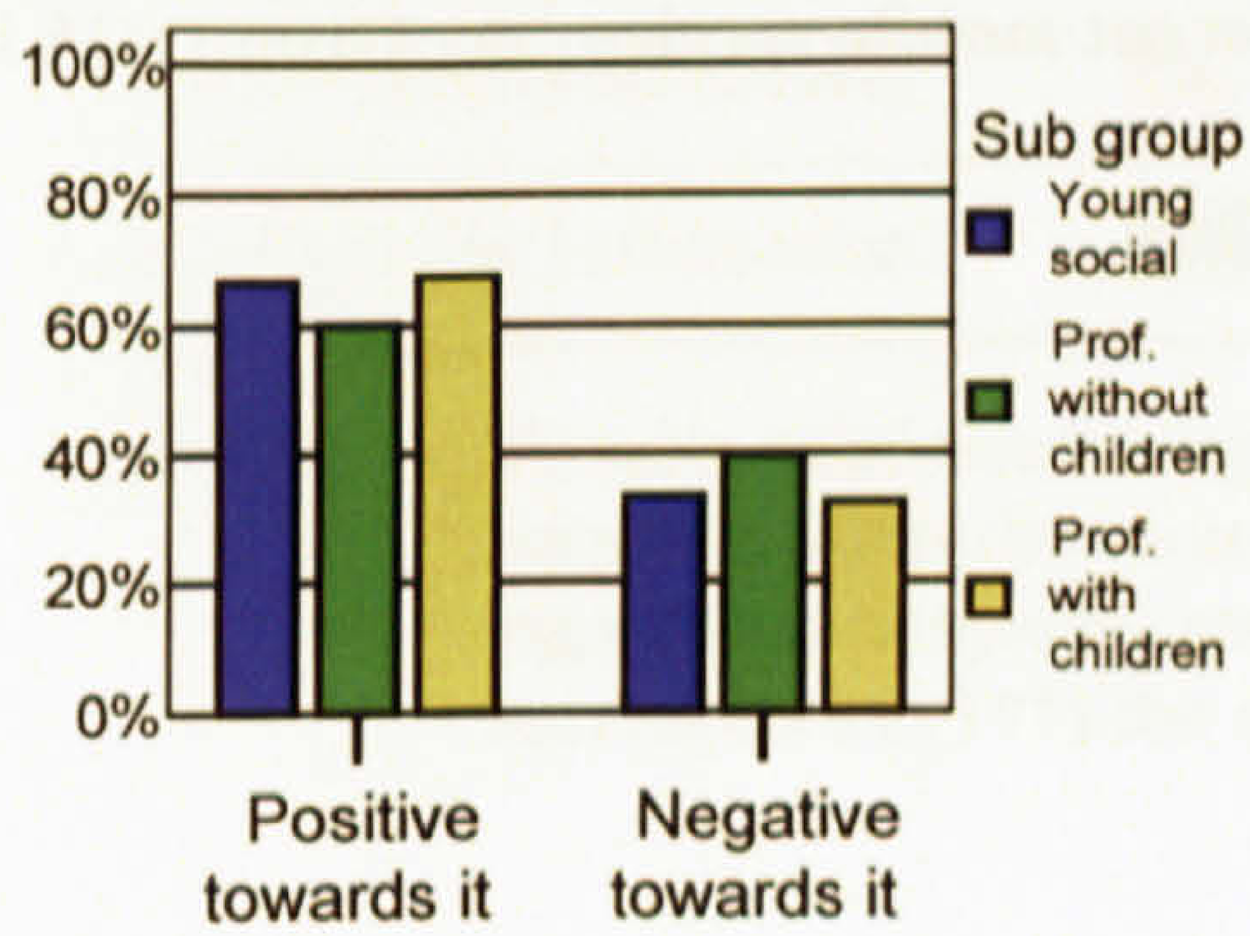
Safety Camera Information:

Overall attitudes towards it, by Group
n = 870, $\chi^2(2) = 10.719$, $p = .005$ (sig)



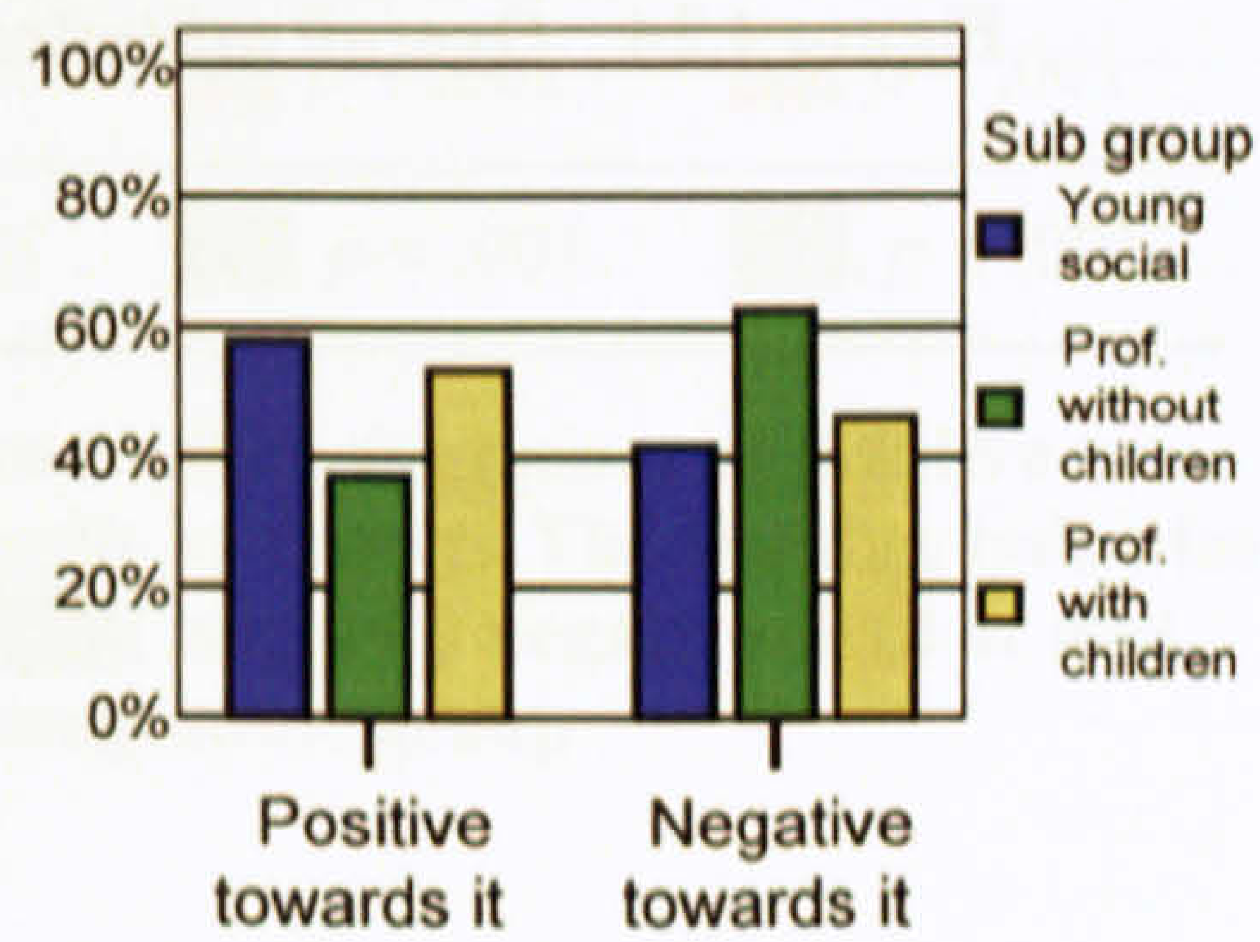
Public Transport Information:

Overall attitudes towards it, by Group
n = 873, $\chi^2(2) = 11.491$, $p = .003$ (sig)



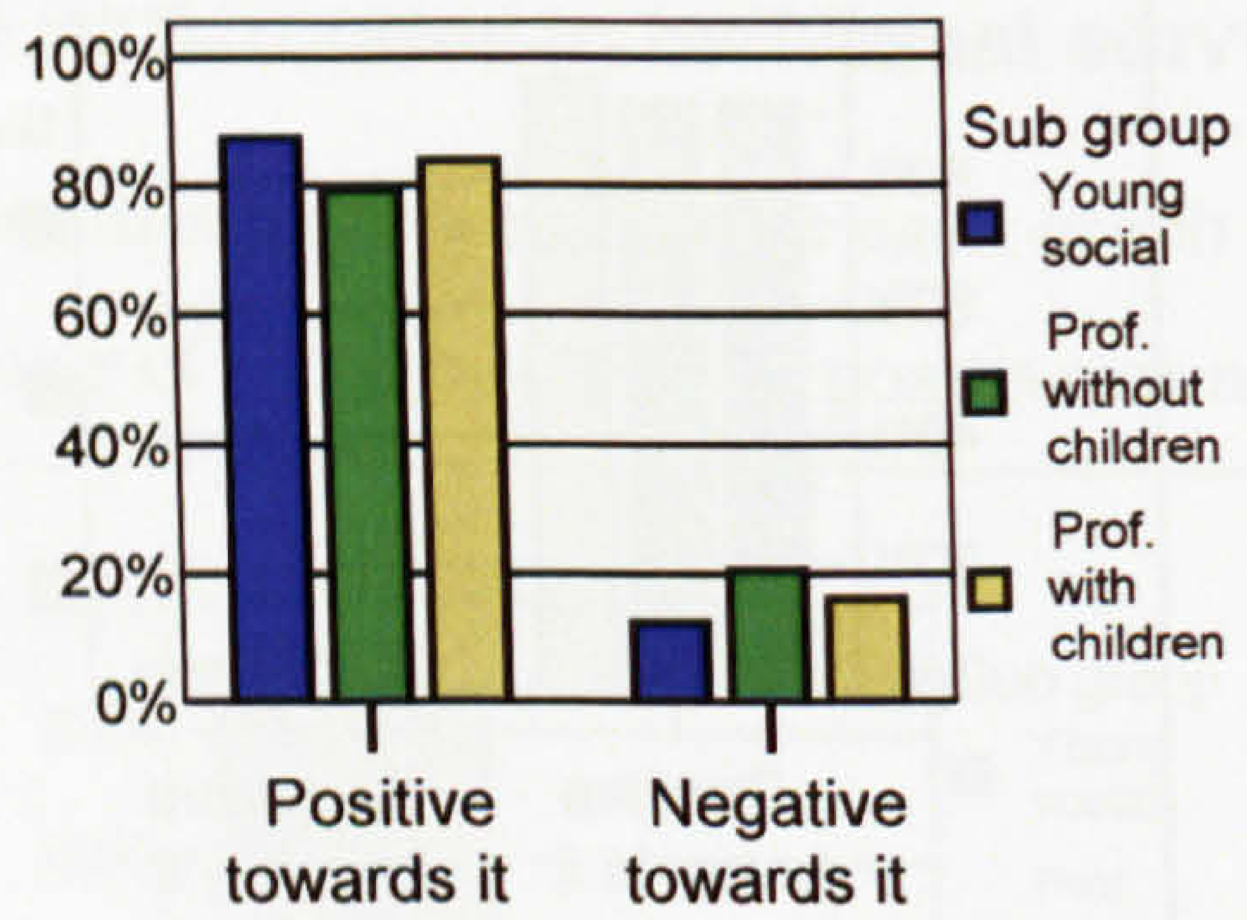
Friend Finder:

Overall attitudes towards it, by Group
n = 866, $\chi^2(2) = 1.709$, $p = .426$ (ns)



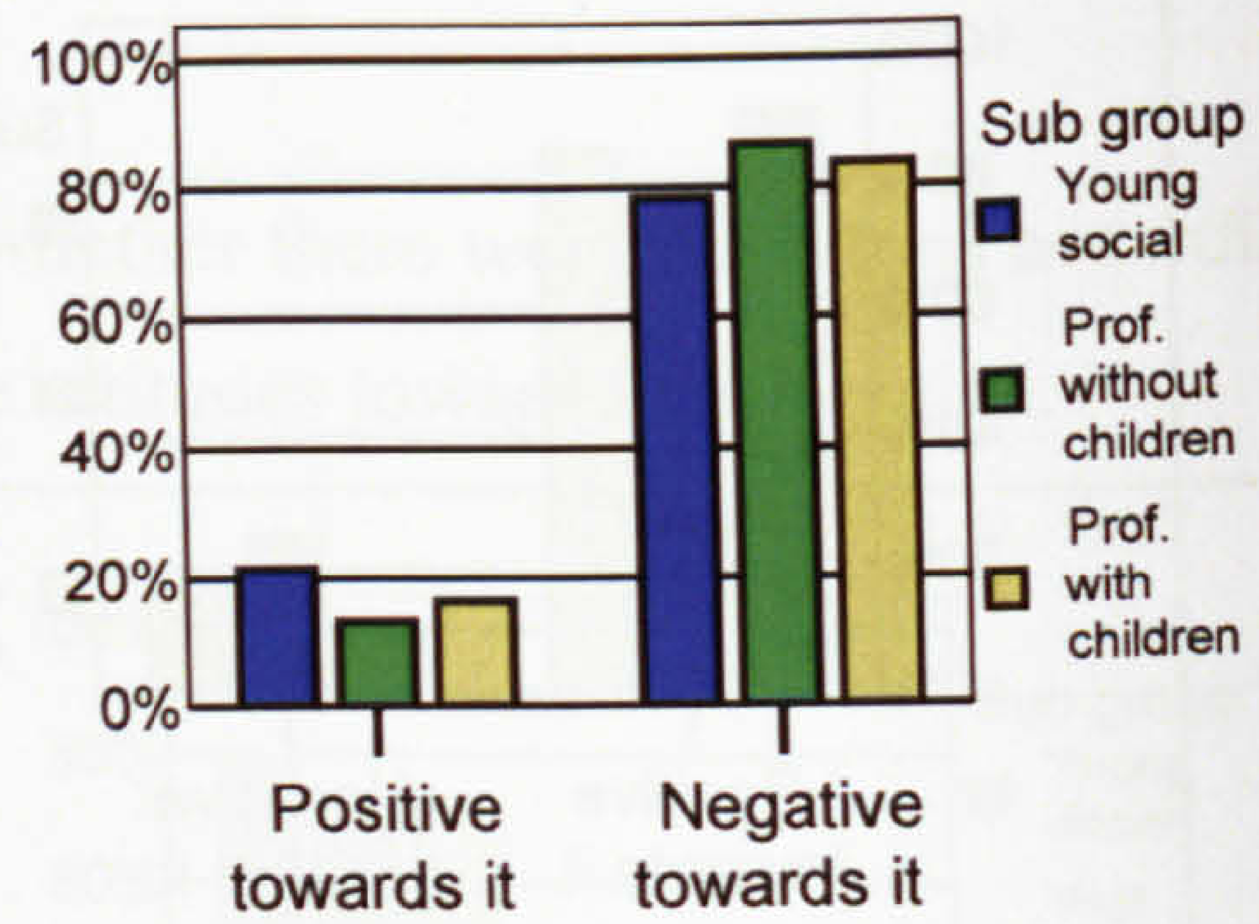
Location-based Games:

Overall attitudes towards it, by Group
n = 854, $\chi^2(2) = 14.759$, $p = .001$ (ns)



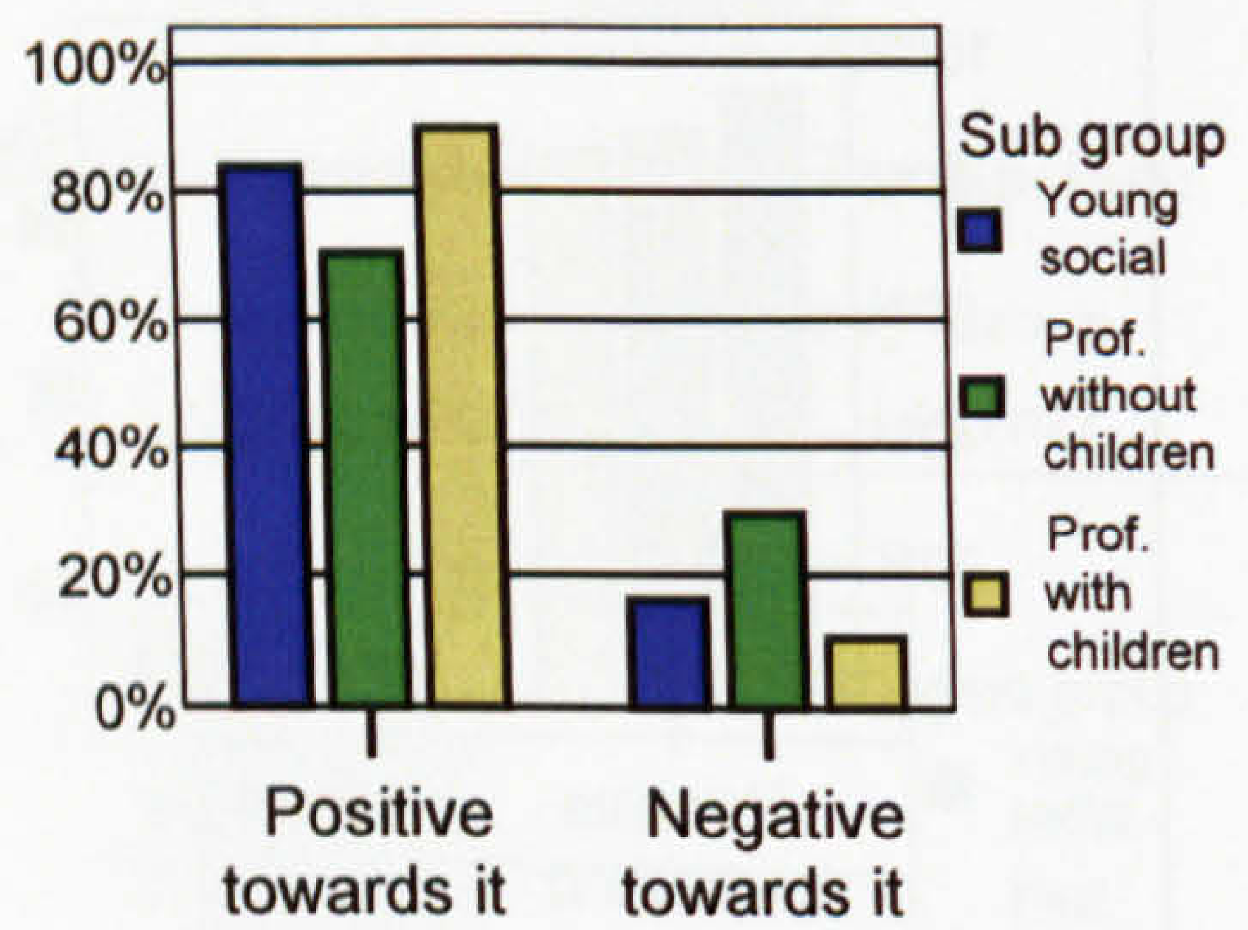
Mobile Booking / Paying:

Overall attitudes towards it, by Group
n = 867, $\chi^2(2) = 5.317$, $p = .070$ (ns)



Location-based Advertising:

Overall attitudes towards it, by Group
n = 876, $\chi^2(2) = 4.285$, $p = .117$ (ns)



Safety / Security Information:

Overall attitudes towards it, by Group
n = 863, $\chi^2(2) = 13.170$, $p = .001$ (sig)

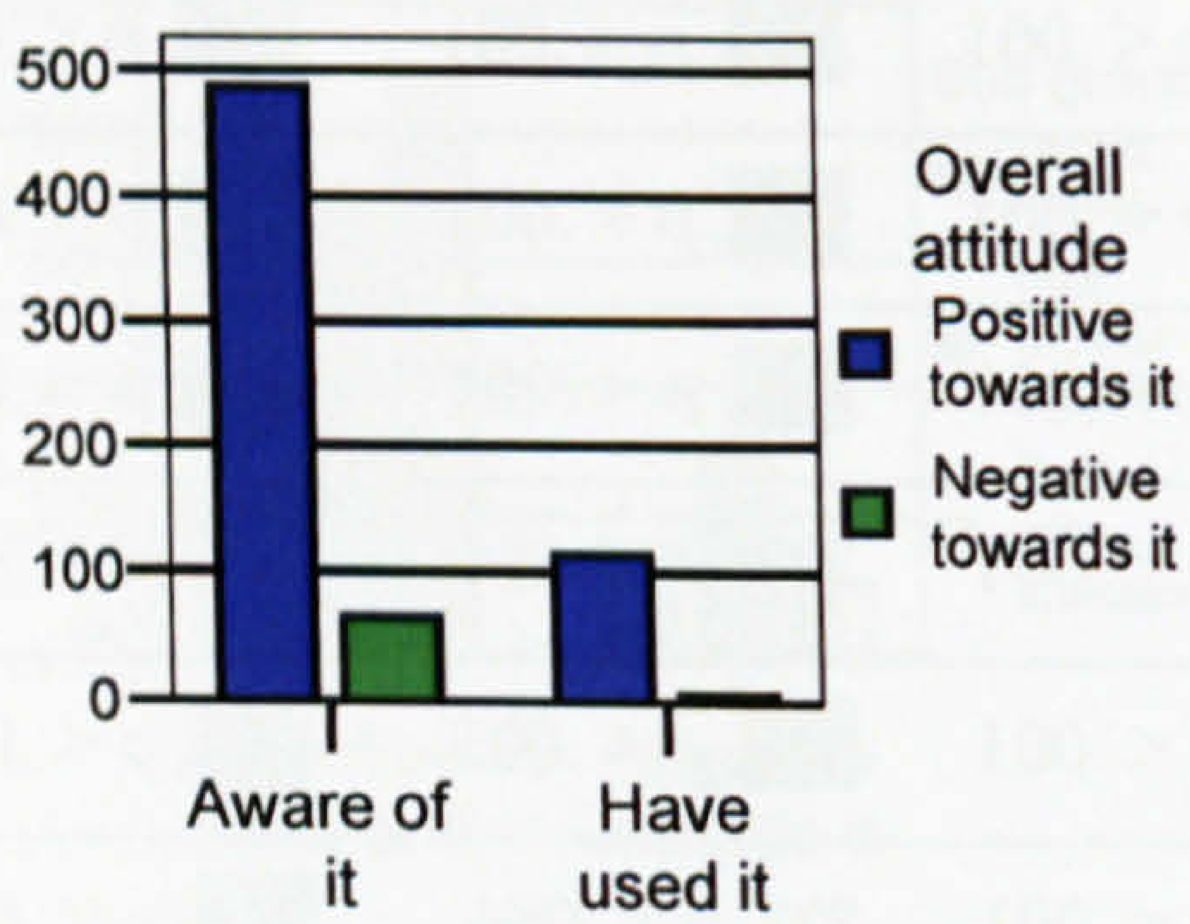
Figure 4.24 Overall attitudes to different mobile services, by Group (Q5.1b - 5.15b)

Mobile location service	**Group 1: 'Young social**	**Group 2 'Professional without children'**	**Group 3 Professional with children'**
'Nearest Services'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Local Weather'	+ve, $p < .001$	+ve, p < .001	+ve, $p < .001$
'City Guides'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Local Phone 'Numbers'	+ve, $p < .001$	+ve, $p < .001$	+ve, p < .001
'Walking Directions'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Driving Directions'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Traffic Information'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Roadside Assistance'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Safety Camera Information'	+ve, $p < .001$	???, $p = .614$	???, $p = .275$
'Public Transport Information'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Friend Finder'	+ve, $p < .001$	???, $p = .054$	+ve, $p = .005$
'Location-based Games'	+ve, $p < .001$	-ve, $p < .017$	???, $p = .625$
'Mobile Booking/paying'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$
'Location-based Advertising'	-ve, $p < .001$	-ve, $p < .001$	-ve, $p < .001$
'Safety/Security Information'	+ve, $p < .001$	+ve, $p < .001$	+ve, $p < .001$

Table 4.6 **Results of binomial significance tests on frequency of positive or negative attitudes to services, split by Group. The shading indicates significant majority positive (+ve), majority negative (-ve) or and mixed views (???) for each demographic group**

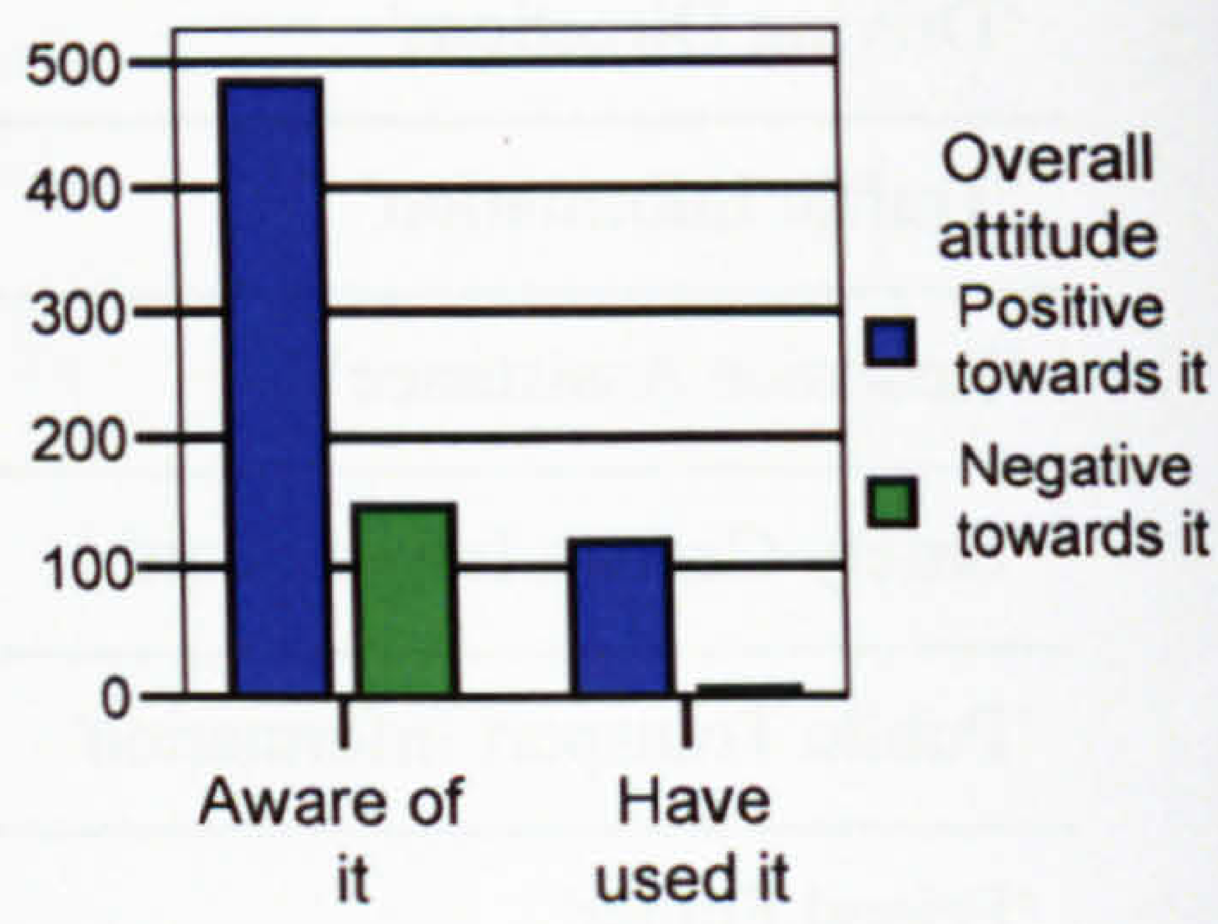
4.5.10 Attitudes based on awareness / usage

The following cross-tabulations demonstrate overall attitudes to different services, according to whether respondents were either aware of the service, or had actually used it. These graphs exclude all respondents who stated they had never heard of a particular service, and no differentiation is made between sample groups. The chi-square statistics for each graph show whether there were variations in proportions of positive versus negative attitudes according to whether participants were merely aware of, or had actually used a service.



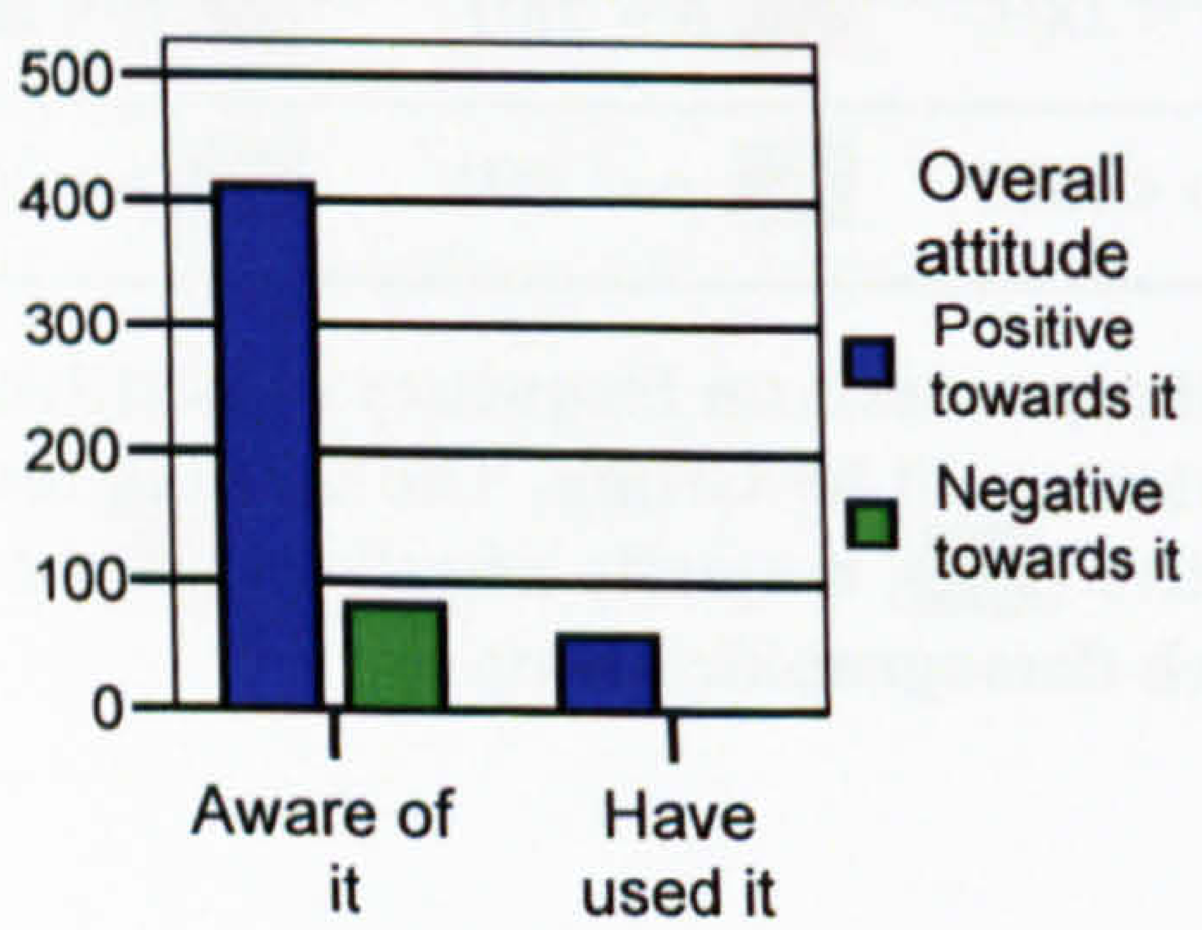
Nearest Services (e.g. nearest cashpoint):

Overall attitudes according to usage
n = 671, $\chi^2(1) = 4.615$, $p = .032$ (sig)



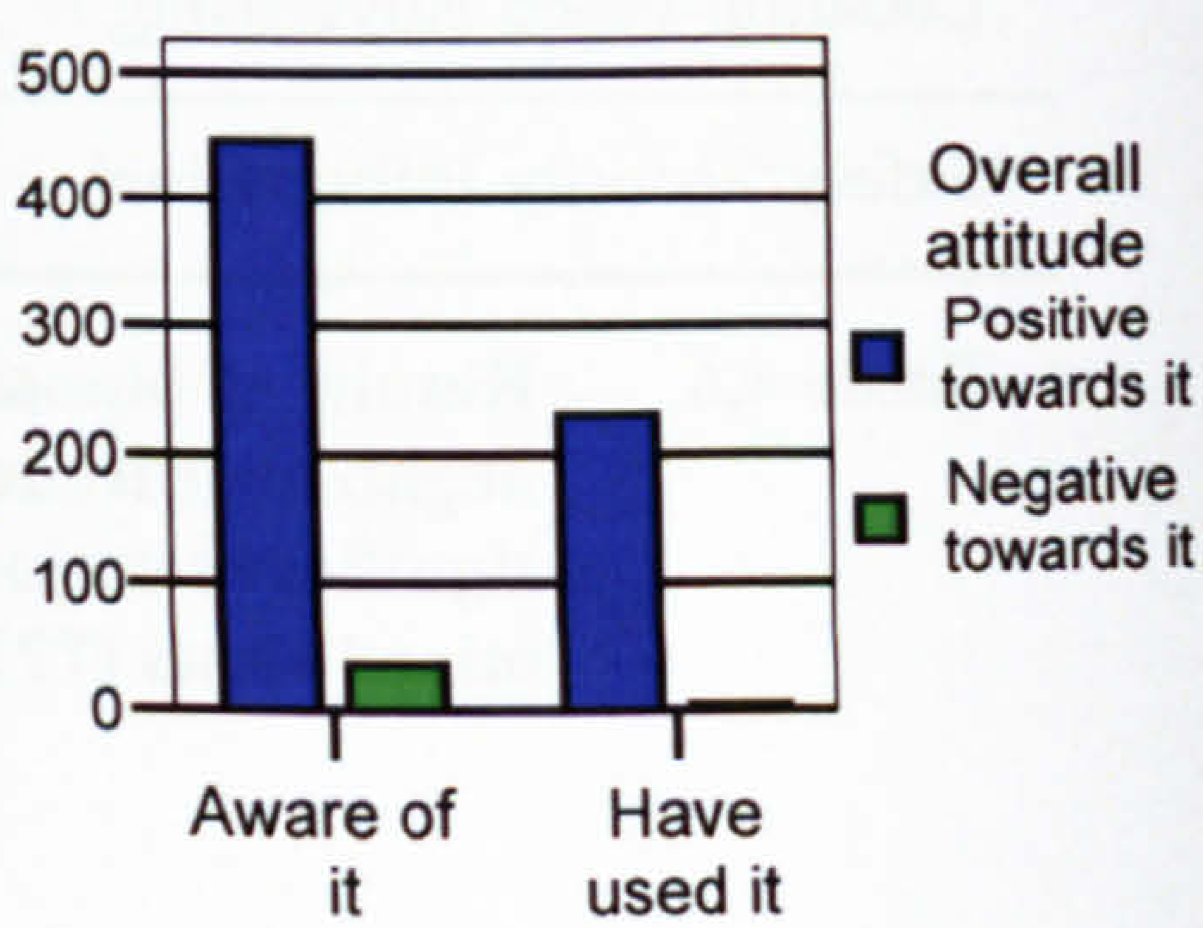
Local Weather:

Overall attitudes according to usage
n = 756, $\chi^2(1) = 22.161$, $p < .001$ (sig)



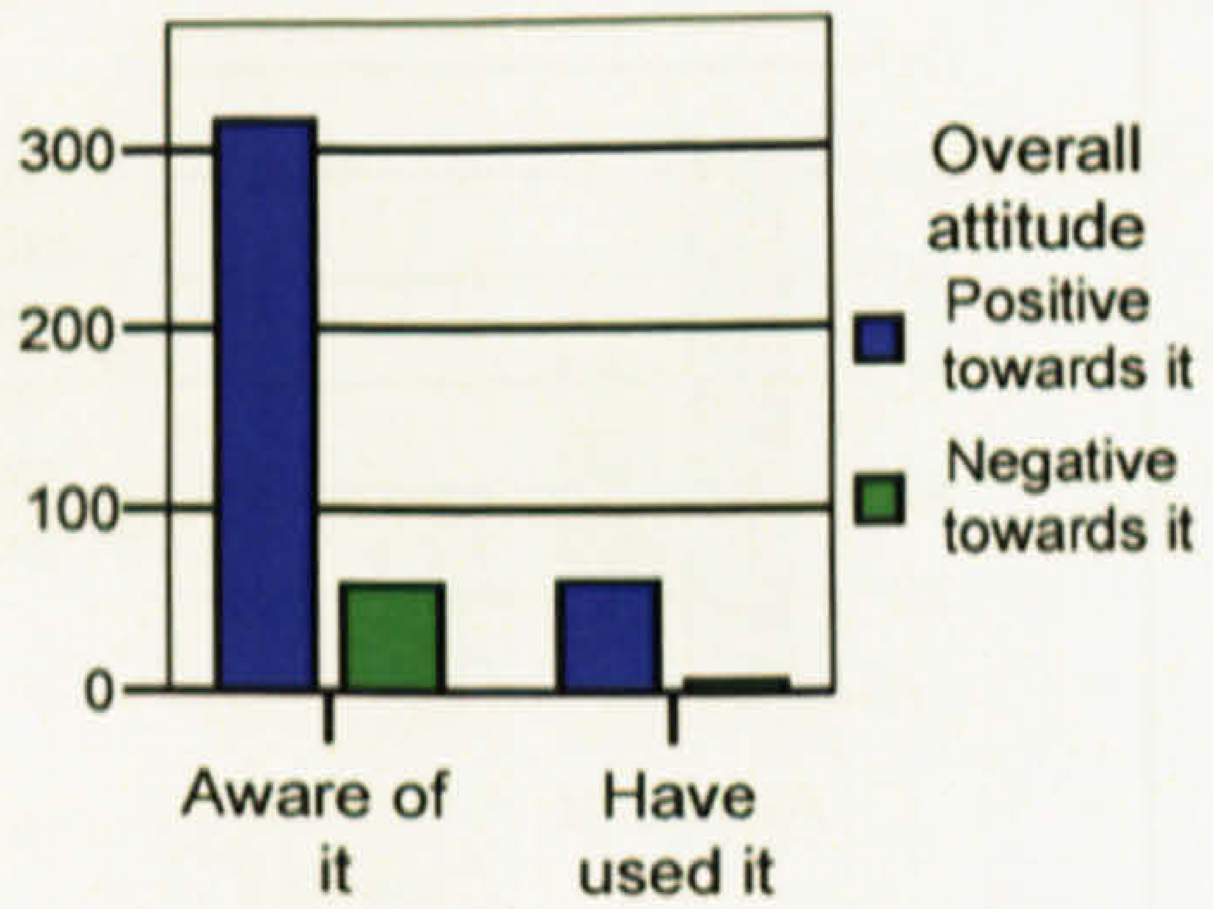
City Guides:

Overall attitudes according to usage
n = 553, $\chi^2(1) = 11.499$, $p = .001$ (sig)



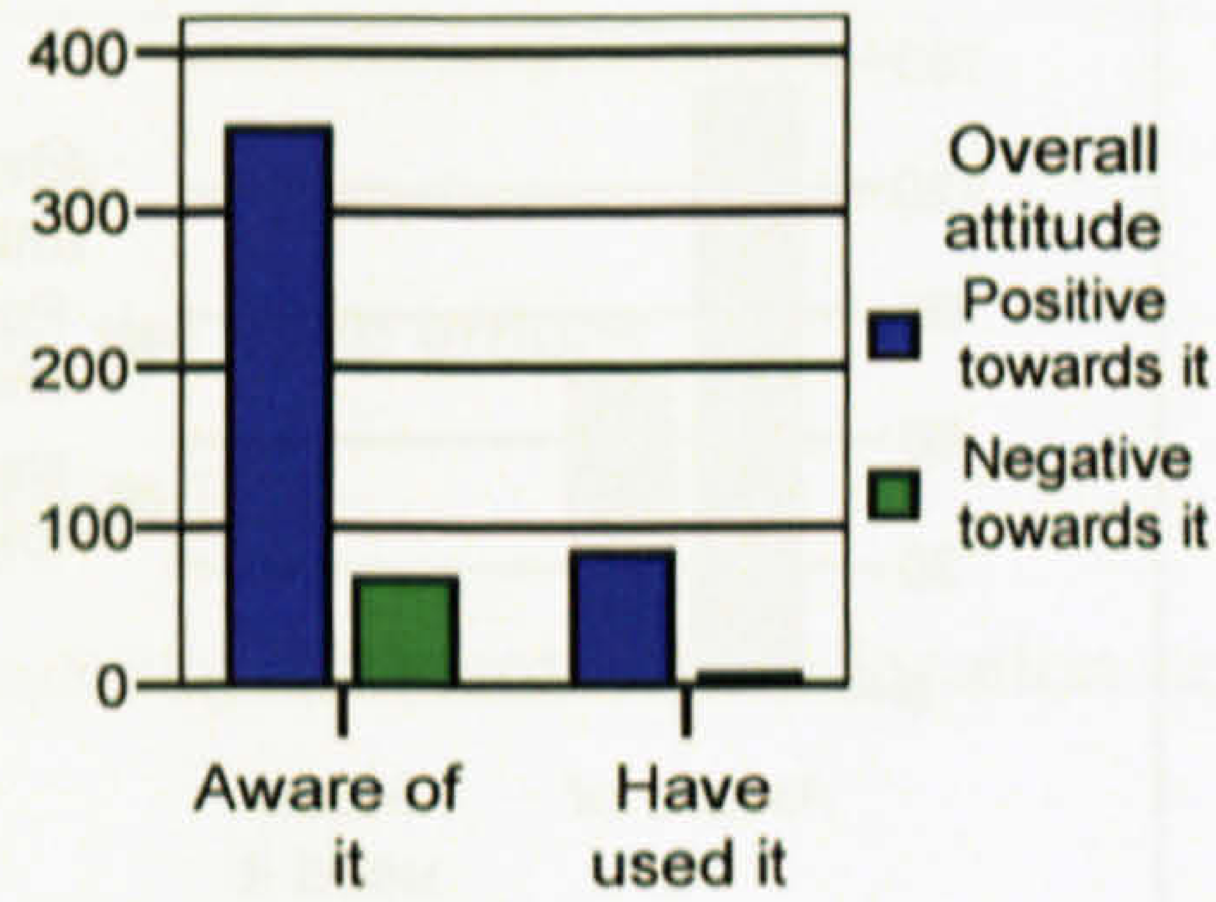
Local Phone Numbers:

Overall attitudes according to usage
n = 716, $\chi^2(1) = 9.907$, $p = .002$ (sig)



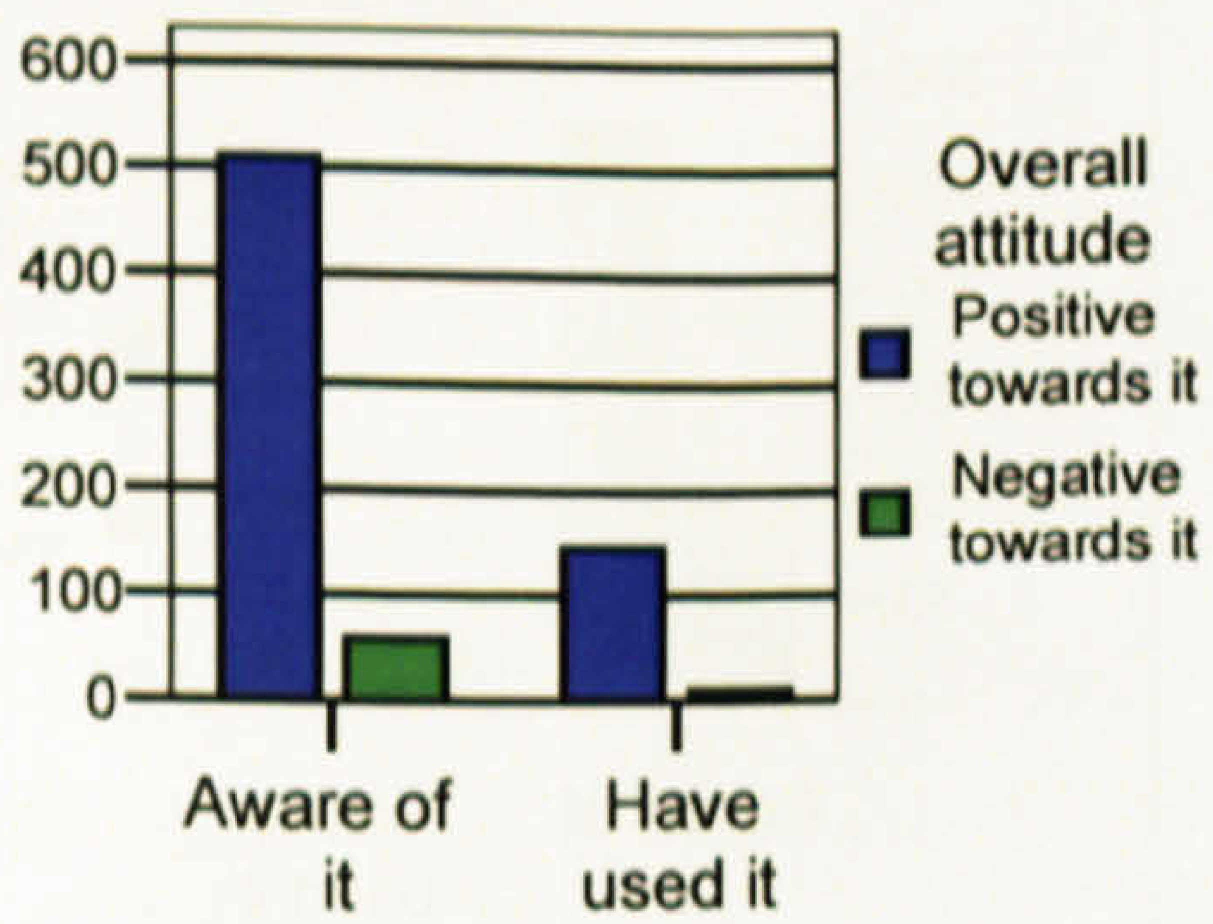
Walking Directions

Overall attitudes according to usage
n = 442, $\chi^2(1) = 2.082$, $p = .149$ (ns)



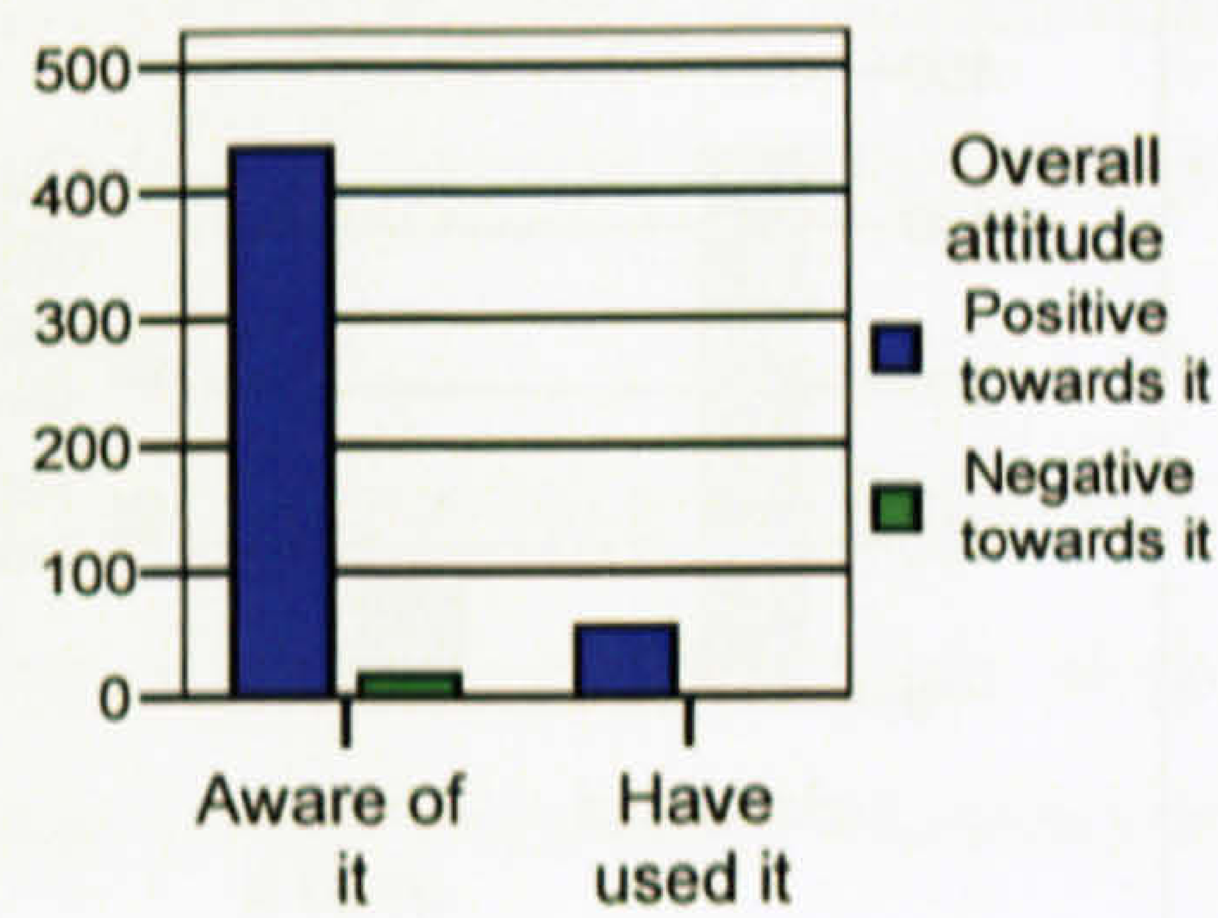
Driving Directions:

Overall attitudes according to usage
n = 510, $\chi^2(1) = 5.211$, $p = .022$ (sig)



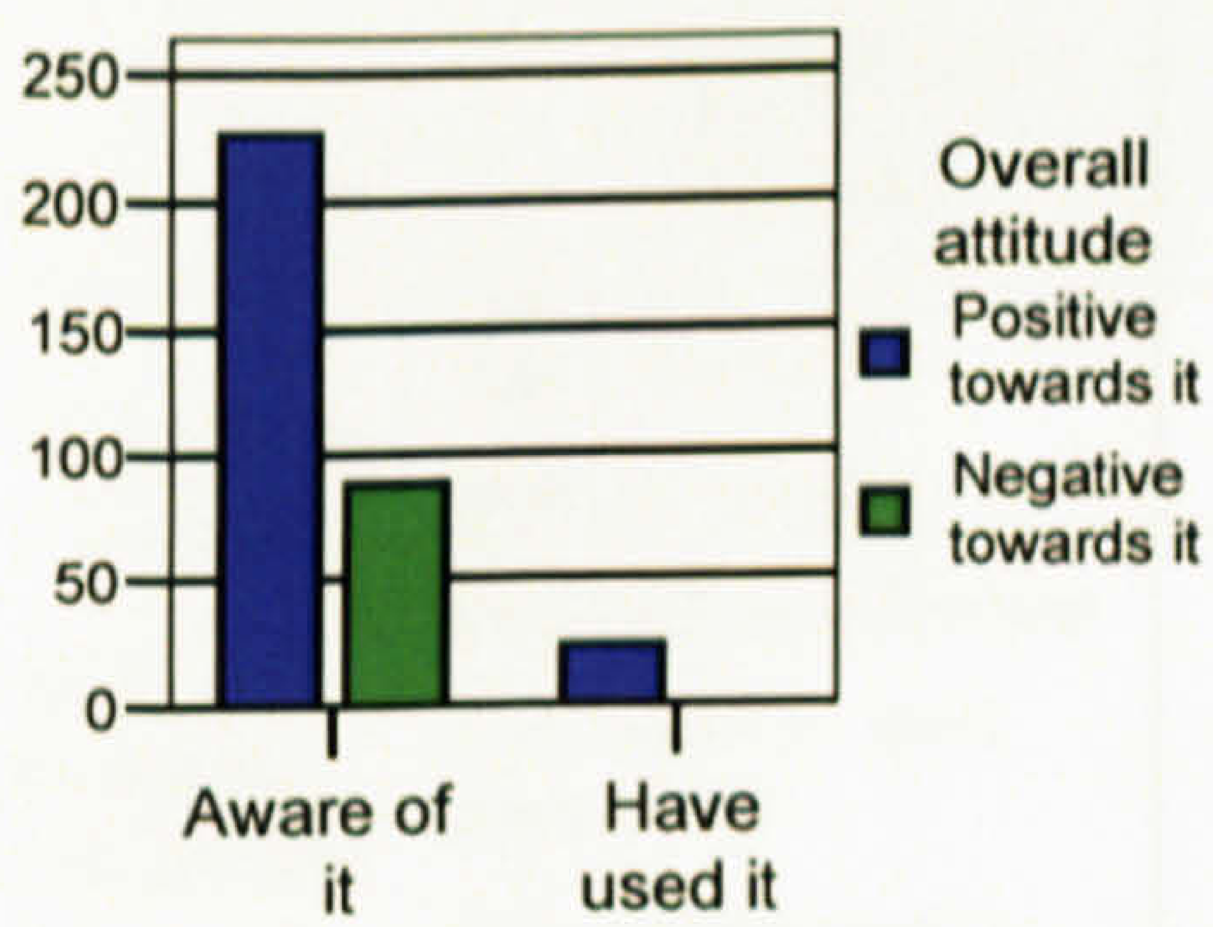
Traffic Information:

Overall attitudes according to usage
n = 723, $\chi^2(1) = 2.810$, $p = .094$ (ns)



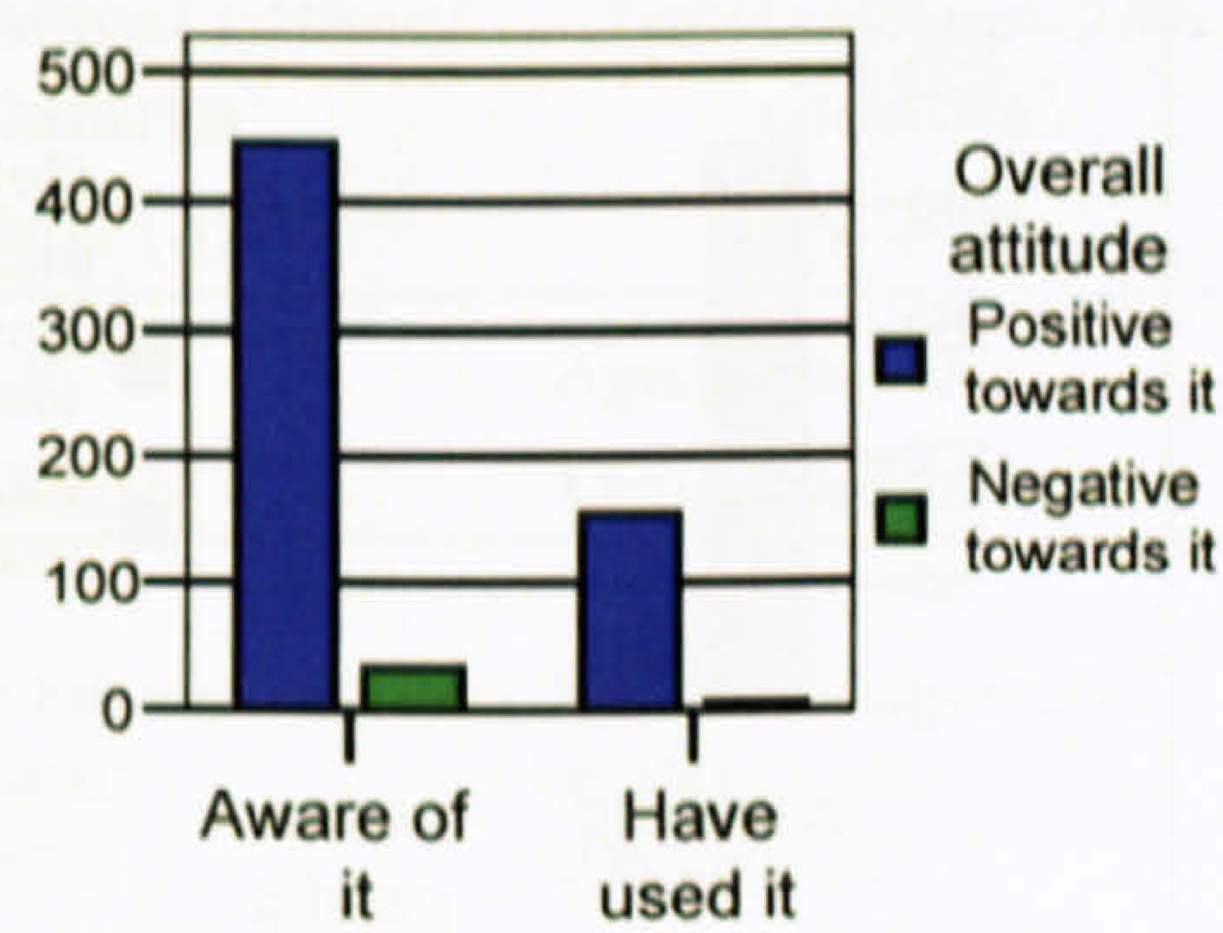
Roadside Assistance:

Overall attitudes according to usage
n = 506, χ^2 = N/A: 1 cell < 5, min = 1.85



Safety Camera Information:

Overall attitudes according to usage
n = 338, $\chi^2(1) = 8.687$, $p = .003$ (sig)



Public Transport Information:

Overall attitudes according to usage
n = 642, $\chi^2(1) = 2.306$, $p = .129$ (ns)

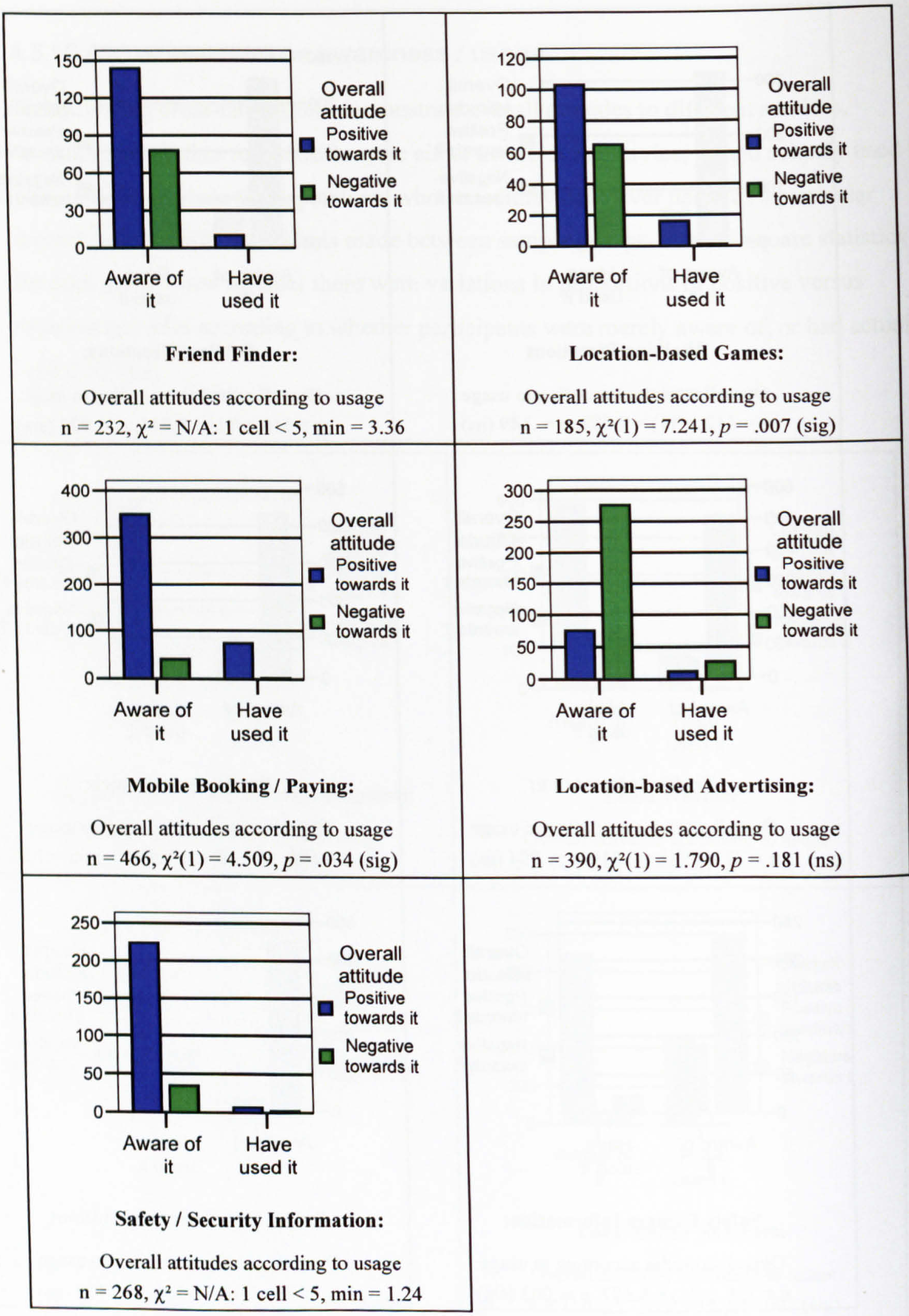


Figure 4.25 Overall attitudes to different mobile services according to degree of use, all Groups.

4.6 Discussion

This discussion of results comprises four sections:

1. Summary of the typical characteristics of the three groups
2. Description of their use of static and mobile ICT
3. Analysis of their awareness of and attitudes to different mobile location services
4. Analysis of their attitudes

4.6.1 Demographics of the sample groups

The sample was split into three groups as described in Section 4.4.2:

- Group 1, termed 'young social', representing 'MOKLOFS' (Lindgren et al. 2002
- Group 2 , termed 'professional without children', equivalent to 'YUPPLOTS' (Lindgren et al. 2002) but without children.
- Group 3, termed 'professional with children', representing 'YUPPLOTS'.

The table below summarises the most typical characteristics of each sample. Note that some criteria were those used to *select* participant groups, therefore a frequency of 100% results (e.g. use of a PC).

	Group 1 'young social' N = 737	**Group 2 'professional without children' N = 102**	**Group 3 'professional with children' N = 72**
About them:	Aged 19 to 23 Male or female	Aged 30 to 36 Male or female	Aged 35 to 40 Male or female
Work and education was defined:	Currently at university 2 or more 'A' level passes Not in employment	Working full time in professional employment	Working full time in professional employment
Living arrange-ments varied:	Living in a town (Loughborough), in official accommodation (e.g. halls of residence), or sharing with friends or lodgers Have no children Have lived in this area for 5 years or less	Living in a town or city with partner or spouse, or living alone Have no children Have lived in the same town for up to 5 years	Living in a town or village as a parent in a family unit Have at least one child Have lived in the same area for slightly longer than Group 2

They were highly mobile:	Walk to university, this trip being 2 miles or less, and taking 30 minutes or less Don't undertake any trips which are directly study-related Typically undertake up to 10 leisure trips per week, these mostly being on foot	Drive to work, this journey being up to 30 miles, and taking up to an hour Undertake up to 5 work-related trips per month, these being by train or car Typically undertake up to 15 leisure trips per week, using a range of transport modes, but these mostly being by car or on foot	Drive to work, this journey being up to 30 miles, and taking up to an hour Undertake up to 5 work-related trips per month, these being by train or car Typically undertake up to 10 leisure trips per week, these almost entirely being by car
They were frequent users of technology:	Use a mobile phone, PC and the Internet, and also likely to use a digital camera and DVD player. May also use a games console, MP3 player and digital TV	Use a mobile phone, PC and the Internet, and also likely to use a digital camera and DVD player May also use a digital TV and PDA	Use a mobile phone, PC and the Internet, and also likely to use a digital camera and DVD player May also use a digital TV, MP3 player, games console and PDA

Figure 4.26 Summary of characteristics of the differentiated groups

In addition to suggesting that respondents were highly mobile and receptive to new technology, the results appear to justify differentiation between professionals with, and without children. The former were older, more likely to live in a village location, undertook fewer leisure trips, but made these trips almost exclusively by car.

4.6.2 The use of static and mobile ICT

The frequency of use of static and mobile ICT is shown in Figure 4.20 which shows the typical usages per *week day* (as indicated by median responses from respondents within each sub group). Figure 4.21 shows equivalent data per weekend day plotted on the same vertical scale; no distinction was made between Saturday or Sunday. Medians were plotted since the frequency data was positively skewed.

It can be seen that the 'young social' group made heavy use of instant messaging on a PC, web access, and SMS, and less use of email and voice calls over mobile. They tended not to access the web on a mobile phone, sent relatively few texts to interactive services, or sent few photo or video messages, and made few landline calls. Kaasinen (2005) noted that although the market share of mobile phones with photo and video features has grown, relatively few users actually *send* photos or videos to others. The patterns of usage for week and weekend days were very similar, with slightly more calls (mobile and landline) being made at the weekend than during the week.

As shown in Figure 4.20 and Figure 4.21, the 'professional with children' group have a similar pattern of usage of static and mobile ICT to those without children. During the week, they make greatest use of email, web access via a PC and landline calls, and also make limited use of calls and SMS via mobile phones. As per the younger group, they do not access the web on a mobile phone, send texts to interactive services or send photo or video messages. During the weekend, they make less use of web access, and send far fewer emails than during the week.

There were several key differences according to group. By inspection, the 'young social' group differed considerably from the two other groups, and the presence of dependent children did not appear to differentiate the use of ICT by older professionals. For statistical analysis, the two professional groups were combined, and comparisons made between the frequency of use of individual ICT by the 'young social group' and a combined 'older professional group', the latter including those with and without children. Mann-Whitney U non-parametric tests were used to identify significant ($p < .05$) differences between the two groups.

The main differences between the two 'young social' and 'older professional' groups were that the younger group made much greater use of instant messaging via PC both during the week ($U = 22421.5, p < .001$) and weekends ($U = 16978.5.5, p < .001$), and greater use of mobile text messaging to other individuals, again during the week ($U = 35124, p < .001$) and at weekends ($U=28523, p < .001$). At weekends only, they also made heavier use of PC-based web access ($U = 42991.5, p < .001$), and mobile voice calls ($U = 38257.5, p < .001$). Although usage rates were very low (and the median is shown as zero in Figure 4.21), at weekends the 'young social' group were also more frequent users of the web via a mobile phone ($U = 46130, p = .008$) and sent more picture/video messages ($U = 46084.5, p = .002$).

In contrast, the older group made a greater number of landline calls during the week ($U = 19584, p < .001$) and at weekends ($U = 24625.5, p < .001$), and sent more emails during the week ($U = 34651.5, p < .001$) but not at weekends. There were no other significant differences between groups.

There were two key patterns of behaviour that emerged from the self-reported use of mobile and static ICT. The younger group made greater use of mobile and instant communication channels than the older group. The older group tended to make more use of static and asynchronous communication and information access. This is despite the similar levels of ownership of mobile phones, as shown in Figure 4.19 and regular use of PCs with internet access by all respondents. There were marked differences in ICT use during the week as opposed to weekends for the older profession group, whereas the distinction between weekdays and weekends made little difference to the 'young social' group'.

There were two likely main reasons for the results shown in Figure 4.20 Figure 4.21: (a) motivators/perceived needs based on lifestyle (including work aspects), and (b) opportunities, enablers and constraints based on the situated context of the two user groups. The use of mobile communication and information access channels by the younger group reflected the highly social and mobile lifestyles of the younger group, and is consistent with the use of mobile messaging to support their needs (Reid and Reid 2005). However, most of the 'young social' group were students, who had unlimited web access either in halls of residence or in their academic department and this is also reflected in the high use of instant messaging and web access by the younger group.

As well as a requirement for more formal electronic communication during the week, the professional group was likely to have greater access to office-based fixed ICT channels, at least for parts of each working day. At these times, the use of mobile media will add little value to them, since when office-based, they have easy access to more convenient and/or cheaper information channels (i.e. PC rather than mobile web access) and communication (landline rather than mobile calls). There is a clear difference between ICT use at weekends and during the week for the professional groups, reflecting the work/home distinction for this group.

4.6.3 Levels of awareness and use of mobile location services

Figure 4.23 shows the level of awareness or usage for each of 15 different mobile location services. There was a low degree of usage of all of these services. There was only one service where more than 20% of respondents had actually used it: local traffic information. Respondents were generally aware of being able to access local weather information via a mobile phone, but had not actually tried this. Respondents tended to be unaware of the existence of services such as 'friend finder', location-based games, access to safety/security information via a mobile, and location-based advertising. This mirrors the lack of sufficient knowledge of services found by Andersson and Heinonen (2002) in the Swedish market, the relatively low level of use of mobile services in Finland found by Carlsson et al. (2005) and the general lack of use of advanced capabilities on phones (Kaasinen 2005). Even more recently, market research has found that 'consumer awareness and understanding of mobile operators' offerings are woefully inadequate' (InStat 2007). For all other services (listed in Table 4.2), respondents were fairly evenly split between having never heard of them, or being aware of them without having actually used them.

There were few differences between the three demographic groups. A greater proportion of the 'young social' group had accessed information on local phone numbers via their mobile. This information was consistent with the social nature of their lifestyle (i.e. a *need*), and the lack of availability of this information via traditional non-mobile means such as the telephone directory and fixed web access (i.e. *constraints* on information access imposed by the mobile context of use).

As shown in Figure 4.16, and contrary to expectations, the younger group did not undertake more 'leisure' journeys (although it is recognised that the description is broad and potentially ambiguous). Rather than having a greater need, this suggests a greater integration of mobile technology within the lifestyles of the younger group.

The older professional group with children tended to make less use of walking directions, and greater use of roadsides assistance via mobile, presumably due their greater use of cars for commuting, work and non-work related journeys. Correspondingly, the 'young social' group tended to make greater use of public transport information.

The clearest findings from Figure 4.23 were that the incidence of use of mobile location services was low, and in most cases was less than a third of the level of awareness of a service. In addition, differences in the level of awareness or usage were much more dependent on the particular service in question, than the demographic group.

4.6.4 Overall attitudes to technology

Figure 4.22 demonstrates a degree of validation of the filtering of data, and differentiation between different user groups. As shown in this figure, the majority response from all three groups was that they liked to try out new technology and were motivated by the opportunity to improve their lifestyle. This supports the suggestion by Lindgren et al. (2002) that these demographic groups (as differentiated within this sample) tend to be early adopters. However, it also shows that these groups cannot be *defined as* early adopters, as there is a sizeable proportion (between 30-40%) of all groups who adopt a 'wait and see' attitude. The majority response from all three groups was that they liked to try out new technology and were motivated by the opportunity to improve their lifestyle. Interestingly, although the 'young social' group had the highest proportion who 'liked to be the first' with new technology, they also had the highest proportion who fell into the 'wait and see category'; this indicates a more heterogeneous sample than for either of the two 'older professional' groups.

Statistical analysis was undertaken using cross-tabulation and chi-square tests based on data being categorical, but also using non-parametric tests (since the categorical responses could also be plotted as ordinal data according to 1 to 5 as shown in the figure). There were no statistically significant differences between the groups in terms of adoption attitudes to new technology.

4.6.5 Attitudes to services

Figure 4.24 shows whether respondents held either negative or positive attitudes to each of the 15 services. This is a very basic analysis, since within the questionnaire, respondents were only asked to indicate their level of awareness regarding each service ('never heard of it', 'aware of it', or 'have used it') and then whether they were 'mostly positive' or 'mostly negative' towards that particular service. Figure 4.24 clearly shows that for most services, the majority response (by a factor of over 4:1) was that respondents were generally positive towards that service. A binomial test was carried out for each group to test for significant consensus of response, based on comparison with an expected random 50:50 distribution. This is shown in Table 4.6. In relation to mobile services more generally, Lindgren et al. (2002) state that there is 'a latent need' for mobile services, and Andersson and Heinonen (2002) describe a high interest in some potential services. However, these authors also highlight the critical nature of usability - termed 'user-friendliness' by Lindgren et al. (2002) - and that users may not actually become users of these services even if they are interested in them.

There were overtly negative opinions towards location-based advertising from all groups. This is probably due to concerns about intrusiveness, privacy and trust issues, which have been discussed by various authors, e.g.: Myles et al. (2003), Kaasinen (2003), Ng-Kruelle et al. (2002), Farrell et al. (2003), and are the specific focus of current research into MLS (CityWare 2006). However, firm conclusions cannot be reached based on the data from this survey. The results of the survey are also counter to the relatively upbeat message of Yunos et al. (2003) who present technical and business barriers, but suggest that users are looking for 'a better user experience and richer media adverts'. While focusing on business and technical issues, these authors fail to discuss how the properties of mobile devices can be used to increase the relevance of adverts.

The 'young social' group showed significant consensus of positive general attitudes to all other services, demonstrating the general acceptance and integration of mobile services within their lifestyles.

Both older groups held mixed overall attitudes to services providing information on safety (speed) cameras. It is likely that attitudes were influenced by the usefulness of knowing where these cameras were, coupled with a desire to see them catch motorists who are speeding (i.e. a conflict between personal and societal good).

The older professional group without children were negative towards location-based games. This may be due to a lack of awareness of these services – a general problem noted by Andersson and Heinonen (2002). In contrast, the older professional group with children were more ambivalent towards location-based games, possibly due a greater exposure to mobile gaming from their children.

The binomial test (using a 50:50 comparison criterion) was a relatively insensitive measure of consensus opinion. By inspection, the older groups were relatively more positive towards to access to local weather services, driving directions, traffic information and safety/security information. This can be related to the high number of car journeys undertaken by this group, the generally increased awareness of safety and security issues while responsible for children, and the impact of the weather on many of the activities undertaken as a family.

An additional cross tabulation analysis was undertaken of the level of awareness ('never heard of it', 'aware of it' or 'have used it') with the overall attitude towards the service ('mostly positive' or 'mostly negative'). This can show whether positive or negative attitudes are associated with either awareness of a service, or usage of a service. It is not possible to state a simple causal relationship between these two variables, since the level of usage of a service will be influenced by the attitudes an individual hold towards it (Ajzen and Fishbein 1980; Davis et al. 1989), but attitudes will also *arise from* beliefs regarding a service, developed through a level of awareness or usage experiences with a service. Figure 4.25 suggests that if individuals actually use services, they tend to be positive about them, consistent with the adoption models that take into account volitional behaviour, e.g. the Theory of Planned Behaviour (Ajzen 1991). Those more positive towards a service were therefore also more likely to be users of a service.

An assumption may be made that where a respondent stated they had used a service, but are negative towards that service, that this negative attitude stems from judgements based directly on that usage (since negative attitudes arising from a mere *awareness* of a service are unlikely to have led to usage by that individual, since usage of these services is almost certainly volitional). Figure 4.25 therefore potentially shows three types of attitudinal response: (1) positive or negative attitudes based on a certain level of awareness of a service, without any direct experience of that service; (2) positive attitudes associated with usage - where there were initially positive attitudes associated with awareness, which then led to usage, and a maintenance of those positive attitudes; (3) positive attitudes on awareness, leading to usage, and subsequent change to negative attitudes. The negative attitudes based on usage therefore probably represent an extreme case of a change in attitude of the individual, and highlight where the user experience with a service has been particularly poor based on positive prior expectations.

4.7 Critique of study

The aims of the study were to understand current early adopter consumer behaviour and attitudes in relation to existing and emerging services that can be delivered over a mobile phone. The study was successful in attracting a substantial number of respondents (1276 of which 365 were discarded as not falling into the demographic groups of interest). However the differentiated sample was dominated by the 'young social' group (81%), with only 11% and 8% falling into the professional groups without and with children respectively. Despite this imbalance, the minimum recommended expected cell sizes for basic cross-tab analyses were met in the majority of cases, since the numbers falling into these categories were still relatively large at N = 102 and N = 72 respectively. Where a minimal expected cell size was less than 5, the chi-square statistic was labelled as N/A and not shown.

There were less than 1% very incomplete responses (less than nine questions answered) which were discarded from analysis. It was likely that many of these were due to inadvertent pressing of the return key part way through the questionnaire. This resulted in the activation of the 'submit' button at the end of the questionnaire. In addition, there were only 1% duplicate returns which were also discarded. These were identified based on names and/or email addresses (which were the last data to be supplied by respondents). From analysis of the time of submission, it was clear that most duplicates were the result of simply pressing the 'submit' button twice, whether this was intentional or not. This should have returned the respondent to a home page, and it was unclear why on occasions this did not occur.

It was clearly stated on the introduction page that photographic identification was required in order for a prize winner to claim their prize. This was to discourage multiple entries under different names. Multiple entries of this form would have been impossible to detect, but in addition, would not have served the respondent any purpose - given the assumption that they were either motivated to complete the questionnaire out of interest, or to be entered in the prize draw, or both. It has to be accepted that there may have been some duplicate responses in different names.

Incorporating field checking in the questionnaire could have potentially forced respondents to complete all of the questions (or a specified subset), and/or dictated the type of answer allowable in particular response fields (e.g. forcing a numerical response for all frequency estimations). However, field checking was not incorporated because it was considered it would: increase the non-completion rate; promote random answers to enable submission; and restrict flexibility of response (e.g. disallowing text responses in numerical fields in order to giving a frequency range or state a more appropriate response time frame). Conversion of text to numeric data was managed during the data cleaning stage.

There was also a high willingness to take part in follow up research as the majority of Group 1 (76%), Group 2 (67%) and Group 3 (71%) stated a willingness to take part in follow up studies (a specific question in the questionnaire). This can be interpreted as potential buy-in to this research from respondents; it therefore increases the level of confidence in the answers obtained from this survey. In addition, a free text field was incorporated for general comments, and there were relatively few adverse comments regarding the design or content of the questionnaire.

4.7.1 Limitations to the study and potential improvements

There were several limitations to the study. The main limitation was the potential difficulty in generalising the results obtained from this sample, to the wider population. This stems from the non-random nature of the sampling used, since a combination of a 'convenience' and 'quota' sampling approach was used. Respondents were segmented according to established demographic criteria (Lindgren et al. 2002), with other respondents not analysed; this increases the potential generalisability or external validity of the results.

There was clearly a self-selection bias, since the sample was self-selecting due to the means of recruiting respondents (via email or web) and the way in which the questionnaire was completed (web-based completion). However, subsequent filtering and segmentation of respondents was based in part on those same criteria influencing self selection. Therefore the recruitment and response mechanisms resulted in self-selection bias when compared to the wider population, but were consistent with the characteristics expected of the groups differentiated in the sample

It is likely that many respondents were motivated to complete the survey because they were interested in the general topic area, and therefore likely to be more aware of services, and perhaps more positive towards them. This was counteracted to some extent by the offering of a prize draw, which would have encouraged completion by a wider range of respondents. The resulting sample was probably biased towards individuals who were generally interested in the topic area, *and* motivated by the financial inducement.

A limitation (and that common to many survey approaches to data collection) is that of the reliability of the data obtained, and particularly errors to do with estimations of frequencies. As discussed by Conrad et al. (1998), respondents may use a variety of strategies for making frequency estimations in surveys, with errors particularly likely when general impressions of frequencies are converted to numbers.

A limitation of *content* was the lack of questions regarding: the reasons for positive or negative attitudes towards MLS, intentions to use particular services, and any perceived barriers (e.g. cost, lack of access via their mobile phone etc). These would have enabled a better understanding of the consumer market for mobile services, but were not included due to the potential open-ended nature of these responses and the unsuitability of a questionnaire for this type of enquiry.

Although in general there were few adverse comments regarding the design/format of the questionnaire, it is acknowledged that some of the questions were potentially ambiguous. The descriptions of the services themselves were probably too brief, since they comprised short textual descriptions. Fishbein and Ajzen (1975) highlight that salient beliefs (and therefore statements of attitudes) can only be formed if there is sufficient information, and the service descriptions may have been insufficiently detailed to enable an understanding of the concepts behind services if respondents had not previously been aware of them. This level of understanding was not checked, although a pilot did not reveal problems in this respect.

Questions requiring frequency estimations used a mix of timeframes (monthly, weekly and daily) in order to facilitate response (e.g. typical use of ICT was based on *daily* report, frequency of leisure-related trips was based on *weekly* reporting, and work-related trips were based on *monthly* timeframes). Although the use of different timeframes was highlighted in the questionnaire, it is possible that this led to some confusion by respondents.

A final limitation is that responses were collected over a period of nine months, with the possibility of changes in the mobile marketplace that would influence levels of awareness or use of services. This extended time frame was a result of the unanticipated and considerable effort needed to target older professional respondents.

4.8 Conclusions

The main conclusion from this survey was that there was a low degree of usage, and also a general lack of awareness, of mobile location services, based on the respondents analysed in this survey. There was little difference between the groups in this respect, with 20% being the highest rate of usage for any one service, even where the majority of respondents were aware of them. MLS, the specific focus of this thesis, are clearly not currently mainstream applications in the UK, since they are not even being used by those demographic groups who are typically 'early adopter' categories. There are several likely reasons for this:

- The existence of services as disparate, discrete applications provided by third party developers, with a lack of integration within handsets or network services.
- A lack of awareness of services being available. In general (and with the exception of navigation applications), these services are little advertised, and if provided on a

phone tend to be relatively 'buried' within a menu structure. As an example, even when set up as a personalised link on an operators' mobile web home page, it took the author nine clicks to access a simple navigation application.

- A lack of *perceived* usefulness or added value of services, potentially indicated by respondents being aware of services without having used them. (Although of course a range of other factors can also lead to a non-use, including cost and availability on individuals' particular phones.)
- A poor experience having actually used a service, as indicated by the proportion of respondents who are negative towards services having actually used them. These negative attitudes based on usage could be due to a range of factors, including poorly specified functionality for target markets, lack of usability or perceived benefit, technical limitations such as inadequate positioning capability, cost of use, and negative perceptions regarding issues such as privacy and trust.

The survey demonstrated low levels of use of MLS. However, as also highlighted by Carlsson et al. (2005), there may be potential for developing such services that are adopted by the groups differentiated within this survey, for the following reasons:

1. There is a high percentage use of mobile phones and other new technology.
2. These groups tend to have highly mobile lifestyles (within a social or work context), and hence opportunity for services to capitalise on mobile and location-relevant delivery.
3. These groups make extensive use of static and mobile ICT (with the exception of mobile access to the internet).
4. They describe themselves as early adopters who are willing to try new technology.
5. They hold generally positive attitudes to a range of different MLS.

Based on the lack of uptake of services, the results of this survey confirm the concerns of Lindgren et al. (2002) in stating 'the mobile marketplace has to offer added value if people are to start using it'. MLS appear to be currently failing to add this value within individuals' lives, even though potential consumers are generally receptive towards potential services. This concept of 'making a difference' or 'adding value' within a mobile ICT context is explored in the next chapter.

5 VALUE WITHIN A MOBILE CONTEXT OF USE

Research questions addressed in this chapter:	
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	**What is user 'value' in the context of mobile location services?**
4	How can a specific mobile location service (driver navigation) be enhanced using a value perspective?
5	What general recommendations can be made for mobile location services research and design?

5.1 Introduction

The survey in Chapter 4 has suggested that early adopters are potentially receptive towards MLS, even though levels of awareness, and in particular usage, are low. There is also recognition within the mobile industry that there must be greater attention to user-centred design (e.g. see Appendix 1A) and in particular a need to understand how to create value for a user (Cockton 2004a; Lindgren et al. 2002). MLS can support the consumer within a dynamic and location-varying information environment since they can capitalise on the 'moments of value' (Keen and Mackintosh 2001) created by a time and/or location-dependent consumer need. Since mobile devices such as phones are personal and highly portable, they can also satisfy ubiquitous needs, i.e. those *independent* of time or location. The *mobile* aspect is therefore a potential constraint to ease of use due to the small form factor required for truly mobile devices, but more importantly, a potential *enabler* for potentially successful services.

The literature review in Chapter 2 identified a range of theoretical perspectives that can be used to take a user-centred perspective on new technology. Perceived value is typically described as comprising 'give' and 'get' components. Information value (from a realised value perspective) describes the need to impact on real world outcomes. Usability and task-driven approaches specify user goals, and determine the extent to which these goals are met.

From the literature it is clear that:

- There is a lack of consensus on value – e.g. Lin et al. (2005) - and its relationship with behaviour in a mobile setting
- The context of use is a critical factor in determining the use or rejection of services – e.g. Kaasinen (2005)

The study reported here was a small, explorative study to investigate how value is (or is not) created for users in a dynamic environment where the personal and ubiquitous nature of mobile devices provides *opportunity* for supporting the information requirements of the user.

5.2 Aims

The aims of the study were to investigate user behaviour in the context of a series of 'critical incident' journeys, and identify the implications for mobile service design and particularly those that incorporate location. Specific objectives were to:

- Understand the types of serious problems arising when people undertake journeys.
- Identify how people accessed and used information, how they made decisions, why they undertook particular courses of action, and the main influences on the above.
- Determine the nature of 'ideal' solutions to any problems that arose, including the role that location plays in increasing relevance or accessibility of information.
- Identify opportunities to create value for the end user: to be able to impact on the course of events; to provide something extra to that available elsewhere; to provide benefit within each travel context.
- Explore how willingness to pay is derived and influenced, and the extent of a link between information needs, perceived value and willingness to pay for information.

5.3 Study rationale

5.3.1 Research approach

This study was inductive and exploratory, i.e. it set out to investigate a phenomenon - that of creating value for an end-user, and was limited in scale. Prior to the study, no a-priori assumptions were made regarding findings, and therefore no particular theoretical stance was taken. However, this study was based on the following assumptions regarding the mobile consumer, based on the review of literature in Chapter 2:

- Mobility provides both challenges and opportunities for mobile information delivery.
- *Realised* consumer behaviour is the only true reflection of the value of a service to an individual.
- Value judgments (and associated factors such as willingness to pay) are highly dynamic, situated and comparative assessments.
- Context of use is a key determinant of both perceived and revealed value, and is only sufficiently explanatory at a personal, micro level.

The study focused on consumer requirements when travelling. 'Travelling' was chosen as the behaviour of interest because it is: inherently mobile; usually involves a highly dynamic information environment where information may be scarce; and is often associated with outcomes which are important - the goal or 'mission' aspect of May (2001). An assumption was made about goal-directed behaviour being undertaken (i.e. excluding travelling described by Allen (1999) as 'exploring', where user outcomes may be relatively unspecified).

The boundary conditions employed within the study (i.e. those criteria that define the limits of applicability of the results) were as follows:

Users	**Constrained by specifying participants:** Working professionals (educated, relatively time poor and cash rich). **Unconstrained:** Gender/age/nationality mix.
Tasks and context	**Constrained by specifying the event of interest:** Problematic travel scenario. **Unconstrained:** The mode(s) of transport. The motivation for the journey (e.g. business or social). The travel environment and the time/date of travel.

Table 5.1 Boundary conditions placed on the study

5.4 Method

5.4.1 Overview

This was a qualitative, exploratory study, using structured interviews to investigate consumers' actual behaviour when travelling - typically a highly dynamic, mobile information environment. Results were interpreted with respect to the: typical problems occurring; access to information; 'ideal solutions'; the opportunities for adding value; and the implications for willingness to pay for services.

5.4.2 Approach

A post-event verbal protocol method was used to explore travelling scenarios, guided by the literature on critical incident analysis (Hoffman et al. 1998), and the need for 'open-ended enquiry and exploration of customer problems, solutions and consequent outcomes' (Smith and Nagle 2002). Consequently, semi-structured interviews (Fowlkes et al. 2000) were used from an interpretivist viewpoint. These were also partly based on the information relevance criteria proposed by Barry and Schamber (1998), since these identify both the intrinsic qualities of information that impact on its relevance to the user, and the influence of context on a user's judgement of the quality of information. A key aim was to understand the nature of the information environment of the individual and its impact on the individual (Menou 1995a). However the study was also mindful of the observation made by Menou (1995a) if asking people directly about their use of information: 'that most end-users .... [will]

not realise that they are using information' and 'will hardly understand what the question is about'. The interview outline is contained in Appendix 5A.

5.4.3 Participants

Twenty participants took part in the study. A duplicity of criteria was achieved in the study by Barry and Schamber (1998) after only 10 respondents; however double this figure was used due to the diversity of the travel scenarios under investigation. The method deviates from the recommendations for true critical incident analysis, i.e. that positive and negative incidents are typically used, and that typical studies examine between 50 and 100 incidents for sufficient theoretical saturation, (Urquhart et al. 2003). However, for a small-scale exploratory study, 20 participants were deemed sufficient. Participants were chosen who were working professionals in full-time employment who travelled independently (for work or pleasure) at least once a week. Participants were split almost equally by gender, with ages ranging from 25 to 66 years, $M = 40.6$ years.

5.4.4 Procedure

Each participant was asked to describe in detail, using a structured interview, a journey where there had been an adverse outcome, and where access to information would have given the individual an opportunity to impact on the outcome. This identified where the *potential* value of information was high, based on the outcome achievable via access to perfect information (Dakins 1999). There was no limitation placed on the mode(s) of transport used, or the recency or purpose of the journey.

Interviews followed a semi-structured format covering the following approximate topics:

- Outline of the journey
- What went wrong, why this had happed and how they felt at the time
- Potential consequences (immediate and longer term)
- Attempts to resolve the problem and the success or otherwise of these
- What information they needed, what they looked for, and what they actually used
- Their stated 'ideal' solution to the problem

- Their willingness to pay (WTP) for a solution, and the basis for this assessment
- Any additional comments or observations regarding the actions undertaken, the decisions being made, the use of information.

The interview outline is shown in Appendix 5A. All interviews were recorded; a summary of this data is shown in Appendices 5B to 5G.

5.5 Results and discussion

Due to the qualitative nature of the study, the results are summarised and discussed together. The data from the interviews is summarised in the Appendices as follows:

- Summary of the journey including journey purpose, mode of transport, the impact on the individual and the initiating factor (Appendix 5B).
- Identification of the main decisions relevant during each journey, the major influential factors on the travellers' decision making behaviour and the actions undertaken as a result (Appendix 5C).
- The main information needed to impact on the situation, the potential sources of this information and the success in accessing this information (Appendix 5D).
- The 'ideal solutions' requested by the travellers based on either requesting a direct solution to the problem and/or information that could be used to impact on the course of events (Appendix 5E).
- The stated willingness to pay for one of the 'ideal solutions', the basis for this figure [shown thus in brackets], and the main influences on this (Appendix 5F).
- The potential to impact on the course of events i.e. whether the causal factor of the problem, and/or the course of events that followed could have been influenced - a basic prerequisite for a service being of potential benefit to a traveller (Appendix 5G).

5.5.1 Journey summaries

A summary of the 20 journeys is provided in Appendix 5B. Interviewees were deliberately unprompted when asked to recall a journey that had had a significantly adverse outcome – they were told they could be business or social journeys involving any mode, or a combination of different modes, of transport. There was no clear bias towards business (n = 9) or social (n = 11) journeys, and approximately half were multi-modal or multi-leg journeys. The 20 journeys encompassed a range of transport modes including car, train, plane, taxi, bus and coach. The end result for many individuals was not necessarily a delay; however the typical impact on the individual was one of increased stress and frustration as can be seen in Appendix 5B, plus financial loss in some cases due to incurring unnecessary additional travel costs. In addition, the female travellers tended to be concerned for their physical safety.

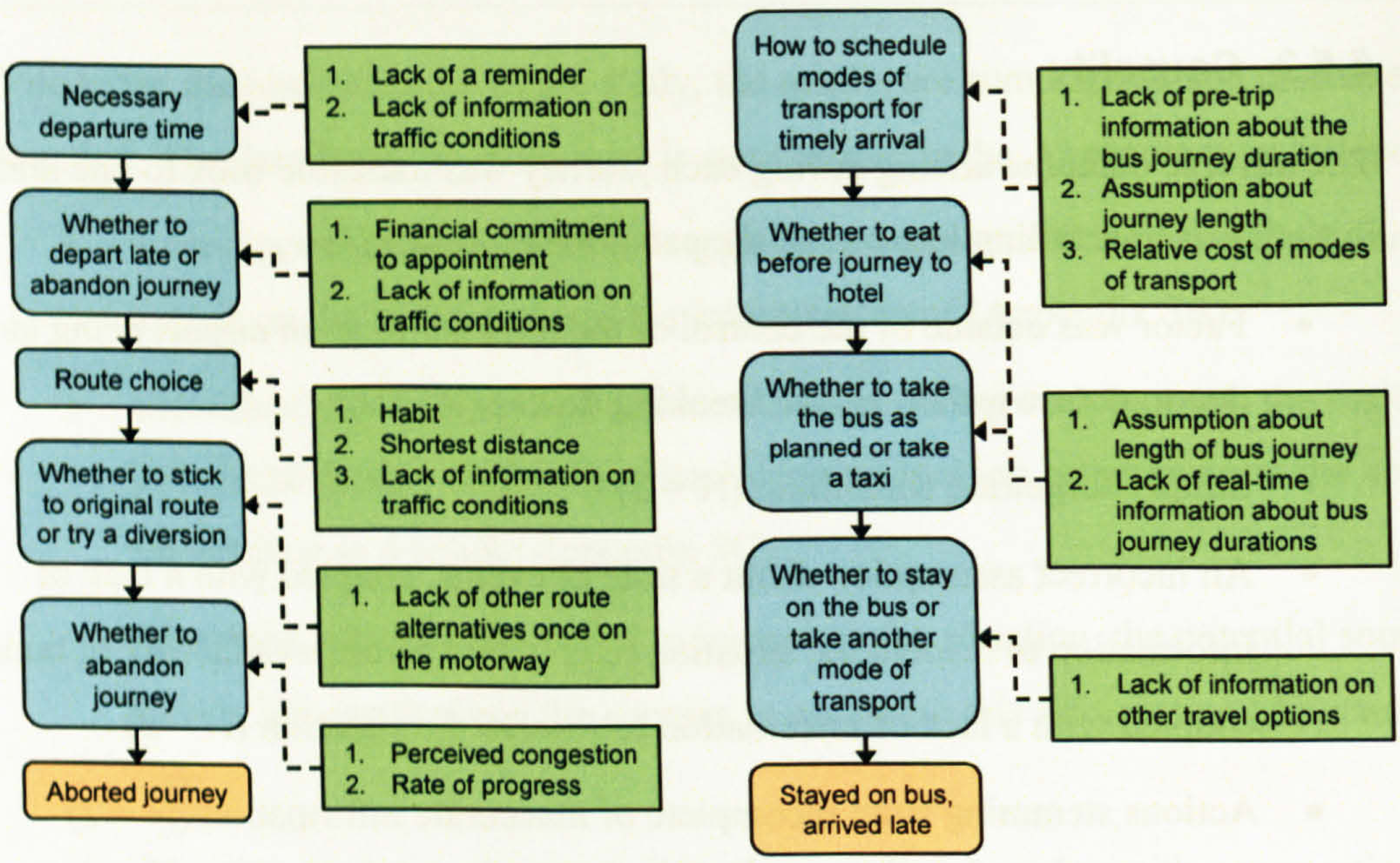
5.5.2 Causality

The adverse outcome arising during each journey was traceable back to one main initiating factor, falling into one of the categories shown below.

- Factor was outside of the control of the traveller (e.g. an airport being closed due to poor weather, a train breaking down) (N = 10)
- Simply forgetting something (N = 3)
- An incorrect assumption about a state of events, coupled with a lack of information to resolve the situation (e.g. traffic levels, availability of taxis) coupled with a lack of information to resolve the situation (N = 3)
- Actions stemming from incomplete or inaccurate information (N = 2)
- Actions stemming from a failure to understand and act on information available (N = 2)

For all journeys, mobile information access could have either prevented the adverse course of events from occurring, or have mitigated the ensuing impact on the individual, i.e. the differences in outcomes resulting from different information sets, described by Ahituv et al. (1998). There were typically a series of knock-on effects and problematic situations that consequently arose during the course of these journeys. These were often at the transitions in a multimodal or multistage journey where there were key interdependencies between activities, but also occurred where the unexpected happened. In some cases there was a lack of declarative knowledge (e.g. not knowing about the existence of traffic congestion, or not knowing a taxi number); in other cases a lack of procedural knowledge (e.g. how to find information on potential traffic delays). A consistent theme related to pre-trip information being not available, not accessed, inapplicable, incomplete or inaccurate, resulting in a need for real time information access to enable key decisions. Appendix 5D summarises sources of information that were used (or could not be used successfully) by the travellers in relation to the main decisions shown in Appendix 5C. There were clear opportunities for providing the consumer with new information via a mobile delivery channel, which are discussed later in this chapter.

5.5.3 Decision making behaviour



Car journey (delays) Bus journey (poor planning)

Figure 5.1 Influences on traveller decision making

During each of the journey scenarios, the travellers needed to make one or more key decisions thus generating an information requirement (discussed in the following section). There was a range of influences on the need to make those decisions and the extent to which they could be reached satisfactorily. Figure 5.1 shows these for a car journey (participant #1) and a bus journey (participant #3), and for all participants in Appendix 5C.

In many cases, individuals tried to ensure that basic human needs - e.g. safety, self esteem (Maslow 1943) - were satisfied when things went wrong. Additionally, the short-term focus of attention often switched to immediate threats (especially to personal safety) rather than longer term goals such as a timely arrival. This was particularly apparent for the female travellers. When considering different courses of action, it was apparent that both static decision models and judgments based on heuristics were employed (Jacob et al. 1986).

Where a choice between alternative courses of actions was made, the trade-offs between options were quite complex, and usually included the following aspects: (1) the *potential* effectiveness of different courses of action; (2) the likelihood of success of those outcomes (i.e. a probability function); and (3) the effort, cost and/or risk involved in pursuing those outcomes. For example, for the passengers whose trains were delayed (#13, #19), the non-cost and non-effort option was to stay on the train until it restarted. Other transport possibilities may have resulted in a quicker arrival, but they would have resulted in additional effort and cost, and in one case required that the passenger got off the train to investigate other options with the risk that the train recommenced the journey without them. In both cases, the decision was made to remain on the train. In general, individuals were only willing to make a decision to undertake a high cost/high effort course of action if they had the information to be certain that this was the best solution. As well as expected payoffs, decision making strategies were also influenced by the availability of information, and the effort (Johnson and Payne 1985) and risk (Kahneman and Tversky 1979) associated with the decision making strategy.

Almost without exception, travellers wanted to be *empowered* to make their own decisions on what their course of action should be. However, the presence of conflicting or ambiguous information increased the uncertainty of the decision-maker, consistent with Smithson (1999). There were also several indications that where information was ambiguous, or different sources were contradictory, there was a tendency to 'do nothing' - to stick with the originally planned course of action plan if this was a viable choice and a low cost/effort option. This was the approach taken by the train passengers described above who both resorted to the default option (i.e. stayed on the train) in the absence of information of sufficient quality. In general, individuals were only willing to make a decision to undertake a high cost/high effort course of action if they had the information to be certain that this was the best solution.

Under time pressure and where there was not ready access to information, decision making strategies tended to be based on heuristics and less complex decision rules (Ahituv et al. 1998), for example a decision to take a taxi, without regard to the potential costs involved. When participants had more time, and/or more complete information, a more considered assessment of alternatives was usually made, consistent with the static models of decision making described by Jacob et al. (1986).

5.5.4 Information acquisition

Information, or lack of it, played a key influencing role in each of the 20 travel scenarios, as shown by the simple decision models in Appendix 5C. With minor exception, participants needed *mobile* access to information in order to enable key decisions to be made. This is consistent with the findings of Lyons (2006), who stated 'there is a significant minority of journeys for which information can prove highly useful' (although low demand was found for information on familiar journeys).

It was clear that pre-trip information was used by some individuals to minimise the anticipated need for accessing/using information in real-time, reflecting the greater perceived costs (in the widest sense of the work, including availability) of *mobile* information acquisition. Problems related to pre-trip information arose when: assumptions about the relevance of this information (e.g. traffic information) or the availability of real-time information proved inaccurate; it was of insufficient quality to enable key decisions and courses of action to be taken; and where circumstances changed and pre-trip information was no longer sufficiently relevant - reflecting its highly dynamic nature (Anderson 1999).

The travel scenarios frequently involved some degree of time pressure; this limited the effort that the travellers were willing to spend on information seeking, consistent with Ahituv et al. (1998), and reflected in the decision making strategies described above. Under time pressure information search continued until that obtained was perceived as sufficient to enable heuristic or satisficing ('good enough') decision making (Simon 1957), or it became apparent that additional effort was unlikely to improve the quality of information obtained. Lyons (2006) also highlighted the satisficing behaviour of travellers, with an unwillingness to investigate more than one travel option that meets minimum requirements.

Where individual sources were of low quality, or multiple sources were contradictory, additional sources of information were sought. For example, radio traffic bulletins were deemed insufficient, and were backed up by visual confirmation of traffic congestion before potential diversions were considered.

5.5.5 Main problems with information acquisition

Consumers encountered problems accessing (and subsequently using) information while mobile for a variety of reasons, summarised in Table 5.2:

Barriers intrinsic to the individual and the context of use	**Example(s)**
Barriers to *identifying* information sources	Not knowing the availability of local radio broadcasts for traffic bulletins
Barriers to *access* by the individual, even though information was potentially available	Not being able to get off the train to read timetables on adjacent platform
Barriers to *understanding* information	Language barriers, formats of timetables, lack of geographical knowledge needed to understand the relevance of road signs
Barriers intrinsic to the information - the quality criteria described by Barry and Schamber (1998)	**Example(s)**
Not available at the time needed - failing to meet the 'windows of opportunity' described by May (2001)	Diversion information provided *after* a potential route alternative
Incomplete - not including key content	Omission of bus departure stand information
Inaccurate – it (as understood) did not represent the actual state of the world	Incorrect destination on the front of a bus
Not detailed enough (e.g. too generic)	'Heavy traffic in the Leicester area'
Carrying insufficient authority for it to be trusted	Provided by an 'unofficial' source such as a fellow passenger on a train
Ambiguous or contradictory	Reasons for train travel delay, and anticipated length of delay
Stated in inappropriate forms such that it did not directly support decision making	Qualitative statements such as '*serious* delays' where quantification was needed by participants

Table 5.2 Barriers to successful use of information

Individuals clearly made an explicit or implicit judgement about the perceived usefulness of information they already held, and need for additional information, and were influenced by the cost and effort of access. However this perceived cost/utility trade-off was very context dependent, with judgments being made at a single point in time, e.g.: 'at the time I didn't think I needed it' or 'I didn't have time to look for it'. The contextual and dynamic nature of information relevance and cost benefit assessments is highlighted by Rouse (1986) and Anderson (1999). This is also consistent with the 'conditional value' described by Sheth et al. (1991).

5.5.6 Users' 'ideal' solutions

Interviewees were asked what their ideal solution(s) would be in the light of the sequence of events that had occurred. These are summarised in Appendix 5E. This question was deliberately framed in an open format to enable the emergence of novel solutions, and expression in terms most meaningful to the individuals. All preferred solutions involved the provision of timely and relevant information, and 80% of the travel scenarios could *only* have been satisfied by real-time (i.e. mobile as opposed to pre-trip) access to information. This demonstrates the potential impact of mobile information channels within the context of this study.

If travellers needed to make real-time decisions, then 'ideal solutions' were in general, to be given enough information to be able to make informed decisions about different courses of action, and to be able to take control of the situation, even if the subsequent decision was to do nothing. Information was clearly acting to reduce uncertainty irrespective of its direct impact on the mobile consumer (Shannon 1949). Where decisions had to be made regarding alternative courses of action, interviewees wanted to be told what these alternatives were, together with the implications of pursuing each of these. An example would be making a decision between remaining on a train and arriving 30 minutes late, or getting off the train to take a taxi and arriving on time, but incurring an additional travel cost. Three additional themes emerged:

1. Information needed to describe the outcomes of alternatives in terms that directly facilitated decision making - alternatives being either the best one (e.g. 'this route is the quickest'), or being good enough (e.g. 'this bus will get me near enough to my destination'). This underlines the importance of the information *format* attribute and is also consistent with the 'use-centred' (rather than user-centred) perspective on system design (Flach et al. 1998), since it relates directly to the goals of the individual within the wider context of use.
2. Information needed to capitalize on 'moments of value' (i.e. where and when there was opportunity for acting on it) to result in a significantly different course of action in relation to the affordances offered by the particular situation.

3. Information could also capitalise on 'moments of convenience' – it could be provided at times of low stress or 'dead time', in order to minimise additional user demands. This is an alternative view of the 'moments of value' discussed by Keen and Mackintosh (2001), focussing instead on the impact of the usage effort, rather than the immediate gain to the individual, consistent also with the 'temporal tensions' described by Tamminen et al. (2003).

Point (1) above demonstrates the need for user tasks, information quality and the wider context of use to be incorporated in behavioural explanations. Points (2) and (3) show the need to take into account the enabling properties of mobile information delivery when describing service adoption.

5.5.7 Willingness to pay

The investigation of Willingness To Pay (WTP) was not the main focus of this study, but was incorporated for two reasons: (1) as a broad measure of the criticality of the situation experienced by the traveller; (2) to explore links between WTP and value, as discussed by Smith and Nagle (2002). WTP was based on stated preference, and was loosely discussed with participants in terms of a financial figure for a *solution* to the situation at the time arising. This captured the personal meanings and references used by individual consumers within their particular context of use, consistent with the highly context-dependent nature of contingent valuation responses described by Schkade and Payne (1994).

Three variations of WTP were proposed by the participants: (1) a *direct solution* to a problem (e.g. '£500 to find the luggage'); (2) payment *for information* that could be used directly; or (3) payment for *access* to a potential source of information. There were various strategies used by the travellers for estimating a WTP. A direct financial loss or gain was used as the basis for a WTP judgement. Where a direct financial comparison was not possible, WTP was typically based on the costs involved in achieving the travel objective in an alternative manner (e.g. an estimation of the cost of taking a taxi was often used as the absolute upper limit for paying for public transport information). However, a major influence was the cost involved in previously obtaining similar information. The cost of a phone call was frequently used as an upper ceiling on WTP, a typical quote of this nature being: 'I sorted it out last time with a phone call, why should I pay more than that this time?'. The stated WTP was highly variable as suggested by Lindgren et al. (2002) in discussing different types of mobile services.

There was a wide range of factors that were identified within this study as influencing the WTP of the consumer. These are shown in Table 5.3, including whether they served to enhance (↑) or diminish (↓) WTP within the context of this study. This table only shows the influences and directions as evidenced by this study, even though many can potentially operate bi-directionally.

Influence on willingness to pay	**Increase or decrease**
Financial motivators	
Expected financial gain or reduction of an anticipated loss	(↑)
The payment process itself – whether it is explicit, immediate, transparent and without effort	(↑)
Internal motivators	
Perception of lack of experience/knowledge of similar events, and/or lack of confidence in such situations	(↑) (↓)
Personal constraints that would otherwise impact on the situation (e.g. travelling with children)	(↑)
A perceived threat to personal safety	(↑)
A 'point of principle' based on a situation being the fault of another party with the responsibility to resolve the situation also lying with that party	(↓)
The belief that the individual could resolve the situation without additional assistance	(↓)
A lack of understanding of the potential seriousness of a situation (i.e. a perceived lack of need for information)	(↓)
Information-based motivators	
A lack of accessible information sources (e.g. when abroad)	(↑)
The degree of certainty associated with information actually having an impact on the situation	(↑)
The expectation that the information needed should have been freely available anyway	(↓)

Outcome-based motivators	
The perception that external influences mean that information may not enable a successful outcome (e.g. an unwillingness to pay for taxi information when there is a perceived lack of availability of taxis; being caught in traffic congestion with no opportunity to divert)	(↓)
The expectations/acceptance of others regarding a certain outcome (e.g. whether a late arrival was relatively accepted practice)	(↓)
A transient opportunity to use information to increase the success of the outcome (e.g. approaching a motorway exit that provides a possible diversion)	(↑)
An inability to judge the impact of a sequence of events (the 'unknown' factor)	(↑)
Being able to communicate with those affected by the situation in order to reduce any adverse impact	(↓)
The existence of other contingency plans that act to lessen any adverse impact (e.g. building in a coffee period at the beginning of a meeting to minimise the impact of late arrivals)	(↓)
The previous ability to resolve a situation at minimum cost	(↓)

Table 5.3 Influences on travellers' willingness to pay

The transient nature of WTP was apparent, linking directly to the 'windows of opportunity' discussed by May (2001). In some cases, explicit reference was made to WTP increasing over time as the perceived need for information increased (e.g. as a delay continued and the likelihood of a late arrival increased, there was an increasing desire for information on potential alternative routes). However, WTP was also described as decreasing over both short (seconds) and longer timeframes, as a situation is assessed, and potential solutions become apparent: 'for a split second [interviewee #15] would have paid £100 due to embarrassment, then the solution became almost worthless' [as she was sure she could resolve it]. This highly dynamic influence is clearly at odds with the static consideration of the influence of contextual factors by some of the user acceptance literature, one example being the static disposition to contextual stressors used by Kwon et al. (2007). WTP was also highly subjective within a single, specific context of use, as exemplified by the contrasting reactions (#20) of a driver stuck in traffic ('not that bothered') and her partner ('frustrated').

A consistent theme was that for WTP to exist, there had to be the potential for the information to 'make a difference' and enable key decisions to be made and courses of action to be undertaken. These findings are consistent with those of Denant-Boemont and Petiot (2003), who (within a more constrained travel scenario) demonstrated the impact of the variance in payoffs on the willingness of a traveller to buy information. WTP was therefore directly contingent on there being a value-adding opportunity, and without this, there was little or no WTP. However, as can be seen from the wide range of influences in Table 5.3, adding value did not necessarily *generate* a WTP. This dissociation may be due to participants feeling that they had 'already paid' in some way. Three other examples of this lack of direct influence of value on WTP are where: (1) a 'point of principal exists' due to expectations over responsibilities for resolving problems; (2) an adverse outcome is perceived as relatively typical, reducing the perceived threat to self-image, and (3) contingency plans are put in place that minimise the impact of an adverse outcome to a specified activity. These are in line with the 'value research' discussed by Smith and Nagle (2002), but include 'softer' issues [e.g. (1) to (3) above] that come to the fore when an explicitly user-centred approach is employed.

5.6 Provision of value to the mobile consumer

This study made no a-priori assumptions about what value comprised for an individual, other than it consisted of a range of factors that eventually influenced behaviour within an information environment, such as shown by Turel et al. (2007) – see page 22. Value was assumed to be created to a limited extent by existing information environments, and potentially enhanced by the provision of 'better' information as may be provided by an MLS.

Having completed the study, it was apparent that a consideration of 'gets' and 'gives' in relation to changes in real-world outcomes appeared to explain participants' behaviour within the travel scenarios, and the potential for information provision (such as via an MLS) to provide benefit. The results can be interpreted in relation to the model of Wang and Soergel (1998) shown in Figure 2.8: a need leads to the assessment of existing information sources. This leads to the creation (or otherwise) of value, in most cases in *functional* terms, which then leads to a decision to use (i.e. act on) that information. The key differences evidenced in the present study were that individuals exhibited a range of decision making styles – e.g. including satisficing (Simon 1957) and heuristics (Todd and Gigerenzer 2000), as opposed to using a criterion-based judgement in relation to different information sources.

From a consumer perspective, the findings were consistent with the notion of functional value (Sheth et al. 1991; Sweeney and Soutar 2001), i.e. the need to provide utility, with a certain level of quality needed, and the expectation that costs (resources) are expended. Although some elements of emotional and social value emerged (e.g. impacts on emotional states; the desire to maintain self-image), the predominant value perspective that emerged was a functional one. This is presumably due to the focus on the tasks studied, e.g. journeys which tended to be functional rather than experiential.

The findings are also consistent with the multidimensional nature of 'value', and the inherent difficulty in measuring this abstract concept directly (Lin et al. 2005). Although it cannot be deduced directly from this study, participants appeared to be forming overall value judgements on using or not using existing information sources, based on the costs and benefits (or 'gives' and 'gets') as shown in Table 5.4 below

The potential benefit (real world impact): An outcome measure, the probable difference in terms of the impact on the individual
The ability to do something new, better, more easily, more conveniently, with less error
The importance of particular outcomes (e.g. does it really matter if you are late)
The potential jeopardy to your desired outcome (e.g. whether a hold up means it is likely that you will be late unless you can find an alternative route, and the impact that this 'being late' will have)
The threat to basic human needs (e.g. safety, comfort, self esteem – whether being late reflects poorly on you)
The judgement of 'do I really want or need this?'
The resources expended: The financial cost, physical effort, risk, cognitive effort needed to access, assimilate and use the information
The effort or cost involved in finding, retrieving, understanding and using information, including the risks associated with accessing information
The cost/benefit assessment involved – whether the expected or most likely benefits outweigh the costs?
The judgement of 'is it worth the hassle?'

Table 5.4 A cost/benefit perspective on 'value'

The context of use was also critical, echoing the findings from a variety of theoretical disciplines, e.g. Sheth et al. (1991), Kaasinen (2005), Barry and Chamber (1998), Tangis (2001), May (2001), Dey (2001). A number of situational factors (that could vary considerably over even short time periods) greatly influenced consumers' perceptions of value.

Value creation can *explain* how users behave in a given situation. As Wang and Soergel (1998) demonstrated with document search, information was judged in terms of a set of quality criteria (e.g. authority). The degree of value created was reflected in the decisions made regarding future actions within the particular context of use.

Value creation can also help derive the requirements for an MLS, based on satisfying user needs within a specified context of use – the *formative* application of a model such as that of Wang and Soergel (1998). Desirable outcomes within a context of use (comprising situational affordances) are determined, desired values are identified, and the necessary information elements from an additional source such as an MLS are specified.

In terms of needing to provide value, services delivered via mobile channels are no different to other information channels that a user may access (e.g. digital or printed media, other bystanders, official sources) against which the added value of a mobile channel will be assessed. However, mobile services have the key properties of: (1) ubiquity which could allow them to capitalise on moments of value within an individual's daily activities, (2) personalisation to the individual, and (3) potential adaptability within a specified context of use. Figure 5.2 summarises the findings from the study in terms of value creation for the mobile consumer. It assumes the mobile consumer operates within an existing information environment, which can then be supplemented via a mobile delivery channel, this providing benefits and requiring resources as above. It shows a set of key influences on value creation related to the individual, what they are doing and the situation they find themselves in.

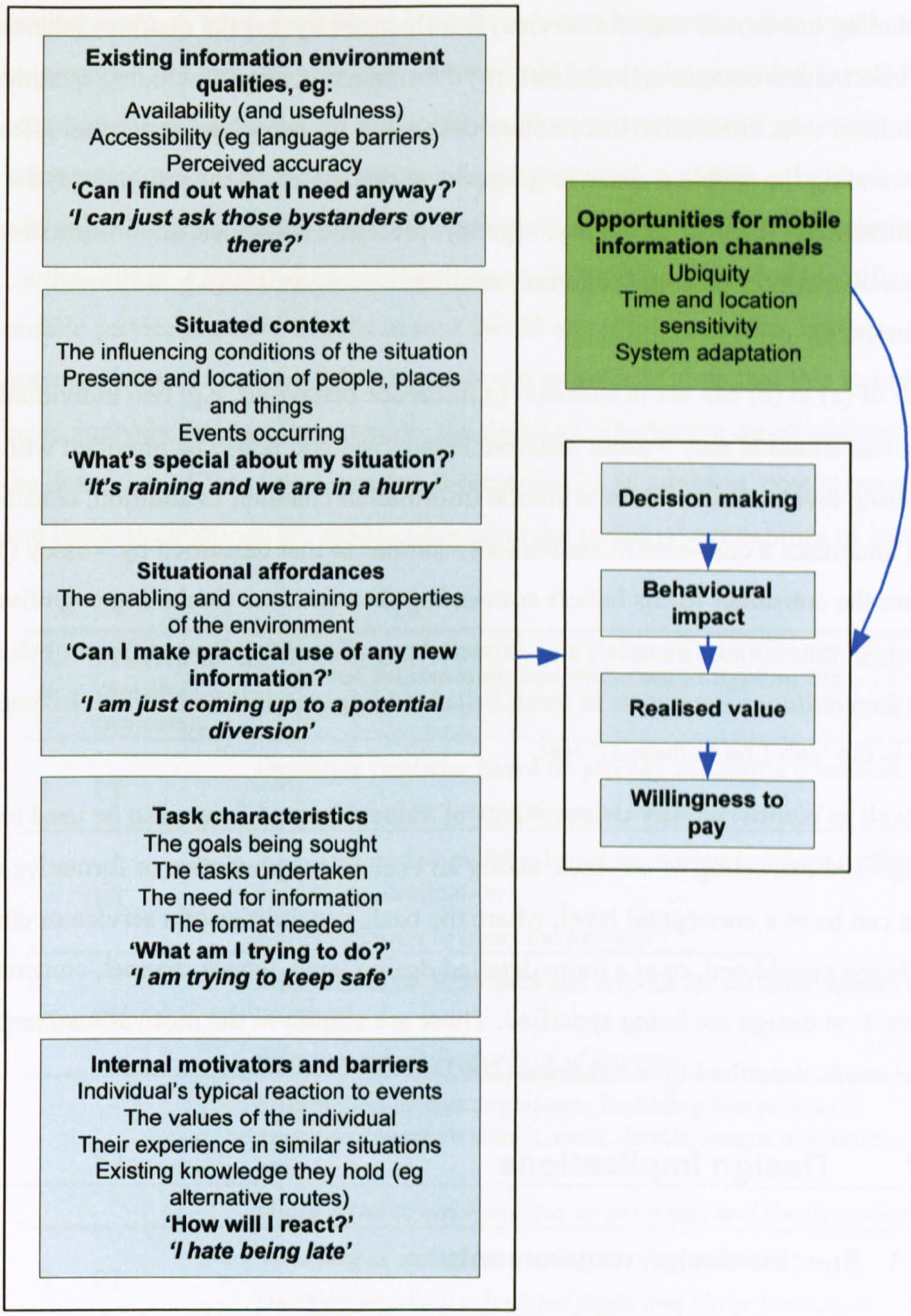


Figure 5.2 Key influences on mobile consumer value

The key points are: (1) willingness to pay is predicated by the need to generate value for the consumer; (2) value is directly attributed by an individual's behaviour, and arises from potential differences in user outcomes within different information environments; (3) value is created in a mobile context by capitalising on the properties of mobile channels: ubiquity; time and location sensitivity; and the ability to capitalise on moments of opportunity, and moments of convenience; (4) consumer behaviour (including use or non-use of a service) is influenced by: (a) the qualities inherent with the information content and channel; (b) the situated context (including qualities associated with alternative information channels); (c) perceived and actual affordances surrounding the problem space (e.g. opportunities for travel diversions); (d) the task characteristics (e.g. the criticality, urgency, preferred strategies, and information requirements); (e) personal (internal) enablers or constraints (e.g. skills and experience).

Each of (a) to (e) can act in isolation to influence behaviour, e.g. two individuals in an identical situation may exhibit different behaviours and hence be provided with differing levels of value from a mobile information channel. In addition, consumers will undertake a cost-benefit assessment - similar to that described by Vessey (1994) - where the consumer forms beliefs concerning the resources (including cognitive, physical, emotional, financial) and expected payoffs arising from different behaviours, and then attitudes in relation to those beliefs (Ajzen and Fishbein 1980). In essence, this is the 'can I be bothered?' test.

As well as identifying key determinants of value, Figure 5.2 can also be used to aid the design and marketing of services, taking an evaluative, predictive or formative stance. This can be at a conceptual level, where the basic capabilities of a service or channel are being considered, or at a more detailed design level, where channel, content and interaction design are being specified. These are similar to the motivational and action-level needs described by Kankainen (2002).

5.7 Design implications

5.7.1 Specific design requirements

The previous sections have discussed the main issues arising from the interviews with the travellers including the concept of adding value within a mobile context. Arising from this discussion are implications for the design of mobile services. Based on the specific problems encountered by the travellers who were interviewed in this study, and the opportunities to impact on the causal factor and/or sequence of events that occurred, information requirements can be identified for a service that would have added value in each of the travel scenarios. 'Added value' implies value creation (as has been discussed) in the light of information that is already present in the usage environment. A basic distinction is made between information that could reasonably be provided pre-trip (PT), or that which would have to be provided in real-time (RT) based on the dynamic nature of the information environment. If accessible pre-trip information could have satisfied an information need, a mobile solution is unlikely to add value by being 'better than the alternatives already out there' as described by Lindgren et al. (2002) when quoting Solveig Wikström. Table 5.5 identifies what mobile services needed to offer across the 20 travelling scenarios, and also their potential impact in each of the cases (shown in *italics*). Note that this is a relatively basic analysis, lacking for example, the detail of 'alternative travel options' [#9], or the definition of 'accurate' weather forecast [#17]. In addition, cost is not considered, and basic assumptions are made concerning the potential availability of information.

#	Pre-trip or real-time provision	Required information and potential impact on the individual
1	PT	Departure reminder based on journey and traffic conditions *Leaving on time, getting to appointment as planned*
	RT	Real-time update on ETA based on current location, traffic conditions, destination *Easier decision to abort the journey*
2	PT	Information on departures and arrivals for different modes of transport *Effective scheduling of legs of journey*
	RT	Information on bus departures, including bus number, operator, departure stands, route details, length of journey, cost *Decision on to catch the bus or get a taxi and timely arrival*
3	PT	Summary of inclusions/exclusions for insurance *Decision to take a scheduled flight and claim back costs*
	PT	Location of roadworks, expected delays and any need for earlier departure *Earlier departure to increase likelihood of catching flight*
	RT	Numbers for local taxis, including availability of large capacity taxis *Easier booking of a suitable taxi to increase likelihood of catching flight*
4	PT	N/A
	RT	Availability of garments and store addresses, plus directions

#	Pre-trip or real-time provision	Required information and potential impact on the individual
		Easier shopping for essential items, less time wasted
5	PT	N/A
	RT	Location of stores with shirts of correct sizes, plus directions. Location of the nearest large dept store *Easier shopping for essential items, less time wasted*
6	PT	Simple reminder to take his ticket *Not forgetting ticket, eliminating all problems*
	RT	Access to information on the procedures for lost tickets *Reduction of uncertainty*
	RT	Electronic access to flight booking/payment to prove prior purchase of ticket *Easy re-issue of lost ticket, reduction in uncertainty*
7	PT or RT	Location/cost/availability of branded local hotels, plus directions from airport incl. expected cost of transport *Ease of booking of appropriate hotel*
8	PT or RT	Details of bus departure times, as well as bus operator, bus number, departure stand, cost, duration of journey *Ensure catching of bus as planned to save a long taxi journey*
9	PT	N/A
	RT	Alternative travel options (information coming out of airline) *Satisfaction with travel arrangements*
10	PT	Bus details including final destination signage *Boarding the correct bus, timely arrival*
	RT	Tracking of the route to enable early notification of going the wrong way & location-based travel options – where to get off the coach, options for getting to her destination, or local contact numbers for different travel options (e.g. train, coach) *Earlier identification of travelling on the wrong bus and planning of alternative solutions to ensure) arrival at destination*
11	PT	Notification of delay of flights before setting out & provision of information re alternative check in procedures *Dealing with the situation in a more relaxed manner*
	RT	N/A
12	PT	Departure reminder, based on automatic scheduling of their departure for the ferry terminal. *Leaving on time, removing problem*

#	Pre-trip or real-time provision	Required information and potential impact on the individual
	RT	Likelihood of getting to the ferry terminal on time based on location, time, traffic speed *Dealing with the situation with more certainty*
13	PT	N/A
	RT	Information on expected delay & availability of other travel options (taxi, coach, bus), with departure and arrival times, costs *To enable a more confident decision on the best travel option*
14	PT or RT	Phone number for local taxi companies *Easier catching of a taxi, or decision to not take one based on lack of availability*
15	PT	Recommended route based on typical traffic congestion levels, plus suggested departure time for specified arrival time. *To enable an optimum route selection and earliest time of arrival, plus provision of estimated time of arrival*
	RT	Recommended route (current or diversion) based on real-time traffic congestion levels, plus estimated time of arrival *To enable an optimum route selection and earliest time of arrival, plus provision of estimated time of arrival*
16	PT	Reminder to take her passport. *Not forgetting passport, avoiding all ensuing problems*
	RT	Flight options - departure locations, latest check in times for alternative flights *To enable a decision about alternative flight options*
17	PT	Accurate weather forecast for region. *To enable a decision about whether to go into work*
	RT	Location relevant information on weather and predictions of how it might change based on intended route *To provide confidence during journey home*
18	PT	N/A
	RT	Name, location and contact details of nearest tyre repair garage or mobile repair service *To provide a quicker and more convenient solution to fixing the flat tyre*
19		As for 13.
20		As for 15.

Table 5.5 Service design requirements for pre-trip (PT) or real-time (RT) information delivery

There were several basic requirements. The travellers needed reminders to do things, or take things with them, these often having a short window within which to influence outcomes by being relevant before setting out. The travellers also needed information related to their travel progress, highlighting whether there was likely to be any impact on the overall success of their journey. The travellers also needed local information, including weather, local transport options and local amenities or resources. The requirements of each individual are very specific, being influenced heavily by the individual situation. Location, as would be incorporated into an MLS, clearly plays an important role in all of the above scenarios, it can: create a need for information; provide an opportunity for that information to 'make a difference'; or determine which information is relevant to the individual at that point in time.

5.7.2 General design implications for mobile services

Section 5.7.1 has detailed the specific information that would have added value to the journeys analysed within this study. However these are highly situational specific, and it is more useful to set out the generic implications that have emerged, so that these are relevant to the design of future mobile (and mobile location) services.

This study has identified a number of key design issues for end-user information services. Some of these are relevant to the design of information services in general; others are applicable to mobile and/or location or context aware services. They are summarised below under three headings: (1) opportunities; (2) challenges; (3) specific points for MLS. Specific examples relate to the travelling scenarios discussed in this study.

5.7.2.1 The opportunities for mobile services:

There are many opportunities for mobile information-based services, including MLS. Some are based on facilitating current activities (focus on convenience); others are based on enabling new possibilities - extending the limits of the possible. These are summarised below, and clearly link to the location and time responsiveness and contextual adaptation described in Section 2.6:

1: To make a difference such that it would be missed if 'taken away'

- To provide information that empowers the individual in those situations where courses of action can be influenced
- To provide information that *informs* the individual, where courses of action cannot be influenced

2: To impact on a course of events

- To provide simple pre-trip information to ensure that the basic things are done (like leaving on time, taking the things necessary, making any bookings necessary); in effect to act as a personal assistant in this respect
- To provide pre-arranged schedules to reduce the need for real-time journey planning
- To provide services that minimise the need for information (e.g. all-inclusive travel tickets that alleviate the need for knowledge of ticket purchase procedures)
- To provide information that enables key outcome-based decisions to be made (e.g. 'how late will this traffic congestion make me?') that could not previously be made with confidence due to lack of information
- To enable the user to deal with the unexpected threats or opportunities (e.g. when unexpected delays occur, when travel plans need to change)
- To capitalise on those situations where information is available but inaccessible to a user (e.g. where there is a language barrier)

3: To enable decision making

- To indicate where a specified course of action is that required, and to support this.
- To promote non-time constrained decision-making by providing pre-trip information
- To enable a choice-between-many to be made when time pressure permits, by providing alternative options and their implications based on key benefit/cost criteria

- To enable a least-effort or satisficing option where individuals are unwilling or unable to consider multiple alternatives (e.g. where time-limited or lacking the knowledge to undertake a comparison-of-alternatives decision)

4: To provide information when most beneficial

- To provide advance information (e.g. pre-trip) to reduce the need to search for and use information during the course of a journey
- To use location to identify context in order to provide information that is relevant, that satisfies a need based on 'here and now', e.g. location and time specific transport options
- To take into account the affordances of the context to capitalise on opportunities to support courses of action (e.g. the approaching of motorway exits that provide opportunities for potential diversions)

5: To provide information in the best manner

- To take into account individual preferences to provide personalised information
- To provide information that minimises the requirements to interact with potentially complex information interfaces (e.g. via access to operator-based services) – in order to shift the 'interface' away from the user
- To help individuals find information
- To provide this information in such a way that decisions can be made based on the impact on the associated outcomes (e.g., not 'severe delays', but 'estimated 1 hour delay')

5.7.2.2 *The challenges for mobile services:*

As well as opportunities, there are several challenges that must be met before successful mobile services (including MLS) can be delivered to the customer. Some of these are consistent with the challenges for context aware applications, described in Section 2.6.6.

To make a difference to the individual

- To ensure that the value/cost of accessing information (using a device) is such that it passes the 'would I get the device out of my pocket?' or 'would I press the button?' test

- To understand more completely the basis for users undertaking value judgements, since both benefits and costs (financial, effort, esteem etc) will influence its access and use, and these are time-sensitive
- To use the knowledge/experience of the user to maximise relevance: to ensure that a service can be *used*, but also that it provides them with 'something extra'
- To provide benefits over and above other sources of information (e.g. to ensure that a pedestrian navigation service adds value over and above free/cheaper alternatives such as asking bystanders or using a paper map)

To impact on a course of events

- To be able to provide information at the point where there is maximum opportunity to act on it based on 'windows of opportunity' opening and closing (e.g. information on flight delays before you leave for the airport; information on congestion before routing decisions are needed)

To understand the nature of decision making in the real world

- To understand how individuals make decisions in particular situations in order to provide information congruent with this (e.g. whether a heuristics-based, alternatives-based or satisficing approach will be used)
- To understand what information is needed for key decisions – at a fine level of detail - but to offer services that are relevant to a wider range of users and contexts
- To understand how 'best choices' are derived, and how perceptions of 'best' relate to objective measures of these

To design information provision based on user need, not technological push

- To present value rather than information, i.e. to prevent information overload for an end-user
- To ensure that information can be easily understood and therefore acted upon
- To understand the minimum level of detail of detail that is required to enable an optimum relevance/effort judgement (e.g. the exact content that is required for public transport: departure, arrival, stops etc)

- To manage the fact that the more detailed the content, the more a user is able to judge the accuracy (and hence quality and value), and the more discriminating a user may become
- To provide, where appropriate, alternative, confirmatory sources of information in order to increase the trust of the user
- To identify the key attributes of information that maximise its perceived or actual usefulness (e.g. timeliness, accuracy, consistency, completeness) and to deliver against those criteria
- To understand how to provide information in such a way that minimal processing or interpretation is needed by the user (e.g. drivers are not necessarily interested in how long a congestion tailback is, they *are* interested in what their estimated delay or estimated arrival time will be)

To take into account key individual influences

- To take into account personality traits - individuals may react very differently in certain situations, and this will influence the perceived need for services
- To take into account that increased experience of a situation will enable: (1) a more accurate judgement of the representativeness of a state of events (e.g. that about 1 in 5 flights are delayed and hence experiencing a delay is not that unusual); (2) an individual to anticipate potential problems and reduce their likelihood and/or mitigate their impact; (3) a more accurate judgement of the usefulness and/or quality of information

To take into account willingness to pay (WTP)

- To understand the WTP for information including how this judgement is formed and when willingness to pay results
- To understand the resources (effort/money) that people are willing to spend on accessing/using information, and the key factors that may influence this such as branding and payment process
- To understand how much people are willing to pay for *preventative* information (e.g. to subscribe to a traffic congestion alerting service)
- To take into account some key factors: (1) that users usually won't pay for information that does not provide value to them; (2) WTP is often transient; (3)

a WTP may only exist retrospectively; (4) the *effort* or transparency involved in payment will influence the WTP

5.7.2.3 Mobile location services

MLS, being a subset of mobile services more generally, present the opportunities and challenges outlined above. However, the location-sensitivity of MLS can impact specifically on the value derived from these services by influencing the 'give' and 'get' components incurred during use. As shown by the information needs of the participants in this study (Table 5.5) and the influences on consumer value (Figure 5.2), location sensitivity can enable the presentation, or availability of information to satisfy task requirements. As evidenced by this study, there appear to be several distinct roles for MLS, consistent with the literature on context-aware computing outlined in Section 2.6:

- Making available location-relevant information in order to reduce the scope of the information environment that the user must interact with during active information search.
- Automatically providing location and task relevant information without requiring active information search from the user.
- Providing access to locally-relevant information resources.

However, as highlighted by the literature on context-aware computing – e.g. Bellotti and Edwards (2001); Brown and Randell (2004) – there are specific design challenges in terms of relevance. In particular, unless the information requirement is very specific, or the application domain is narrow, it will be difficult to design services that reliably meet user needs. In addition, it is necessary to understand how information is used within a task context, and when information making is involved, whether it is based on for example, 'choice of alternatives', or a 'satisficing' approach.

5.8 Critique of study

This study used post-event enquiry to investigate the concept of 'adding value' to mobile users within a dynamic (and often critical) information environment. Travelling (encompassing a range of modes of transport) was used as the application domain. The study extracted key issues relating to (1) the use of existing information sources by participants, and (2) the potential for an MLS to create additional value for an end user. However, there are a number of potential limitations which are discussed below.

5.8.1 Limitations to the study

The study was undertaken from an interpretivist perspective, with a focus on discovery (Remenyi et al. 1998) and the natural emergence of phenomena and the meanings attached to them (Klein and Myers 1999). Although this type of study is usually associated with high discoverability, an associated weakness is the potential low generalisability to a wider population: Do the results say anything about information consumers in general? Are they applicable to different kinds of people, using different modes of transport, or undertaking different activities altogether? Two countermeasures were employed to address this concern: (1) the results were based on a diverse range of travel scenarios, and (2) there was an attempt at interpretation in relation to the broader classes of behaviour that emerged, and particularly decisions regarding mobile information access.

The study was also relatively small-scale, comprising only 20 incidents which is less than the 50 to 100 typically used within critical incident analysis (Urquhart et al. 2003), and only focussed on negative incidents rather than also including positive incidents. This potentially biased the results by not specifically including enablers of positive outcomes as well as mitigators of negative outcomes. In retrospect, the interviewing technique could also have been more sophisticated. For example the more formal application of an explicitation interview (Urquhart et al. 2003) may have generated more insights. Explication involves putting the interviewee into a state of evocation where they 'relive' an example of the activity under question. This is achieved through: the use of open , non-leading questions; focussing on the detail of a particular event; focussing on interviewee recall rather than interpretation; and encouraging recall of seemingly trivial detail.

There were undoubtedly response biases relating to the particular journeys described by participants. Few restrictions were placed on the journeys that were investigated, the main criterion being that the participants felt able to recall them with completeness and accuracy. There was in effect a deliberate introduction of an availability bias (Perrin et al. 1993) in order to facilitate this. Although improving confidence in the internal validity and reliability of the data, it is likely that some of the individual cases verbalised by participants were relatively unique.

The retrospective nature of data collection (in some cases occurring several years after the event), and the recognised limitations of verbal protocols (Russo et al. 1989) make the results prone to errors of omission and commission, and the potential post-hoc rationalisation of behaviours. Other than being aware of this when exploring the consumers' behaviours (e.g. probing the same issue in several different ways), there is no means of ensuring that participants actually 'told it as it was'. Although the interpretivist viewpoint is based on personal interpretation of the world, it is quite possible that some objective elements of the scenarios were simply inaccurately stated by participants.

5.8.2 Potential improvements to the study

The main improvements relate to the need for greater methodological depth. A greater number of positive and negative incidents would have increased theoretical saturation of the data. In addition, enhanced interview techniques such as 'explication' (Urquhart et al. 2003), described above, may have created more accurate recall.

Alternatively, the study could have been done as a genuine case study, following the recommendations of Klein and Myers (1999) for undertaking interpretivist case studies. In particular, multiple data collection methods (which could have included structured interviews as undertaken), and triangulation of data, would have enabled greater corroboration of events, and greater interaction between researcher and the participant. This should lead to greater accuracy of recall of the event and the accompanying context, and a deeper level of insight into the subjective aspects of the situation.

In addition, the interpretivist, qualitative nature of the study needs to be supplemented with a multiplicity of approaches as discussed in Chapter 3. In particular, there needs to be empirical investigation of how value can be added to mobile users. This need for investigating value through empirical investigation, was tackled in Chapters 6 to 9.

5.9 Conclusions

This study helps demonstrate why some models of consumer adoption of technology may explain only 10% of the variance in *actual* usage within a mobile context, e.g. Hung and Chang (2005). The contextual and situated aspects (Dourish 2001b) of use have a considerable impact on what a consumer *actually* does, and their choices regarding information use. These situated factors need to be incorporated into studies with end users, a theme incorporated in the empirical work that follows in this thesis.

Some authors have suggested that it is the communication-based mobile services that will be real winners with consumers (Harper 2003). However, the travel scenarios investigated in this study have clearly shown that consumers in a dynamic and mobile context of use can potentially derive considerable value from information-based mobile services. Value in this study was described from a pragmatic perspective, comprising benefits in terms of differences in outcomes, and the costs or resources expended as per Table 5.4.

The travel scenarios investigated in this study have shown how information was sought (and used where available) based on its value-adding potential - to enable key decisions regarding courses of action, but also to reduce uncertainty and perceived risk to the individual. Where the situational affordances - similar to the 'facilitating conditions' of Lu et al. (2003) - allow, a suitable mobile information channel potentially *empowers* the individual; in other cases it can *inform*.

Location sensitivity can therefore play a key role in adding value. It can increase the potential benefits to an end-user by providing information that empowers or informs the individual in the physical location they find themselves in. It can do this by providing information that is relevant to the current or likely future location of the user, and filtering out that which is not relevant – the contextual sensing and adaptation described by Dey et al. (1999). Location can also be used to enhance the *meaning* that information needs to convey – i.e. recognising that individuals aren't interested in information, they 'just take care of their business' (Menou 1995a). A location aware service can either provide information that directly supports the decision making associated with that location, or can indicate a preferred course of action at that location – the active or passive adaptation described by Chen and Kotz (2000). With reference to the mobile location services described in Table 4.2 in the previous chapter, some examples would be levels of risk associated with locations (friend finder), speed limits on approach to safety cameras, turn-by-turn navigation directions and length of delays caused by localised traffic congestion.

A mobile consumer's assessment of value within a particular context depends on its intrinsic qualities such as its relevance, accuracy and completeness. However, equally important are factors such as ease of access, ease of understanding, timely delivery and the extent to which information is expressed in ways which either reduce the need for decision making by the individual, or facilitate this. In addition, value is heavily dependent on the wider context of use and the 'bigger picture' since both of these influence the extent to which enhanced user outcomes will actually occur.

6 LITERATURE REVIEW: DRIVER NAVIGATION

Research questions addressed in this chapter:	
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	What is user 'value' in the context of mobile location services?
4	**How can a specific mobile location service (driver navigation) be enhanced using a value perspective?**
5	What general recommendations can be made for mobile location services research and design?

6.1 Introduction

The survey in Chapter 4 has indicated that, at least for some user groups there is *potential* for the adoption of MLS, despite the current lack of awareness and usage. The study in Chapter 5 showed that a wide range of factors influence the creation of value for individuals within a specific context of use. Location (and the wider context of use) was shown to play a major role in generating a requirement for information, determining the content that was needed, and providing opportunities for benefiting from a mobile delivery channel.

A key objective of this thesis is to address the problem of designing MLS using a user, and value-based perspective. This is achieved by focusing on a particular application within the remainder of this thesis – those location-aware services that deliver real-time navigation information to the driver – and taking a more situated and empirical perspective within the remainder of this thesis. This chapter reviews literature on driver navigation, and describes how value can be used to enhance the design of MLS that provide navigation information to a driver.

6.2 Vehicle navigation systems

6.2.1 A technological solution

Vehicle navigation systems (also termed satellite navigation or route guidance systems) offer a technological solution to aiding drivers' navigation, and are increasingly a mainstream product in both domestic and commercial categories of vehicles (Amos 2005; Rowell 2001). When first developed, systems were usually OEM products built into vehicles. More recent developments have been the proliferation of portable navigation systems designed specifically for the vehicle, navigation applications that run on personal portable devices such as PDAs, and also the emergence of applications that run on mobile phone handsets. Recent market research has predicted that the world-wide market for portable navigation devices (which can include both driver and pedestrian applications) will reach 56 million units worldwide, up from 14 million in 2006, and that the navigation market will be increasingly targeted by mobile phone handset applications (InStat 2007).

Typical systems use a combination of satellite GPS and digital map-matching to calculate an optimum route to a destination that a driver has specified. Systems then present a series of map overviews and turn-by-turn instructions in real time to drivers, using a combination of auditory (verbal and non-verbal) and visual (text and graphics) information. A typical turn-by-turn instruction is an auditory 'left turn in 300m', accompanied by a visual left turn arrow plus a distance-to-turn countdown bar that reduces to zero as a manoeuvre is approached (see Figure 6.1). In addition, more advanced systems may integrate traffic and travel information, and calculate optimum routes accordingly, as well as identify when safety cameras are being approached.

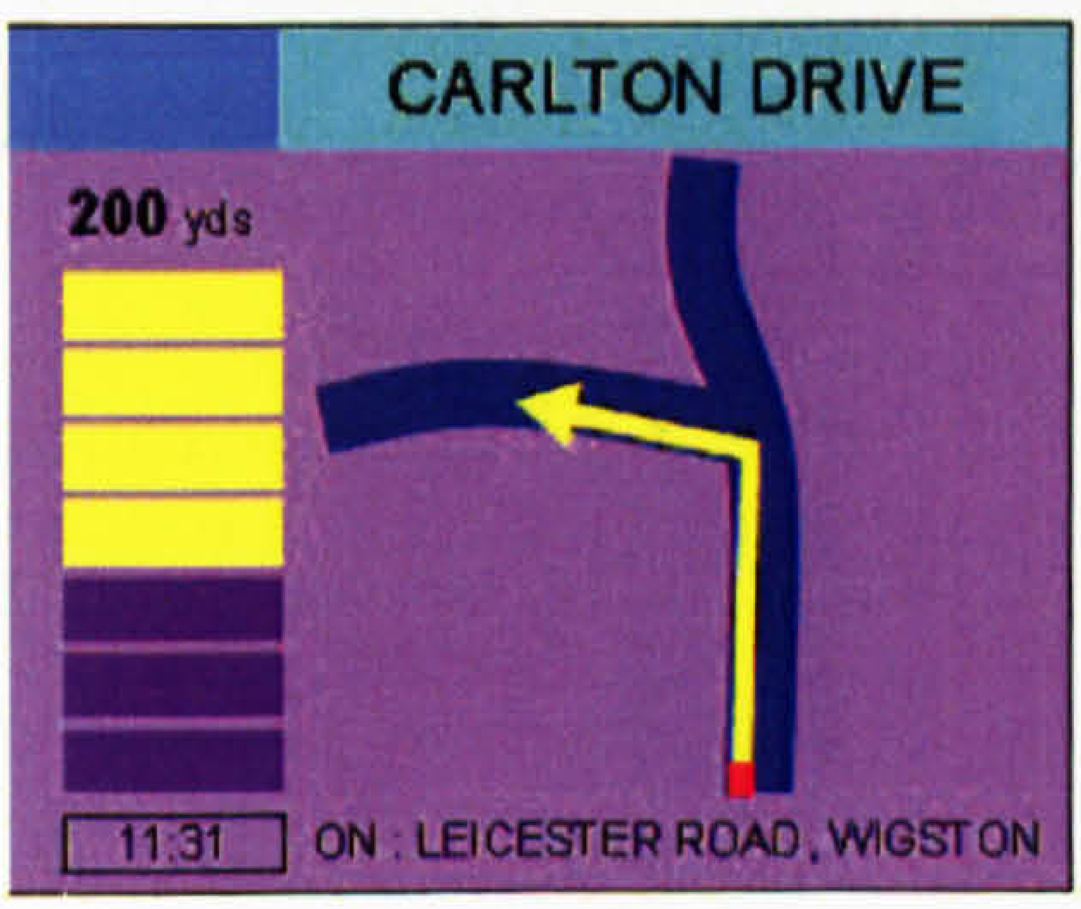


Figure 6.1 A typical visual display from a navigation system

6.2.2 A value-adding mobile location service

Value can be interpreted in relation to driver navigation systems in two different ways, consistent with the motivational and interaction level needs described by Kankainen (2002). In terms of their *adoption*, the relative success of navigation systems can be explained by a number of different theoretical perspectives:

- They can provide new freedoms (Keen and Mackintosh 2001) within certain driving contexts, especially where drivers are unwilling to travel independently without navigation assistance, e.g. some older drivers - (Burns 1997).
- They supply information which is time and location relevant, and may be mission-critical (May 2001).
- They create functional value (Sheth et al. 1991) by enabling a driver in an unfamiliar area to achieve navigational objectives.
- The ratio of the 'gets' versus the 'gives' (Lapierre 2000) has increased as map coverage and accuracy has improved and system cost has reduced.
- They offer relative advantage (Rogers 2003) over existing methods of navigation in unfamiliar areas, particularly where information is scarce.
- Their usefulness and ease of use (Davis et al. 1989) has increased as their design has improved.

Stay (2001) specifically identifies routing information as one category of information that can empower and add value to the driver. In addition, driver navigation systems are consistent with the principles/guidelines proposed by Bellotti and Edwards (2001) and Brown and Randell (2004) for incorporating context successfully within system design. In particular, changes in context and system adaptation are observable and predictable, and due to the simple use of context (i.e. chiefly the location of a single user), the system is relatively unlikely to 'get it wrong' when mapping desired system behaviour onto contextual changes of the end user.

As well as explaining their recent popularity, a value perspective can also be used in a formative manner to improve their design. In particular, an information value perspective, and a consideration of the 'gives' and 'gets' can be used to address the human factors issues with their current design. These human factors issues are outlined below.

6.2.3 Human factors issues

Satellite navigation systems generally function well from a technological viewpoint. However, there are several potential limitations to their current design: their concept is based around that of procedural, paced information push to the driver; they generally use distance information to enable a driver to locate a turn; and some systems employ complex visual human-machine interfaces (as well as corresponding auditory information).

A large number of articles over at least a decade (Alm 1993; Lee et al. 2001; Lunenfield 1989; Mollenhauer et al. 1997; Srinivasan 1999; Wierwille 1993) have highlighted the potential distraction caused by visual and verbal information presentation to the driver, and the potential safety impacts. The situation may be particularly problematic for navigation systems due to the dynamic presentation of detailed information and their possible use within complex and unfamiliar driving environments. It is now widely recognised that the usability and safety requirements for in-vehicle systems should take account of international design standards for dialogue management, visual and auditory information presentation (ISO 2002, 2003a, 2004), and a procedural standard for assessment of in-vehicle systems for suitability for use whilst driving (ISO 2003b). In addition to formal standards, specific codes of practice exist in Europe (EC 2005), Japan (JAMA 2004) and the USA (AAM 2003).

Dale et al. (2003) state that there is evidence that route descriptions closer to those produced by humans are preferable to the procedural descriptions produced by current systems. They underline three key ways in which instructions generated by humans differ to those generated by procedurally driven systems:

1. They omit unimportant or obvious steps
2. They typically use landmarks and visible features
3. They produce complex clause structures, chunking relating information

Srinivasan (1999) identifies the need for more research under four key human factors topic areas: mode of information presentation; information content and format; timing of information; driver interaction with information devices. However he fails to identify three key areas which are addressed in this thesis:

1. The need to add value with a vehicle navigation system at an interaction level, i.e. ensure that the 'gets' are meaningful, and outweigh the 'gives' when a system is used.
2. The need to optimise information presentation to the driver according to task-based descriptions and human information processing capabilities.
3. The contextual influences on information requirements and the implications for system design.

Sections 6.3 to 6.6 of this chapter review literature that describes the information needs of drivers when navigating. This chapter then concludes with how the concept of 'value' may be applied within a navigation context.

6.3 Navigation and wayfinding

Two terms are commonly used to describe the process of planning and following a route from one physical location to another. Burns (1998) makes the distinction between *wayfinding* and *navigation*. Wayfinding is described as 'the dynamic step-by-step decision making process that is required to negotiate a path to a destination.' Navigation is described as 'a broader term that refers to both the strategic route planning level of the spatial problem-solving task and wayfinding'. Wayfinding involves the execution of those plans. In addition, wayfinding is distinct from navigation, in that it is generally restricted to conscious decision-making processes in a relatively differentiated environment (Ungar 2003). It is therefore 'wayfinding' that more accurately describes driver navigation within a road environment, as supported by a driver navigation system when it provides navigation instructions at driver decision points.

Wayfinding tasks can be categorised into three general types based on their purpose (Allen 1999): the 'commute', the 'explore' and the 'quest'. The 'commute' involves 'travel between two places known to the traveller along a route that is familiar'. The chief characteristic of the commute is that uncertainty is low. The 'explore' involves 'travelling into unfamiliar territory for the purposes of learning about the surrounding environment'. The 'quest' involves 'travel from a familiar place of origin to an unfamiliar destination, a place which is known to exist but which the traveller has not visited previously'. By differentiating between different categories of wayfinding tasks, Allen (1999) has proposed relationships between those categories of wayfinding tasks and the means by which those wayfinding tasks are accomplished – see Figure 6.2. It is also noted that in describing this behavioural phenomena, there may be indistinct boundaries between, and that this simple model may be incomplete.

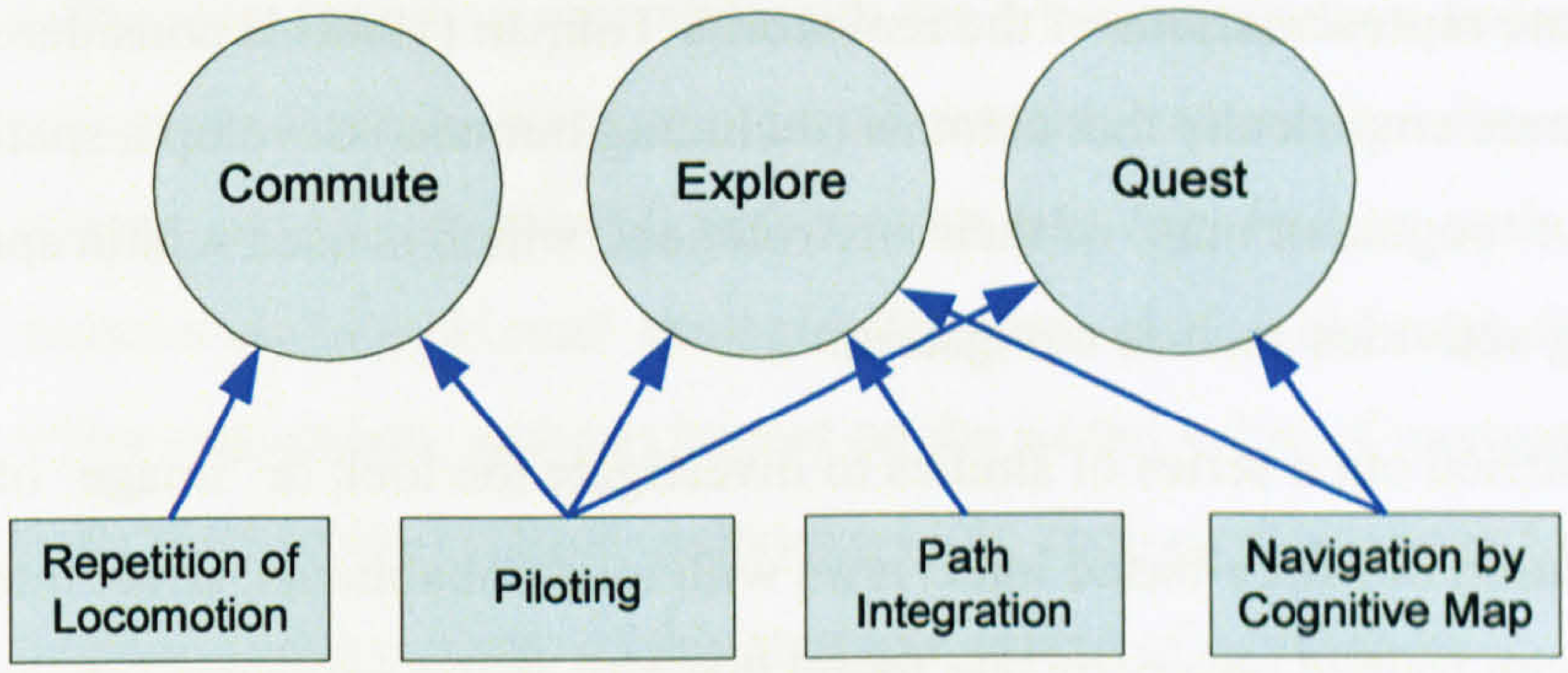


Figure 6.2 Methods used for different navigation tasks (Allen 1999)

The 'quest' navigation strategy is of most relevance within the context of the remainder of this thesis, since the focus is on the unfamiliar traveller operating in a destination-directed fashion - rather than the traveller undertaking a regular familiar journey (commute), or exploring an unfamiliar area. Allen (1999) identifies that 'piloting' and 'navigation by cognitive map' are the strategies used to support 'quests'. Piloting is described as landmark-based navigation where progress is measured in terms of 'where the traveller is in the temporal-spatial sequence of landmarks that intervene between the point of origin and the final destination'. Note that it is assumed that the term landmark is used by Allen in it broadest sense; landmarks are discussed in more detail in Section 6.6.5. In contrast, navigation based on a cognitive map is a 'knowledge-based means of wayfinding in which the traveller refers to an internal representation of a set of systematically related places in planning and navigating a route' (Allen 1999). This strategy is highly flexible, and progress during this form of navigation is assessed by the traveller by reference to known intervening landmarks and estimations of time-space between those landmarks.

There is a large body of research that has investigated how cognitive maps are formed, the role they play in human navigation, and how they may be distorted or otherwise fail. Chown (1999) highlights the contribution that an individual's cognitive map makes: the 'advantages of some stored information is to predict environmental events before they occur by using information from past experiences to go beyond what is present in the sensory array'.

Trowbridge (1913) is recognised as the first to describe the prevalence of what he termed 'imaginary maps' and described their role in the 'readiness of man to be confused with respect to a new environment' – underlining how these representations may be inaccurate representations of the real world. Tolman (1948) is considered the first to demonstrate empirically that animals (including humans) develop a spatial representation or 'cognitive map' of their environment, which is used within spatial problem solving activities such as navigation.

Lynch (1960) carried out a series of studies to investigate the look or 'image' of cities, using a combination of office-based interviews with local inhabitants, street interviews and fieldwork with trained observers. He found that city centre environments were categorised into five types of element: (1) Paths - defined as the channels along which people move; (2) Edges - linear elements that serve as boundaries between districts or other areas; (3) Districts - the medium-to-large sections of an environment, which the observer mentally enters 'inside of'; (4) Nodes – strategic spots in a city, or a convergence of paths, e.g. junctions; (5) Landmarks - external reference points which are easily observable from a local or distant viewpoint.

Kuipers (1978) describes how knowledge about particular environments can comprise five elements: (1) route instructions describing a series of actions taking the traveller from one place to another; (2) places; (3) paths along which a traveller may progress; (4) regions; and (5) coordinate frames which enables headings to the defined and attributed to streets. Progression through an environment is based on the observation of views and performance of actions, i.e. a stimulus-response model of navigation. A known route is stored as a sequence of these view-action pairs. A route description (and therefore that which can be supported by navigation systems) is described as a sequence of 'turn' and 'go-to' descriptions leading from a start point to a destination.

Timpf (2002), however, describes how wayfinding in *unfamiliar* environments generally *precludes* the existence of cognitive maps. An interesting observation by Jackson (1998) and others is that navigation systems may actually inhibit the development of cognitive maps. In addition Jackson (1998) states that 'one could argue that the whole point of route guidance instructions is that they remove the need to form a cognitive map'. Despite such concerns, the design of navigation systems around piloting to fulfil 'quests' is compatible with minimising cognitive demands on drivers. Allen (1999) describes how 'piloting' places few demands on working memory, does not require movement monitoring, distance and direction computation or cognitive map knowledge.

Due to the implications for system design, this thesis focuses on supporting piloting, rather than cognitive map strategies for driver navigation. Indeed, although early navigation systems were map-based, current systems are compatible with a piloting strategy, since they provide information on a turn-by-turn basis. In addition, this thesis does not discuss drivers' strategies for *route choice*, although this is a key element of driver navigation, and can impact on the added value of navigation systems (Section 6.7). Navigation systems undertake route choice calculations for the driver, and hence generally relieve them of this strategic aspect of navigation.

Although 'wayfinding' is the semantically correct term for describing a driver's use of a navigation system to follow a route, the term 'navigation' will be used throughout this thesis, as it is that used widely within an automotive context.

6.4 Navigation in the context of driving

6.4.1 The importance of navigation

One of the most demanding activities for drivers is navigating in an unfamiliar environment. A range of studies dating back 20 years has identified the difficulties that drivers have in planning and following efficient routes (King 1986; Streeter and Vitello 1986; Wierwille et al. 1989). If drivers are unable to navigate successfully, there is a range of individual and societal consequences including: driver frustration and anxiety (Barrow 1991) and reduced mobility for those groups wary of travel in unfamiliar environments (Burns 1997). In addition, there are potential increases in congestion and pollution: King (1986) found in an empirical study in the US that up to 20% of the miles driven could be considered 'navigation waste. Jeffrey (1981) made a more conservative estimate that four percent of travel in the UK falls into this category.

6.4.2 Navigation as a strategic and tactical element of driving

A widely referenced hierarchical model of the driving task is proposed by Michon (1985), in which navigating is seen as an integral element within the structure of the driving task. This model differentiates between strategic, tactical and operational driving tasks. The strategic level involves the planning of tasks such as route choice decisions. The tactical level involves tasks directed towards more specified, discrete actions, for example undertaking specific turns. The operational level involves highly automated, and relatively subconscious behaviour involved in controlling the vehicle, such as lateral or longitudinal vehicle control via the steering wheel, accelerator or brake. Burnett (1998) identifies how drivers need navigation information at the strategic level in order to plan route choices. This information includes traffic and weather conditions, parking options, journey time estimations. Burnett (1998) describes how information requirements at the tactical level are quite different, and are needed in order to 'help decide where and when to turn'. This information includes a driver's direction of travel, location of landmarks, road signs, distance information and road and junction layout.

Vehicle navigation systems operate at both the strategic and tactical levels of the driving task, (and aim to reduce the strategic demands on the driver by fulfilling the route planning role). However, according to Burnett (1998) it is information operating at the tactical level (i.e. that which enables specific manoeuvres to be undertaken) which is critical to the effectiveness and safety of vehicle navigation systems. This support for specific manoeuvres is therefore the focus of the remainder of this chapter, consistent with the piloting strategy described by Allen (1999) and the view-action pairs of Kuipers (1978).

6.5 Driver decision making and information needs

Chown (1999) describes the general problem of an agent interacting in a real world environment, the general problem being that of deciding what to do next. This is the task facing the driver navigating a route – they must make a series of decisions on the route to follow, and where a route is unfamiliar, a level of uncertainty exists at each potential manoeuvre. Frank (2003) highlights how 'information is used to make decisions about actions' and how a navigation message (which may come from a navigation system or other source) becomes information when it is used to decide on some action.

If a driver does not have sufficient information (from whatever source) to make a rational decision within the time available, heuristics will lead a driver to make navigation decisions which may or may not be correct. A navigation system can therefore promote their use when beneficial, but more importantly, needs to counter their effects when these heuristics would lead to navigation errors.

Heuristics are used by decision makers when they have limited information, time, and/or computational resources to make a rational decision based on considered assessment of alternative choices (Perrin et al. 1993; Todd and Gigerenzer 2000). The driving environment places considerable demands on the navigator; their ability to attend to visual information sources is limited due to the visual demand of the driving environment - the driving task often quoted as being at least 80% visual (Sivak 1996). Humans do not possess unlimited memory capacity and processing power (Todd and Gigerenzer 2000). In addition, the navigation task may be undertaken within a high workload, time-pressured environment, where there may be a lack of, incomplete or conflicting information and decisions must be made within discrete time windows.

Burns (1998) highlights the resource-limited nature of the driver and Ungar (2003) describes how human wayfinding is rarely exhaustive or optimising due to the limited capacity of the human as an information processor. Todd and Gigerenzer (2000) provide a useful categorisation of human decision-making. Their main message is that when knowledge and time are limited, and considered thought (i.e. that described as 'rational' decision making) not possible, heuristics are both (1) used by humans, and (2) can lead to good decision performance. Heuristics ('rules of thumb') are simple rules that guide information search, identify when stopping rules should be employed, and enable quick decisions to be made. Tversky and Kahneman (1974) identified a range of heuristics, plus 'biases' which were associated systematic deviations from what might be expected from 'rational' decision makers.

In the face of uncertainty and an inability to undertake considered information search, assimilation and processing, a driver will tend to use heuristics to make a navigation decision (Perrin et al. 1993). They may be 'satisficers' (Simon 1957), with the 'replacement of the goal of maximizing with the goal of satisficing, of finding a course of action that is *good enough*.' A summary of other heuristics is provided in Table 6.3, with potential impact on navigation behaviour discussed in Section 6.7.

Category	Heuristic(s)
Ignorance-based decision making	**Recognition heuristic** – the one that is recognised is chosen
One-reason decision making (stop looking for cues as soon as one is found that differentiates between the options being considered)	**Take the best** – search for cues in the order of their validity **Take the last** – the cue that was used for the most recent decision is checked fist **Minimalist** – select cues in a random order
Elimination heuristics for multiple option choices	**QuickEst** - use successive cues to eliminate more options **Categorization by elimination** – choose the one category, from several possible, that an 'object' falls into
Satisficing heuristics	**Aspiration level** – a search for alternatives is stopped as soon as an aspiration level is met (i.e. 'this one is good enough')

Figure 6.3 Categories of heuristics, based on Todd and Gigerenzer (2000)

There are two main sources of information in order to make navigation decisions: '(1) a model of the world based upon prior experience [i.e. cognitive maps] and (2) immediate sensory information' [i.e. that obtained from internally from the vehicle, or externally from the environment] (Chown 1999). Similarly, Frank (2003) describes how navigation decisions are made based on (1) previous knowledge, (2) information from a navigation message, and (3) knowledge that can be obtained from the world, and additionally discusses how the contribution from these three sources varies. Although not explicitly stated by Frank (2003), the information from a navigation message, or that obtained from 'the world' may be that made available to the driver at a particular point of need, or that *previously* assimilated if it remains relevant (e.g. a 'continue ahead' indication, which remains applicable).

A navigation system should also *manage* information presentation to the driver. Chown (1999) quotes Clark (1989) in highlighting that you need to 'know only as much as you need to know to get the job done'. Specifically in relation to the driving task, Jackson (1998) underlines how previous research by Streeter et al. (1985) and

Dingus and Hulse (1993) has suggested that 'the amount of information provided to drivers in-transit should be limited to what is absolutely necessary owing to the attention and information processing demands of the driving task'.

Burns (1998) makes the key point that a driver needs to be presented with an *optimum* amount of information in order to reduce their navigational uncertainty. Excessive information constrains effective information processing – task performance is limited by the driver's resources available. Too little information results in data-limited performance, where a driver requires information, and has the resources available to process it, but insufficient information is available. Denis et al. (1999) also underline how route directions should contain 'neither too much nor too little information'.

The information presented to a driver at a potential manoeuvre should therefore take into account three key factors:

- Their navigation need at a particular decision point, e.g. the likely outcomes if that information is not used to make decisions, and the resulting heuristic-driven behaviour
- The impact of other information available to them
- Information previously assimilated

Information provided by a navigation system has to promote correct navigation decisions and driver confidence in the light of supporting, or potentially conflicting, cues from the environment. A potential conflict would be a requirement for a driver to turn off the major road: explicit environmental cues (e.g. a sign for 'all major routes'), implicit environmental cues (e.g. directions of traffic flows) and affordances (e.g. widths and orientations of paths) may lead a driver to take a particular route, which may or may not be that required. It is necessary to counteract heuristic-driven navigation behaviour where this would result in a navigation error. Conversely, this heuristic-driven behaviour can be capitalised on where it is likely to result in a correct navigation decision. These are discussed in more detail in Section 6.7 where the implications for adding value to drivers are identified.

6.6 Empirical studies

There are three main sources of empirical research that explicitly identify the information drivers need for route following (and hence that information that a navigation system can present in order to supplement that already present):

- Requirements studies, *generating* those information cues used in navigation
- Empirical studies (within real or simulated navigation environments), *testing* the effectiveness, acceptance of different navigation cues
- Surveys of driver *preferences* for navigation information

These map approximately onto the notions of quality defined by Lovelace et al. (1999), who undertook a study to identify what 'high quality' means in the context of route directions, and how this differs according to the level of traveller familiarity with the environment. Three notions of quality are defined: (1) as a function of the number of elements included in a verbal route description; (2) a subjective rating by individuals; (3) a functional quality, defined in terms of how well the instructions facilitate the wayfinding. These overlap with the normative, subjective and realistic perspectives described by Ahituv et al. (1994). Although Lovelace et al. (1999) describe how 'it is the convergence of the methods which is most useful in determining quality', they unfortunately focus on (1) and (2) above, rather than the functional or realistic quality which is more consistent with the value-adding perspective taken within this thesis.

The sections below summarise some of the requirements studies, empirical studies and surveys. These help identify the information cues that add navigation value, and additionally highlight the underlying theoretical frameworks and coding taxonomies that have been used to formulate studies and interpret results.

6.6.1 Requirements (information generation) studies

Alm (1990) and Obata et al. (1993) undertook similar studies investigating the information unfamiliar drivers would need to navigate a route. In both cases, participants familiar with an area generated sketch maps and/or written directions to identify the navigation information, and used the categorisation of Lynch (1960) to analyse the cues generated. In both cases, participants predominantly generated landmarks, node and path information. Alm (1990) additionally broke down the landmark category to show that traffic lights were the predominant landmark used, followed by traffic signs, shops, petrol stations and bridges. Obata et al. (1993) in a related road study using only five participants, produced similar results to both their requirements study and that of Alm (1990), and showed that the information most commonly referred to was traffic lights, followed by distance to turn and then node or junction information.

Schraggen (1990) conducted a road-based study in which participants drove predetermined routes which were marked on a map. They gave verbal protocols to describe their information searching during these journeys. Out of all utterances, 42% of references were made to street names, followed by: topological information (25%) – including road types, counting of streets and junction angles; landmarks (15%); road signs (14%); and metric information (4%) – including compass directions and distances. The prominence of streets names was probably due to the use of a map as the information source - as opposed to the participants' cognitive maps, as in the case of Alm (1990) and Obata et al. (1993).

Akamatsu et al. (1997) used a verbal protocol method to investigate the information drivers used when navigating with map-based navigation systems. Eight participants took part in this study, with the navigation task involving driving to a series of sub-destinations, after referring to a paper map, choosing a route and programming each navigation system. Words relating to landmarks were extracted from the verbal protocols. Note an extremely broad definition of landmarks was used, being 'information to identify a location', and comprising structures or large land features, road geometry, names of streets, intersections, places, and distances and directions provided by road signs or maps. The most frequently used landmarks were structures (20%) and street names (18%), followed by intersection names (14%), distance information (11%), and place names (10%). In addition, road signs (6%), directions (5%) and railway tracks (5%) were used. Information was obtained from both the navigation system and the environment, consistent with Frank (2003). In addition, the authors highlight the influence of the specific driving environment (central Tokyo) where there is a predominance of large, distinctive buildings. By analysing the structures used as landmarks, the authors summarise the following characteristics of good landmarks: visible from a distance; possessing distinctive features; names being visible from an intersection; and situated close to the roadside or an intersection. The authors recommend that signs showing street names are made clearly visible, and that navigation systems should also display road sign information consistent with their appearance in the real traffic environment.

Denis (1997) provides a framework for the analysis of descriptions of routes, based on descriptions of *pedestrian* routes generated by 20 participants. Although much of this article refers to the generation of discourse, the author also describes how landmarks are referred to, and the functions they play in route descriptions. The first function is 'signalling sites where actions are to be accomplished', i.e. supporting the view-action pairs of Kuipers (1978). The second function is to 'help locate other landmarks' which are then used to describe actions to be taken by the navigator. The third function is 'confirmation', when landmarks are described to provide confirmation that the navigator is on the correct route.

Each route description generated by participants was rewritten by Denis (1997) to isolate the individual information items contained in a description. The content of this standardised data was then classified according to five classes of items: (1) description of an action without reference to a landmark, e.g. 'turn left'; (2) an action associated with a landmark, e.g. 'cross the parking lot'; (3) introduction to a landmark without an associated action, e.g. 'you come to a large building'; (4) description of non-spatial properties of a landmark, e.g. 'the bar is called Take Two'; (5) descriptions which were 'commentaries' e.g. 'it will take about 15 minutes'.

The main finding of relevance from this study was the 'special importance given to landmarks in route descriptions'. Only 17% of items were actions described without reference to landmarks (class 1 above). Thirty three percent were actions directly linked to landmarks (class 2), and 36% were items introducing landmarks (class 3). Class 4 and 5 comprised 11 and two percent respectively.

Janes (2000) undertook a road-based trial to determine the navigation information requirements of older drivers, and whether this differed according to whether they were able to consult a map at the outset. In contrast to the discourse or verbal protocol generation methods employed above, this study used a 'question-asking' approach, where participants asked the experimenter for information as it was needed during the route. The advantages of this approach are that: it allows collection of data relating to information content and timing; participants are likely to focus on information that has navigation relevance; and information seeking and provision is flexible and in realtime, as it can be sought/provided when needed, and elaborated if necessary. Categorisation schemes based on Kuipers (1978), Lynch (1960) and Burnett (1998) were used. Eighty percent of questions were asked on approach to junctions. At an overall level, there were few differences between the percentage of questions falling into the high level question categories (i.e. direction, distance, node, landmark, path and sign). Grouping age and map or no-map participants together, mean percentages were as follows: direction-related questions (44%), distance-related questions (10%), node-related questions (17%), landmark-related questions (9%), path-related questions (7%), sign-related questions (13%).

Direction-related questions were predominantly ego-centred (93%) such as 'where do I turn?', as opposed to local or globally-referenced. Distance-related questions were predominantly absolute (40%) such as 'how many miles?' or cost-based (50%) e.g. 'how long?' as opposed to relative (10%) e.g. 'do I carry on until the next junction?'. Node-related questions comprised those relating to junction type (35%) or their use as a reference (65%) e.g. 'which way do I go at the roundabout?'. The majority of landmark questions referred to traffic lights (68%); these were subdivided into questions relating to: the name of the landmark (25%), the description of the landmark (10%), the location of the landmark (24%) and its use as a reference (41%) e.g. 'which way do I go at the traffic lights?'. Path-related questions comprised: path class (21%), lane information (15%), prior path – which side road to turn into (59%) e.g. 'there's a turn off here soon, is it the next left?', path geometry (5%).

6.6.2 Empirical tests of information categories

In contrast to above, a range of studies has empirically *tested the impact* of different types of navigation information on driver performance.

Schraggen (1993) summarised a number of studies, including those that compared navigation performance with navigation systems versus that with conventional maps. On this basis, it is not recommended that map-based displays are used for driver navigation systems. The author concludes that road signs and left-right instructions are both potentially effective as sources of navigation information. Road signs were found to be particularly useful when driver decision points were complex.

Bengler et al. (1994) undertook a simulator-based study in order to assess the impact on navigation performance of providing landmarks (compared to junction representations alone), and chunking of instructions, via a visual display. Twenty four participants viewed video tapes of routes, performed a tracking task using a steering wheel, and used their turn signal to indicate the location of turnings. The display of landmark information (stop signs and traffic lights) at junctions – termed 'context' information by Bengler et al. (1994) – was found to reduce indicator errors, i.e. the too-early, too-late, or incorrect operation of the indicators.

Jackson (1998) undertook a study to investigate the impact of different navigation instruction sets on spatial knowledge acquisition. Eighty participants viewed a video of a route, with either no auditory turn instructions at driver decision points, full instructions, or information comprising landmark information and directions (e.g. 'turn left at the garage'). The 'full' instructions mimicked those provided by navigation systems, although they are not described in detail. The best participant performance was obtained from using instructions that linked direction instructions with landmarks visible at the decision point, consistent with the theories of Kuipers (1978) and Allen (1999). However, a limitation with this study is that the outcome measures were based on tasks designed to measure the acquisition of spatial knowledge, even though the results are interpreted in terms of the design of future route guidance instructions. Therefore the output of the study actually demonstrates the direction guidance that promotes a cognitive representation of an area, rather than that needed to navigate a route effectively and safely.

Philips (1999) undertook a simulator study to test the effect of landmark information in route guidance displays on navigation performance. Forty eight participants drove a route using route guidance displays that did, or did not, include landmark icons to represent selected buildings, vehicle signs and traffic lights that were present in the simulation environment. Age and visibility (presence of fog) were included as independent variables. The inclusion of landmark icons was found to help drivers make turn decisions more quickly, and were particularly beneficial to the older drivers when driving in fog. It was stated that a pilot study was undertaken to determine suitable landmark icons. However, no details are provided of whether landmarks were selected according to specific attributes (e.g. visibility or familiarity attributes), or whether their context of use (e.g. junction characteristics) were incorporated into the research design.

In a *pedestrian* wayfinding task Tom and Dennis (2003) showed that route directions referring to street names were less effective than those that referred to landmarks. In their study, 'effectiveness' was defined by the number of navigation errors, and the degree to which participants stopped, and checked the directions they were given.

6.6.3 Surveys of driver preferences

There have been relatively few surveys of drivers' preferences for navigation information –the *subjective* quality of route directions (Lovelace et al. 1999). Streff and Wallace (1993) carried out a postal survey of over 2700 US drivers to determine, amongst other details, drivers' use of, and preferences for travel information. This survey focused on information source, rather than information content, showing that a combination of verbal, written and map sources were used for navigation purposes in an unfamiliar area.

In contrast, Burns (1997) undertook a large-scale postal survey in order to understand drivers' wayfinding strategies *and information needs.* A total of 160 questions were asked of respondents. The three most useful categories of information for travelling on a *major road* were road numbers (74%), place names (73%) and junction numbers (57%), N=1157. The totals sum to greater than 100% since most respondents gave three responses to this question. For travelling *through a city,* the three most useful categories of information were street names (67%), lane position (48%) and landmarks (48%), N=1158. Of particular relevance to the design of vehicle navigation systems is how respondents would want a passenger to describe a turn. Several authors, including Burnett (2000) have described an informed passenger as the 'ideal' source of navigation information. The three most popular types of information determined by (Burns 1997) were left-right directions (60%), landmarks (44%) and road numbers (41%), N=1158.

Burnett (1998) undertook a face-to-face questionnaire survey of 200 experienced drivers. This was a broad survey of the information preferences of drivers, and differentiated between (1) dual carriageway and motorway environments, (2) single carriageway roads, and (3) road within towns and cities. A summary of results is shown in Table 6.1, based on the mean ratings from a 9-point rating scale, where 1 = 'very useful' and 9 = 'useless'. The percentages in brackets denote the proportion of participants who rated that information category as 1, 2 or 3 on the 9-point scale. Note, this table excludes ratings for distance and compass directions, since these were not rated as useful by participants.

	Dual carriageways and motorways	**Single carriageway roads (out of towns and cities)**	**Roads within towns and cities**
Road numbers (e.g. A417)	1.7 (93%)	1.8 (89%)	3.6 (59%)
Place names (e.g. Loughborough)	1.8 (93%)	1.8 (95%)	3.1 (66%)
Junction numbers (e.g. junction 3)	1.5 (96%)	N/A	N/A
Road/street names (e.g. Park Drive)	3.4 (61%)	2.6 (73%)	2.0 (90%)
Landmarks (e.g. traffic lights)	3.1 (66%)	2.7 (72%)	2.0 (88%)
Road/junction layout (e.g. T-junctions)	3.3 (59%)	3.0 (67%)	2.4 (82%)

Table 6.1 Preferences for navigation information (Burnett 1998)

6.6.4 Models of driver navigation

Several models exist for *pedestrian* navigation such as that of Raubal and Worboys (1999). This differs from Kuipers' (1978) view-action pairs, by also taking into account 'knowledge in the world', or the 'information we can get directly from the objects and places we observe, namely their affordances'. Raubal and Worboys (1999) differentiate between information affordances (e.g. 'there is a route this way') and action affordances (e.g. 'you can take this route to get somewhere'). Affordances (as discussed in more detail in 2.3.2) are used to help identify where value may be delivered with navigation systems at the end of this chapter.

Several authors have developed specific models that describe the navigation task from a driver's perspective. Burns (1997) describes a theoretical model of wayfinding based on the use of a driver's cognitive map and short and long term memory, plus information cues from the environment, to resolve navigational uncertainty. This model is based on the information processing model of Wickens (1992), but also adapted to take into account wayfinding theories such as those proposed by Chown (1995), Passini (1984) and others. It is also consistent with Monk (1998), since it incorporates information processing with a post-action feedback loop that provides continual information cues to the driver.

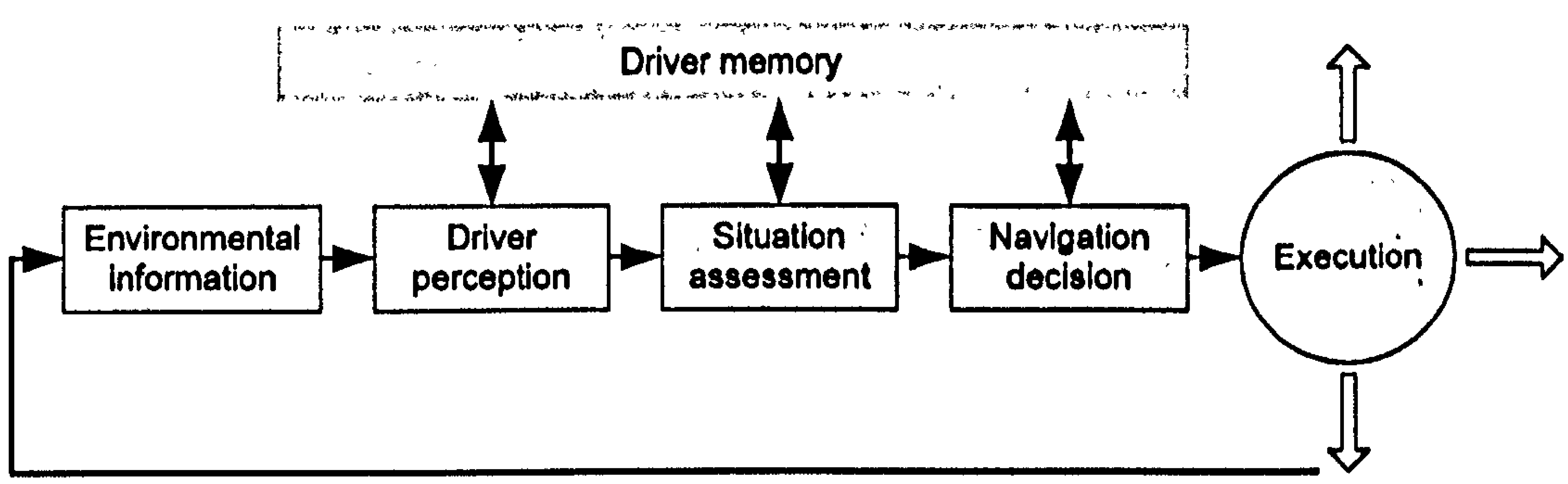


Figure 6.4 Theoretical model of driver wayfinding, from Burns (1997)

Figure 6.4 shows that when a driver encounters a decision point, they must resolve the uncertainty of having more than one potential travel option. In order to reduce this uncertainty, information is extracted from the environment and/or retrieved from the cognitive map stored in the driver's memory. As described in Burns (1998), the principal types of spatial information are distance, location, orientation, landmarks, path (i.e. road) segments, and decision points. This spatial information may come from a variety of sources, including road signs, maps, prepared notes, instructions from passengers, and in-vehicle navigation systems. This information is used by the driver to assess their progress, their orientation and their path (i.e. route) options. A particular route, and required direction of travel, is then selected. This process is repeated at each driver decision point. Burns (1998) identifies how the majority of wayfinding errors are likely to be knowledge based *mistakes*, where the intended response is incorrect, due to a misinterpretation or flaw in the choice of response. These are distinct from *slips* where the intended action was correct, but it was incorrectly executed, or lapses, where a necessary response was omitted, usually due to a failure of memory (Reason 1990).

Burnett (1998) describes a model which focuses on the temporal nature of the navigation task, and identifies the basic information requirements for each of the navigation stages. A slightly adapted version of this model is shown in Figure 6.5.

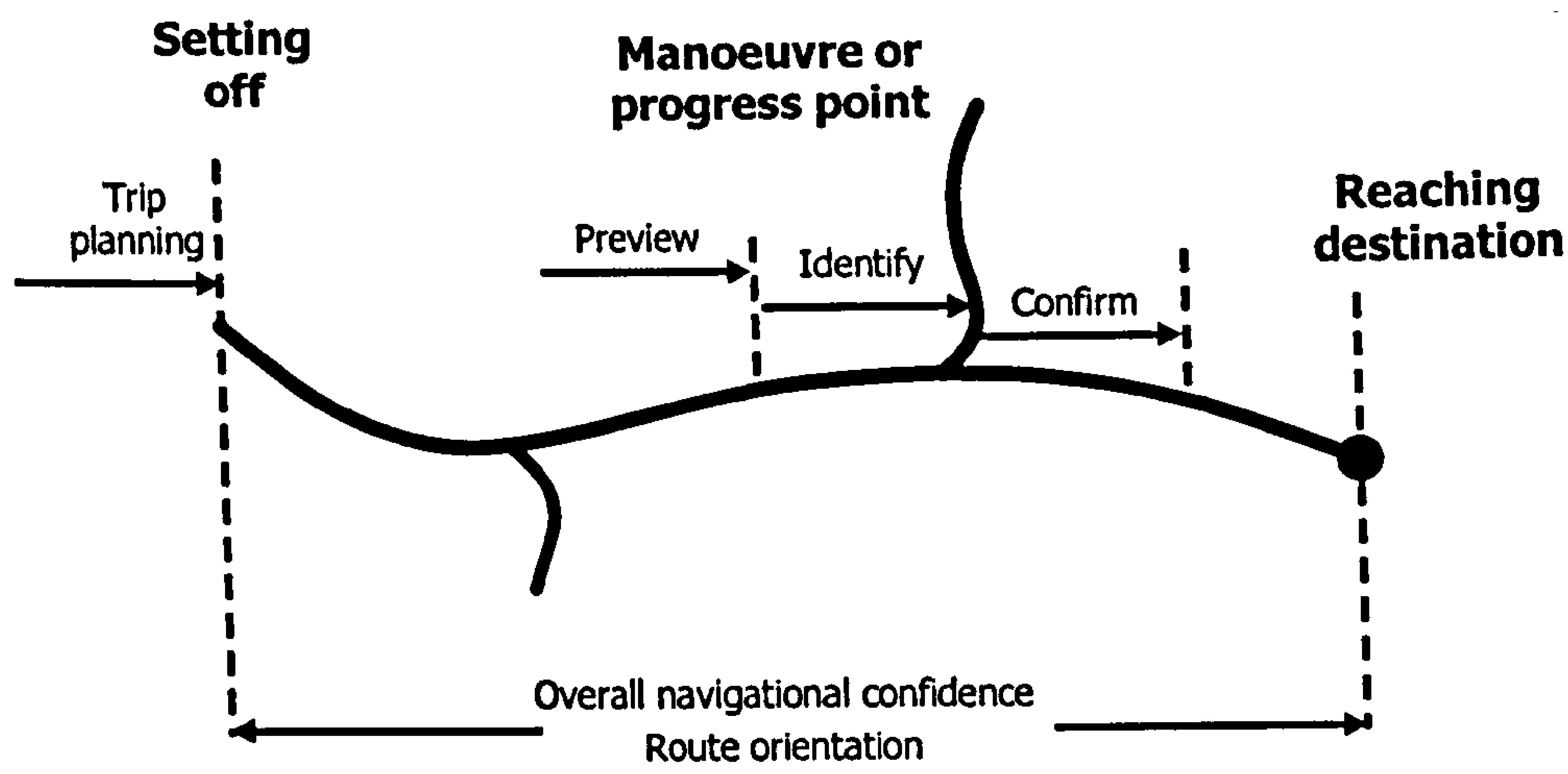


Figure 6.5 A task-based model of navigation, after Burnett (1998)

This describes trip planning as a function prior to setting off, with the maintenance of navigation confidence and orientation occurring throughout the route. It identifies three temporal aspects to the information needed at each driver decision point: preview information that prepares a driver for a turning, identifying information to locate a turn, and confirming information that identifies whether a correct turning has been made.

6.6.5 The role of landmarks in vehicle navigation systems

It has been proposed that future navigation systems can be made more effective and safer by incorporating landmarks as key navigation cues (Burnett 2000). In line with Kuipers (1978), by being prominent features of a large-scale environment, they can help form the associations between a particular view of the environment, and the actions needed at that location. By providing external reference points which are easily remembered and recognised, they can potentially reduce the need to refer to an information display in order to locate a navigation decision point. Richter and Klippel (2004) highlight the three roles that landmarks can play within driver navigation: (1) at or near a decision point, they identify the location of that decision point; (2) between decision points they describe the route and act as confirmation that the driver is on the correct route; (3) in the distance (and potentially off-route) they act as beacons to aid orientation.

As well as being key elements within 'quests' (Allen 1999) - i.e. directed instructions to unfamiliar destinations - landmarks have been shown empirically to be widely used within drivers' wayfinding strategies (Alm 1990), and valued by drivers as information cues (Burns 1997; Streeter and Vitello 1986; Wochinger and Boehm-Davis 1997). The *potential benefits* of landmarks are relatively well established. A range of studies has empirically demonstrated how landmarks have the potential to enhance driver navigation systems in terms of: (1) effective navigation decisions (Bengler et al. 1994; Jackson 1998; Tom and Denis 2003); (2) reduced cognitive effort and distraction (Burnett 1998), and (3) increased confidence and satisfaction (Alm et al. 1992; Green et al. 1993).

6.6.5.1 Definitions of 'landmarks'

Landmarks have been defined from varying theoretical perspectives. Lynch (1960) described them as external reference points which are easily observable from a local or distant perspective. Richter and Klippel (2004) differentiate between point-like, linear or aerial landmarks. Point-like landmarks 'are located in small, restricted areas of an environment'; 'linear and areal landmarks extend across an environment like a river or a forest'.

Kaplan (1976) defines a landmark as "a known place for which the individual has a well formed representation", and outlined two theoretical factors that lead to a place or object acquiring landmark status: the frequency of contact with the object or place, and its distinctiveness. Three type of distinctiveness were hypothesised: visual distinctiveness (a predominantly objective quality relating to the physical attributes that discriminate it from the surrounding environment); inferred distinctiveness (knowledge concerning its structure or form that makes it stand out from what is usual); functional distinctiveness (the salience in terms of the goals or sub-goals of the individual). In addition to the visual characteristics of landmarks and their functional or social importance, the location of an object within the environment has also been shown to impact significantly on its effectiveness as a landmark (Allen et al. 1978; Carr and Schissler 1969). Sorrows and Hirtle (1999) define landmarks as 'prominent, identifying features in an environment, which provide an observer or user of a space with a means for locating oneself and establishing goals'. They describe three forms of landmarks: *visual* landmarks have prominent visual features; *cognitive* landmarks have meanings that stand out – they may be visually similar to other nearby objects, and hence can be missed by those unfamiliar with the area; *structural* landmarks are those whose importance stems from its role or location in the space. The strongest landmarks will score highly on all of these three factors. Klippel et al. (2005b) broaden the term 'landmark' to include road junctions and intersections. They additionally highlight several benefits of junction/intersection information: they are readily, and reliably identifiable from electronic map databases; reliably identified by drivers; stable in appearance and presence, and highly visible under different environmental conditions.

6.6.5.2 Landmarks suitable for driver navigation

Lynch (1960) highlights how the location of landmarks is crucial for their use within the mental imagery of a city and that they are 'more useful if the direction of view can be distinguished', and if 'identifiable from near and far, while moving rapidly or slowly, by night or day'. In addition to the theoretical definitions of good landmarks - e.g. the visual, cognitive and structural dimensions of Sorrows and Hirtle (1999) - several studies have commented specifically on the characteristics of landmarks that are useful for driver navigation purposes. Akamatsu et al. (1997) state that popular landmarks in their study were visible from a distance, unique in appearance, and close to or part of the road infrastructure. Green et al. (1995) state that the best landmarks are those which can be seen from a distance, are close to the road, near junctions, and permanent. Burnett et al. (2001b) identified five attributes that were characteristic of 'good' landmarks for vehicular navigation: permanence, visibility, usefulness of location, uniqueness (incorporating distinctiveness), and ability to be described with brevity. Pauzie et al. (1997) highlight how the ability to present landmark information is critical, and that for branded landmarks (such as specific fast food outlets) it is the familiarity of the logo that is important, rather than the appearance of the building itself.

6.6.6 Contextual influences on drivers' information requirements

A surprisingly small number of relatively recent studies have highlighted how the context of a navigation decision impacts on what 'right' (Hollnagel 1988) means in terms of presenting navigation information to a driver. Context was discussed in Section 2.6.3 - in this respect the broad definition of context by Dey et al. (2001) is used: 'any information that can be used to characterize the situation of entities (i.e. person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves'. Context can have a major influence on the value of information to a driver at a specific decision point, i.e. in terms of their need, or the impact on their resulting behaviour.

Denis et al. (1999) in a series of studies of (pedestrian) route directions in Venice conclude that the impact of good and poor navigation directions was dependent on the nature of the descriptions, but also the context of their use. Klippel at al. (2005a) describe how a change in direction can be imbued with different meanings according to the type of intersection at which it takes place (and hence the need to understand the physical context surrounding the manoeuvre).

Bradley and Dunlop (2002) undertook a small-scale interview study, identifying the information that pedestrians needed to navigate a route. They underlined the need for context dependent presentation of information. However, their discussion of context focussed on the individual differences with respect to their contextual descriptions of the environment, and not how the nature of decision points influenced the information generated by participants.

Raubal and Egenhofer (1998), again in relation to pedestrian navigation, describe a simple model of the complexity of wayfinding tasks within built environments. This model combines (1) the number of decision choices and (2) the clue available – including affordances (Norman 1988) - (either being good, poor or not present), to suggest those combinations where navigation is likely to be difficult. A simulated navigation scenario was used to identify the visual elements used to navigate within an airport, and their impact on perceived complexity.

Sugiyama et al. (2001) developed a model of the demand (i.e. user need) for navigation assistance at different types of manoeuvres. They identify the need to select situations where guidance is necessary, in order to minimise the navigation errors that *pedestrians* make. However drivers have arguable even greater requirement for selective information presentation, due to their greater resource-limited characteristics. Based on presenting a variety of schematic navigation scenarios to questionnaire respondents, Sugiyama et al. (2001) propose that the need for navigation information depends on three factors:

- Non-linearity (the change in direction of travel before and a decision point) – the greater the change of direction, the greater the navigation demand.

- Complexity (the angle between the required route and other possible routes) – the smaller the angular difference, the greater the navigation demand.
- The change of road width at a decision point – moving from a major route to a minor route creates greatest navigation demand, followed by moving from a minor to major route. Continuing on a major route decreases navigation demand.

In addition, they recognise that interactions occur between the above factors, and that they can act in combination to increase or decrease the need for navigation information. Dalton (2003), consistent with the model by Sugiyama et al. (2001), describes how people preserve linearity between start and end points, and minimize angular differences between pairs of bearings.

Klippel and Winter (2005) highlight how the visual and semantic (i.e. cognitive) salience properties are properties of objects that are independent from routes and the street network. In an earlier article, Winter (2003) highlights the need to take into account the advance visibility of landmarks, and proposes a model that calculates this. Limited testing demonstrated both the confounding impact of the context of a decisions point, but also evidence that wayfinding improved when the presentation of landmarks takes into account their advanced visibility.

Richter and Klippel (2004) discuss how the lack of adaptation of navigation systems to route and environmental characteristics is a 'major drawback'. They propose a model for generating context-specific route directions and distinguish between *structure* and *function* in wayfinding. Structure refers to the features physically present in the environment, which is a relatively static description. Function is described as the 'relation of these structural elements to actions performed in the environment', i.e. the demarcation of those features relevant for a wayfinding task. A key point made by Richter and Klippel (2004) is that not every decision point has to be mentioned explicitly in a route instruction, since different decision points require differing degrees of attention by the wayfinder. Procedurally-based rules, as applied by current navigation systems, can lead to unnecessary guidance. In addition, the structure of the environment influences the kind of instructions that can be given. The context of the environment (and particularly that associated with each decision point), determines both the need for explicit navigation instructions, and the kinds of instructions that can be provided to drivers.

The solutions proposed by Richter and Klippel (2004) are based on analysis of the route network, generation of 'abstract route directions' at *each* decision point, analysis of these directions to identify sub-sequences that share the same elements (e.g. 'straight on' directions), and then chunking of the abstract route directions to reduce the number of navigation instructions. This chunking could result in an instruction: 'straight over three junctions, and then right'. This is termed numerical chunking. In addition the authors describe *landmark chunking*, where an unambiguous landmark is used to mark a direction change, without specifying intermediate decision points (e.g. 'turn right at the petrol station'). *Structural chunking* exploits spatial features that are unique in a given environment, again without referring to intermediate instruction, e.g. 'turn right at the T junction' or 'follow the river'.

Their article usefully underlines the need for information presentation to be contextually-based, driven by both the *need* for information at a particular decision point, and the *availability* of information within the environmental structure. In addition, they highlight the need to use heuristics to enable contextually-based route guidance to be generated, due to the computational impossibility of providing individual rules for each specific navigation situation.

In one of the few identified articles to explicitly discuss information value in relation to navigation instructions, Frank (2003) describes how a message received becomes information when it is used to decide on some action. Consistent with the more general discussion in Section 2.5 he highlights how 'information is used to make decisions about actions'. The 'pragmatic' perspective is underlined by re-iterating how the content and meaning of navigation messages must be investigated in a 'decision situation', as opposed to the encoding, transmission through a channel and decoding as described by Shannon and Weaver (1949). Frank (2003) underlines how navigation decisions are made based on (1) previous knowledge, (2) information from a navigation message, and (3) knowledge that can be obtained from the world, and that the contribution from these three will vary according to the individual, the state of the world and the message. Frank (2003) describes three scenarios. For a knowledgeable user, a succinct instruction with low pragmatic information content is sufficient, since a more detailed instruction will have similar meaning for that individual, and hence still a low pragmatic information content. An individual with less previous knowledge needs a higher pragmatic information content and therefore can extract greater information value from a more detailed instruction. Where information is available from the world, the same content within a message may have a lower information value. An extreme case is also described, where an individual who knows how to get from a start point to a destination derives no pragmatic value from a navigation message, irrespective of the content within that message. There is no value contained within the message for that individual.

A final point made here is the issue highlighted by various authors e.g. Burnett (2000), Richter and Klippel (2004) - that much of the information needed to contextually generate instructions is not yet available in an accessible digital format, e.g. the nature and location of road signs, and the location of conspicuous landmarks. By way of example, in the UK, information on traffic lights is managed locally by local and regional councils, and this information is not always easily accessible to third parties.

6.6.7 Summary of literature

The main points arising from the summary of literature in this chapter are:

- A turn-by-turn navigation strategy is that which is most compatible with (1) a driver navigating in an unfamiliar area, and (2) resource-limited processing by a driver.
- The 'right' information from a driver's perspective should resolve uncertainty, promote driver confidence and enable correct decisions to be made at driver decision points.
- With a lack of information from the environment or an in-vehicle source, a driver may use heuristics to arrive at navigation decisions. Although often effective, these may lead to navigation errors.
- Information presentation to the driver needs to be managed due to the attention and information processing demands of the driving task – a 'give' component with a value perspective. That provided by a navigation system therefore needs to take into account what new information will have the greatest positive impact on the driver.
- A range of information cues are useful to drivers. Landmarks in particular have been shown to be inherent components within drivers' navigation strategies for unfamiliar routes, and are useful and valued cues for navigation by drivers.

- Research to date has placed little emphasis on the context (in the broadest sense of the word) associated with manoeuvres, and the implications for information needs.
- There has been little emphasis on the *quality* of navigation cues on navigation performance – reflecting the likely variability within a real-world environment.
- There is a lack of consideration of *value-add*, i.e. research that identifies the pragmatic information value of instructions and particular cues at specific manoeuvres.

6.7 Adding value with navigation systems

Chapter 5 highlighted the way in which MLS can potentially add value, and driver navigation systems are clearly consistent with the enabling properties shown in Figure 5.2: they 'travel with' the user, are time and location sensitive, and adapt their behaviour according to the systems (i.e. designer's) assessment of the user needs. The literature on driver navigation has generally failed to take a value-adding perspective on system design – i.e. identify when navigation information 'makes a difference' (and should therefore compete for the resource-limited attention and processing capabilities of the driver). An exception was Frank (2003), who describes value in terms of its pragmatic value and the decision that information leads you to take.

For a driver navigating along a route, the potential impact of a navigation system can be assessed at various levels, with differing implications, as shown in Table 6.2:

Level of assessment	Outcome in terms of:	Assessment criteria	Design implications
Subtask	Decision making	Whether the driver makes a correct navigation decision at a manoeuvre	Information provision at manoeuvres
Task	Impact on journey	Whether the driver experiences a delay to the journey (there may be alternative routes available)	Functionality embodied in the system, e.g. re-routing
Individual	Impact on the individual	Whether a delay has particular consequences for the driver	Design/marketing of product according to consumer needs

Table 6.2 Levels of assessment for system value

There are a range of different design implications as shown in Table 6.2: (1) implications for the provision of information at manoeuvres to ensure that correct navigation decisions are taken; (2) implications for the functional algorithms embodied in a system that select route choices and offer automatic rerouting; (3) implications for the design of systems for particular markets based on perceived usefulness.

Although value-add can be considered at various levels, as shown Table 6.2, the focus of the remainder of this thesis is on value-add (and therefore information provision) at the manoeuvre level. Value-add must also take account of the particular strategy that is being employed, since the match or fit (Vessey 1994) between the content and timing of information delivery and the user needs will depend on the strategy that is being employed to accomplish a particular task. It is assumed that a turn-by-turn navigation strategy - i.e. 'piloting' (Allen 1999) - is being employed, with information required at key driver decision points to (1) enable correct navigation decisions to be made and (2) maintain driver confidence, as per Burnett (1998) and Burns (1998).

In most cases, a route will consist of a multitude of locations where a driver has more than one navigation option, and hence navigational uncertainty. The *need* for navigation information (i.e. the value it provides at that location) will vary:

- At some potential manoeuvres (e.g. continuing along the more major road past minor turnings off) a driver would not normally expect an instruction of the form "continue past the road on the left". With or without a navigation instruction, a driver would almost certainly continue confidently along the correct route. Explicit instructions add little value in these situations - they may add unnecessarily to driver workload due to their attentional demands and be perceived as superfluous by the driver. The 'give' component will outweigh the 'get' component.
- At other locations (e.g. continuing straight over a mini roundabout with more minor turns to the left and right) a driver may prefer an instruction to continue over the mini roundabout, but would almost certainly choose this navigation option anyway without an explicit instruction at that location. They might expect, but not necessarily need, information in this situation.
- A third category of manoeuvres represents those locations where a driver *would* expect a navigation instruction, and would either commit a navigation

error, or experience substantial navigational uncertainty, without that information. Examples would be turning left at a roundabout, on approach to a T junction, or turning off the major road. The 'get' component will outweigh the 'give' component.

The main influence on *driver confidence* on approach to a manoeuvre will be the extent to which there is navigational uncertainty at that manoeuvre (Burns 1997). Those factors that promote navigational uncertainty are proposed in Table 6.3 below. As noted in Section 6.6.4, the fact a driver is confident on approach to a manoeuvre does not mean that they will necessarily take the correct turning – they may erroneously believe that they are taking the correct option – a 'mistake' as opposed to a 'slip' or 'lapse' (Reason 1990).

The main influences on *navigation behaviour* will be whether there are unequivocal navigation instructions that can be followed, and the potential applicability of heuristics at that manoeuvre. The applicability of heuristics may lead to correct or erroneous assumptions about the desired route. Based on the literature in this chapter, the contextual factors leading to the potential application of these heuristics are also shown Table 6.3.

In practice, a driver will use a combination of all of the factors to make a navigation decision, and will trade off factors against each other where they are contradictory. However in general, the more heuristics that can be applied, *and* that will result in a navigation error on their application, the greater the need for unequivocal information to support decision making at that potential manoeuvre, and the greater the potential to add value with information from a navigation system.

Additional factors will influence decision making at manoeuvres due to the inability to rationally assimilate and process information (Todd and Gigerenzer 2000). If the *perceived complexity* of the manoeuvre is high, this will increase the likelihood of the use of heuristics to simplify the navigation decision. If the *driver workload* at that manoeuvre is high (e.g. due to heavy traffic levels), this will also increase the likelihood of the use of simplifying heuristics. Driver workload has been measured widely in terms of six constructs (Fairclough 1991; Hart and Staveland 1988), and therefore any of these may promote the use of heuristic-based decision making: *mental demand* (e.g. planning, thinking, deciding, remembering, looking, searching); *effort* (concentration); *physical demand* (physical activity); *time pressure* (being hurried or harassed); *distraction* (visual and/or aural that decreases vigilance); *stress level* (i.e. annoyed, frustrated, worried, irritated). Driver workload can be interpreted as the value-based 'give' component of vehicle navigation use.

Factor	Impact on driver confidence on approach to and at the manoeuvre	Impact on the driver's likely course of action
Relative location of the manoeuvre	Driver will tend not to expect a manoeuvre immediately following a previous turning	Driver will have expectations regarding when they should be turning of the current road
Poor visibility of manoeuvre on approach (driver perception)	A manoeuvre that is suddenly visible or not anticipated will reduce driver confidence	Driver will tend to follow the present route
Visual appearance of a potential route	Driver will experience uncertainty when the appearance of a route does not match their expectations	
The existence of a single more major route at the manoeuvre	Driver will experience uncertainty with a lack of a single more major route	Driver will tend to follow the single more major route
The existence of multiple navigation options	Uncertainty will increase with a larger number of potential navigation options	An obvious route choice will be less apparent
The existence of a major route that continues the global direction	Uncertainty will increase if it is not viable to continue the previous direction	Driver will expect to continue along the same route
The direction of the major traffic flow at a manoeuvre (may not be a more major route)		Driver will tend to follow the major traffic flow
The existence of a route which is more heavily signposted		Driver would expect to take the route that is more heavily signposted

Table 6.3 The main influences on driver confidence and navigation behaviour

The basic relationship between the *potential* value of information and driver outcomes without that information (as might be provided by a navigation system) is shown below in Figure 6.6. According to the discussion of information value in Section 2.5, and consistent with Frank (2003), it assumes a 'realised' or 'pragmatic' perspective.

The value of information is reflected in behavioural outcomes relating to 'gives' and 'gets'. In addition, it is a relative concept based on a comparison of outcomes due to behaviours that result from differing information environments.

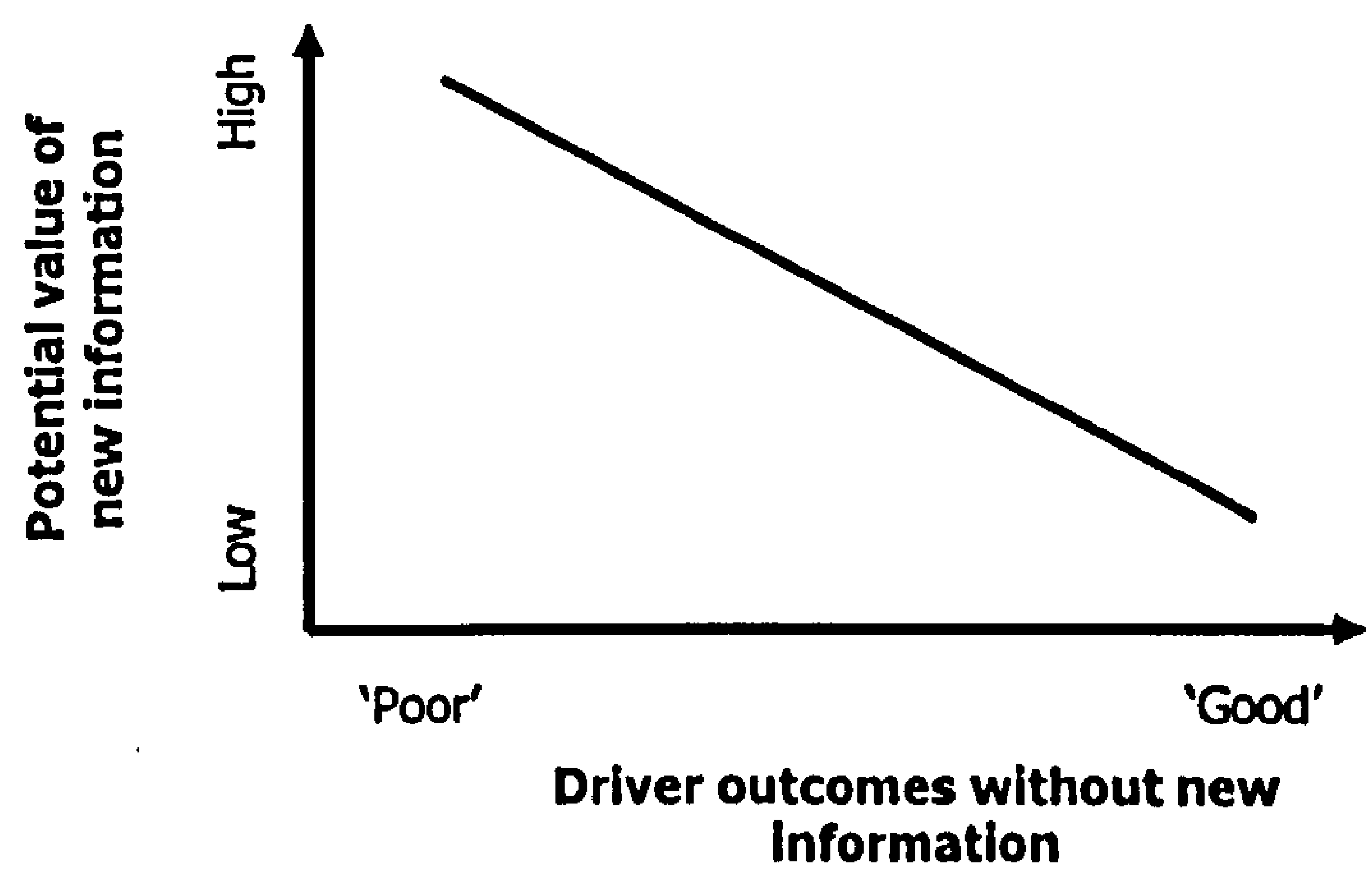


Figure 6.6 The relationship between the potential value of new information and driver outcome measures

The potential value of providing new navigation information (e.g. via a vehicle navigation system) at a manoeuvre is highest when the absence of this new information is likely to result in 'poor' driver outcomes (i.e. navigation errors and/or high uncertainty). By providing information to the driver it is possible to influence the driver outcomes as shown in Figure 6.7, the value-add being indicated by the difference between driver outcomes in the two information environments.

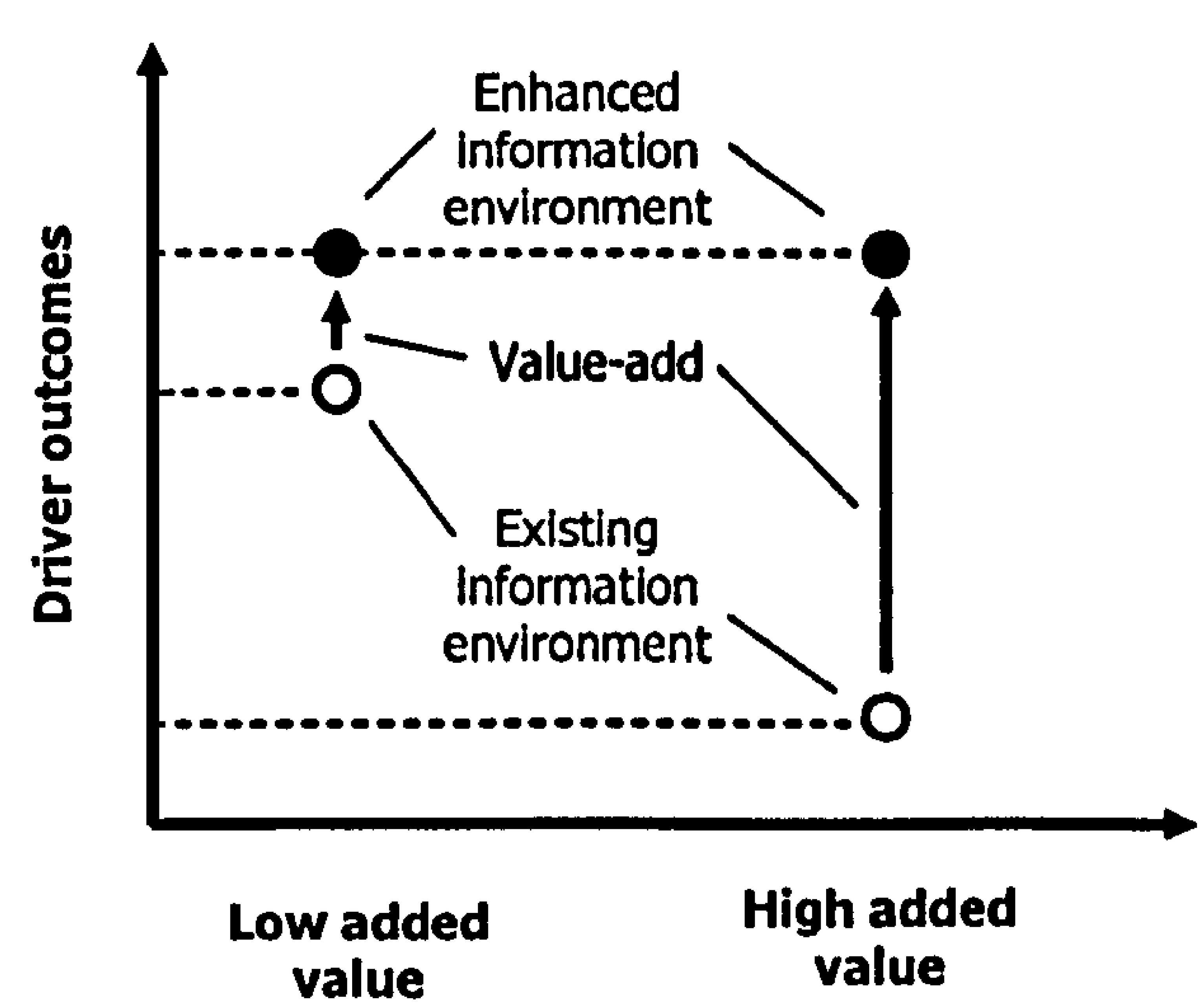


Figure 6.7 A comparison between low and high added-value scenarios

The key indicators of 'good' navigation outcomes are a lack of navigation errors, maintenance of driver confidence and acceptable levels of driver workload. However, driver navigation is normally considered an integral element within the structure of the overall driving task (Michon 1985). Added value must therefore incorporate those behavioural indicators that can be used to assess any positive or negative impact on the safety of the driver and any safety impact on others. These are described where applicable in the empirical studies that follow.

In addition, there are a range of human, environment and social impacts which are related to the use of driver navigation systems. These include: the potential restricted development of cognitive maps highlighted by Jackson (1998) and others, and increased environmental impact (MacDonald 2006) due to greater mobility. Although of interest, these wider concerns fall outside the scope of this thesis.

6.8 Conclusions

The main conclusion from this chapter is that a value-adding approach to navigation system design can help understand what 'right' (Hollnagel 1988) implies when presenting navigation information to a driver. This perspective has had little attention within the literature, despite the need to carefully manage information presentation to the driver. Although there is abundant literature describing in general terms those cues which are useful to drivers when navigating, there is a lack of understanding of: (1) how important individual cues are, (2) how the context of manoeuvres impacts on the need for navigation information, and (3) the impact of the quality of cues on driver behaviour. These questions are tackled in the remaining chapters of this thesis.

7 DRIVERS' NAVIGATION INFORMATION REQUIREMENTS

	Research questions addressed in this chapter:
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	What is user 'value' in the context of mobile location services?
4	**How can a specific mobile location service (driver navigation) be enhanced using a value perspective?**
5	What general recommendations can be made for mobile location services research and design?

7.1 Introduction

Navigation systems can clearly capitalise on the ability to deliver location-relevant information and functional value to the consumer. The 'mission' may be important (May 2001), and the alternatives as referred to by Solveig Wikström, quoted by Lindgren et al. (2002) may not be present (e.g. absence of passengers who can map-read), or inaccessible (e.g. foreign roadsigns). In addition, due to their relatively simple use of context (i.e. driver location in relation to the road topology) and the predictable and observable system behaviour that results, they are consistent with the recommendations for context-aware applications made by Bellotti and Edwards (2001) and Brown and Randell (2004).

The navigation market, and especially that based on personal portable devices (including mobile phones) is projected to increase over the next five years (InStat 2007). The design of driver navigation systems needs to be optimised in order to maximise their effectiveness, and limit their impact on driving safety. Current systems tend to provide the same template of information at each manoeuvre, predominantly junction layout and distance to turn. The information they present is largely independent of (1) the external information cues that may be available, and (2) a driver's need for an explicit navigation cue at a particular manoeuvre. A value-based approach can help manage information provision to the driver, by presenting effective cues to them, in those situations where they are needed.

Despite considerable literature on driver navigation going back over two decades, there is a lack of research with a value-based perspective. The work reported in this chapter investigated the information requirements for vehicular navigation by a driver along an unfamiliar route. Consistent with models of navigational uncertainty (Burns 1997), information (value) being that which makes a difference (Ahituv et al. 1994), and the need to limit information provision to the driver, e.g. Srinivasan (1999), this study investigated the importance of particular information cues, and the impact of context on the need for information.

7.2 Aims

The aim of this study was to investigate how a value perspective may be used to understand the information requirements for a driver within a demanding and highly location-dependent information environment – navigating an unfamiliar, complex urban route. It therefore addressed value at an interaction, rather than motivational level (Kankainen 2002). In particular, the objectives of the study were to identify:

- The *need* for navigation information provision at different locations along a route (the context-dependent value of information augmentation).
- The *information cues* needed to navigate a particular route, and the value attached to those cues.

In addition, the study objectives included providing recommendations for enhanced design of navigation systems, based on adding value to a driver at a point of need.

7.3 Study rationale

7.3.1 Choice of methodology

The study reported here was an *information generation* study: it set out to understand the information *needed* in order to navigate a particular route. This methodology is in contrast to an *observational* approach which would identify the information *actually used* when someone navigates from a start point to a destination. An observational approach would identify more 'real' behaviours – i.e. identify what people *actually did*, particularly in terms of their navigation strategies employed. This would be valuable in terms of understanding how people navigate, and would inform the conceptual design of future navigation aids. However, to capture this 'real' behaviour, it would be necessary to place few if any constraints on the particular route or navigation strategies employed by participants. The main drawback is that the information requirements identified would depend on those strategies employed by particular participants, and in particular the routes that individuals would choose to take. Aggregation of data would be difficult, and results would be more informative regarding strategy and route choices, than information choices, which was the focus of interest in this study.

Other methodological approaches that could have been used to investigate drivers' requirements for navigation information, but were discounted were: (1) an evaluation study from a deductive viewpoint, as employed by Philips (1999) - this approach enables the testing of hypothesis, but requires the prior definition of independent and dependent variables and their causal relationship; and (2) a question-asking approach, as employed by Janes (2000) - this identifies where and when information is needed, but not the direct identification by participants of those cues that satisfy contextually-driven information needs.

7.3.2 Representations within a requirements study

Participants in this study provided navigation instructions for a driver who was totally *unfamiliar* with the local area. This ensured results were meaningful, bounded and generalisable. In addition there were no statements made regarding particular driver preferences (e.g. for travelling on minor roads). The *activity* (i.e. user task) was described in terms of *navigating and driving* a particular route without additional aid from passengers or other information sources. Within a navigation context, the most valid representation of the *information environment* is direct exposure to that environment itself (e.g. where participants are drivers or passengers in a car, so they can record the information that they would use to describe that route to a third party). However this viewing of a route in real time was discounted for the following reasons:

- Different participants would experience different visual cues, e.g. particular turnings or signposts may be obscured by parked cars for some participants. Therefore the use or non-use of information would be influenced *between participants* by the availability of, as well as preference for, information sources. (The availability of particular information sources is likely to be a key determinant of what is used, and is discussed in Section 7.10.1.)

- There are practical (and safety-related) issues with trying to record information use while travelling in a car: there would be sections en-route where it would not be possible to stop, so even as a passenger it would be difficult to note down information as required. If done retrospectively (either at the end of the route, or in stages) it is likely that information would be lost (Russo et al. 1989).

Within the study reported here, two basic assumption were made: (1) information cues would be generated by participants based on them being *useful*; (2) that where information cues were generated by participants, they would be chosen based on those which were visually prominent, and/or those which were easily recalled from memory (i.e. that the visual demand and cognitive effort expended by a participant in *identifying* cues would be consistent with those needed by drivers in *using* those same cues – a 'give' component of the value they provide). Note the term cue is used to describe any reference that is potentially useful in supporting the navigation task - i.e. judgement within a task (Wood 1986). It therefore includes physical objects, descriptive terms, sources of information and references to distance and time. In addition it was assumed that there were opportunities for navigation benefits due to information presentation (e.g. external influences such as traffic delays were discounted). It therefore assumed that a user-centred perspective produced the same results as a use-centred or more ecological perspective (Flach et al. 1998).

The study used two different participant groups: one group (termed the 'video' group) had no previous knowledge of the area, and viewed a video image of the routes - the navigation information identified by this group was therefore based purely on the visual representation of potential navigation cues along the route. The other participant group (termed the 'cognitive map' group) had extensive local knowledge of the area (they had all lived or worked in the area for at least five years). In order to identify navigation relevant information, this group used schematics of the routes which were designed to provide just enough information to inform the participants of the required route, but not to provide any further information such as road names/numbers, junction layouts, geographical features etc. The schematics were derived from a Geographers A-Z street map, and presented to the participants at a scale of 1:10,000, i.e. 10cm per kilometre.

These different approaches had associated advantages and disadvantages as shown in the table below. For a fuller discussion of the relative merits of different types of information sources used within such requirements studies, see Burnett (1998).

Information based on:	Advantages:	Disadvantages:
Single visual experience of the route via a video	Based on direct observation: the view of an unfamiliar traveller	A 'snap-shot' experience of routes: therefore, limited by specific views available, time of day etc.
Long-term experience of the area based on the memory of locals (i.e. cognitive map)	Based on repeated exposure to the task environment – information used by 'expert' navigators	Individual's memory for particular cues prone to subjective biases

Table 7.1. Comparison of different information sources for direction giving studies, after Burnett (1998)

There are some potential biases introduced by using these two different sources of information. These are discussed briefly in Section 7.10.1 in the light of the results from this study.

7.3.3 The recording of information

A potential influence on the amount and type of information identified by participants is the means by which they are required to record their navigation cues. There are a variety of ways in which a participant could record the navigation directions they generate, the most obvious being: written instructions, sketches, or verbal (voice) instructions. Sketches are a spatial representation of what is basically a spatial task. However the drawback is their ambiguity in explicitly identifying the different navigation cues used to describe the route (e.g. if a road is drawn with a slight curve in it, it would be unclear whether the curve in the road is being explicitly referred to or not). Similarly, if two junctions are drawn some way apart, the analysis of this data would have to make an assumption about whether the participant was making a statement about the distance between the two junctions. In addition, the use of sketches would provide little or no information on the terminology used for particular cues.

Written directions were felt to overcome many of the potential drawbacks of participant sketches: in particular they forced participants to make explicit reference to navigation cues. This method was chosen in preference to the recording of verbal instructions because it allowed a participant to easily review and amend their directions, and also enabled easier data analysis, since the written reports could be coded directly without being transcribed or summarised. Potential biases introduced by this data recording method are discussed in Section 7.10.1.

7.3.4 Study boundary conditions

The boundary conditions (i.e. those that limit the degrees of freedom, promote reliability and define the generalisability of results) are summarised in Table 7.2.

Users	**Constrained by specifying participants and intended recipients of instructions:** Participants with extensive local knowledge (cognitive map participants) or no local knowledge (video participants). Generation of instructions for a driver unfamiliar with the route, with no specified preferences or constraints. **Unconstrained:** Gender/age/nationality mix.
Tasks and context	**Constrained by specifying the desired outcome, route representation method and experimental protocol:** The reaching of a specified destination successfully (goals).. The task strategy (promotion of a turn-by-turn navigation strategy). **Constrained by specifying the information environment within the requirements study:** The presentation of three specific routes. The lack of availability of other information sources (i.e. paper maps, navigation systems, passengers, passers-by could not be accessed). **Unconstrained by varying the varied by the location-dependent context:** The manoeuvre characteristics (e.g. nature of the junction, road, route infrastructure). The information environment (availability of different information cues within the environment.

Table 7.2 Boundary conditions placed on the study

7.4 Method

7.4.1 Overview

This study was an empirical requirements study, where participants used either a video or their cognitive map of a series of demanding urban routes, to produce navigation directions so that a driver, unfamiliar with those routes, could navigate them successfully. The navigation instructions were written down by participants. The information contained within those instructions was then coded as described in Section 7.6 and then analysed in terms of the number and types of cues used, their use as primary or redundant cues, and their value based on the context associated with each manoeuvre en-route.

7.4.2 Participants

A total of 36 participants took part in the study, with 13 males and 5 females in each of the video or cognitive map groups. Participants were selected such that for both the video and cognitive map groups there was a range of ages within three age groups (20–34, 35–49, 50+), with a mean age of 34 years (SD = 13.1) for the cognitive map subjects and a mean age of 36 years (SD = 9.2) for the video subjects.

To ensure that participants were able to identify navigationally-relevant information, all participants were required to have had driven regularly for at least two years. All participants in the video condition had no prior knowledge of the test routes concerned. All cognitive map participants had extensive local knowledge, having either lived or worked in the area for at least five years.

7.4.3 Experimental routes

Three complex routes were used as outlined in Table 7.3. These were based in and around the city of Coventry (population approx. 300,000), located in the Midlands region of the UK. Researchers such as Burnett (1998) have highlighted the importance of the route used within studies of this nature, as this determines the type and amount of information available. In addition, a demanding route increases the difficulty of the navigation task, and consequently increases the need for accurate information.

Route	Characteristics	Typical traffic speeds	No. of main decision points
1. Urban	Built up, single & dual carriageway, ring road	< 65 kph	13
2. City centre	Retail, central business district, one way streets	< 50 kph	11
3. Out of town	Out of town, fast single & dual carriage way	< 80 kph	13

Table 7.3. Summary of route details

All three routes were filmed using a digital video recorder with a focal length of 38mm. This generated an image which had a sufficiently wide angle of view to include a clear view of all side roads and junction exits, with a resolution such that most of the road signs and street names were clearly visible. This was used for participants in the video condition. For the cognitive map participants, a minimal schematic was used, as described in Section 7.3.2. A summary of the three routes is contained in Appendix 7A. For the sake of brevity, the three routes were considered as three sections of a single route, and henceforth are described as 'the route'.

7.4.4 Procedure

Participants were informed that the general nature of the study was to investigate how people navigate within a range of environments. Throughout the study, no specific mention of any particular navigation cues was made in order to reduce bias towards particular types of information. Participants were told that they were to provide written, sequential directions to enable a driver, totally unfamiliar with the particular routes, to navigate those routes successfully. This approximates the 'piloting' strategy of navigation used for 'quests' - (Allen 1999). They were told that these directions could take any form, and could include any information that was deemed necessary, but could consist only of written directions and could not include any diagrams.

The participants in the *video* group viewed a video recording of the route, and wrote down their instructions based on this video, for each route in turn. They were able to rewind and replay the video as many times as they wanted, until they were happy with the instructions they had generated. If there were any aspects of the video that were not clear (e.g. if any of the road signs or street names were obscured or indistinct), the participants could ask the experimenter for clarification. The participants in the *cognitive map* group used their route schematics to write down their directions for each route in turn. There was no time limit placed on either participant group. All participants were then de-briefed, and paid for their time. The data was then coded as described below. The results are presented in Section 7.7.

7.5 Path-node network

The basis for much of the analysis within this study was the division of the route into a path-node network (Lynch 1960), a categorisation used in several previous studies, e.g. Janes (2000), Obata et al. (1993) and Alm (1990). A detailed route description was developed that identified *manoeuvres*; sections of the route between these manoeuvre points were termed *progress* points; in general, these referred to the nodes and paths respectively, adapted to a driving context. A manoeuvre was defined as a point on the route where there was a potential navigation decision, i.e. navigational uncertainty (Burns 1997), for example a left or right turn, an exit at a roundabout, or going straight on at a set of traffic lights. It could be argued that each time a driver passes even a minor turning off a major road, they are required to make a navigation decision of either turning off, or continuing along, the current road. However, it would have proved impractical to code all such points on the routes. A driver would normally just continue unless told otherwise (i.e. would tend to ignore minor turnings), and any navigational aid providing turn-by-turn instructions would be unlikely to refer to all such minor turns.

Therefore *manoeuvres* were defined such that they excluded points on the route where there is just one right of way AND the driver is following that right of way. In practice, a manoeuvre was a point where a driver would expect some navigation information at a point of driver uncertainty. In contrast, a *progress* point was defined as a point on the route where there is no potential manoeuvre, and where that progress point is being identified in order to locate the driver relative to the route and provide confidence that they following the correct route. Progress points were those sections of the route *between* manoeuvres.

There were 42 manoeuvres en route, labelled from 0 through to 41. However, as the 'route' actually consisted of three separate routes, comprising departures and arrivals at waypoints, the following manoeuvres were omitted from analysis: M0 (Leaving Jaguar Car plant), M14 (Turning into Holyhead Pub car park), M15 (Leaving Coventry Train Station), M27 (Arriving at Coventry City football ground), M41 (Turning into the Showcase Cinema car park). A description of the route is shown in Appendix 7A.

7.6 Data coding

This study resulted in a series of navigation cues being generated by each participant referring to manoeuvre and progress points along the route. The written instructions generated by the 36 participants were analysed in detail and each reference to a navigation cue along the route was identified. A cue was defined as any piece of information about the attributes of a stimulus object (Wood 1986) that was potentially useful for navigating. When used, these information cues act to increase the knowledge that an unfamiliar driver would have about the route that they were required to take (Burns 1997), or increased their confidence regarding the actions they were taking or needed to take. Information cues normally reduce uncertainty in the recipient, but as pointed out by Badenoch et al. (1994) do not necessarily do so, as ambiguous or contradictory cues may actually increase uncertainty. Cues included references to objects, distances and times, as well as attributes of visible objects.

Based on the navigation instructions generated by the 36 participants, there were over 2600 references to approximately 450 different navigation cues. To enable analysis, each of these 2600 references was coded according to the following criteria:

1. How information was used in relation to the navigation task, based on Burnett (1998).
2. The extent or detail of information provision at a manoeuvre.
3. The information category being used (type of information).
4. Whether that information was used at or between manoeuvres.
5. The primacy or redundancy of the cues used at that manoeuvre.

The coding associated with each of the above analysis is described in detail in Appendix 7B.

7.7 Results & discussion – use of information

For sake of clarity, this section is a combined results and discussion. The design implications arising from this study are discussed in Section 7.9.

7.7.1 Information in relation to the navigation task

The coding schema described in Appendix 7B outlines how each of 2600 navigation cues was assessed in terms of the role they played in supporting the navigation task as described in Figure 6.5 in the previous chapter. Figure 7.1 below shows the frequency with which all information cues were used in either (1) a *preview* role, (2) to *identify* a manoeuvre or progress point, or (3) to provide *confirmation* that a driver had completed a manoeuvre correctly, as per Figure 6.5. In this graph below, no distinction is made between information used at manoeuvres and information used at progress points (i.e. between manoeuvres).

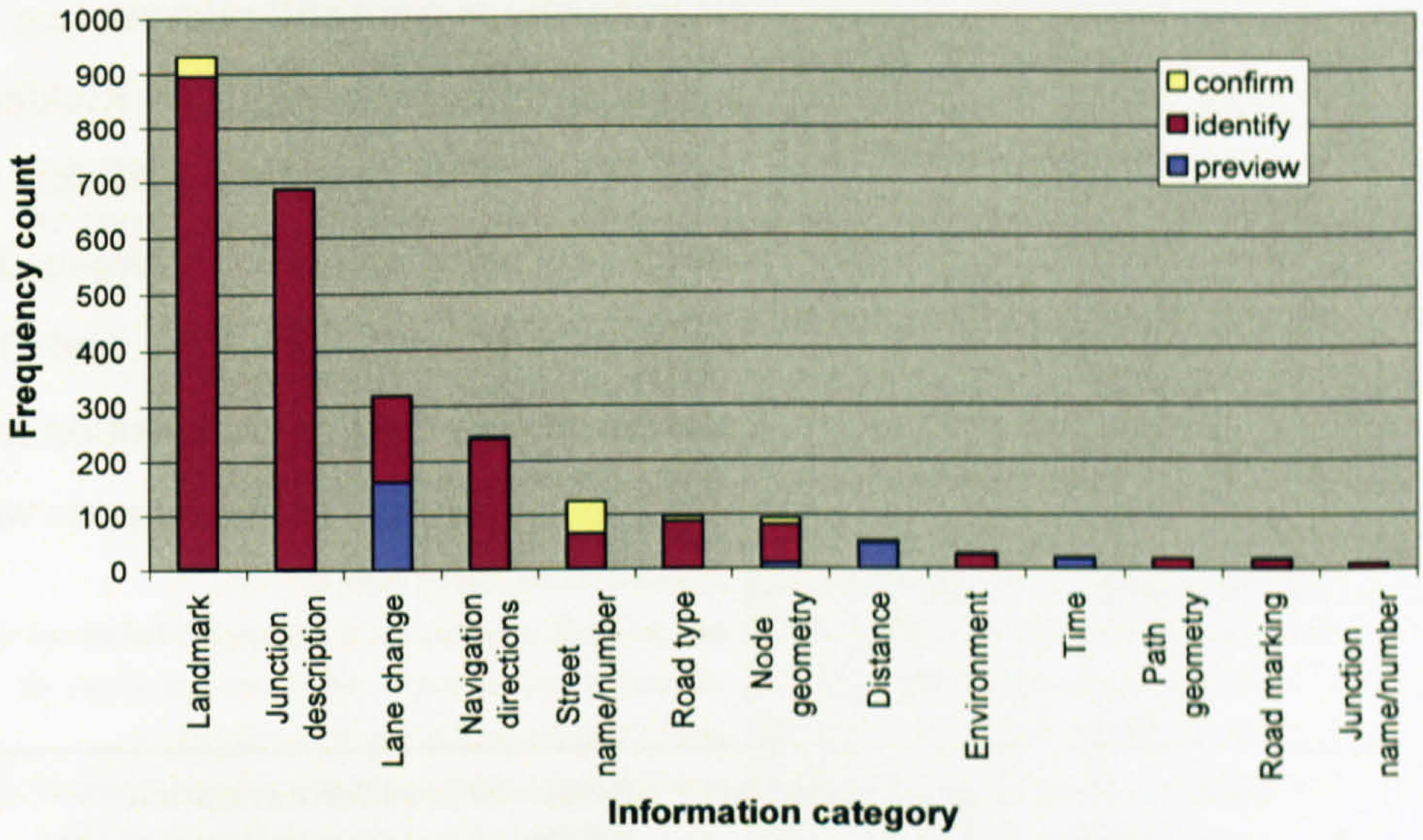


Figure 7.1 The use of different information categories within the navigation task

As shown in Figure 7.1 most categories of information were used in an *identification* role, i.e. to help locate either a manoeuvre or a point en-route *between* manoeuvres. Over all information categories, 86% of information was used in this identification role, compared with information used to preview a manoeuvre (10%) and that used in a confirmatory role (4%). The main exceptions shown in Figure 7.1 were lane change information, where 51% was used in a *preview* role (e.g. '*keep to the left* as you approach the roundabout'), street names or numbers where 46% was used to confirm to a driver that they have taken the correct turning (e.g. 'at the next lights turn left into *Bayford Way*'), and distance (84% preview) and time (95% preview) used to give advance warning of a manoeuvre. Based on the predominance of cues used to *identify* the location of a manoeuvre, the remainder of this section focuses on information used in that role.

7.7.2 Extent of information cue generation at manoeuvres

A basic assumption underlying this study was that participants would identify the navigation information needed by an unfamiliar traveller, i.e. that which adds (functional) value within a task context. The limitations of this are discussed in Section 7.10.1. If a participant did not generate an instruction at a particular manoeuvre, it was assumed that this was because the perceived value of the provision of *new* information at this location was low. This could be due to a perceived lack of a task *need*, or a perception that previous instructions were still relevant (e.g. a prior instruction to 'keep left'). This is consistent with the observation by Richter and Klippel (2004) that not every decision point has to be mentioned explicitly in a route instruction. Frank (2003) also underlines how navigation decisions are made based on (1) previous knowledge, (2) information from a navigation message, and (3) knowledge that can be obtained from the world, and that the contribution from these three will vary. Four categories of information generation at manoeuvres were identified, outlined in Table 7.4.

Cat.	Information cues generated by the participant at that manoeuvre	Perceived need for navigation information by participants at that manoeuvre
A	None (and prior information not relevant)	There was no need for navigation information at that manoeuvre
B	None (prior information relevant)	There was no need for the provision of a new cue since previous instructions could be followed
C	Direction information (e.g. "turn left", "turn right", "straight on")	A simple direction indication (e.g. 'turn left') was sufficient to enable completion of the manoeuvre
D	Direction information, plus one or more of the categories described in Section 7.7.1	Information in addition to direction cues was needed at that manoeuvre

Table 7.4 The different degrees to which navigation cues were provided at each manoeuvre

A frequency plot of the different levels of information generation by participants at the manoeuvres en-route is shown in Figure 7.2.

Figure 7.2 **Frequency of provision of different levels (A, B, C or D) of navigation information at each manoeuvre**

A frequency plot was generated to aggregate the data shown in Figure 7.2. This shows the number of manoeuvres where proportions of participants (based on quartile percentages) perceived differing information needs. The levels of information need are shown by coding according to (A) to (D), in Table 7.4. The participant quartile percentages were based on: 1st quartile (0 – 9 participants); 2nd quartile (10 – 18 participants); 3rd quartile (19 – 27 participants); 4th quartile (28 – 36 participants). Figure 7.3 below therefore shows the proportion of manoeuvres where either minorities (1st quartile) or majorities (4th quartile) of participants perceived different levels of information needs. The most explicit findings are those relating to the 4th quartile (representing the responses of 'most' participants). This shows that most participants (4th quartile, i.e. 75% plus) gave an instruction of type (D) – information in addition to a turn instruction – at the majority of manoeuvres, as shown by the tall dark blue bar. All bars in any single shaded row (information category) are mutually exclusive, since the participant quartiles are separate and not summative. In addition, the four coloured bars within a quartile row are also mutually exclusive, since information generation by a participant consisted of one of (A), (B), (C), or (D).

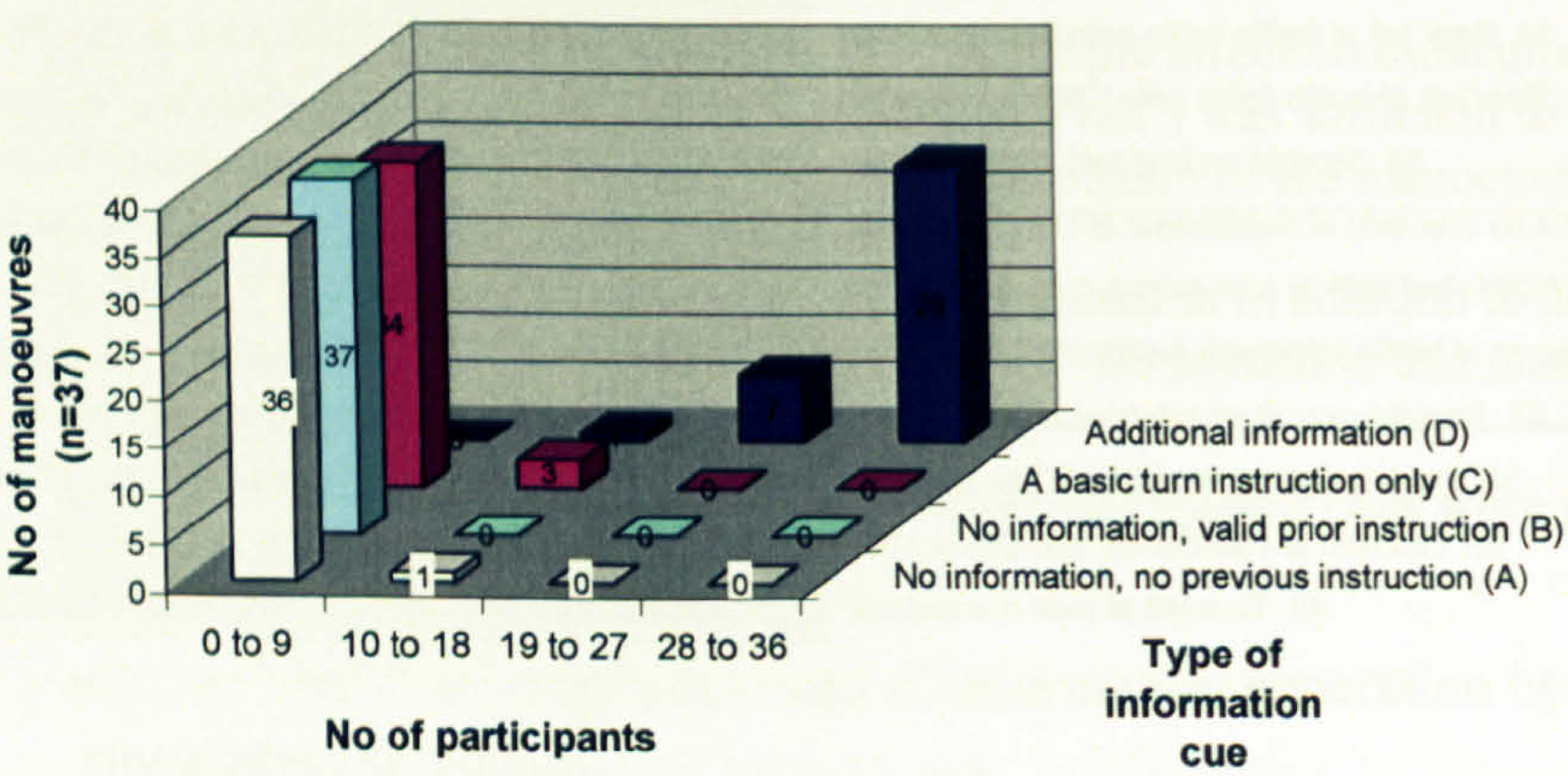


Figure 7.3 Distribution of the generation of cue types at manoeuvres by participants

Figure 7.3 shows that for the vast majority of manoeuvres, levels of information categorised by (A), (B) and (C) were generated by few participants (i.e. between 0 and 9, representing the 1st quartile). This is shown by the white, pale blue and purple bars. This is in contrast to information instructions comprising a direction indication, plus additional information cues. This type of instruction was used by at least 75% of participants at the majority (78%) of manoeuvres. These differing levels of information generation are interpreted as the value of augmenting the existing environmental information at that manoeuvre, and are discussed below.

By reference back to Figure 7.2, participants provided no information to the unfamiliar driver (category A instruction) at two main types of manoeuvre – continuing straight on at traffic lights, and continuing past exits on the ring road. There was only one manoeuvre (M3 – straight over a set of traffic lights) where a significant proportion (25 and 50%) of participants did not perceive any need for a navigation cue to enable an unfamiliar driver to complete that manoeuvre successfully. The driver was continuing along the previous 'path'; this continued in the same direction as previously travelled; and they were following the major traffic flow. In addition, the appearance of M3 was such that it did not appear to be a major driver decision point. The judgement of low added value at these manoeuvres is consistent with the summary of factors shown in Table 6.3, with participants assuming a driver would follow the intended route without further instruction.

For all manoeuvres, less than 25% of participants provided no new navigation cues based on prior instructions still being valid (category B). The main instance of this occurring was on the ring road, where instructions such as 'follow signs for Birmingham' had been given at previous manoeuvres and were still valid.

Where category (C) cues (only direction instructions such as 'turn left') were used, this occurred in two main situations, both of which required the driver to stop and give way to other traffic: at T-junctions where the affordances of the environment were such that a driver would have to make a decision to either turn left or turn right; and at a set of cross roads (M16) where the cross roads were the first driver decision point following the previous instruction. In both these cases, there was no ambiguity concerning the location of the manoeuvre, and hence little need to describe the manoeuvre in more detail.

The main finding from the analysis described in this section is that participants (as indicated by the majority response) clearly perceived that additional information over and above a simple turn direction added value to the unfamiliar driver at the vast majority of the manoeuvres en-route. Sections 7.7.3 to 7.7.5 present an analysis of this additional information, specifically:

- What information cues were used
- How usage differed at and between manoeuvres
- Which individual cues (and categories) were perceived as adding most value

7.7.3 The type of information used by participants

The previous section has shown the high perceived need for additional information at manoeuvres, over and above simple direction information. The coding scheme described in Appendix 7B was used to determine the frequency of use of the additional information categories in the navigation instructions generated by the participants. This is shown in Figure 7.4 below:

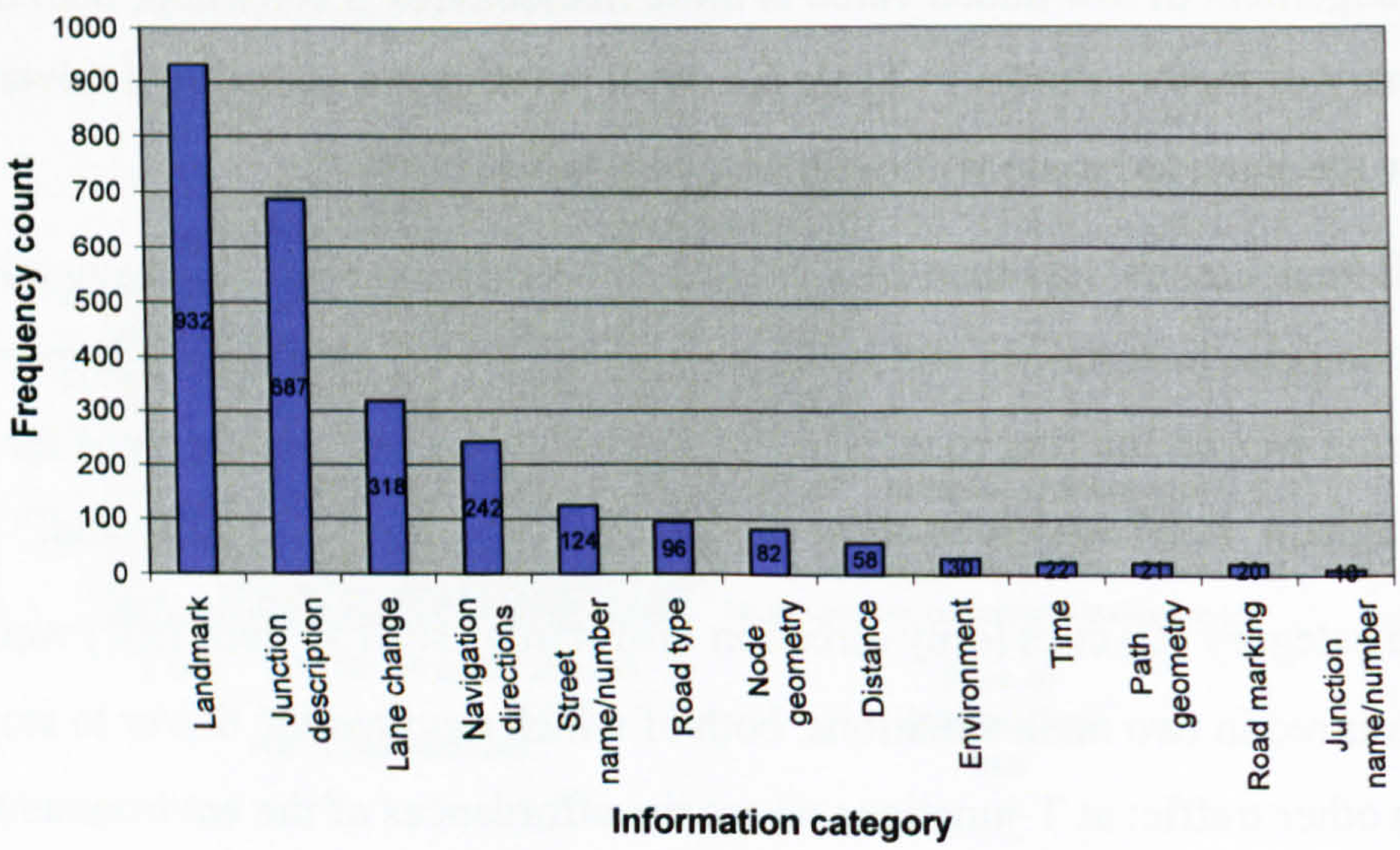


Figure 7.4 Frequency of use of main information categories (over and above direction cues)

Landmarks were the most commonly used information cues, comprising 36% of all references throughout the route. The frequent use of landmarks is consistent with the findings of Burns (1997) who undertook a survey of 1158 drivers and asked participants what information they would want from passengers to help them navigate. After left-right directions, landmarks were rated as the second most popular information type. Other studies - e.g. Streeter and Vitello (1986); Burnett (1998) - confirm these findings.

The frequent use of landmarks is due to a number of factors - the landmarks category included a wide range of different types of information, and therefore the availability of information within this category was high. (The list of landmark categories included traffic lights, bridges, pedestrian lights, petrol stations, public houses, parks, restaurants, post boxes, phone boxes, plus a wide range of other buildings). In addition, many landmarks have a functional purpose and are therefore associated with particular goals for individuals (e.g. restaurants, parks, public houses) (Kaplan 1976), or have a symbolic, cultural or historical role within a community (Sorrows and Hirtle 1999). Landmarks can play a fundamental role in driver navigation (Allen 1999).

However, it is likely that the predominance of the landmarks cues is at least in part an artefact of the road topology within the area of study: if this study was repeated in cities with a grid-like road topology, landmarks may be used less frequently and other descriptions such as road names and numbers, block numbers and compass directions would be used instead.

After landmarks, junction descriptions were the next most frequently referred to category, comprising 26% of all references. Indeed Klippel et al. (2005b) actually broaden the term 'landmark' to include road junctions. The junction description category included descriptions of the type of junction such as 'roundabout', 'T junction', 'cross road', but excluded descriptions of the appearance or nature of the junction such as 'large', 'mini', or 'sharp', 'gentle' (these were included within the 'node geometry' category). Since the navigation task can be conceptualised as the travelling between points of navigational uncertainty (Allen 1999; Burns 1997), the description of these points of navigational uncertainty (usually junctions) is one of the easiest ways of describing a route. The lack of availability of a junction name or number for many junctions resulted in the low frequency count for this category.

Instructions regarding lane changes or lane positioning (e.g. 'move into the left hand lane' or 'keep over to the right') were the third most popular category of information cues, comprising 12% of all references. The relatively high frequency of use of these cues are a reflection of the multi-lane nature of much of the route (dual carriageway and ring road) and the importance of correct lane positioning for navigation and safety reasons. Information concerning lane changing and lane positioning was most frequently used at large roundabouts, multi-lane traffic light controlled junctions, and for entering and exiting the ring road section. In the context of a survey of driver preferences, lane positioning was found by Burns (1997) to be the second most useful information type for travelling through a city.

Direction signs were used both for the navigation information *they conveyed*, but also as *objects* that could be referred to. When referred to as objects, they were classed as landmarks, and categorised accordingly, see Figure 7.5. When used for their information content, they comprised 9% of navigation cues. A wide range of different type of directions were used, including motorway signs, A and B road numbers, local regional signs and signs relating to individual places or objects. In almost all cases, direction signs were used as a means of directing a driver along the correct pathway, with the actual destination on the sign itself having little or no relevance to the route that the driver was following. Typical instructions were 'follow the signs for the M69 motorway' or 'turn left at the roundabout, signposted B4122'. One section of the route within the study included Coventry Ring Road, and a frequent use of the road sign category was the guiding of drivers around the ring road by giving them instructions such as 'follow the signs for Birmingham'. The relatively high frequency of use of direction signs has clear implications for the design of driver navigation aids, discussed in Section 7.9. Road numbers were found by Burns (1997) to be the most useful category of information for travelling on a major road. Road *numbers* were not used frequently in this study due to the largely urban environment.

The four categories of information cues outlined above (landmarks, junction descriptions, lane changes/position, and navigation directions) accounted for 83% of all cues generated within this study. All other categories of information cues (street name/numbers, road type, node geometry, distance, environment descriptions, temporal references, path geometry, road markings and junction name/numbers) were infrequently used. Paradoxically, many of these infrequently-used categories of information are those incorporated within current vehicle navigation systems. The results from this study, and other findings such as Burnett (2000) suggest that future vehicle navigation systems can be enhanced by presenting information cues which are more congruent with those used naturally when navigating within an unfamiliar environment. This is discussed further in Section 7.9.

The landmark category was sub-coded to distinguish between different types of landmarks. There was a total of 38 *categories* of landmarks referenced by at least two participants, and a further 19 which were referenced by only one participant. The landmark categories were sorted in descending frequency count, with Figure 7.5 below showing the individual categories (or items) which accounted for cumulative 95% of all references. All other landmarks are included in the miscellaneous category. As described in Appendix 7B, the subdivision of the landmark category included both categories of objects (e.g. 'traffic lights'), but also specific objects that were relatively unique and/or frequently referred to in relation to other similar items. Therefore buildings such as the fire station, council house and Asda™ supermarket were not apportioned to landmark subcategories, but were assigned individual codes and treated as a separate 'category' as can be seen in Figure 7.5.

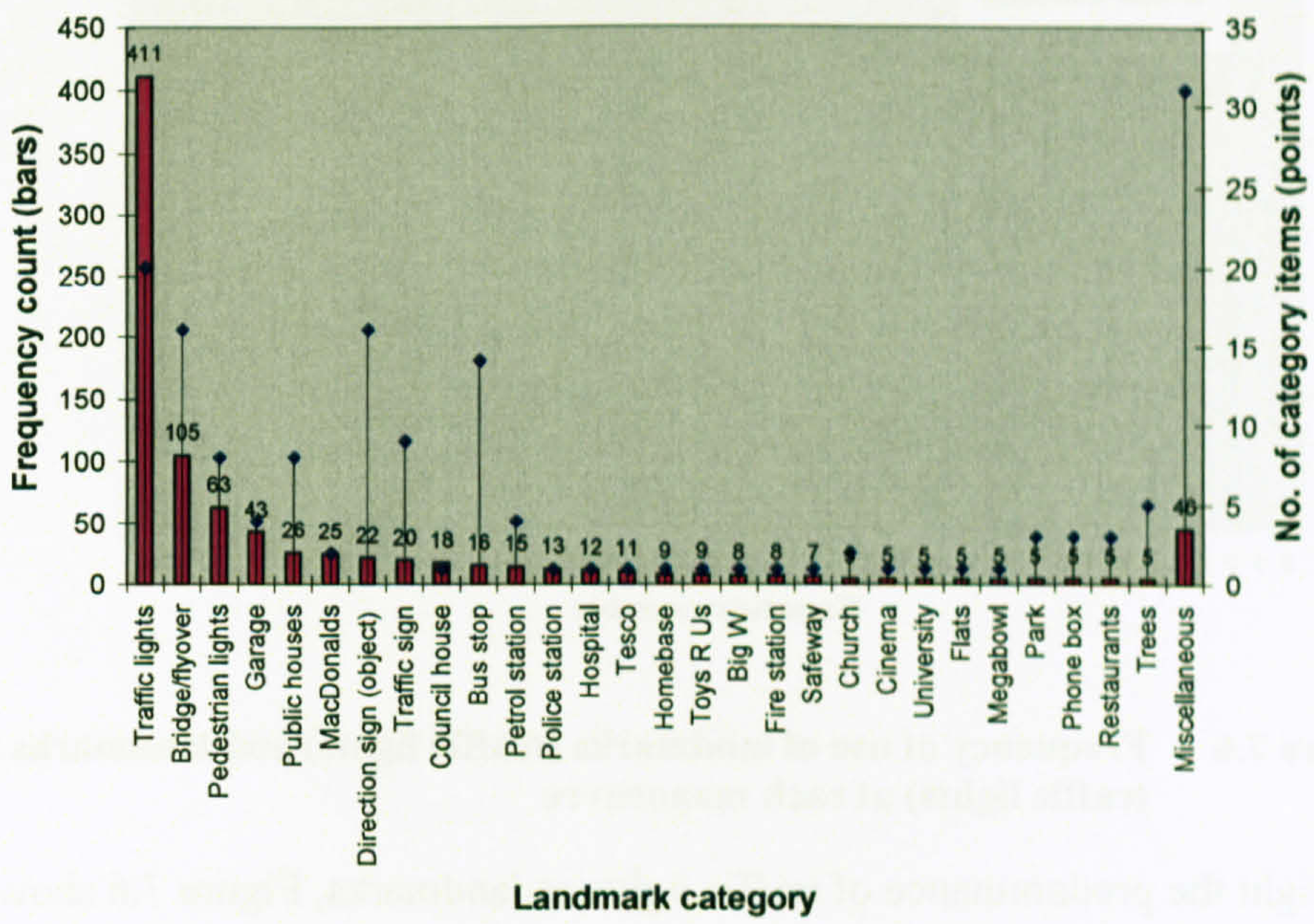


Figure 7.5 Frequency of use of different landmark categories

Traffic lights were by far the most frequent landmark category, comprising 44% of all landmark references, supporting the findings of Obata et al. (1993) and Alm (1993). The line chart displayed on the right hand axis of Figure 7.5 helps interpret the results, since it identifies the number of different items that contribute to the overall frequencies shown by the bars on the left hand scale (the numbers quantify the bar values in Figure 7.5). For example there were 105 references (left-hand scale) to bridges and flyovers in the study, and this was based on bridges/flyovers situated in 16 locations (right hand scale). There were some clear differences in terms of the frequency of usage in relation to the number of category items that contributed to that usage, for example: relatively few traffic lights contributed to a high overall frequency count; a relatively high number of public houses, direction signs and bus stops contributed to a low overall frequency count for these items; the usage of pedestrian lights and garages stemmed from relatively few individual items; and some landmarks that appeared very few times en-route (or even just once) were referred to by a large number of participants, e.g. MacDonalds™ restaurant, the Council House and individual prominent stores.

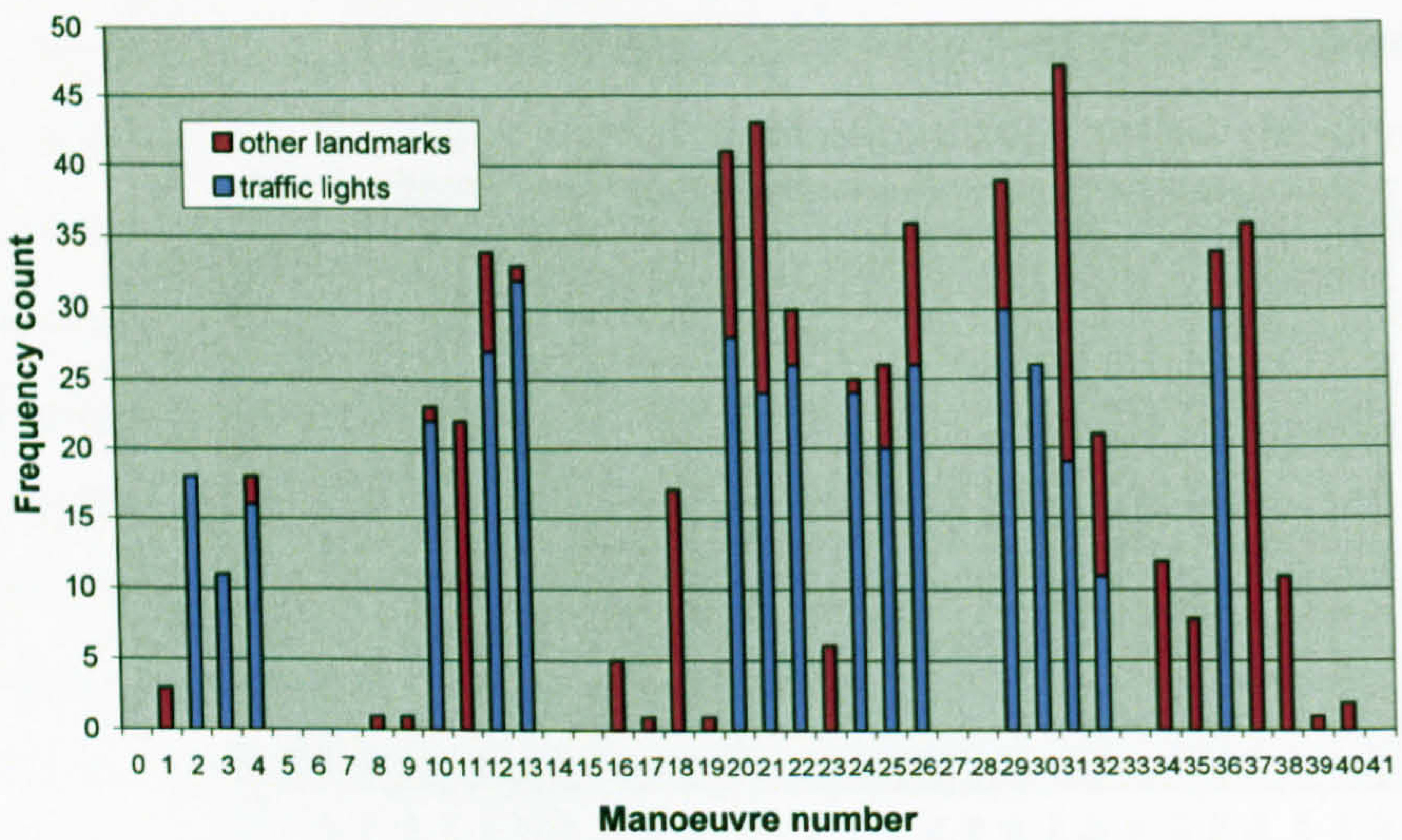


Figure 7.6 Frequency of use of landmarks (traffic lights) and landmarks (non-traffic lights) at each manoeuvre

To highlight the predominance of traffic lights as landmarks, Figure 7.6 shows, for each manoeuvre, the total number of references to landmarks, and the proportion of these arising from traffic lights. It is clear that where present, (or more strictly where they were referenced by participants), they were referenced with a higher frequency than other landmarks.

7.7.4 Information use *at* and *between* manoeuvres

Figure 7.4 and Figure 7.5 above show the overall frequency of use of individual information categories. Figure 7.7 shows the frequency of use of different categories of information *at* each of the 37 manoeuvres along the route. Figure 7.8 shows a similar breakdown of the information categories used *between* manoeuvres. Where participants used information cues *at* manoeuvres (Figure 7.7), these related to relatively distinct geographical locations. However the progress points represented in Figure 7.8 relate to any point between respective manoeuvres – the 'paths' or 'channels' along which people move (Lynch 1960). In Figure 7.8, Progress point 3 refers to the pathway between manoeuvres 3 and 4; progress point 4 is the pathway between manoeuvres 4 and 5, and so on.

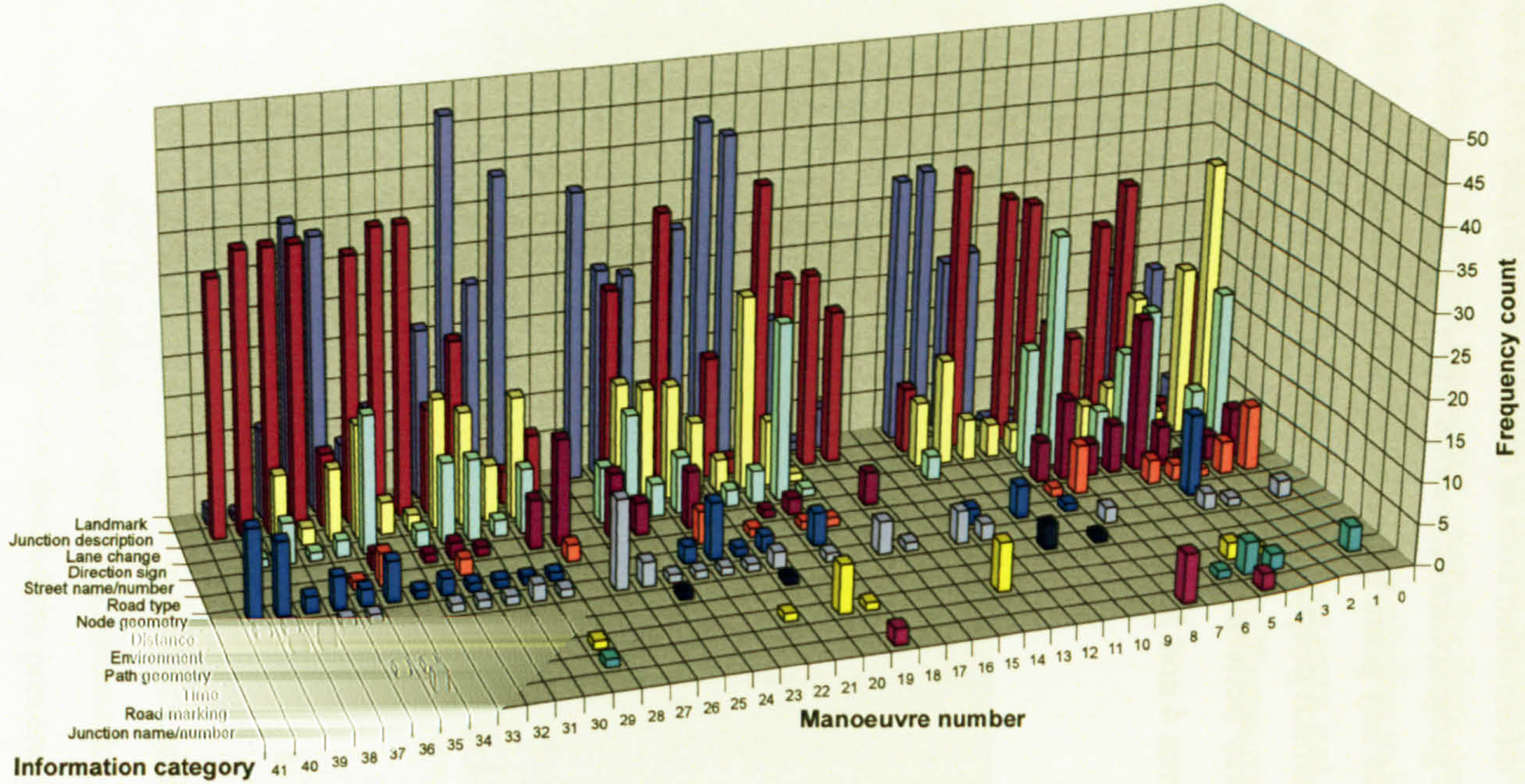


Figure 7.7 Use of main information categories *at* manoeuvres

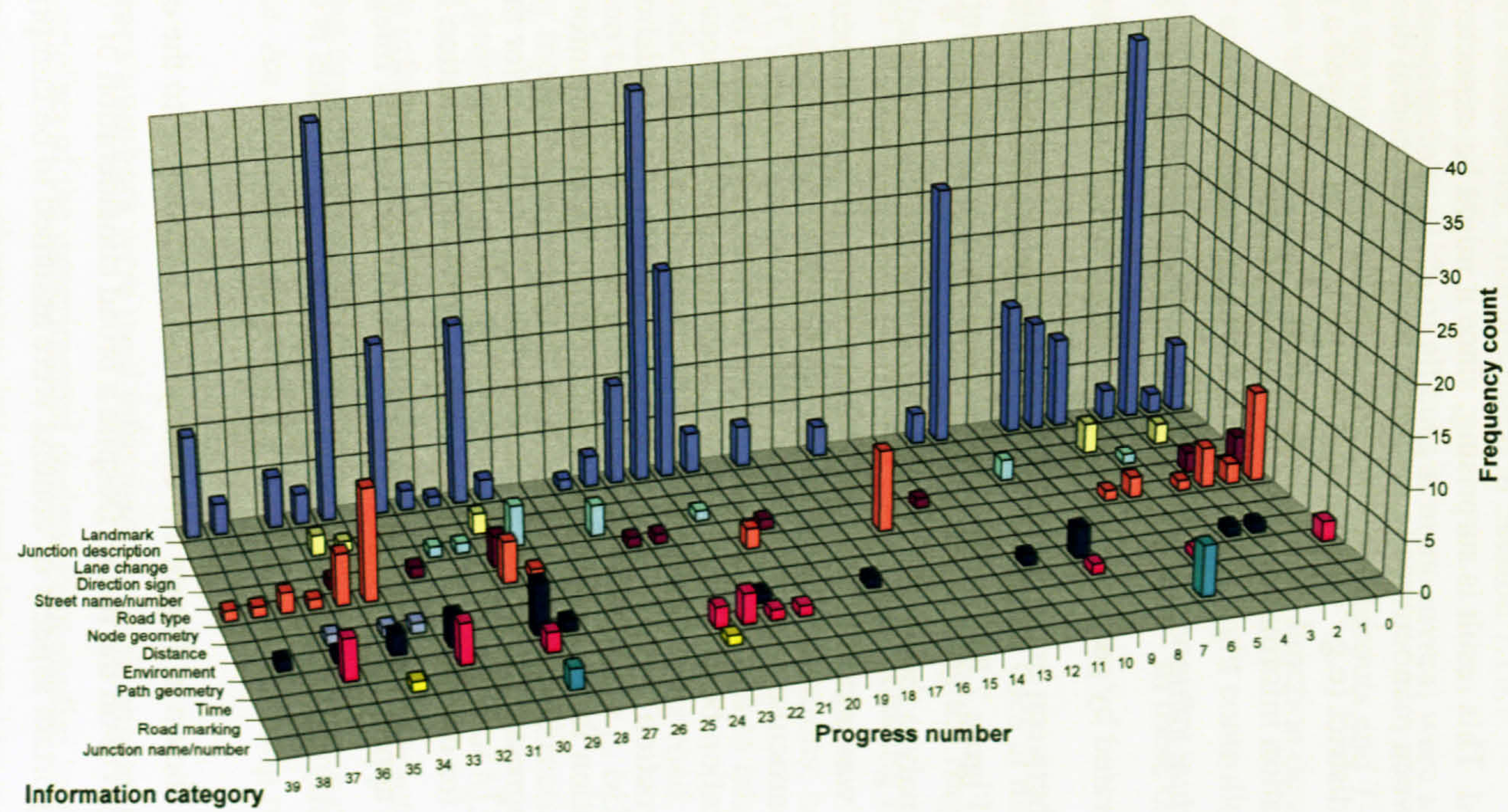


Figure 7.8 Use of main information categories *between* manoeuvres

7.7.4.1 Comparison of information use at and between manoeuvres

In contrast to Figure 7.7 a single category of information cue, landmarks, were predominantly used *between* manoeuvres, comprising 67% of cues shown in Figure 7.8 (an example of their use being 'keep going past the *hospital*'). Although road type information was also used (12% of progress cues), all other categories were infrequently used. This result is surprising, since it might be expected that descriptions of the paths between manoeuvres (e.g. '*bendy* road'), and general descriptions of the environment or district (e.g. 'pass through a built up area') played a greater role in providing navigation information to an unfamiliar driver.

7.7.4.2 Contextual influences on information categories at manoeuvres

Of all cues generated by participants, 83% were relevant to manoeuvres (as opposed to progress points between manoeuvres).The appearance of cues in either Figure 7.7 (*at* manoeuvres) or Figure 7.8 (*between* manoeuvres) was to some extent a function of the coding used to analyse the use of individual information cues. In particular, all information that was textually referenced by participants to a manoeuvre was coded in relation to that particular manoeuvre (and hence shown in Figure 7.7), even if the geographical location being referred to was actually between manoeuvres. For example an instruction 'keep to the left as you approach the roundabout' was coded as *preview* information for that roundabout manoeuvre, rather than information identifying a progress point between manoeuvres. The rationale for this was based on the implications for navigation system design – preview information has direct relevance on the approach to a manoeuvre and could be usefully integrated with information specifying the turning to take at the manoeuvre. (This is discussed further in Section 7.9.)

The information shown in Figure 7.7 clearly varied according to the context of the particular manoeuvre on the route. Despite a broad consideration of 'context' (Dey et al. 2001), the important aspects of context were assumed to be comprised mainly of physical attributes of the environment, and 'activities', i.e. what the driver, and other traffic were doing.

Landmarks were used widely throughout most of the route, comprising 29% of all cues at manoeuvres, but particularly so during the town centre sections (manoeuvres 16 to 26) due to the high availability of distinctive buildings along this section of the route. Landmarks were used less frequently along the ring road (manoeuvres 5 to 8). Within the landmark category, traffic lights were used consistently (often to the exclusion of other information categories) at traffic light controlled cross roads. The use of landmarks appeared to be more influenced by the availability and quality, e.g. their visual salience (Klippel and Winter 2005) of these cues than characteristics of the manoeuvres themselves. This discussed in Section 7.10.1.

Junction descriptions (31% of all cues at manoeuvres) were also used widely throughout the route, especially to describe roundabouts and T-junctions and manoeuvres which were not standard cross roads. Junction descriptions were less frequently used at cross-roads which were traffic light controlled, especially where the driver was continuing straight on at these junctions - in these cases, instructions were typically of the form 'go straight over the traffic lights'.

Lane change and lane positioning cues (14% of all cues at manoeuvres) were used: on merging with more major roads; joining and exiting the ring road; and positioning prior to and through complex, multi-lane junctions (including filters and roundabouts).

Direction signs (10%) were used in the following situations: navigating onto and off the ringroad (and in particular to identify the correct exit to take to leave the ring road); to indicate where to continue past exits on the ring road; at manoeuvres where the direction to take is contrary to normal expectations, e.g. M20 - reflecting the complexity model of Sugiyama et al. (2001); and where direction signs were especially prominent, e.g. the motorway signs (M6/M69) at M35.

Road type information was used to describe where the characteristics of the forthcoming road were very different to the current one, i.e. a *change* in visual appearance. An example of this was the transition from a slip road onto a more major road.

Street names/numbers were used infrequently. Their appearance in Figure 7.7 was largely an artefact of the experimental design. Pilot studies had demonstrated the need for information on the schematics that allowed the cognitive map participants to initially orientate and locate themselves. A street name was included on the schematic at the start of route section three resulting in their use by cognitive map participants at M28.

Node geometry (i.e. descriptors such as 'large', 'mini', 'sharp' applied to junction descriptions) were used infrequently and mainly to describe roundabouts which were either very small (i.e. a mini roundabout) or particularly large and/or complex.

Distance - in qualitative (e.g. 'quite a long way') and quantitative (e.g. 'for 200m') terms was also infrequently used. Its use at M27 arose from describing the arrival at a destination at the end of one of the three routes.

Environment descriptions (e.g. referring to built up areas, town centres, industrial areas) were infrequently used, despite 'districts' being described by Lynch (1960) as one of the elements that people used to categorise their surroundings.

Road markings were not used except as indications for joining the ring road.

Path geometry was not used at all in the context of manoeuvres (since this information refers to the physical description of the pathway between manoeuvres).

Time in qualitative (e.g. 'some way') and quantitative (e.g. 'for 5 minutes') was very infrequently used, except at to indicate where either a destination (e.g. M14) or a turning (e.g. M20) was close to a preceding manoeuvre.

Junction names or numbers were not used except with reference to the ring road, and particularly the ring road exit (M8).

7.7.4.3 Contextual influences on information categories between manoeuvres

A similar analysis by inspection can be done of the information at different progress points along the route as shown in Figure 7.8, demonstrating that much less information was generated *between* manoeuvres. Information between manoeuvres can increase a driver's overall navigation confidence (Burnett 1998). They fulfil the role highlighted by Richter and Klippel (2004) i.e. describing the route and acting as confirmation that the driver is on the correct route. The rationale for coding information cues as being at or between manoeuvres was described in Appendix 7B.

Landmarks were referred to with varying frequency throughout the route, and accounted for 67% of all information used between manoeuvres. The most frequently referred to landmark between manoeuvres was the bridge shown below, demonstrating its visual prominence (Sorrows and Hirtle 1999).

Figure 7.9 A prominent landmark at progress point P2

Road type information was the second most frequently used information cue between manoeuvres, accounting for 12% of these cues. It was particularly used at the start of the route to describe travelling along slip roads, between manoeuvres M15 and M16 to indicate a one-way street, and between manoeuvres M34 and M35 to describe a dual carriageway.

Lane change/positioning information, direction signs, street names/numbers, distance, environment descriptions, path geometries, time and **road markings** were categories of information infrequently used. It is surprising that greater use was not made of some of these categories, especially path geometry (e.g. 'go round the *bend* in the road') and descriptions of the environment through which a driver passes. These information cues could have increased the confidence of a driver, fulfilling a similar role to that of landmarks in indicating that a correct route is being following and enabling a sense of location in relation to the surroundings (Golledge 1999).

Junction descriptions, node geometry and **junction names/numbers** were not used at all between manoeuvres as these were manoeuvre-specific cues.

7.7.5 Importance of the information categories

7.7.5.1 Primary and secondary usage of information categories

A limitation of the analysis so far is a lack of consideration of the value provided to the driver by particular navigation cues (i.e. the extent to which cues are critical for achieving navigation objectives). In the context of this study, a navigation cue added maximum value by being instrumental in changing task performance from an incorrect to a correct navigation decision. A cue added less value if it helped, but was not *necessary* in enabling a manoeuvre to be undertaken successfully. Taking a similar approach, Frank (2003) describes data as redundant if it is not required in order to reach a target destination.

As discussed in Appendix 7B, all cues were coded on a case-by-case basis to distinguish between primary cues (essential for navigation purposes) and secondary cues (helpful but not essential). A primary cue is the reference to the traffic lights:

'Turn left at the *traffic lights.*'

A secondary cue is the reference to the Birmingham signpost:

'First exit at the roundabout, *sign-posted Birmingham.*'

Figure 7.10 shows the extent to which main information categories identified by participants were used as primary or secondary information.

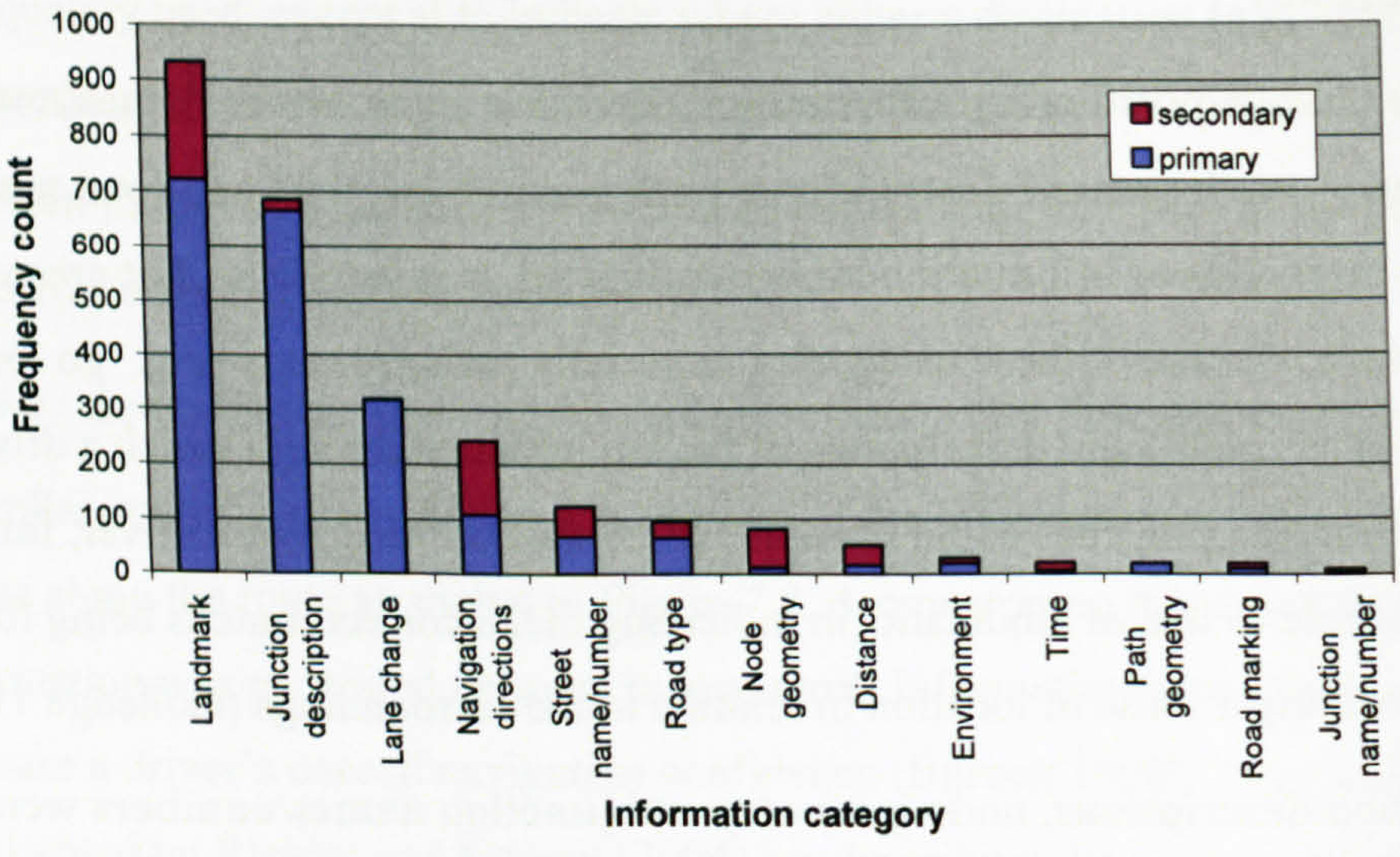


Figure 7.10 The use of main information categories as primary or secondary information

The majority of information was used in a primary role - if that cue were omitted from the navigation instructions generated, the driver would have been unable to complete that particular manoeuvre. Taking into account all information cues, 77% were used in a primary role, 23% in a secondary role. The results underlined the potential importance of landmarks as navigation cues (where 77% were used in a primary role), but also highlight the value-adding potential of junction descriptions and lane change information, due to the overwhelming use of these categories of information as primary information (97% and 99% respectively).

Direction signs used for their navigation information (as opposed to their use as a landmark) were used in 55% of cases as additional information to reinforce a primary navigation cue. A typical use of a direction sign was an instruction of the form 'turn left at the roundabout, following *signs for the industrial park*'. Figure 7.11 shows the degree to which different *landmark categories* were used as primary or secondary information cues.

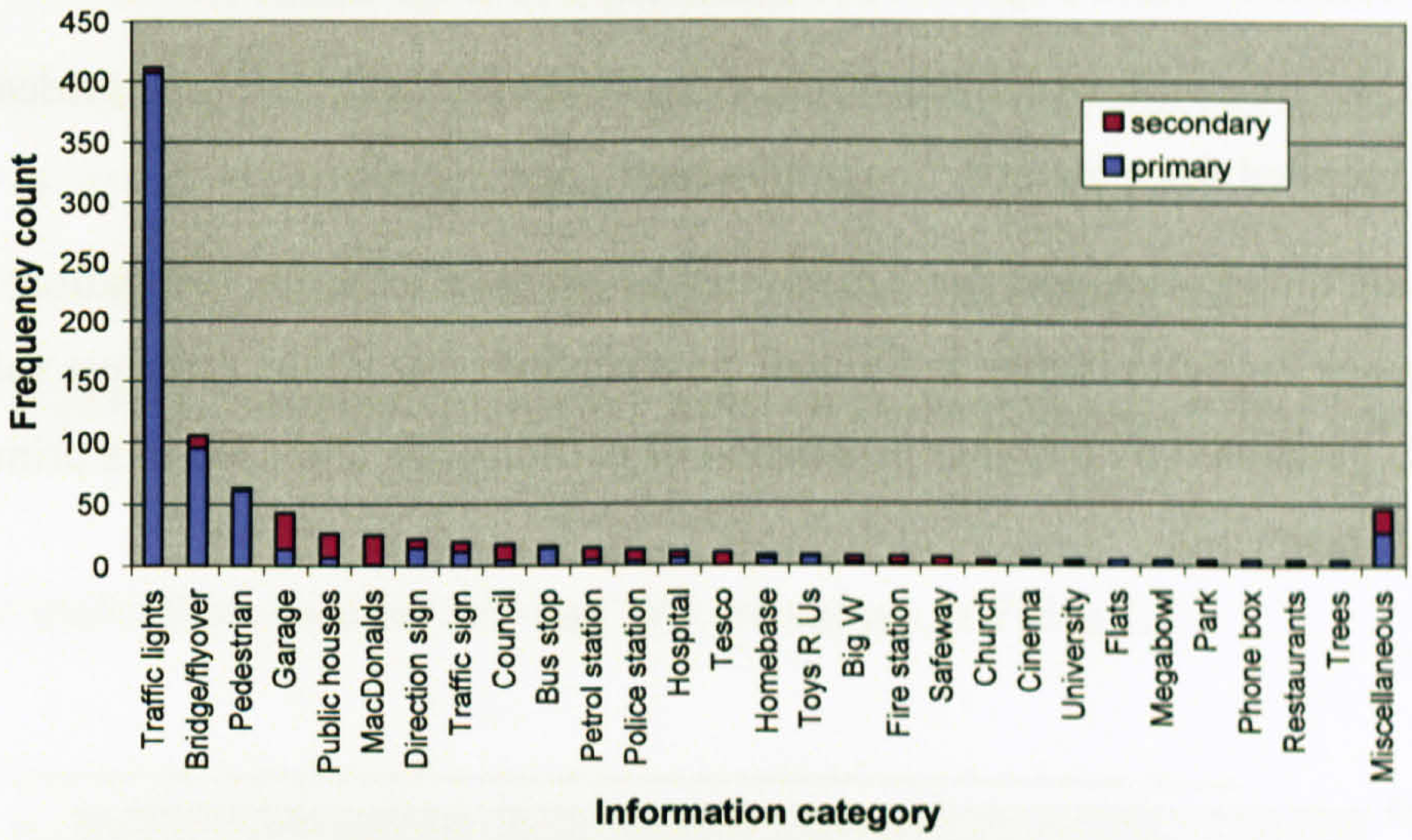


Figure 7.11 The use of landmark categories as primary or secondary information

It is clear that there was consideration variation in value provided by different categories of landmarks (i.e. the proportion of each category used as primary or secondary cues). Traffic lights, bridges and pedestrian lights were almost entirely used as primary cues, whereas categories such as garages, pubs and other significant buildings such as MacDonalds™, the police station, the fire station and Tesco™ were used as secondary cues. Several studies have commented on the characteristics of landmarks that are useful for navigation purposes. Akamatsu et al. (1997) state that popular landmarks in their study were visible from a distance, unique in appearance, and close to or part of the road infrastructure. Green et al. (1995) state that the best landmarks are those which can be seen from a distance, are close to the road, near junctions, and permanent. Traffic lights, which were frequently used, and overwhelmingly used in a primary role, clearly satisfy all of the above criteria.

7.7.5.2 *Attribution of value to information cues*

Section 5.9 discussed how derived value from an information based mobile location service is a function of both potential benefit to the user and the effort required to access and use the information within a particular context. A basic assumption was made in this study that participants identified navigation cues for an unfamiliar traveller based on:

- The usefulness of that cue to the unfamiliar navigator (i.e. an assessment of its benefits within a specific context of use).
- The ease with which they were visually spotted and identified (video group), or recalled from memory (cognitive map), and described.

Assuming that participants were motivated to generate effective navigation instructions for participants, individual cues perceived as adding greatest value would be those generated by a higher proportion of participants, and used in a primary, rather than secondary role.

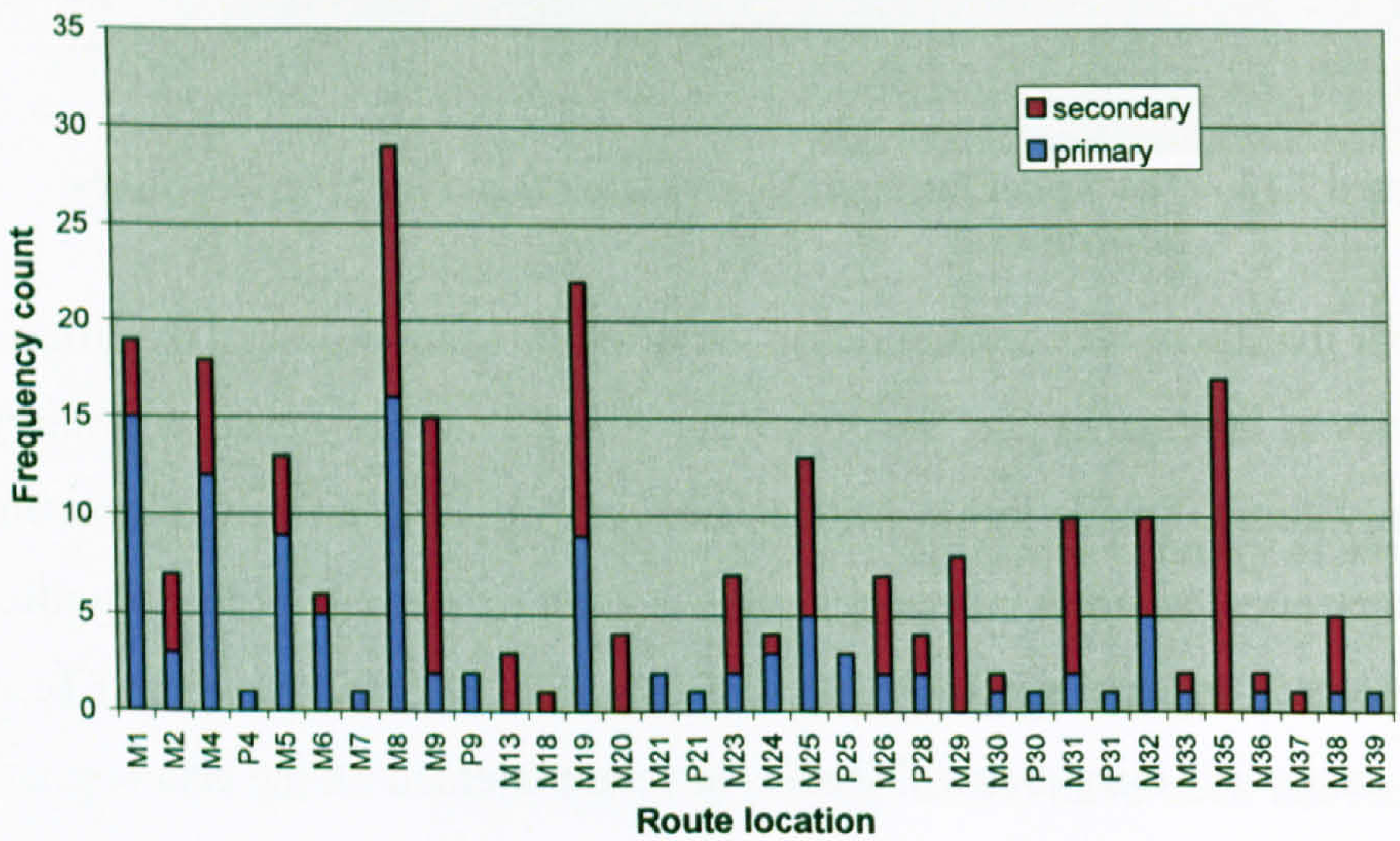


Figure 7.12 The primary and secondary use of navigation sign information at different route locations

Figure 7.12 shows the contextual variation of different cues within the navigation sign category by plotting the frequency of primary and secondary usage of navigation signs at different route locations. Note that navigation signs were used at manoeuvres (marked M along the route location) and also at progress points between manoeuvres (marked P).

The value of specific cues (as defined by the participant group) is clearly a function of both the number of participants generating the cue, and whether its use by each participant was in a primary or secondary role. A value score can be attached to each individual cue using the following simple linear model:

$V = W_P N_P + W_S N_S$ where:

V is the calculated value of a particular cue

N_P and N_S are the numbers of participants referring to that cue as primary or secondary information respectively

W_P and W_S are the multipliers for primary and secondary cues

Equation 1 Attribution of value based on primary and secondary usage

The multipliers used for WP and WS are shown in Table 7.5.

Multiplier	Apportioned where the cue was:
2	Used as primary information
1	Used as secondary information
0	Not used

Table 7.5 The multipliers used for primary and secondary use of cues

It is recognised that the nature of the model shown in Equation 1 and multipliers shown in Table 7.5 are relatively arbitrary for several reasons:

- The lack of previous research to guide their development
- The assumptions relating to the identification of cues by participants (e.g. that the frequency of identification is a function of their value)
- The subjective nature of the original assessment of cues as primary or secondary

Using the model in Equation 1 and the multipliers shown in Table 7.5 enables the calculation of a value 'score' for each of the information cues identified and coded within the study. Figure 7.13 shows a scatter plot of the value scores for all information cues, according to the main information categories shown in Appendix 7B. Figure 7.14 shows a similar scatter plot for the items sub-coded within the landmark category. Note that within these figures, the location labels are not attached to those items having a value score of less than 10 (all cues, Figure 7.13) or 5 (landmarks, Figure 7.14). A random 3% jitter was applied to show where multiple data points are co-located. Note also that some cues were used by participants more than once (in both preview and identify instructions), resulting in a possible value score higher than the product of $W_P N_P = 2x36 = 72$.

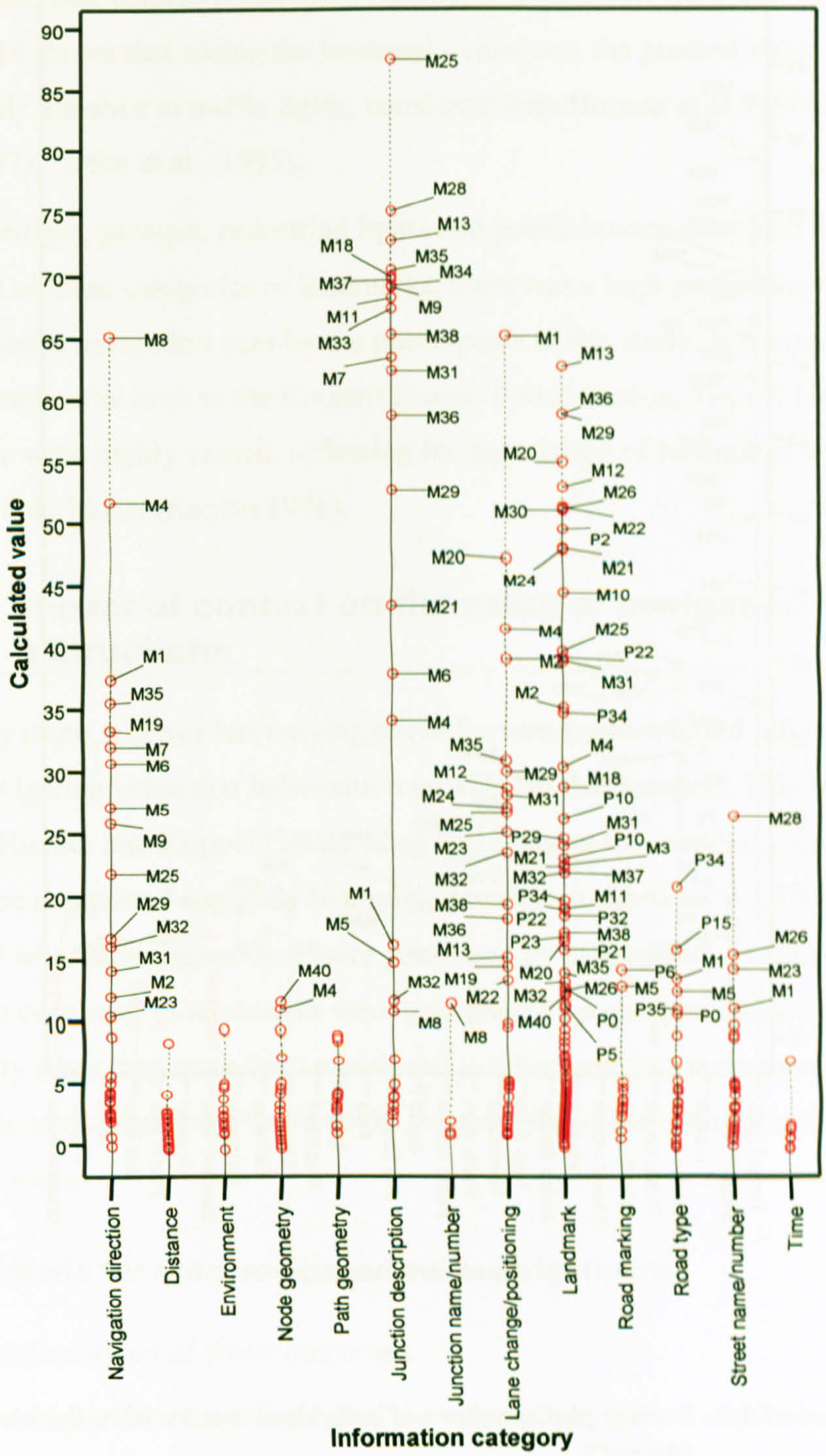


Figure 7.13 Scatter plot of values of individual items within the general category

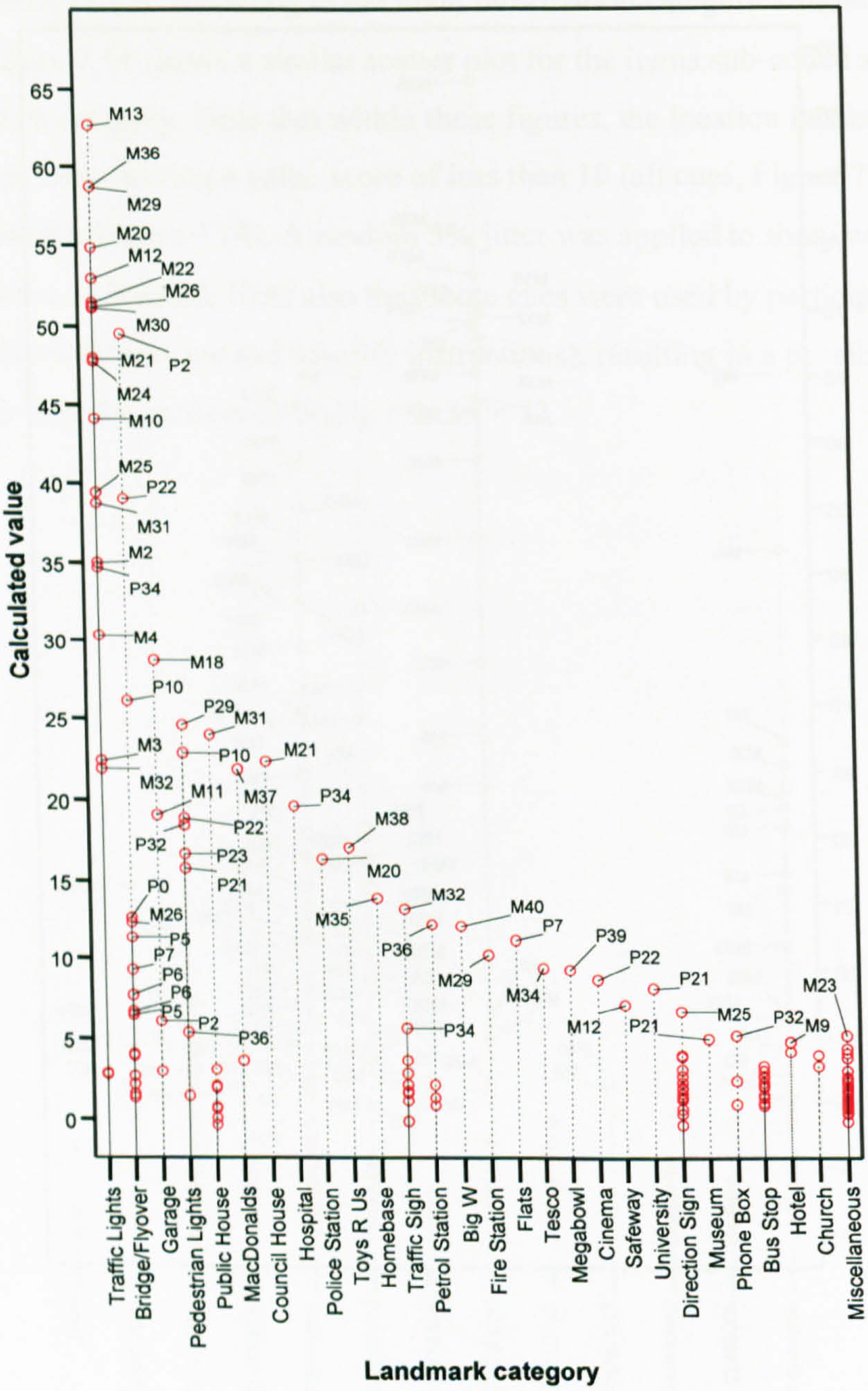


Figure 7.14 Scatter plot of values of individual items within the landmark category

Figure 7.13 shows considerable variation in the value of information cues both across, and within information categories i.e. the impact of context resulting from different locations along the route. The cues of highest value were specific junction descriptions, lane change/positioning information, direction signs and landmarks. Figure 7.14 shows that within the landmarks category, the greatest value was consistently attached to traffic lights, consistent with Burnett et al. (2001b), Akamatsu et al. (1997), Green et al. (1995).

Specific bridges, garages, pedestrian lights and public houses were also highly valued, but for all of these categories of landmarks, there was a high proportion that were not deemed useful navigation cues by the participants in this study. It is interesting that specific landmarks such as the Council House, Police Station, Toys R Us and Homebase were highly valued, reflecting the association of landmarks with particular goals for individuals (Kaplan 1976).

7.8 Impact of context on the value of navigation instructions

Along any route, a driver has varying needs for turn-by-turn based information based on the navigation value that information provides at that location. This is the point made by Richter and Klippel (2004) when highlighting that not every decision point needs to be mentioned explicitly in a route description. Sections 7.7.3 to 7.7.4 have identified *what* information cues were *generated* by participants. However, it was likely that cues such as landmarks were generated by participants based on need *and* availability (they may have been mentioned just because they were there). Therefore it is useful to understand how the need for (or potential value of) information varied along the route.

7.8.1 Criteria for outcome-based value judgements

7.8.1.1 Comparison of driver outcomes

The experimenter-based assessment of the value of navigation cues is based on two information environments and the difference in resulting driver outcomes as shown in Figure 6.7. The 'before' information environment is the information available to a driver within the natural and built environment – that which would be available to a driver without additional provision of navigation instructions from any source. It therefore includes road and junction layouts, road signs, traffic flows, lane markings, landmarks etc. The 'after' information environment includes the navigation information provided by the participants in the study – it represents all those cues available in the 'before' environment, plus those additional cues generated by the participants in the study. Although not as optimum as real-time provision of information to the driver from a passenger (since it does not adapt to real-time variants in context), the information cues generated within this study can be considered as approaching the 'ideal' information provision to an unfamiliar driver of the route, with the impact of this information being similar to the expected value of perfect information (Dakins 1999). The difference in driver outcomes in the 'before' and 'after' environments indicates the value added by turn-by turn navigation information at each manoeuvre. It is 'a relative value, based on comparisons between payoffs gained under different sets of information' (Ahituv et al. 1994). (See also Sections 2.5 and 6.7.)

7.8.1.2 Driver outcome measures

Driving safety

The maintenance of driver safety is often the key evaluation criteria used when assessing driver behaviour when interacting with new technology (Srinivasan 1999), whether this is done in a real or simulated environment. However, for a requirements study such as the one reported here, driver safety in the 'before' or 'after' information environments cannot be reliably assessed as it depends on the following factors:

- Dynamic factors such as point in time traffic flows.
- The behaviour of other road users.
- The realtime behaviour of the driver.

Within this study, the likely impact on driver safety was not assessed. It was assumed that the driving safety in the 'before' environment would be acceptable, since a driver, in the absence of navigation instructions, would be capable and motivated to maintain driving safety. The 'after' information environment includes the 'ideal' navigation instructions such as those generated in this study (given the limitation regarding the lack of real-time contextual influences on the timing and content of the instructions generated). These should ensure correct and timely lane positioning, and provide sufficient preview information to enable speed control on approach to a manoeuvre

(Burnett and Parkes 1993). Therefore, the value of navigation information in this requirements study was considered independently of the impact on the safety of the driver. This omission was remedied in the final studies in this thesis (Chapters 8 and 9).

Driver workload

For similar reasons to above, driver workload (a resource that may be considered a 'give' aspect) was not considered in this study, but was included in the final empirical study in this thesis.

Driver confidence

The increasing of driver confidence is a key means of adding value (providing a 'get') to a driver navigating an unfamiliar route. For each manoeuvre en-route, driver confidence in the absence of navigation information provided to them (the 'before' state) was assessed by the author as low, medium, or high as follows:

Confidence rating	Based on:	Route choices	Driver implications
Low	Driver would have little or no idea about the turning they were needing to take	There is no obvious route	Driver would *need* navigation information
Medium	Driver would be relatively confident about the direction they needed to take	There is a *preferred* route	Driver would *expect* navigation information
High	Driver would be confident about which route to take	There is an *obvious* route choice	Driver may not perceive a need for navigation information

Table 7.6 Criteria for assessment of driver confidence

It was assumed that driver confidence when using the information cues generated by the participants in the study (the 'after' state), would be high in all cases. Note that although driver confidence may be high on approach to a manoeuvre, this does not imply that they will take the correct route.

Driver navigation performance

Drivers' navigation outcomes were the main criteria used for assessing the value of providing information along the route of the study. As for the driver confidence assessments, this was based on an assessment of the driver as an information processor and decision maker (Burns 1997) discussed more fully in Section 6.4. This assessment by the author identified whether drivers were likely to follow the correct route based on those cues already available (the 'before' information environment).

7.8.2 Assessment of value at manoeuvres within the study

Section 6.7 has discussed, from a theoretical perspective, those influences that are likely to impact on driver confidence or route selection in the absence of additional information from a navigation source. These factors therefore determine the value of additional information to drivers navigating a route, and in particular, where added value is high as shown in Figure 6.7. For each manoeuvre en-route, based on an absence of additional information over and above that available in the natural environment, an assessment was made of:

- The driver confidence on approach to each manoeuvre.
- The likely route that the driver would take, and whether this was correct.
- The main contextual influences on the above.

This was based on a single experimenter judgement whilst driving the route during off-peak traffic conditions. The value of providing additional information to an unfamiliar driver was assessed for each manoeuvre as follows:

- The value of information was assessed as *low* if the driver would be expected to take the correct route and their confidence on approach to the manoeuvre was likely to be high.
- The value of information was assessed as *medium* if the driver would be expected to take the correct route but their confidence on approach to the manoeuvre was likely to be lower.
- In all other cases the value of information was assessed as *high*.

This assessment of the potential value of information to a driver is shown in the route description table in Appendix 7A. This indicates the extent to which additional information (such as that identified by the participants in this study) would add value to an unfamiliar driver by promoting the following of the correct route or increasing their confidence on approach to a manoeuvre. From a theoretical perspective, the factors contributing to *driver confidence* and *route selection* can be analysed separately. In practice, it makes no sense to promote confidence on approach to a manoeuvre unless the driver is also likely to take the correct route; therefore discussion of the analysis of these results focuses on where information adds value by promoting driver confidence *and* enabling a correct route choice.

The results from Appendix 7A are summarised in Table 7.7 below:

Level of information value	Main contextual influences
Low	The driver was following the main road, straight over a traffic light controlled junction (either a cross roads, or a single turning off)
	The driver was continuing on the more major road, straight over a roundabout, where other turning off this roundabout were minor
	The driver was following the more major road (not necessarily straight on), and all other routes were not legitimate turnings
Medium	The driver was continuing ahead at a roundabout, but this was not indicated as the more major route (all routes had equivalent seniority)
	The driver was following the more major route but this was not in a straight ahead direction
High	There was not a single major route indicated
	The driver was approaching a large, multilane junction
	The required route was not that which was indicated as more major
	The driver was required to turn off the more major route
	The driver was required to change direction of travel at a roundabout without it being the more major route

Table 7.7 Contextual influences on value assessments

Within this study, it was apparent that there were two main influences on driver confidence and navigation behaviour: the intended versus the preceding direction of travel and the existence and following of a more major route. This lends some support to the complexity model of Sugiyama et al. (2001) and Raubal and Egenhofer (1998) (in a pedestrian context), but also shows that these are insufficient determinants of value-add. Equally important are the factors discussed in Section 6.7. The following factors were indicators of a more major route:

- A relatively larger road.
- Signs to more major routes.
- The direction of the major traffic flow.

- A greater number of traffic lanes.
- The *absence* of local or POI signs.
- A road accessed by a dashed filter lane.
- Being required to give way at the junction with another road.

The design implications of the differing value of navigation information according to the context of the manoeuvre are highlighted in Section 7.9 below.

7.9 Design implications

The literature review in Chapter 6 demonstrated a number of basic requirements for driver navigation systems. They must provide *sufficient* but not *excessive* information to the driver and provide information where it adds value by enabling the completion of manoeuvres and the promotion of driver confidence. There were three main design implications arising from this study, which are discussed below:

1. That current navigation system design can be improved.
2. That it is possible to identify better navigation cues to the driver, and take into account the context where they are most useful.
3. That there is potential to provide information to the driver based on its value-adding capacity, i.e. contextual sensing and contextually-based information provision.

7.9.1 Effective navigation cues

Current navigation systems (whether built-in or based on portable devices) use a combination of graphics and text, and auditory verbal commands to provide information to the driver on approach to a manoeuvre. A typical visual display is shown in Figure 6.1 in the previous chapter. The visual display may provide street name or number information, a graphical representation of the junction layout, and a distance countdown bar to indicate the distance to the manoeuvre. There may also be basic representations of environment information, e.g. residential or commercial areas. Sections 7.7.3 to 7.7.4 have shown that much of the information portrayed by navigation systems is not that which is typically used to describe a route to an unfamiliar driver. Distance to turn is a key information cue used within navigation systems for identifying the location of forthcoming manoeuvres. However, this was used infrequently by participants in this study.

The design of navigation systems can be improved by providing the information that humans actually use within a turn-by-turn route following strategy, i.e. 'piloting' (Allen 1999). This has also been noted by several authors, including Burnett (2000). As described in Section 7.7.5, the cues that added most value to drivers within this study were landmarks (particularly traffic lights), junction descriptions, direction signs and lane change or lane positioning information. Traffic lights were particularly effective cues, since they were predominantly used in a primary role (whereas direction signs were often used as secondary cues), and there was relatively little variability of the value of individual traffic lights within the overall traffic light category. Landmarks are generally not included in current navigation systems, except as points of interest i.e. objects or places to *navigate to*, rather than *navigate by*.

Junction descriptions were a key primary navigation cue and are already included in navigation systems, either as simple representations of basic junction types, or as more realistic schematic layouts. There is even a trend for 3D or 'birds eye' views (Velde 2003), although there is little evidence of the effectiveness of these more complex 'fly-by' views.

Local, national and motorway signs were used by participants where available, but often in a secondary role to support other information provision. A typical use of direction signs was to reinforce the direction of turn (e.g. 'turn left at the roundabout, following signs for Birmingham'). Direction signs for more major routes were seen as adding more value that local signs (based on being used more frequently), but it was interesting that local signs were still used in the absence of national or motorway route signage. Burns (1998) has recommended that greater emphasis is placed on provision of direction sign information to drivers.

Lane choice (e.g. 'move over to the left hand lane') or lateral positioning (e.g. 'keep to the left') information was also seen as important by participants as the route contained several sections of dual carriageway, and multi-lane junctions. Correct lane position is important for maintaining safe interaction with other traffic and particularly valued by drivers when navigating in cities (Burns 1997).

It is therefore recommended that future navigation systems incorporate: (1) prominent landmarks (especially traffic lights), (2) schematic representations of junctions, and (3) road signs (especially national and motorway signs) within turn instructions in order to describe the location and nature of forthcoming manoeuvres. In addition, within the preview information given on approach to a manoeuvre, lane change or positioning information should be provided.

7.9.2 Presenting information when it adds value

Section 7.8.2 has shown how the need for information varied along the course of a particular route. Several authors have highlighted the need to limit the amount of information presented to the driver, e.g. Jackson (1998); Burns (1998). Based on a value-adding perspective, it is possible to provide information cues to the driver where the added value is greatest. This would address the lack of adaptation that is described by Richter and Klippel (2004) as a 'major drawback'. This is a fundamental shift away from the proceduralised presentation of information by current navigation systems, where the same format of information is provided to the driver at each manoeuvre, independent of the need at each manoeuvre, or the availability of explicit or implicit navigation cues at that location.

The value of information to the driver at particular locations may be categorised as high, medium or low, and information presentation managed accordingly. Where information value is high (i.e. impact of navigation instructions greatest), the driver will need explicit navigation instructions, incorporating redundancy within those instructions if possible, a repeat of verbal instructions, plus support for the preview and confirmation aspects of navigation. The high value-adding situations are where:

1. There are major journey consequences if the turn is not completed due to the lack of alternative feasible routes, e.g. missing a motorway exit, one-way traffic systems.
2. There are potential safety implications due to lane positioning, e.g. approaching complex multi-lane junctions.
3. The driver would not expect the location of a turning, e.g. a turn in close proximity to a preceding junction.
4. The turning is partially obscured and not visible from a distance, e.g. a built up area with high-sided parked vehicles.

5. Driver uncertainty would be high due to several potential navigation options, without a clearly marked more major route, e.g. approaching a multi-exit roundabout, a T junction, or a set of cross roads.
6. The driver is not following the more major route, e.g. exiting a motorway, an 'A' to 'B' road transition, taking a minor turning off the major road, taking a more minor exit at a roundabout.
7. The required navigation direction appears inconsistent with the original heading being followed, e.g. an exit at a roundabout that is at an acute angle to the original direction of travel.
8. The required turning does not match the drivers expectations regarding its visual appearance e.g. a turning that looks like a farm track, or an ambiguous entry into a business park.
9. The driver is required to make a navigation decision without necessarily stopping, e.g. a turning off a more major road, which is not controlled by traffic signals.

The value-adding potential for information is less where the driver would be likely to make a correct navigation decision without additional information, but may not be confident that they have completed the turn as required. In those situations the driver should also be given explicit navigation instructions, but information presentation can be minimised by limiting redundancy and repeat of verbal instructions:

- The driver is continuing straight on, but this is not clearly indicated as the more major route, e.g. continuing over a four-way crossroads where all roads are of equal seniority.

There are situations where information value to the driver is low: the driver would be confident throughout the manoeuvre and would follow the correct route without explicit instructions even thought there are potential navigation choices. In these cases the driver could be given a visual only indication of the desired direction of travel:

- The driver is following a clearly indicated more major route, and this is in a straight on direction, e.g. continuing along a major route past turnings off, or passing over more minor roads at a cross road.

There are several pragmatic and commercial limitations to incorporating the above recommendations in the design of future navigation systems. At present, some of the information such as the location of traffic lights, and lane information is not readily available, a point made by Richter and Klippel (2004) and Burnett (2000). This information is held locally, in a variety of different formats, by bodies such as local councils, and it is therefore time consuming and costly to source and maintain this data on navigable map databases. If the information presented to drivers is incorrect (e.g. has become out of date) it has been shown to lower a driver's confidence, as reported by May et al. (2002). The development of future navigation systems will be influenced by that functionality (e.g. information provision) which can be reliably supported. Vehicle and system manufacturers have consistently stated the need for 'systems to be right' before they are marketed, for both customer acceptance and product liability reasons.

A second limitation relates to the development of algorithms that incorporate the rules for presentation of information to the driver. These rules essentially describe context-aware information provision, context-aware computing originally being seen as one vision of the future for computing (Weiser 1991). However, there are also arguments that computers will never achieve reliable contextual understanding (Bellotti and Edwards 2001; Brown and Randell 2004; Greenberg 2001), being able to fulfil the role of an informed human (i.e. in this case a knowledgeable passenger managing information provision to a driver according to the value it provides). Future navigation systems would need actual (or reliable surrogate) measures of factors such as direction of travel, route seniority, as well as operational metrics for softer constructs described above such as 'feasible alternative route', 'complex', 'obscured', 'expectation of appearance' etc. In addition, more research is needed to understand the relative impact of the variety of factors, and their interaction, that would in practice influence the value of information to a driver at a particular location.

Future design must also take into account the most appropriate means of *presenting* information to the driver. Although not the focus of this thesis, there are several recommendations for the presentation of navigation information to the driver, such as those provided by Srinivasan (1999), and the standards outlined in Section 6.2.3.

7.10 Critique of study

The objectives of this study were to identify:

- The *need* for navigation information provision at different locations along a route (the context-dependent need for information to support the task).
- The information cues needed to navigate a particular route.
- The value attached to information cues (i.e. how important particular cues or categories of cues were).
- The value of navigation information according to their context of use.
- Design recommendations for enhanced design of navigation systems.

Value was conceptualised as a difference in driver outcomes resulting from an *augmented* information environment – a key capability of context aware computing (Dey et al. 1999). It was assumed in this study that cues would add value by providing benefit at an acceptable level of cost, and that these aspects of benefit and effort would be instrumental in the participants identifying information cues at particular points throughout the experimental route:

- They would identify information that was perceived as being of benefit (i.e. useful in terms of navigating a route).
- They would necessarily identify information based on the cognitive and perceptual effort involved in extracting and representing this information (and this would represent (at least to some extent) the concomitant effort needed by a driver in accessing and using these cues when navigating the route.

This study attempted to maximise the usefulness and validity of the results generated via the careful selection of participants and navigation tasks (routes), the use of 'video' and 'cognitive map' representations of the route, a comprehensive data capture process and coding taxonomy, and the use of theoretical models to explain and generalise the results. Clear instructions were given to participants that navigation instructions should be based on the assumption that the driver was unfamiliar with the area, and that alternative information sources were not available that by themselves would enable successful navigation of the route. Destinations were chosen that specifically prevented the use of global instructions (e.g. follow signs for the motorway), and therefore ensured that value-adding information was needed at most of the driver decision points on a turn-by-turn basis. There were several limitations and potential improvements which are described below.

7.10.1 Limitations to the study

It could be argued that the overall philosophy behind the study was flawed, since it was based on the premise that navigation systems need to provide some form of proceduralised information to drivers - i.e. to support 'piloting' (Allen 1999). Future navigation systems may support totally different strategies for navigation which require the driver to do little more than just drive the vehicle and perform a following task (thereby removing much of the cognitive effort of information integration and decision making). This could be achieved through augmented reality, or the use of highly dynamic contextual information to supplement the static information environment. 'Micro guides' – preceding vehicles which are taking the required route could be used as reference cues for a following vehicle. This would be equivalent to a passenger stating 'follow that blue van'.

The value of navigation information was assessed at a manoeuvre level. However, a true assessment of value would take into account the importance of correct navigation within a more global context - i.e. the overall impact of errors at specific locations on being able to reach the desired destination as shown in Table 6.2, consistent with an ecological perspective (Flach et al. 1998). It was not realistic to represent this within the study, although it is possible that the cognitive map participants may have placed greater emphasis on instructions at manoeuvres where a navigation error (i.e. incorrect turning) was difficult to recover from.

Aside from the points made above, the most basic threat to validity within this study was centred on the contention that those cues that added most value to an unfamiliar driver *were* those that were identified by participants in the study. In particular, it is assumed that participants identified cues based on them being *useful* to a driver in an unfamiliar area by supporting a turn-by-turn navigation strategy *and* being *accessible* (the benefits and resources of Table 5.4, relating to the 'get' and 'give' components of value). An analysis was undertaken of the extent of information provided to the unfamiliar driver at manoeuvres (i.e. no information, basic direction cues, and/or additional information, Section 7.7.2) versus the assessed value of information at each manoeuvre (Section 7.8.2). These are shown in Appendix 7C. They demonstrated only a limited relationship between these two factors, the conclusions being that although participants generated instructions based on those that enabled an unfamiliar traveller to complete a turn-by-turn navigation strategy, the generation of cues was also highly influenced by the nature of the cue itself, and particularly the availability and visual prominence of potential cues and the ease with which they could be described. This highlights the need to empirically investigate the value of information cues. This is described in Chapters 8 and 9.

There were a number of alternative rationale that participants may have employed when identifying navigation cues. They may have identified cues which were easy for them to identify, without regard to their use by drivers. An example (generated by the cognitive map group) would have been street name signs which were either absent or not legible to drivers. There is some evidence for this, since Figure 7.15 shows that a greater number of cognitive map than video participants generated street names/numbers. Some of these street names are not apparent to a driver e.g. the major road between M1 and M4 is known locally as the 'London Road' (and marked as such on maps), however this road is not clearly signed to drivers in this way. A comparable example for the video group are those direction signs which could be picked out on the video, but would have been relatively difficult for a driver to identify based on their likely direction of visual attention during the driving task and their concurrent mental workload demands.

Participants were not placed under time constraints and additional task demands when generating their navigation instructions, which is at odds with the resource limited and temporal nature of navigating in an unfamiliar environment. In addition, it is likely that there was personal bias present, resulting in the generation of landmarks which have a personal or cultural significance (Sorrows and Hirtle 1999). This limitation was addressed as far as possible through the provision of explicit instructions to participants as above, and the selection criteria for participants (e.g. requiring local knowledge and at least two years driving experience).

Figure 7.15 below shows how the frequency of reference to different categories of information cue (as in Figure 7.4) differed according to whether they were identified by the participant group extracting information from a video, or by the equivalent group using route schematics to recall information from their own cognitive map of the local area. This dual approach was taken to address some of the potential limitations described above. It can be seen that there is surprising consistency between the two participant groups for the two most popular information items of landmarks and junction descriptions. However it also demonstrates the differences in reference to lane change/positioning and navigation direction signs, discussed above.

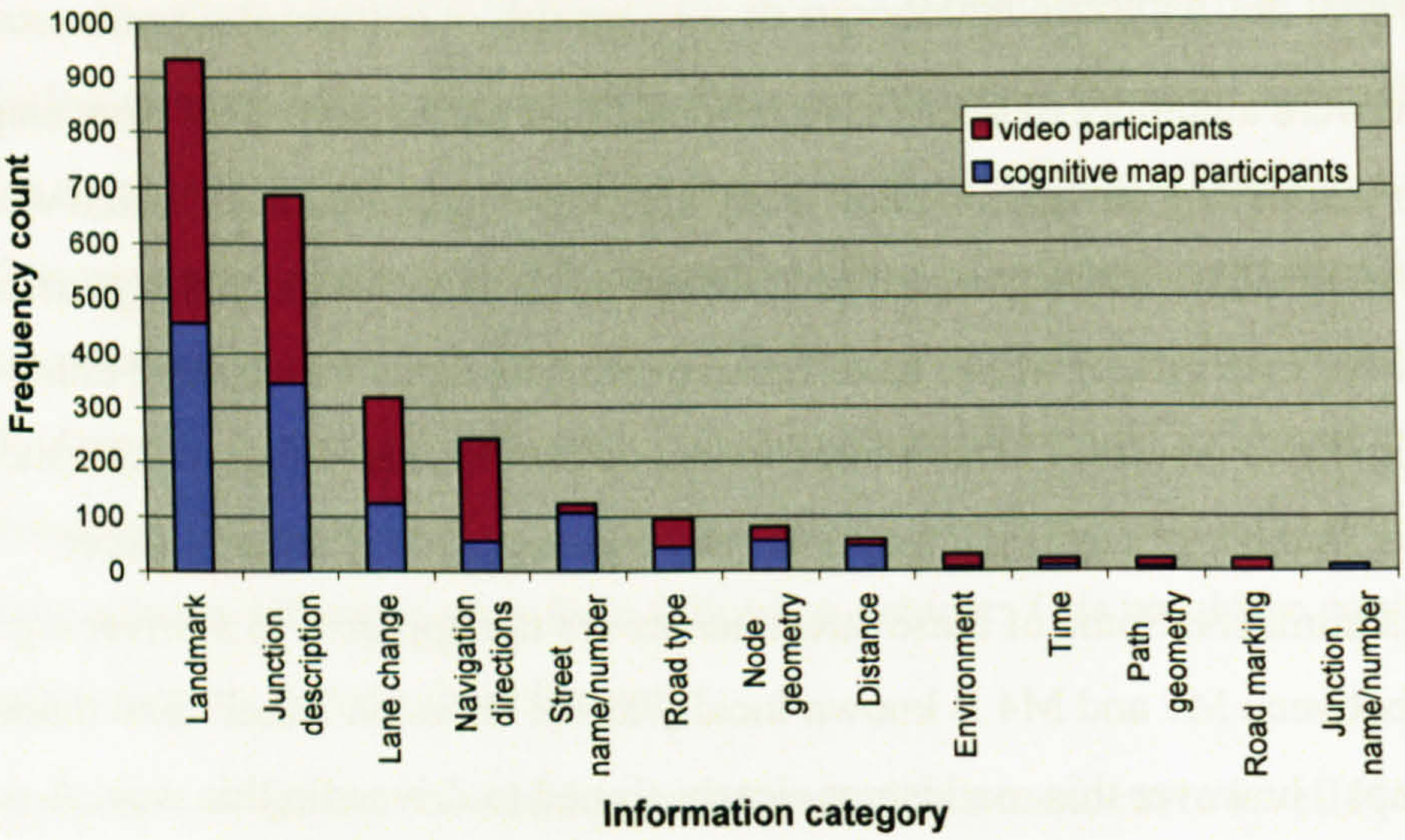


Figure 7.15 Number of information cues identified by participant groups

Another potential study limitation relates to the basis by which value was attributed to the information cues (Figure 7.13 and Figure 7.14). The primary or secondary nature of each cue generated by each participant was assessed subjectively by the author; this was felt to be relatively valid (as the judgement being made related directly to the impact of the cue on navigation performance) and reliable since discussion with other human factors researchers revealed general consensus during the assignment process. No formal reliability checking was undertaken (as recommended in Chapter 3), which is a recognised weakness. Aside from the subjective nature of the primary/secondary distinction, there are two main threats to validity. The first is the use of a frequency count to indicate value, i.e. the assumption was made that the greater the number of participants that identified cues, the greater the value attached to those cues. Apart from the more basic arguments relating to the basis by which participants identified cues in the first place (discussed above), the frequency count metric is really a measure of consensus within the participant sample, rather than a strict indicator of value. However, even if the outcomes are discussed in terms of participant consensus, this still provides useful design input, since navigation systems are designed based on suitability for the majority.

The second threat to validity for the results shown in Figure 7.13 and Figure 7.14 is the relatively arbitrary nature of the assignment of the multipliers to the primary and secondary usage of information: primary cues were assigned a frequency multiplier of 2; secondary cues a frequency multiplier of 1. No previous research was found on which to base these multipliers. At a basic level it is clear that cues used in a primary role have a greater value than those used in a secondary role, hence the need to differentiate between these two patterns of use. However it is recognised that the use of the particular multipliers was based on only that contention and that a true indication of value may not result from a linear model as described. In particular, there is little theoretical basis for stating that a cue used by 20 participants in a primary role (resulting in a value score of 2x20=40) actually has a greater value than a cue used by 30 participants in a secondary role (resulting in a value score of 1x30=30).

A potential limitation of the results shown in Figure 7.13 and Figure 7.14 is that it emphasises the information that *is used*, even if by a small proportion of participants, and does not consider the information that is potentially available and *not used*. A similar pilot study with 32 participants in Loughborough, reported in May et al. (2002), *did* analyse the extent to which cues were available within the environment, but not used for driving directions. However, this analysis proved infeasible within the present study, due to the increased scale of the experimental route.

A further limitation was the single, experimenter-based judgement of driver confidence and likely navigation behaviour in the absence of navigation information, as shown in Appendix 7A. This limitation was remedied with the final studies of Chapters 8 and 9 where driver confidence was incorporated as an outcome measure.

Finally, there are potential difficulties in generalisation of results from this study, even within the boundary conditions shown in Section 7.3.4. Although the route was specifically designed to include a wide range of road environments, it focused on an urban environment and did not include inter-urban dual carriageway or motorway routes. In addition, the UK perspective enables only a limited applicability of the results to non-UK driving environments. In other road topologies, such as a traffic light-controlled grid structure (e.g. as found in some US cities), the relatively homogenous visual appearance of junctions may mean that cues such as street names are those that add most value to the unfamiliar driver.

7.10.2 Potential improvements

Several improvements could have been made to this study:

(1) An inclusion of a more qualitative aspect to the study, where participants were asked to explain why particular cues, at specific manoeuvres, were, or were not, generated by them. This would have helped identify how the context of use and the characteristics of the cue itself influenced its perceived value.

(2) The inclusion of stricter time constraints during cue generation, particularly for the video group. This would have more closely approximated the role of a driver undertaking a temporally demanding task, and resulted in a greater prioritisation of information by the video group. There was quite marked variation in the number of cues generated by the video group: some participants included reference to cues such as trees, and distinctive buildings. These are legitimate navigation cues (e.g. an accompanying passenger may refer to them when directing a driver along the route), but would be unlikely to figure in future navigation systems. Linked to this point is the need to distinguish between the time available to *extract* relevant information cues, and that available to *record* those cues. It is not helpful to impose restrictions on the recording of cues, although in practice it may be difficult to differentiate between these.

(3) An alternative to limiting the time that participants had to generate cues would have been to limit the amount of information cues that could have been generated. This again would have promoted a prioritisation of cues, and counteracted a tendency to provide a 'journey narrative'.

(4) A means of more closely tying navigation instructions to geographical locations. The basis of much of the analysis in this chapter was the linking of navigation instructions (comprising particular cues) to driver decision points at specific locations en-route. In most cases, it was possible to identify the location relevance of the cues, but the physical location associated with some instructions was less clear. It would have been useful to have had a means of recording where en-route an instruction had relevance to the unfamiliar driver. This would have also speeded up the coding process

by eliminating the need to manually associate each cue generated with a specific geographical location.

(5) The use of participants (in preference to experimenter assessment) to empirically determine their likely navigation behaviour in order to assess the value that information provides at each manoeuvre (shown in Section 7.8).

7.10.3 Future research

The study leads to several avenues for future research.

(1) The empirical testing of the value of different navigation cues to a driver in an unfamiliar area. This study has shown how certain information cues are deemed useful for navigation whilst others are less so, a point made by several authors dating back a couple of decades. However, there has been a lack of empirical testing (in a deductive sense) within a real road environment (in contrast to simulator studies of drivers, and field studies with pedestrians).

(2) The potential for supporting other strategies for driver navigation that are not based on turn-by-turn - i.e. 'piloting' (Allen 1999) - instructions and procedural information provision.

(3) The integration of a navigation MLS within a more holistic view of mobile lifestyles. This implies placing greater emphasis on the other activities a driver and passengers may wish to undertake within a vehicle. Navigation may be considered as a means to an end (i.e. something that drivers aren't actually interested in). Alternatively, navigation within a vehicle may be an enabler of other opportunities – the concept of the car as a 'space', potentially capitalising on the mobility of the occupants.

(4) Requirements for navigating in other European countries and generalisation of results based on a European, rather than a single country perspective. This is important from a vehicle manufacturers or navigation system developer perspective, since they generally aim to develop a single product for global markets, and then tailor this product to specific large-scale markets such as Europe, North America, Asia, Australasia.

7.11 Conclusions

Due to the diversity of the information environment encountered by a driver along a route, a wide range of information categories are potentially useful navigation cues. However, a limited set of information categories are those that are consistently used and add value within a navigation context. Landmarks, junction descriptions, lane change/positioning information and navigation directions add most value, although navigation directions are often used in conjunction with other cues. The landmark categories that add greatest value are traffic lights and bridges. Other specific landmarks add value, e.g. particular superstores and fast food outlets where these are sited prominently at junctions.

Many navigation information cues such as direction signs are used in a secondary or redundant role in combination with other cues. An analysis of the information required to navigate a route should take into account the primary or secondary role of information at a driver decision point. The availability of cues within the environment and their variability as a category should also be taken into account. Those available, and most useful, are junction descriptions, references to traffic lights, lane change/positioning information. Navigation signs are also useful, particularly those that are signposted to major routes (e.g. instructions such as 'follow signs for the motorway').

It should be possible to enhance the design of navigation systems by making them more context aware, and in particular capitalising on contextual sensing, contextual adaptation, and context augmentation, as outlined by Dey et al. (1999). As well as being more location (and context) sensitive, the design of vehicle navigation systems can be enhanced by incorporating landmarks within the information provided. A good first step would be to include traffic lights within navigation systems, since they are widely available as information cues in urban environments, and as a category, appear to consistently add value within a driving context.

8 THE IMPACT OF THE CONTEXT OF MANOEUVRES ON THE VALUE-ADD OF NAVIGATION INFORMATION

	Research questions addressed in this chapter:
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	What is user 'value' in the context of mobile location services?
4	**How can a specific mobile location service (driver navigation) be enhanced using a value perspective?**
5	What general recommendations can be made for mobile location services research and design?

Note: data for the studies described in Chapter 8 and Chapter 9 was collected simultaneously as part of one data collection exercise. They were written up separately as they had separate aims, analysis and conclusions. Where there are commonalities in approach and method, these are described more fully in Chapter 8, and referred to as necessary in Chapter 9.

8.1 Introduction

The study described in Chapter 7 demonstrated the wide variety of information cues which are deemed potentially useful in a range of contexts from a navigation perspective. These results are consistent with those of Tom and Denis (2003), Burnett (2000), Burns (1997) and others. The nature of the previous study was such that the only method of assessing driver impact - i.e. a comparison of pay-offs (Ahituv et al. 1994) due to context sensing, adaptation and information augmentation (Dey et al. 1999) - was a *subjective* assessment of the value of providing cues at each of the potential driver decision points en-route. In addition, it was clear that participants were generating cues based on where they were *useful*, but also based on them being *present* in their representation (video or cognitive map) of the route. The study in Chapter 7 therefore provided no *evidence* of the value (in terms of the impact on outcomes) of different navigation cues to an unfamiliar driver at particular types of manoeuvres.

Current navigation systems provide distance-to-turn and junction layout information to enable a driver to follow an unfamiliar route. It is likely that additional value can be provided to drivers through the use of enhanced instructions, as commonly generated by participants in the previous study (e.g. see Section 7.7.2), but also that the need for 'better' information would vary according to the physical context of the particular manoeuvre.

The work reported in this chapter is an empirical investigation of how the context of a manoeuvre influences the potential to add value at those manoeuvres, for a driver unfamiliar with the route. Context in this respect is assumed to comprise those physical (as opposed to social) aspects that are relevant to the user, and in particular the environmental context which is hinted at by Kim et al. (2002). By identifying the impact on 'value-add' within a navigation scenario, it is possible to identify how the relevant factors should influence the adaptation of system behaviour – a need suggested by Richter and Klippel (2004) within driver navigation, and by many authors – e.g. Dey et al. (1999), Chen and Kotz (2000), and Dix et al. (2000) – within a wider context. Since value-add is contingent on different user outcomes (Section 6.7), this study generates a set of driver outcomes using basic navigation information at a wide range of manoeuvres, and then discusses the extent to which additional value can be derived from more effective navigation instructions at those manoeuvres.

8.2 Aims

This study sought to understand where and how value can be added to a driver of an unfamiliar route, over and above that provided via distance and junction layout information as commonly employed in current navigation systems. Value has been described as a relative concept (Section 6.7), benchmarked against a level of performance achievable within a specified information environment. This study investigated how driving and navigation performance varied along the course of an unfamiliar route, when using basic navigation instructions (distance and junction layout) to indicate the location and nature of manoeuvres. Specifically, this study sought to understand:

- How driving and navigation performance varied according to the characteristics of the manoeuvre being undertaken.
- The extent to which additional navigation value (over and above simple layout and information) could be added at different types of manoeuvre (i.e. where it makes a navigation difference).

- The main contextual influences on the need for enhanced navigation instructions at manoeuvres.

It was assumed that the indicators of where greatest value could be added to a driver following an unfamiliar route were (1) low levels of driver confidence and (2) the committal of driving and navigation errors at manoeuvres. It was expected that the greatest value could be added at manoeuvres where there were multiple navigation options, similar to Raubal and Egenhofer (1998), Sugiyama et al. (2001), and the environmental affordances were such that a driver was likely to either have low confidence throughout the turn, or was likely to commit navigation errors, or exhibit poor driving performance. It was assumed that turnings off the current road were likely to be a type of manoeuvre where particular value could be added.

8.3 Study rationale

8.3.1 Choice of methodology

The rationale behind this study was to expose drivers to a range of potential navigation decision-making situations within a given information environment and determine their levels of performance in each of these situations. A 'realised' value-add perspective could then be used to determine where additional value could be generated by an enhanced information environment, e.g. instructions which were more effective than those currently used by navigation systems.

The contextual factors relevant at each manoeuvre could also be identified and used to generate propositions for *where* value could be added. The study was therefore quasi-experimental in nature, but more inductive than deductive: although there was experimental manipulation within the study (the type of manoeuvre was varied), the focus was on trying to *understand the relationship* between what was specifically varied (the manoeuvre and associated context) and the outcome measures (driver behaviour at each manoeuvre). Of critical importance was the need to: (1) accurately represent the context surrounding different driver decision points (i.e. potential manoeuvres), (2) capture the measures that would indicate the extent to which value could be added to a driver of an unfamiliar route, and (3) link the measure outcomes with the changes in context.

A situated study involving driver navigation around an actual route was employed, i.e. a 'field experiment' (Robson 2002). To ensure consistency of information delivery to the driver, a vehicle navigation system was used to present navigation instructions to the driver. This provided a benchmark against which potential added value could be assessed, as driver behaviour could be assessed in relation to an established, and consistent process of information delivery.

8.3.2 Boundary conditions

The boundary conditions employed within the study (i.e. those criteria that define the limits of applicability of the results) are shown below in Table 8.1.

Users	**Constrained by specifying participants:** All fulfilled the following criteria: aged 21+, normal vision, clean driving licence, regular drivers, unfamiliar with the area, no previous experience with navigation systems. **Varied on the following criteria:** Age, gender, self-reported navigation and distance judgement ability
Tasks and context	**Constrained by specifying the experimental task:** The driving of an unfamiliar route using a turn by turn strategy with a navigation system **Constrained by specifying the information environment within the requirements study:** The unfamiliar urban environment. The availability of the navigation system as the single information source over and above environmental cues (i.e. paper maps, passengers, passers-by could not be accessed). **Varied according to location-dependent context** The characteristics of each (N=32) manoeuvre en-route. The information environment (availability of different information cues within the environment).

Table 8.1 Boundary conditions placed on the study

8.4 Method

8.4.1 Overview

This study comprised a road-based trial to assess the potential to add value to a driver following an unfamiliar route. A single group of (n=16) participants navigated a complex urban route using a standard vehicle navigation system which presented visual and verbal navigation instructions based on distance and junction layout. A range of dependent measures were collected at each manoeuvre, namely driving errors, navigation errors and self-stated navigation confidence at defined points throughout each manoeuvre.

8.4.2 Participants

As stated at the beginning of this chapter, the data for this study was collected in parallel with that used within the study described in Chapter 9. In practice, a single set of (n=48) participants were recruited, and data collected from the 48 participants according to Appendix 8A. The data from one third (n=16) of these is reported in this chapter; this enabled a *within-subjects* investigation of the impact of varying manoeuvre contexts on driver behaviour. The remaining 32 participants were added to the data from the 16 described in this chapter to enable a *between-subjects* investigation of the impact of providing different forms of navigation information to the driver. The results of this between-subjects study are described in Chapter 9. Recruitment details are provided in Section 9.4.2.

8.4.3 Apparatus

A Land Rover Freelander™ was used which was fitted with a state of the art, on-board DVD-based satellite navigation system that provided visual and verbal turn instructions, and map overview information, to enable a driver to navigate to one or more specified destinations. On approach to each of the manoeuvres en-route, the satellite navigation system displayed a direction arrow integrated into a simplified junction overview and also incorporated a distance countdown bar that showed the distance to the turn (starting at 500 metres and counting down to zero in 50 m increments), the name of the current road and the name of the road being turned into (see Figure 8.1). Each distance bar represented approximately 50m (system used yards) which emptied from bottom upwards on approach to a manoeuvre. Note that the display used in this study actually comprised 10 distance bars, not the 7 as shown in the figure below. In between manoeuvres, the visual display presented a map overview to the driver.

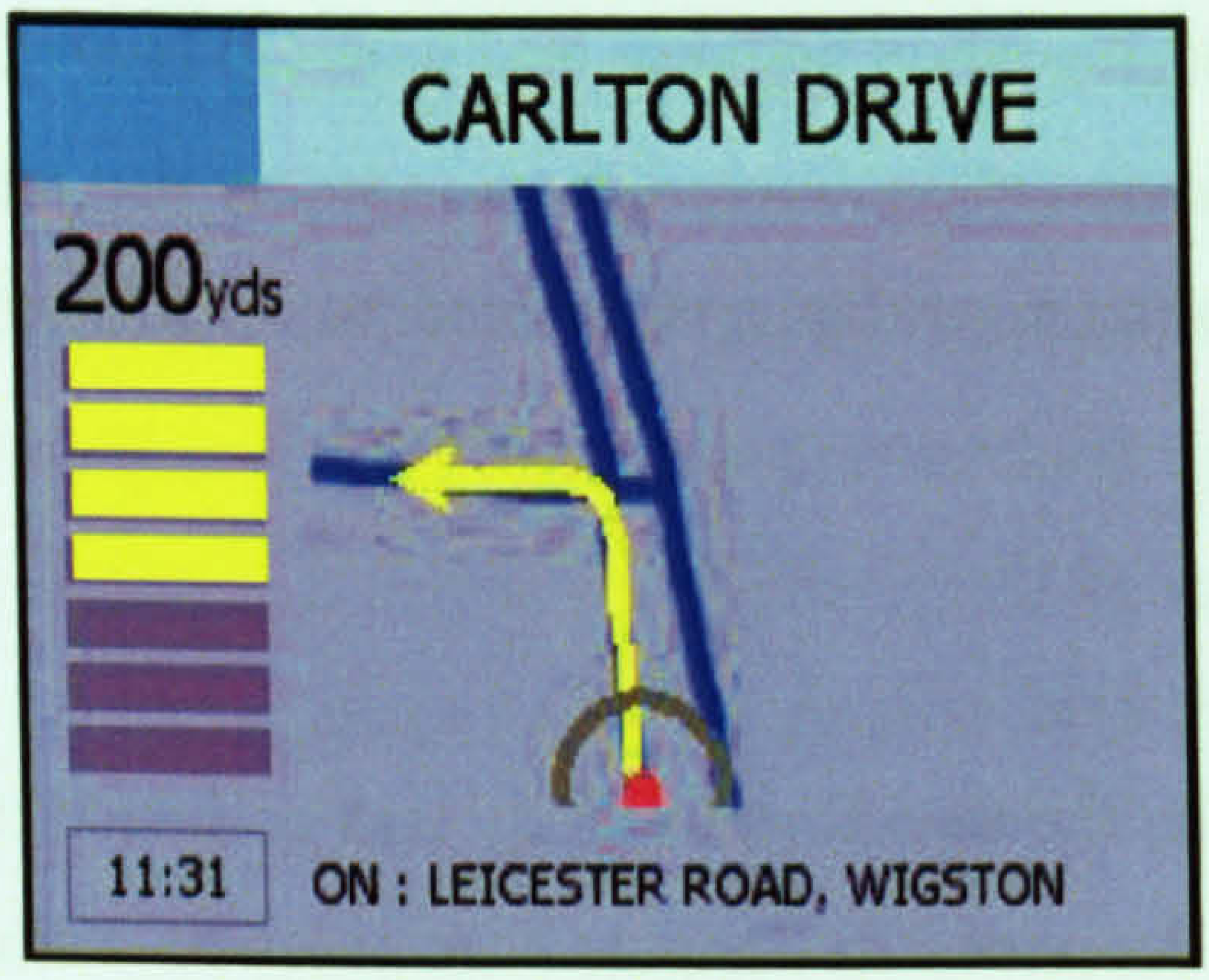


Figure 8.1 The visual information shown on approach to each manoeuvre.

To ensure consistency of presentation of the voice messages for the between-subjects comparison described in Chapter 9, all of the auditory messages presented to the participants in this study were re-recorded, and triggered and played to the driver in lieu of the auditory output generated automatically by the navigation system. The messages consisted of up to three verbal prompts as follows: a Preview 1 message given at the earlier of 500 m or the completion of a prior manoeuvre (this was omitted if subsequent manoeuvres were closer than 300 m); a Preview 2 message given at the earlier of 200 m or the completion of a prior manoeuvre; a Final auditory tone (beep) given at 50 m to the manoeuvre. This presentation strategy is typical of that employed by most current vehicle navigation systems incorporating distance information.

8.4.4 Experimental route

An experimental route was chosen based around the south of Leicester, a city in the UK with approximately 320,000 inhabitants (see Table 8.2):

Total length	17.5 km
No. of driver decision points	37
Road description	10% dual carriageway and 90% single carriageway
Built environment	75% residential housing, 25% urban (but not city centre) retail/commercial
Total driving time	Approx. 40 minutes
Speed limits	Majority 50 kph

Table 8.2 The route characteristics

The route was explicitly designed to be navigationally challenging, based on the number of driver decision points within its total length. A driver decision point was defined as a location where a driver had more than one navigation option and was not following a single major traffic flow, or had to potentially stop or give way to other traffic. In practice, these were geographical locations where a lack of navigation information would normally result in a navigation error, or navigation uncertainty, as per Burns (1997).

The route was chosen to encompass a range of different junction types within an urban environment, including: turnings off the major road, T junctions, cross roads and roundabouts. In addition, the route contained eight manoeuvres that were employed in the between-subjects manipulation described in Chapter 9. A description of the route is given in Appendix 8B.

8.4.5 Experimental design

A within-subjects experimental design was used to investigate the varying impact on driver behaviour of using basic (distance and junction layout) information to navigate an unfamiliar route. However, as described in Section 8.4.2 the data for the study described in this chapter, and the data relevant to Chapter 9 were collected as part of one data collection exercise, with the two sets of data being analysed separately. The data reported in this chapter is based on an analysis of the behaviour of *one third* (n=16) of the participants, over the *whole* experimental route. There were 37 manoeuvres en route with data collected at *each* manoeuvre (the dependent variables are described in Section 8.4.6). However real-time data was not collected at the following manoeuvres due to either the close proximity of turns, or the necessity to stop the vehicle en-route in order to re-programme destinations: 1, 5, 10, 14 and 34. (The data reported in the following chapter (9) is based on an analysis of the behaviour of *all* of the participants (comprising 3 independent groups, n=16, 16, 16), over a subset of 8 target manoeuvres. The distinction between the data analysed in this chapter and the following is shown in Appendix 8A.)

The experimental design in this chapter was therefore a 32 way (manoeuvre location) within-subject design with (n=16) participants. Due to the constraints of driving an actual route with a real navigation system, it was not possible to randomise or balance the within-subjects factor, i.e. all participants completed the manoeuvres in a set order.

It is recognised that this was a potentially confounding influence when analysing differential driver behaviour at the 32 manoeuvres; this is discussed in Section 8.8.1. All trials took place mid morning or mid afternoon between, i.e. during off-peak traffic conditions. This was done to minimise the impact of variations in traffic levels on the study: previous experience had demonstrated how peak traffic hours not only increased the influence of other traffic, but more importantly, increased the *variability* of this influence which would act as uncontrolled context operating at manoeuvres en-route.

8.4.6 Dependent variables

The dependent variables used in the study were based on those that enabled (within the constraints of an empirical study) a value-based analysis of the impact of information cues on the driver. The dependent variables comprised 2 categories:

1. Potential benefits (or dis-benefits) to the driver
2. Expenditure of resources by the driver

As per Chapter 6, the dependent variables within the study were defined as those which described both primary (the driving task) and secondary (navigation) task performance. Value is described in Chapters 5 and 6 as comprising potential benefits through the expenditure of resources (i.e. 'give' and 'get' components). As driver navigation using a turn-by-turn strategy is highly paced, and the driver is resource-limited, driver confidence is not only an outcome measure, but also indicative of whether the resources available from the driver are sufficient to resolve the navigational uncertainty at a manoeuvre.

The following measure and metrics were used in this study, reflecting driver safety (Srinivasan 1999), navigation performance (Burns 1998) and navigation confidence (Burnett 1998). The metrics are also consistent with the usability constructs (ISO-9241 1998) which are applied to interface design: effectiveness (navigation and driving performance), efficiency (visual and cognitive resources) and satisfaction (driver confidence), and the assertion that they need to be considered, and measured as independent factors (Frøkjær et al. 2000).

Measure	Metric
Driving safety (primary task performance)	Driving errors whilst undertaking manoeuvres
Navigation (secondary task) performance	Actual or potential navigation errors at each manoeuvre
Driver confidence	Driver confidence throughout each manoeuvre

Table 8.3 The measures and metrics used in the study

These dependent variables are described below.

8.4.6.1 Driving safety

Driving errors while completing each manoeuvre were assessed by a UK Driving Standards Agency Approved Driving Instructor who accompanied each participant during the trial (and was unaware of the exact nature of the independent variable manipulation). This mirrored the use of a driving instructor by Zaidal and Noy (1997) to rate 'quality of driving'. Errors were recorded as minor, serious or dangerous using a checklist developed in conjunction with the driving instructor. This employed six error categories as used in the UK Driving Examination, and was found to be an effective measure of driving performance by Allerton (2000):

1. Use of mirrors and rear observation when signalling, changing direction and speed
2. Appropriate use of signals (indicators)
3. Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users
4. Junctions, including speed of approach, observation, turning left or right and cutting corners
5. Positioning in normal driving and lane discipline
6. Awareness and planning

Driving errors that participants committed were therefore recorded as minor, serious or dangerous within the six error categories above. A minor error was one that was not in itself potentially dangerous unless it was habitual. A serious driving error was one where potential danger had occurred. A dangerous error was one involving actual danger to the driver/passenger or other road users. These are exemplified in relation to a UK driver (driving on the left) turning right into a more minor road (Brutnell 2002): If the driver turned early, cutting the corner, without full observation of the road being turned into and there were no parked vehicles or obstructions near to the junction it would be considered a *minor* driving fault. However if the driver continued to turn right in this manor it would be considered habitual and therefore categorised as a serious driving fault. If there were parked cars close to the junction such that the driver had to brake and/or steer suddenly to avoid them, this would be considered *serious* in its own right. If the driver cut the corner and there was a moving car approaching the junction such that either one or both of the cars had to brake or steer suddenly to avoid a collision, this would be classified as a *dangerous* error. The data sheet used by the driving instructor to record driving errors is shown in Appendix 8C.

8.4.6.2 Navigation performance

Navigation performance was assessed on the basis of participants committing actual or near navigation errors at each manoeuvre. An *actual* navigation error was one where the participant made an incorrect navigation decision at the manoeuvre, and either turned too early, turned too late, or did not complete any turn when required. A *near* navigation error was one where the participant demonstrated a clear *intention* to take an incorrect turn – by indicating, changing lanes, and/or slowing down on approach to an turning which was not that desired. Near navigation errors were included in this category due to the safety implications of either erroneous use of indicators, or inappropriate lateral positioning, inappropriate speed control, or sudden correction of any of these. The data sheet used by the experimenter to record navigation errors is shown in Appendix 8D. This also included the protocol for following the desired route.

8.4.6.3 Driver confidence

Driver confidence was measured after the driver had received each verbal instruction from the navigation system (at approximately 450, 150 and 30 m from each manoeuvre). This employed a simple verbal subjective rating procedure which required the driver to state 'high', 'medium, or 'low' to indicate their confidence with knowing where to turn *and* being able to complete that manoeuvre successfully. After completing each manoeuvre, participants gave an additional confidence rating of 'high', 'medium, or 'low' to indicate their confidence that they had taken the correct turn. Stated driver confidence was also recorded on the data sheet shown in Appendix 8D.

8.4.7 Procedure

On arrival, participants were introduced to the study and signed consent forms. After familiarising themselves with the vehicle controls, the participants completed a mixed-road familiarisation drive lasting approximately 25 minutes. They then drove for about 10 minutes using the vehicle navigation system, receiving eight navigation instructions during this period, and then undertook a practice session lasting a further 10 minutes where they drove using the navigation system and gave confidence ratings at five manoeuvres. All participants were able to complete this familiarisation process successfully and without requesting additional practice time, which was offered in all cases.

After familiarisation and training (lasting approximately 45 minutes), the participants drove the trial route using the navigation system with simulated auditory output, giving the three pre- and one post-manoeuvre confidence ratings. They were prompted if necessary to provide these; this was only occasionally necessary, and their response was recorded on the sheet shown in Appendix 8D. During each manoeuvre, the nature and severity of any driving errors were recorded by the driving instructor using the predefined checklist (Appendix 8C), and navigation errors were recorded by the experimenter (Appendix 8D).

8.5 Analysis and results

8.5.1 Driver confidence

Stated confidence levels were obtained from participants on approach to all manoeuvres en-route. Drivers gave a judgement of 'high', 'medium' or 'low' (coded as 3, 2, 1 respectively) immediately following the presentation of the Preview 1, Preview 2 and Final navigation instructions. They also gave a confidence judgement after completing each turn. At some manoeuvres which were close together, the navigation system omitted some of the preview instructions or it was impractical for participants to provide multiple confidence ratings: at these manoeuvres there were fewer confidence ratings on approach to that manoeuvre. Participants were only prompted once to provide their confidence ratings, and some missing data did result.

Four confidence ratings (3 on approach, 1 post-manoeuvre) were obtained for the following manoeuvres: 2, 6, 7, 8, 9, 11, 12, 13, 15, 19, 22, 24, 25, 29, 30 and 37. Three confidence ratings (2 approach, 1 post) were obtained for the following manoeuvres: 3, 4, 16, 17, 18, 20, 21, 23, 28, 31, 32, 33, 35 and 36, Two confidence ratings (1 approach, 1 post) were obtained for the following manoeuvres: 26, 27. Data was not collected for the reasons stated in Section 8.4.5 at manoeuvres: 1, 5, 10, 14 and 34.

An overall confidence level for each manoeuvre was calculated for each participant, based on a mean of the confidence levels throughout the manoeuvre (i.e. all approach levels and the post-manoeuvre level). The mean overall confidence of all participants at the manoeuvres en-route is shown in Figure 8.2. Where missing data is present, this is excluded on a manoeuvre-by-manoeuvre (rather than listwise) basis.

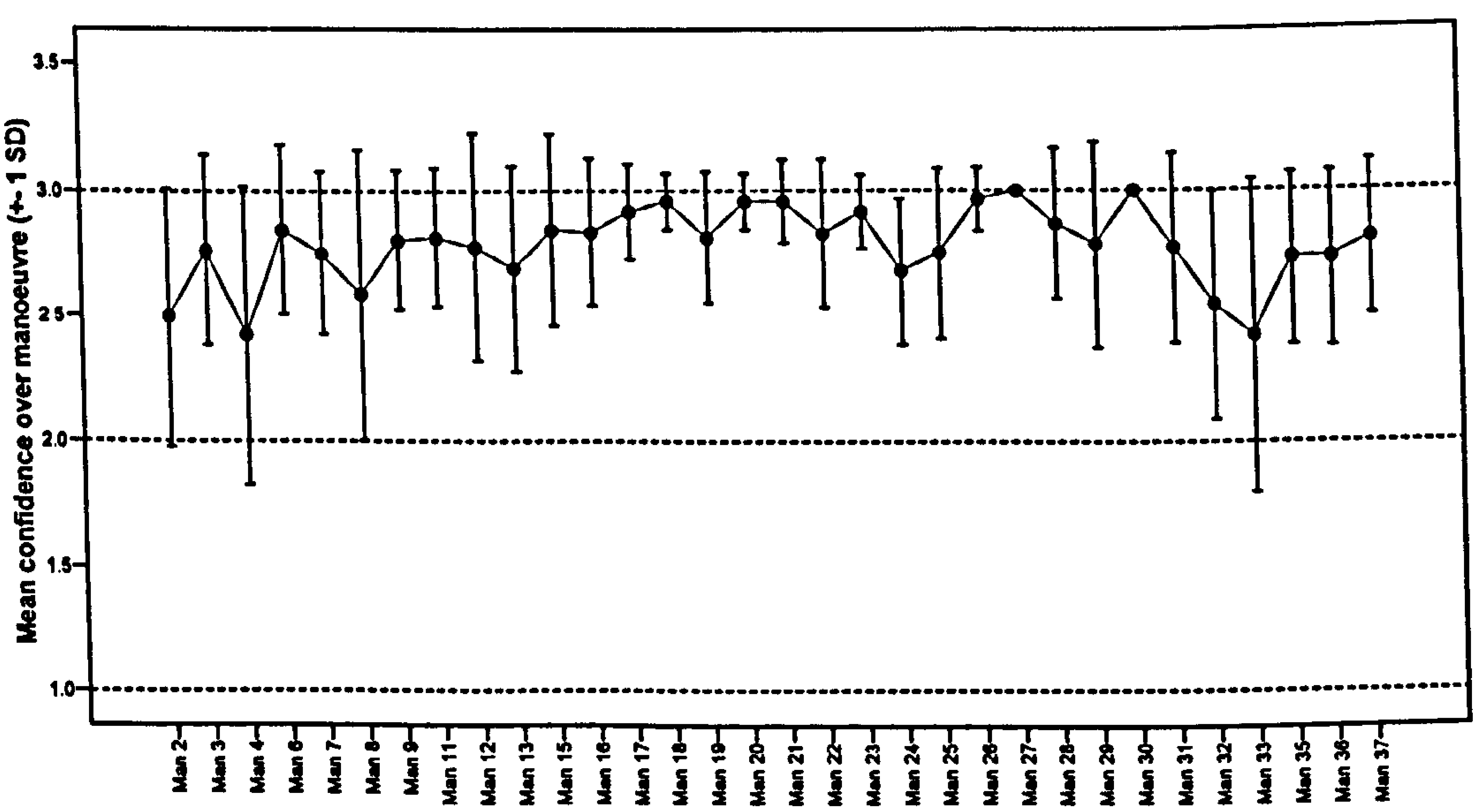
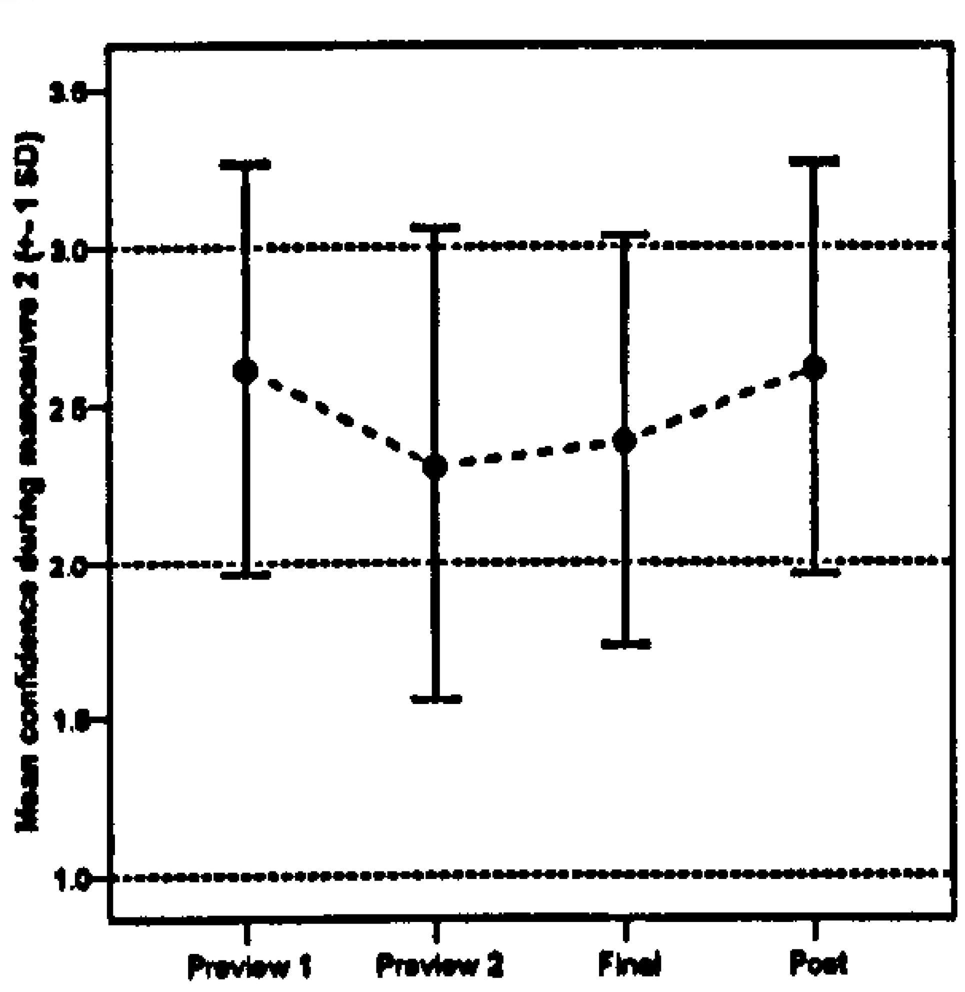


Figure 8.2 Overall confidence levels during each manoeuvre (all participants)

Although *means* are shown in the figure above, the confidence ratings were ordinal data since they were generated from stated confidence levels of high, medium or low which were coded as 3,2,1 respectively. A Friedman non-parametric test for multiple related samples showed that the overall confidence during a manoeuvre was highly impacted by the manoeuvre, $\chi^2(31) = 94.167$, $p < .001$. A Friedman test was also undertaken across the Preview 1 confidence ratings over the route, and similarly across all of the Preview 2, Final and Post confidence ratings. Note that due to the variation in the length of approach to manoeuvres, Preview 1 confidence ratings were obtained at 16 manoeuvres, Preview 2 confidence ratings at 29 manoeuvres, and Final and Post manoeuvre ratings at all 32 manoeuvres that were analysed. The results of these tests showed that Preview 1 confidence was significantly impacted by the particular manoeuvre ($\chi^2(15) = 31.104$, $p = .009$), as was Preview 2 confidence $\chi^2(28) = 49.952$, $p = .007$), and Final confidence ($\chi^2(31) = 59.151$, $p = .002$). There was no significant difference in Post manoeuvre confidence at different manoeuvres en-route $\chi^2(31) = 40.897$, $p = .110$, ns).

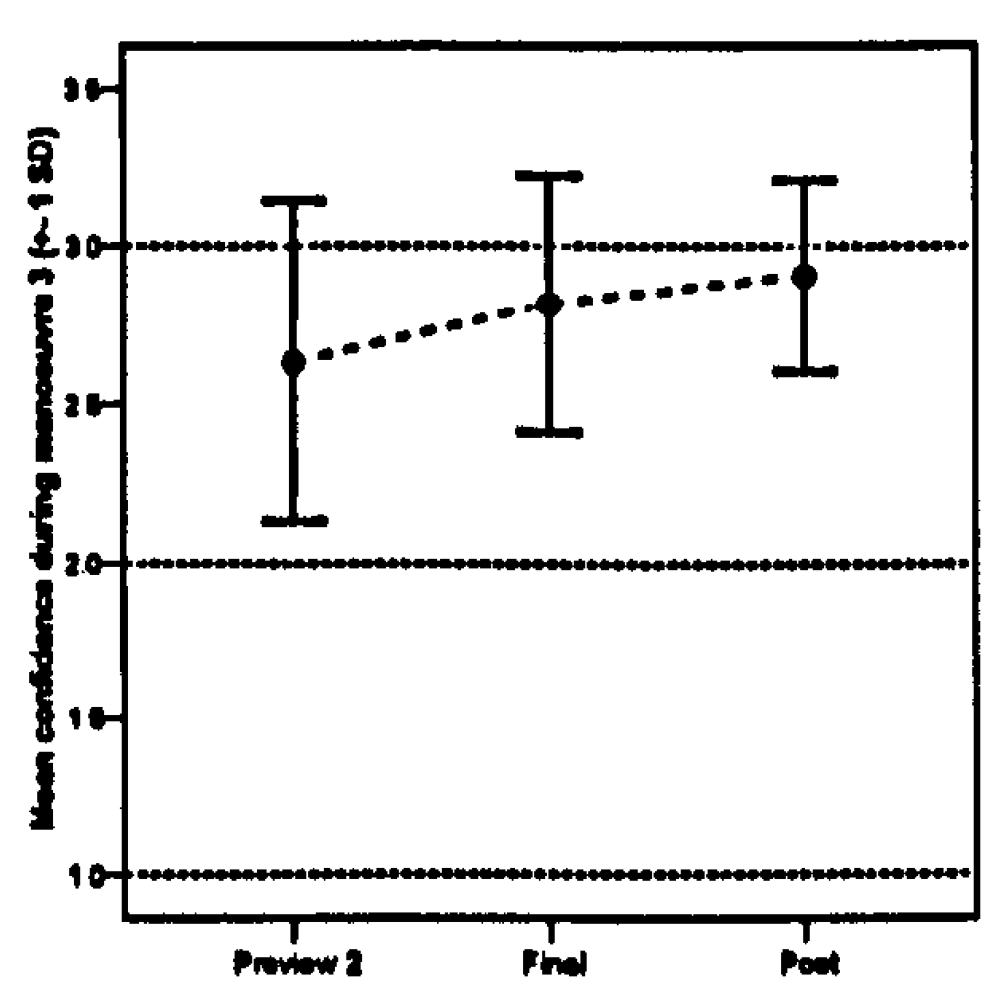
The multiple confidence sampling throughout each manoeuvre also enabled an analysis of changes in confidence throughout each manoeuvre. Figure 8.3 shows a plot of the mean stated confidence as measured at the pre and post manoeuvre confidence points and the results of a Friedman non-parametric test for changes in confidence throughout each of the 32 manoeuvres analysed, indicated as significant ($p < .05$) thus: [redacted], otherwise non-significant (ns).

The y-axis reference lines represent confidence ratings of high (3), medium (2) and low (1).



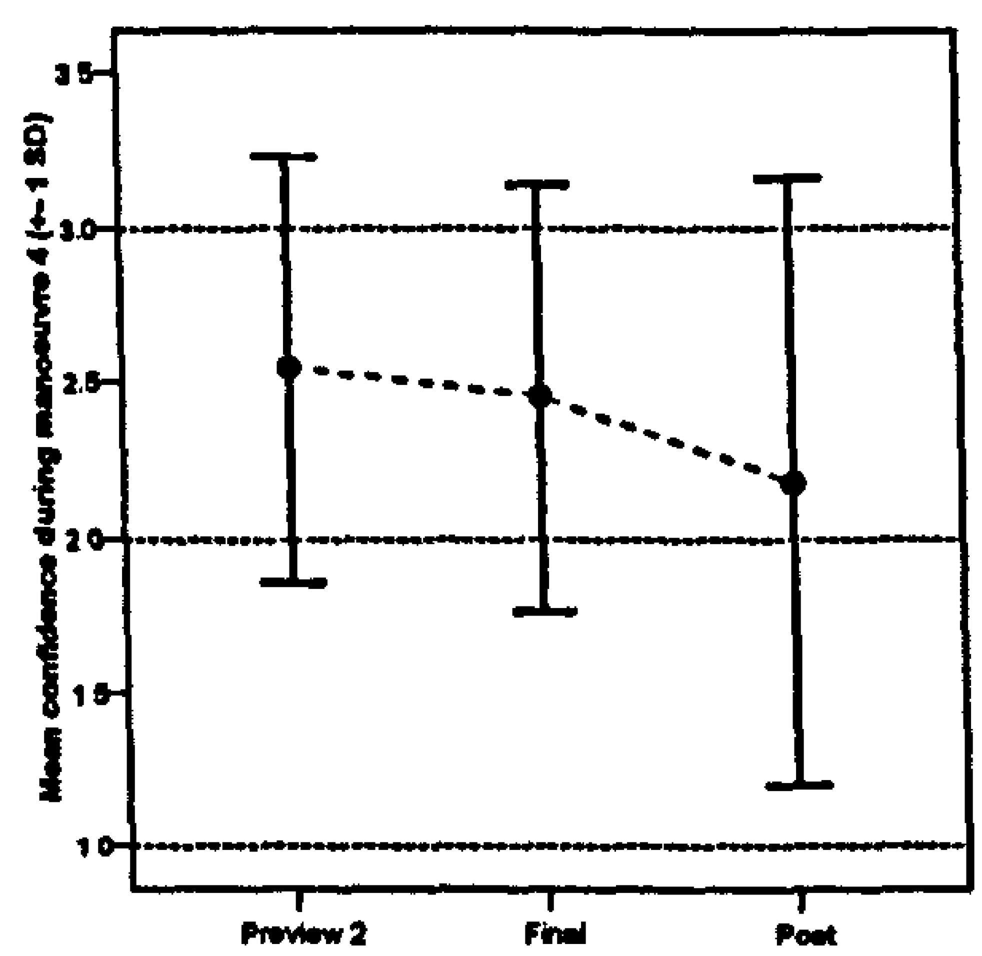
Changes in confidence during M2

N = 13, $\chi^2(3) = 4.905$, $p = .179$ (ns)



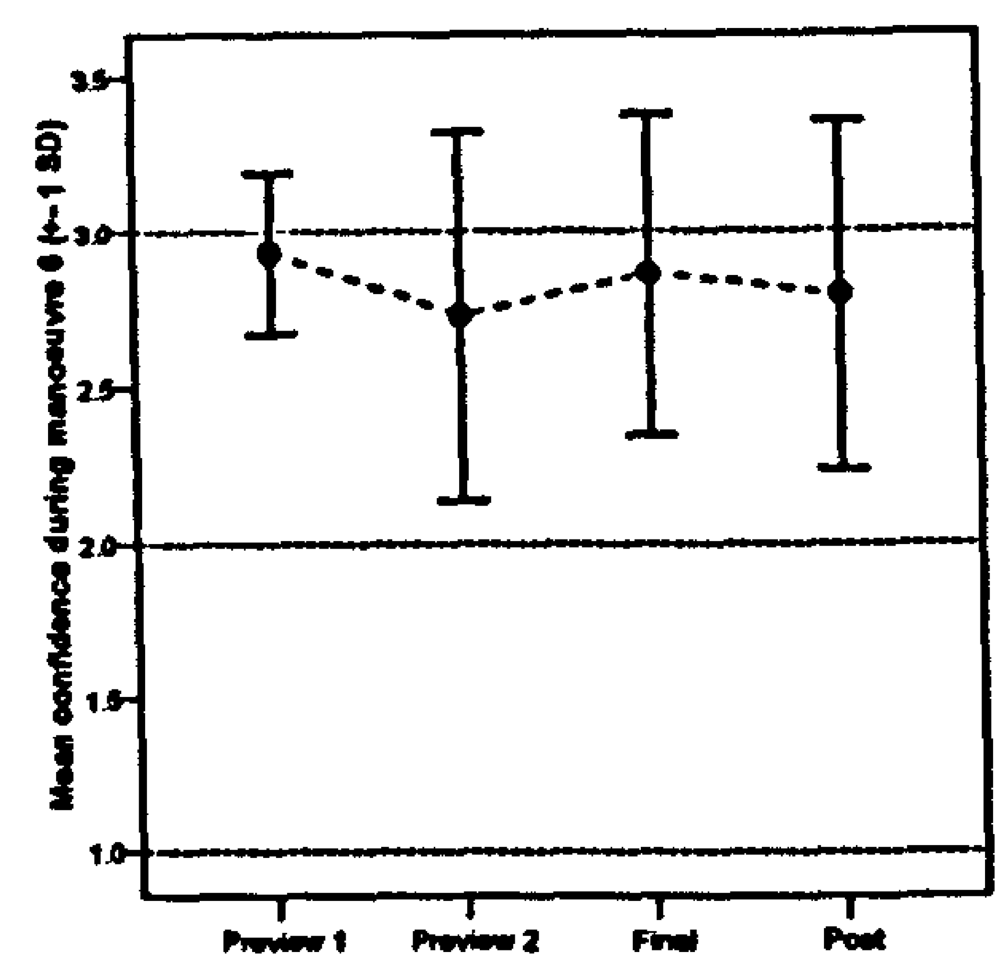
Changes in confidence during M3

N = 11, $\chi^2(2) = 4.667$, $p = .097$ (ns)



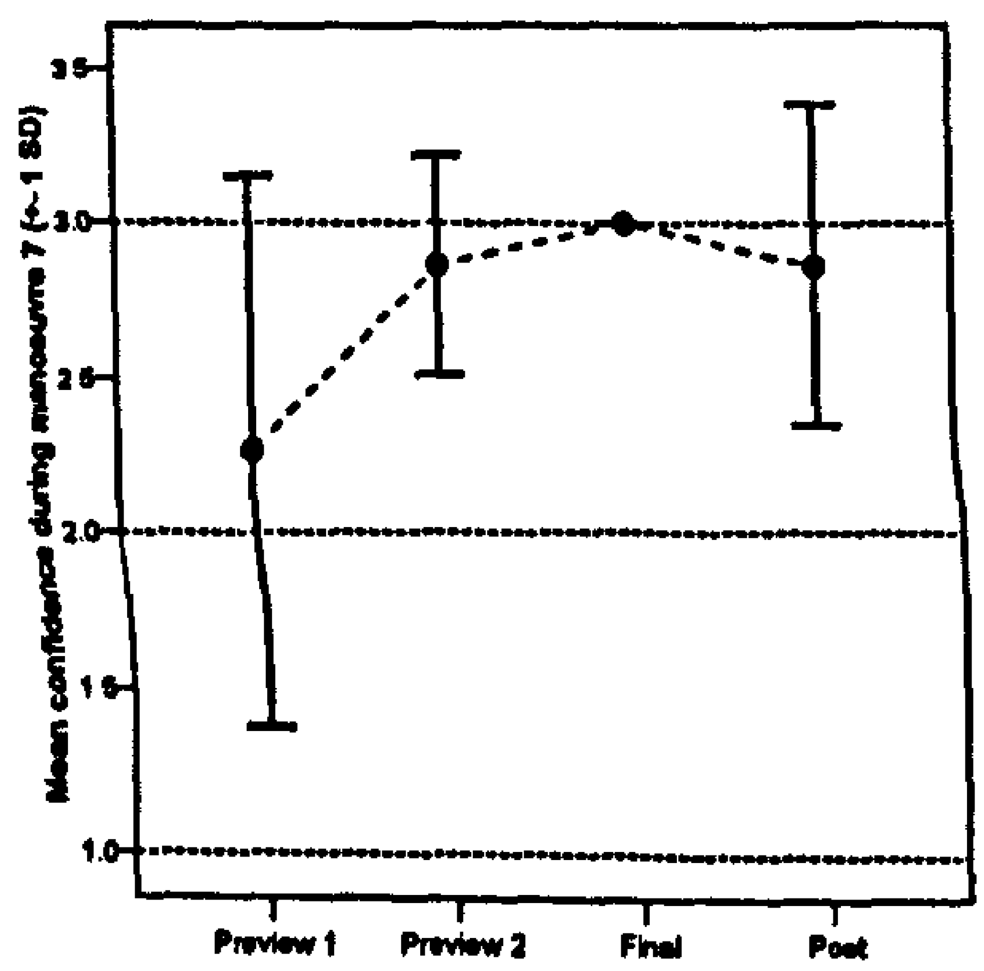
Changes in confidence during M4

N = 11, $\chi^2(2) = 1.182$, p = .554 (ns)



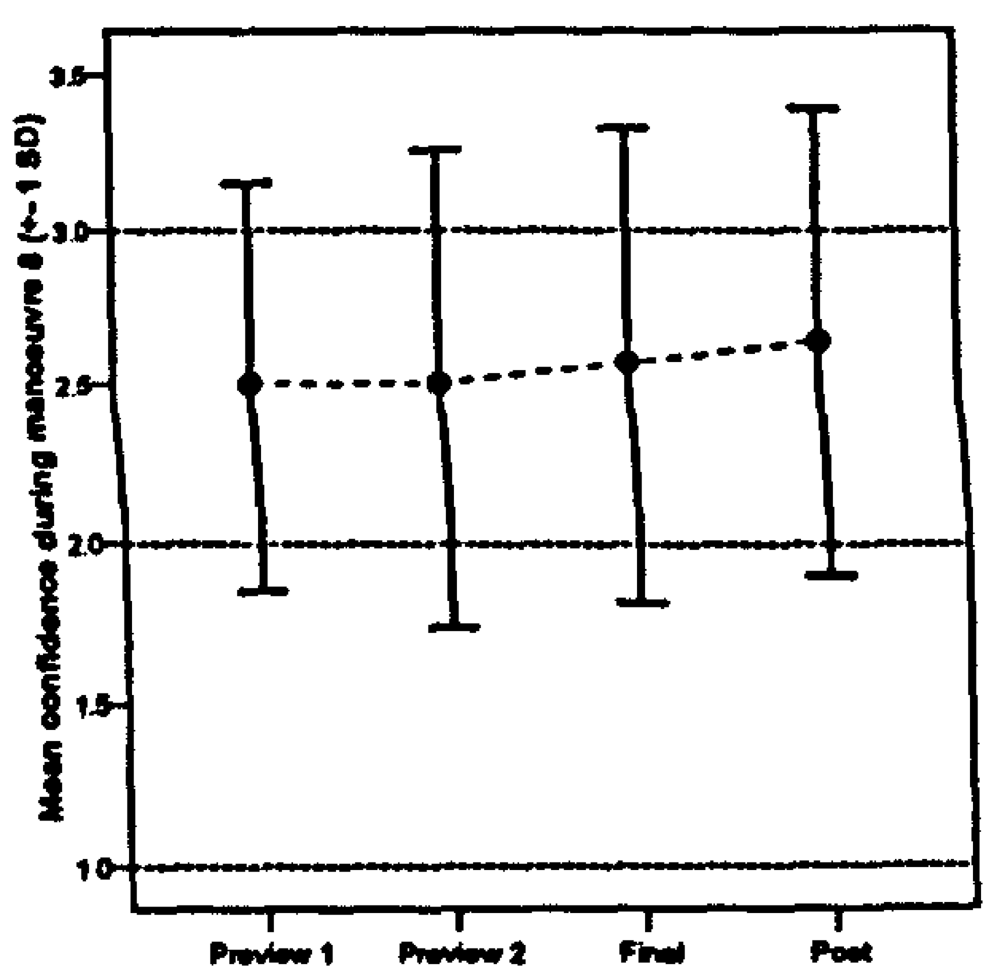
Changes in confidence during M6

N = 15, $\chi^2(3) = 1.345$, p = .719 (ns)



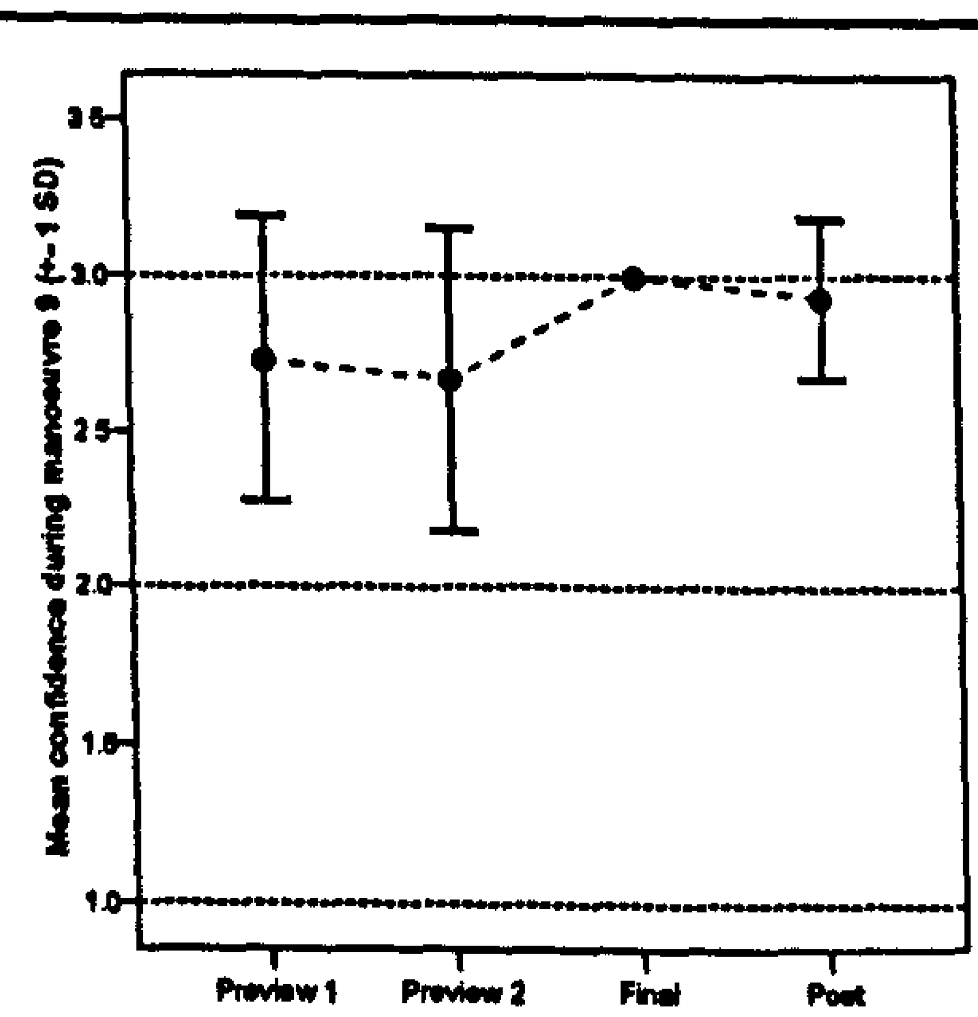
Changes in confidence during M7

N = 15, $\chi^2(3) = 15.490$, p = .001 [redacted]



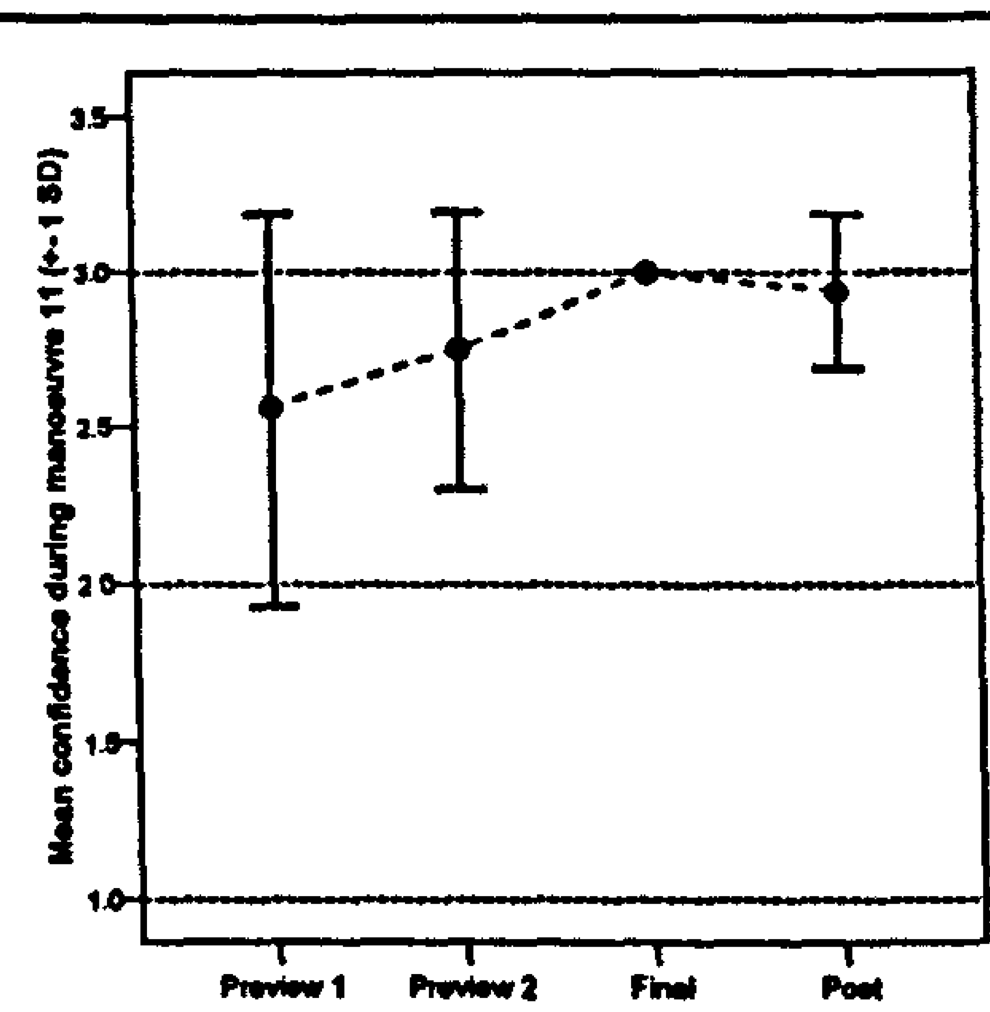
Changes in confidence during M8

N = 14, $\chi^2(3) = 2.707$, p = .439 (ns)



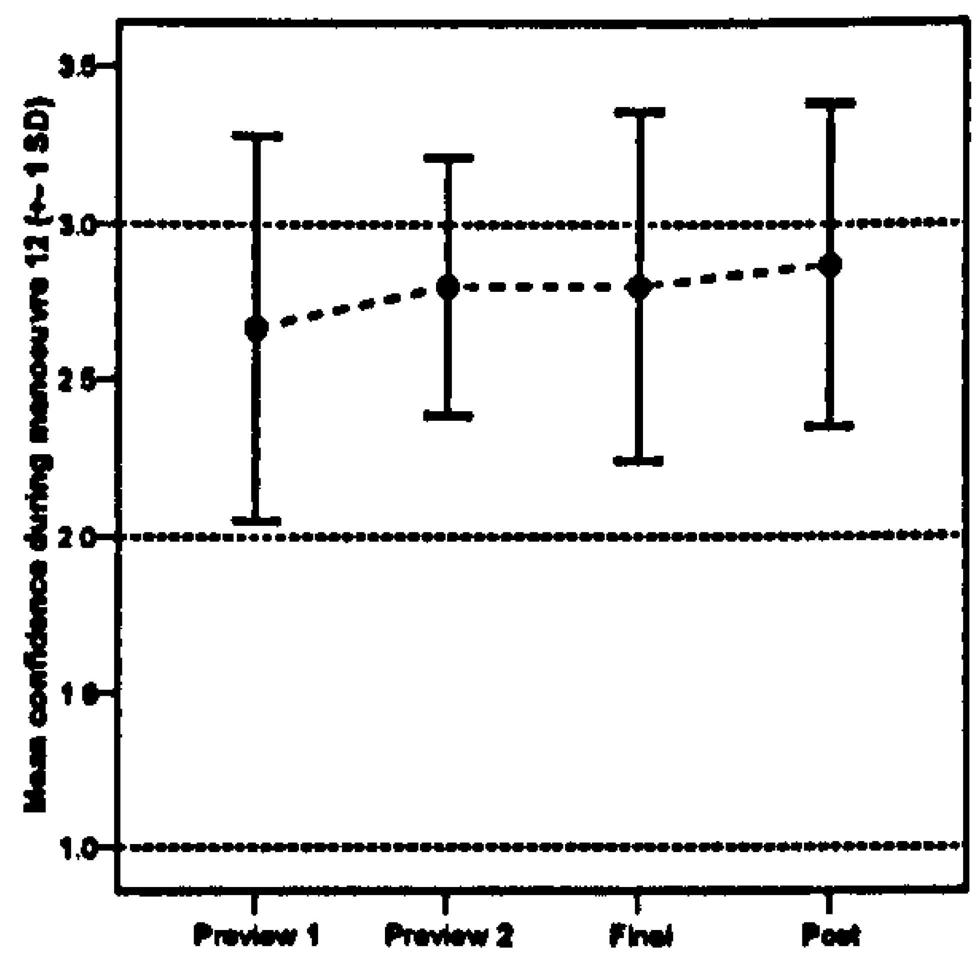
Changes in confidence during M9

N = 15, $\chi^2(3) = 11.333$, p = .010 [redacted]



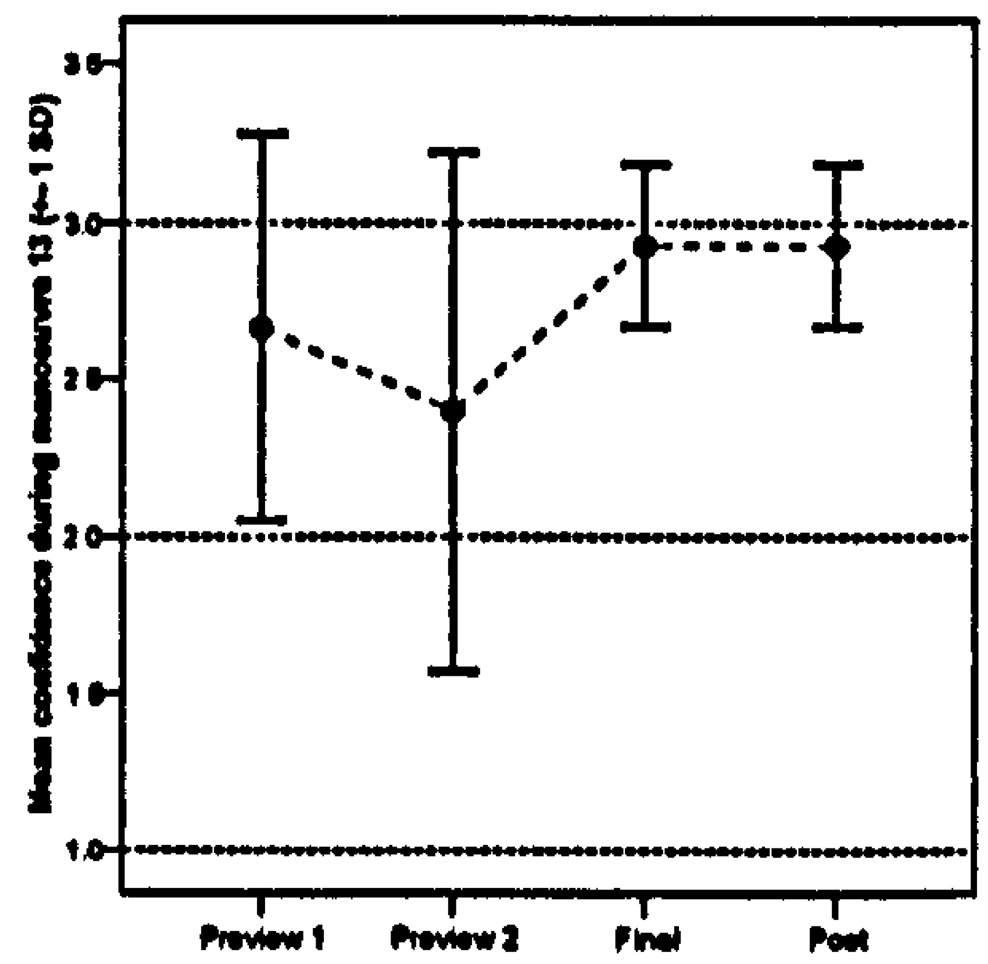
Changes in confidence during M11

N = 16, $\chi^2(3) = 13.326$, p = .004 [redacted]



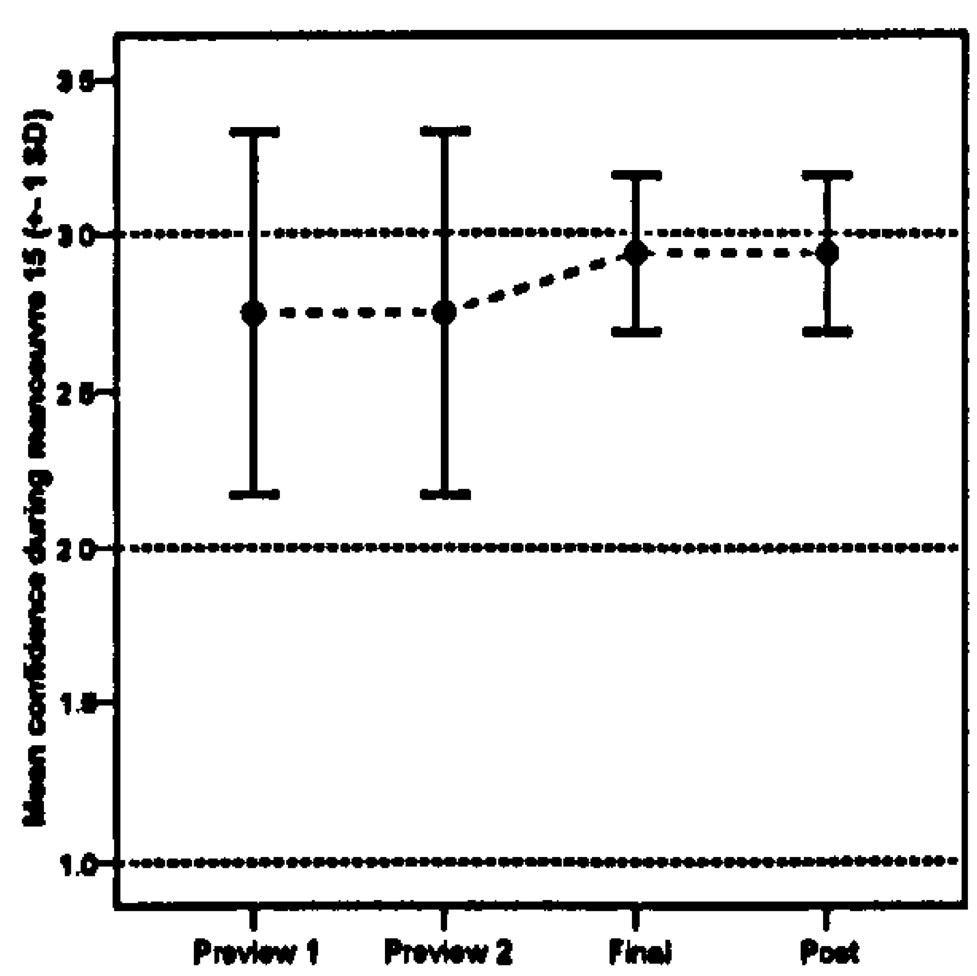
Changes in confidence during M12

N = 15, $\chi^2(3) = 3.800$, p = .284 (ns)



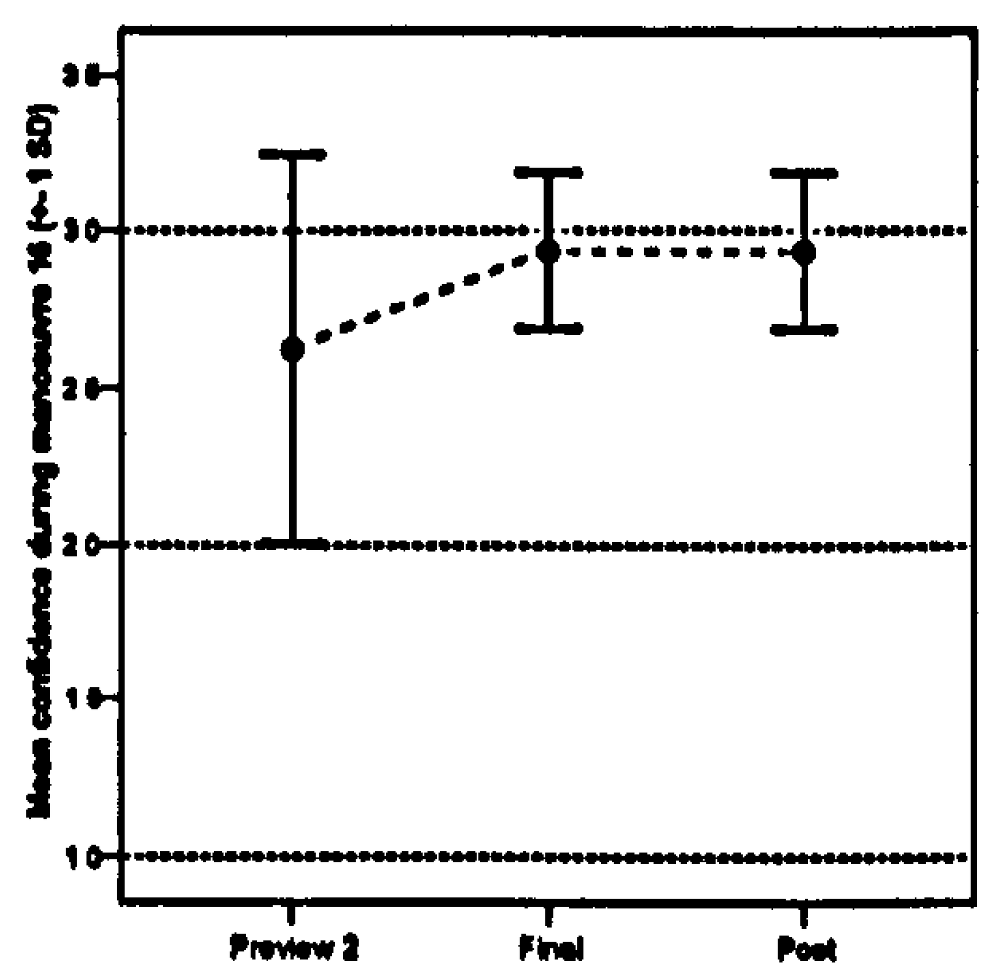
Changes in confidence during M13

N = 15, $\chi^2(3) = 11.750$, p = .008 [redacted]



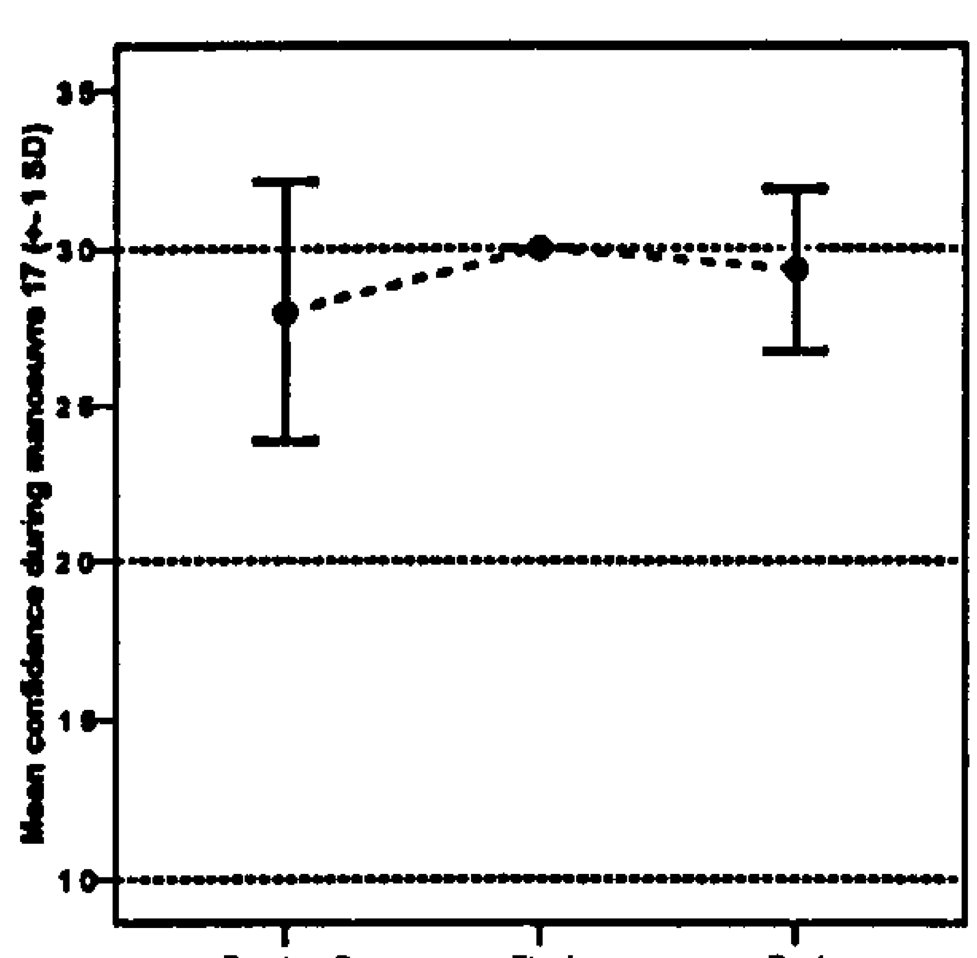
Changes in confidence during M15

N = 16, $\chi^2(3) = 7.714$, p = .052 (ns)



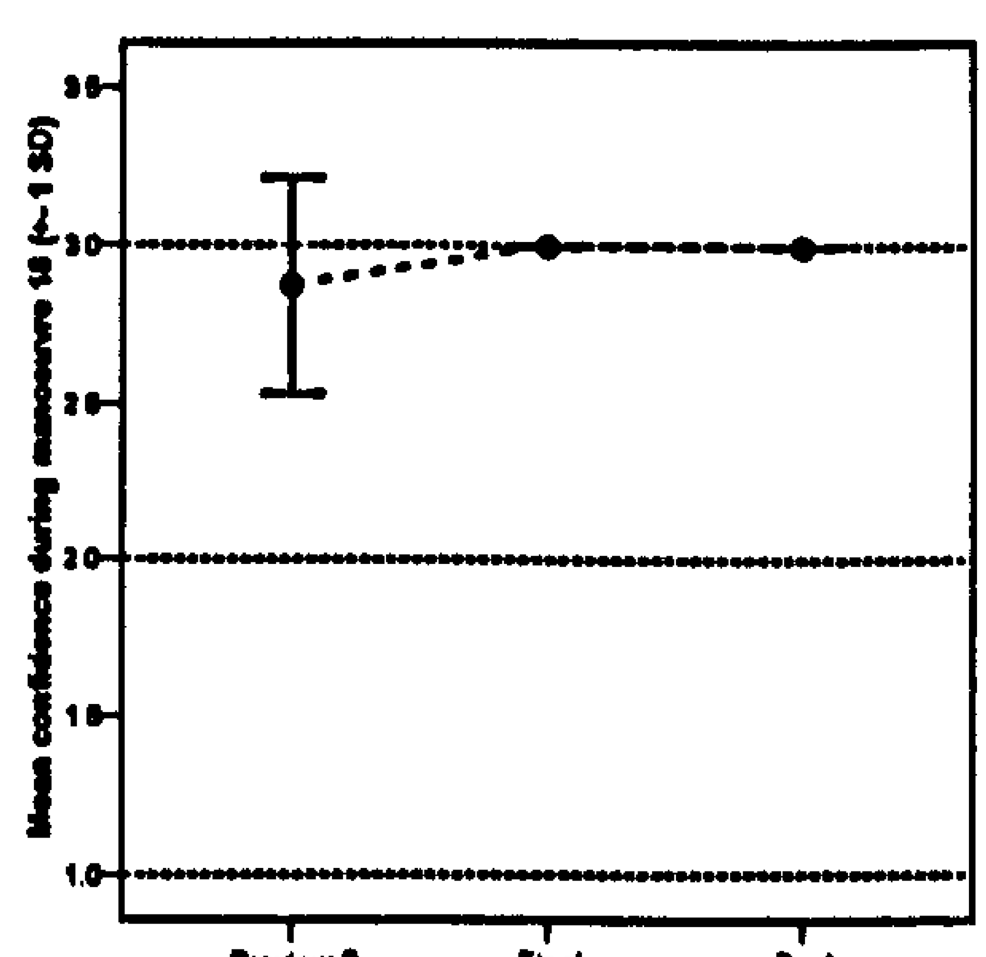
Changes in confidence during M16

N = 16, $\chi^2(2) = 7.625$, p = .022 [redacted]



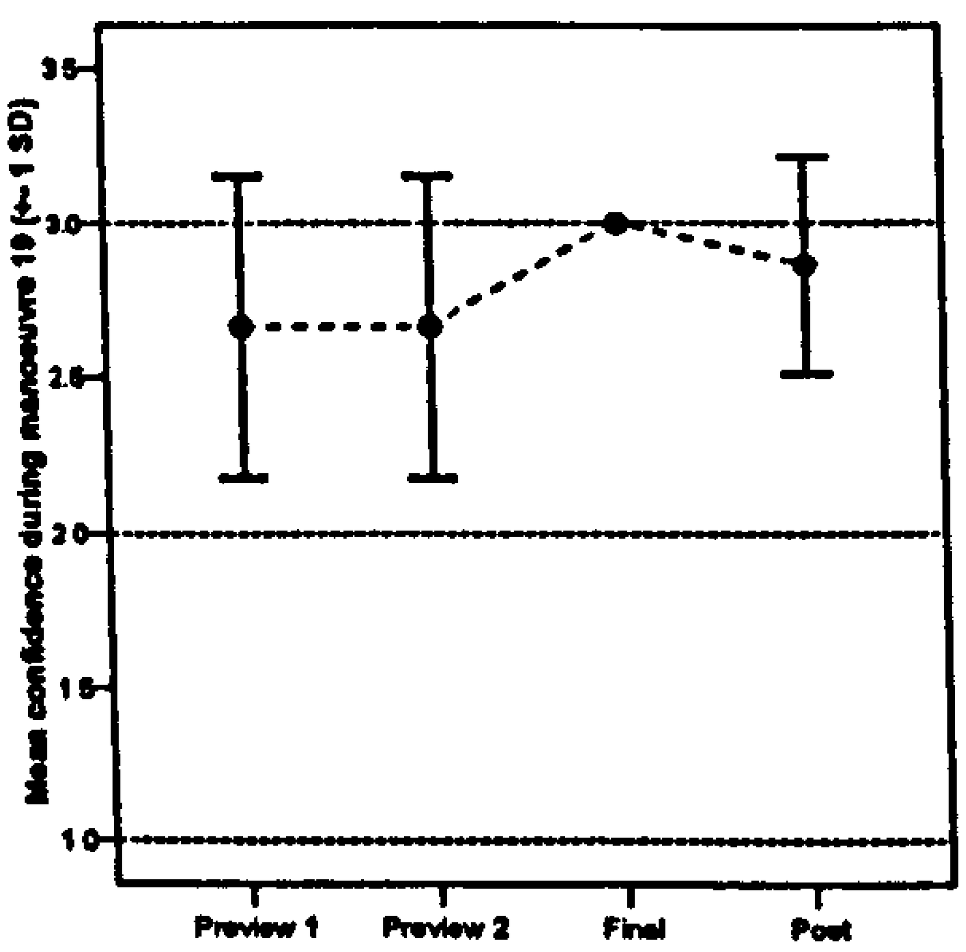
Changes in confidence during M17

N = 15, $\chi^2(2) = 4.667$, p = .097 (ns)



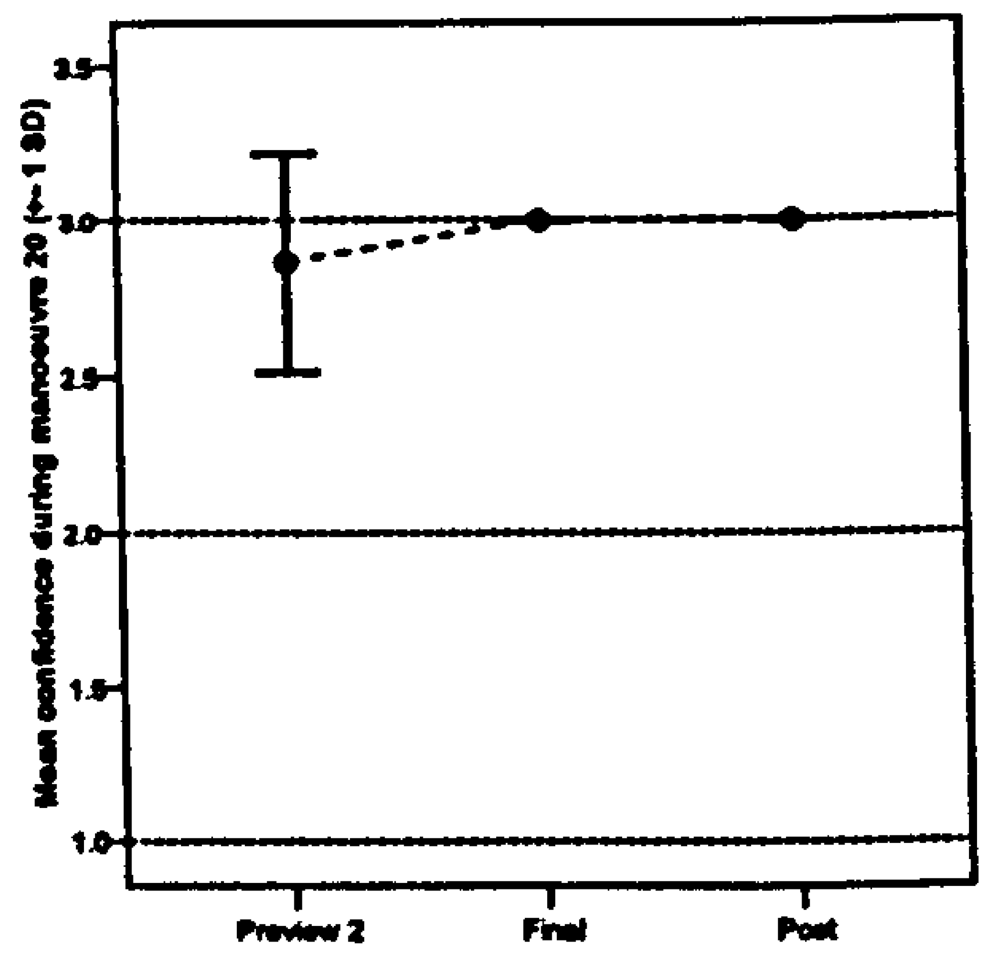
Changes in confidence during M18

N = 16, $\chi^2(2) = 4.000$, p = .135 (ns)



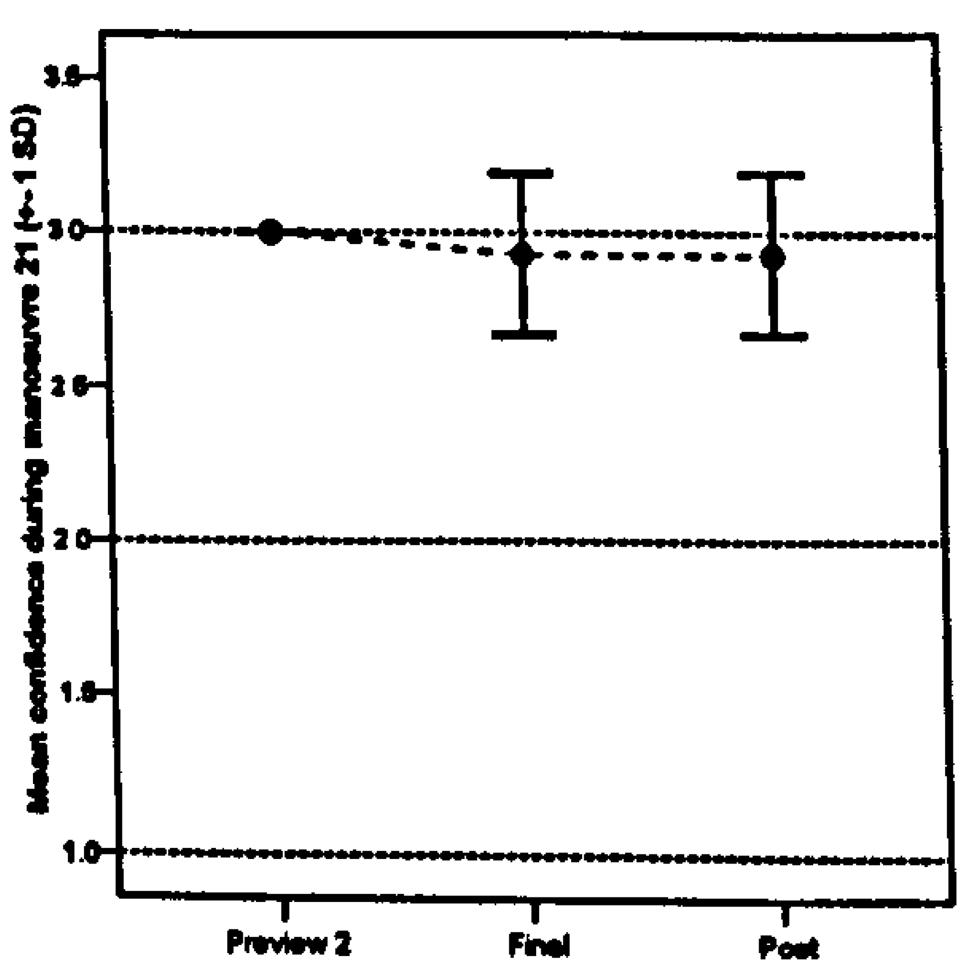
Changes in confidence during M19

N = 15, $\chi^2(3) = 9.818$, p = .020 [redacted]



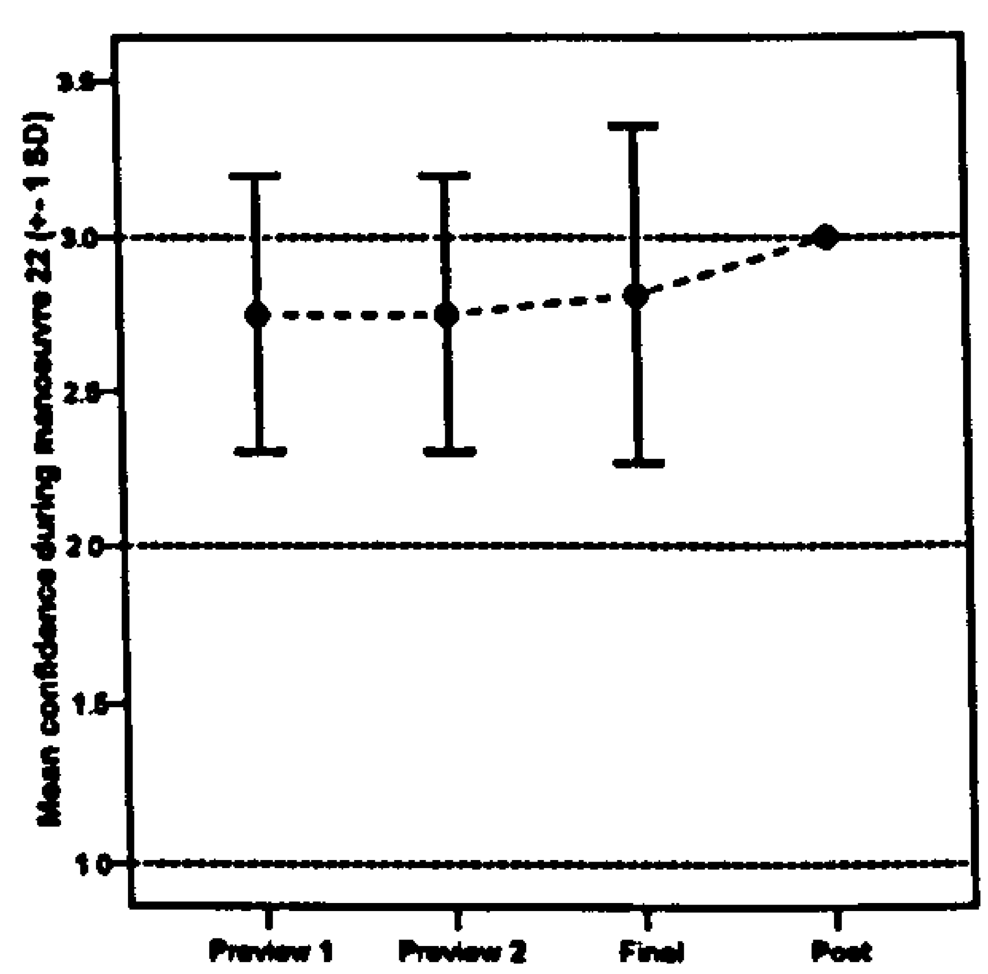
Changes in confidence during M20

N = 15, $\chi^2(2) = 4.000$, p = .135 (ns)



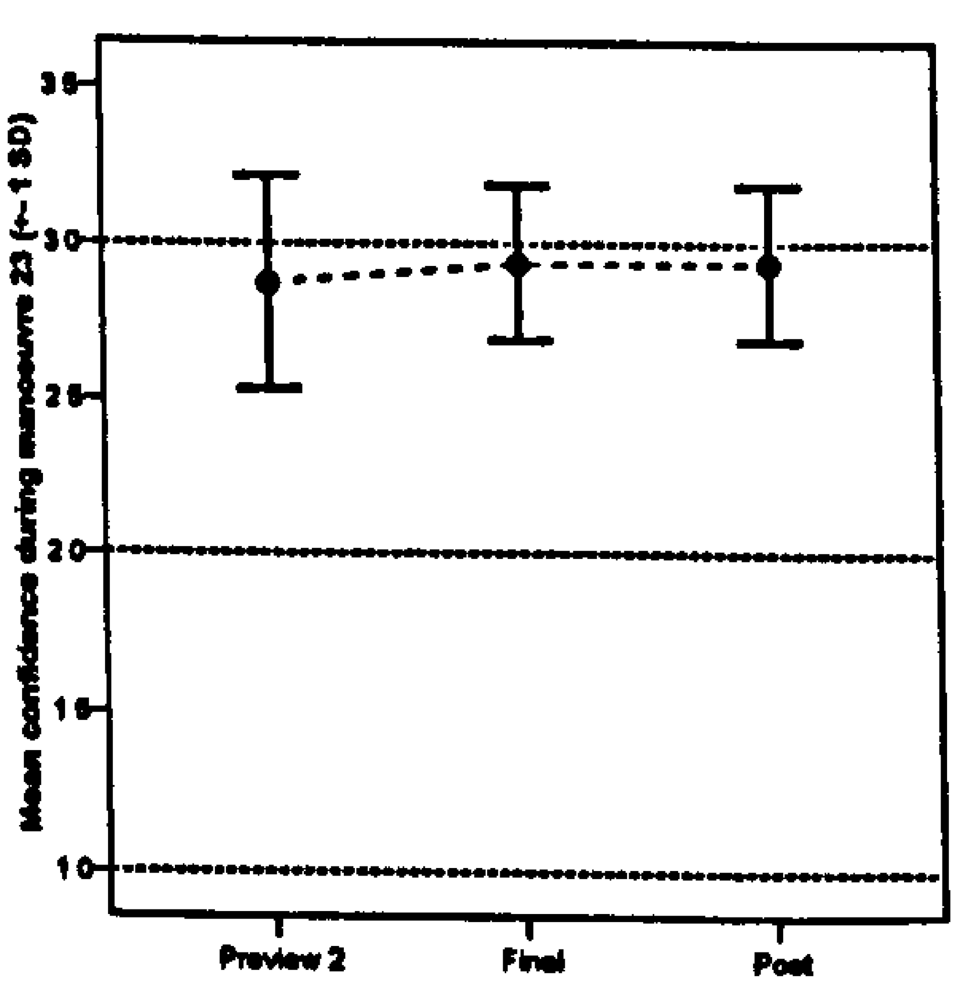
Changes in confidence during M21

N = 15, $\chi^2(2) = 2.000$, p = .368 (ns)



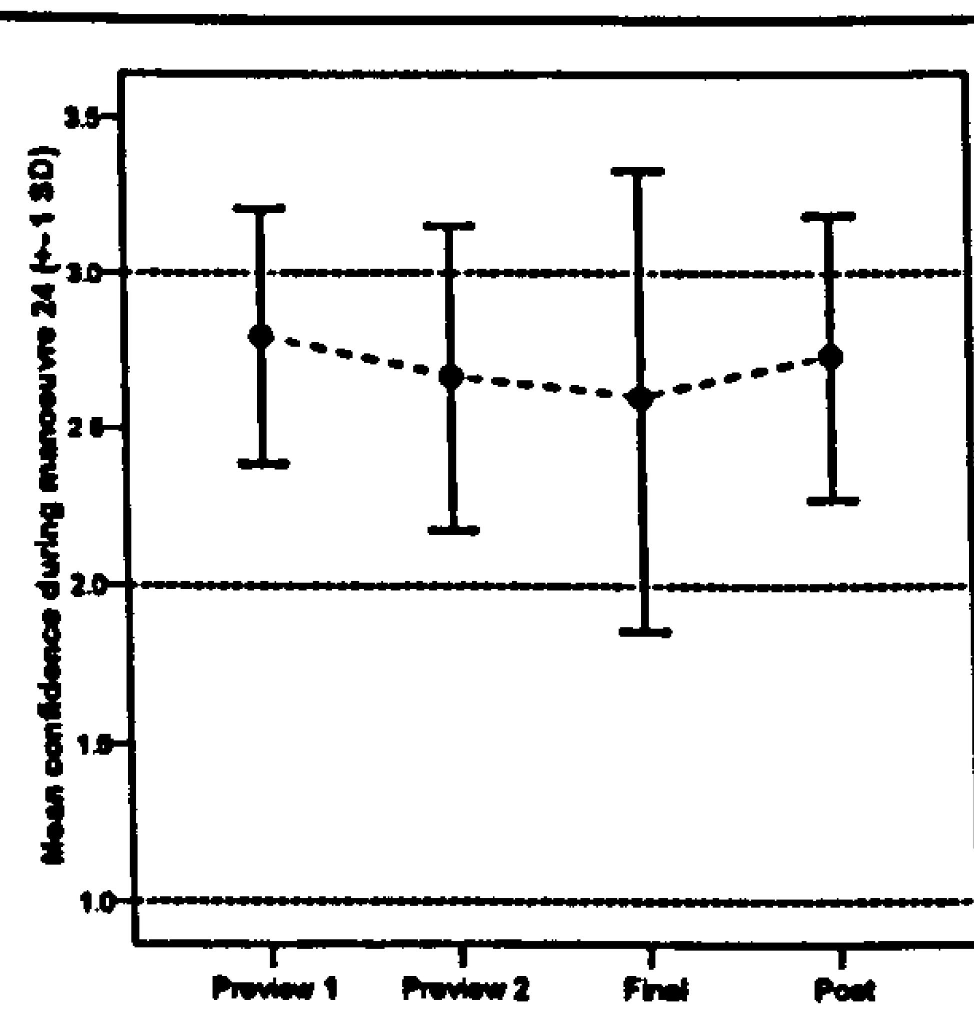
Changes in confidence during M22

N = 16, $\chi^2(3) = 5.769$, p = .123 (ns)



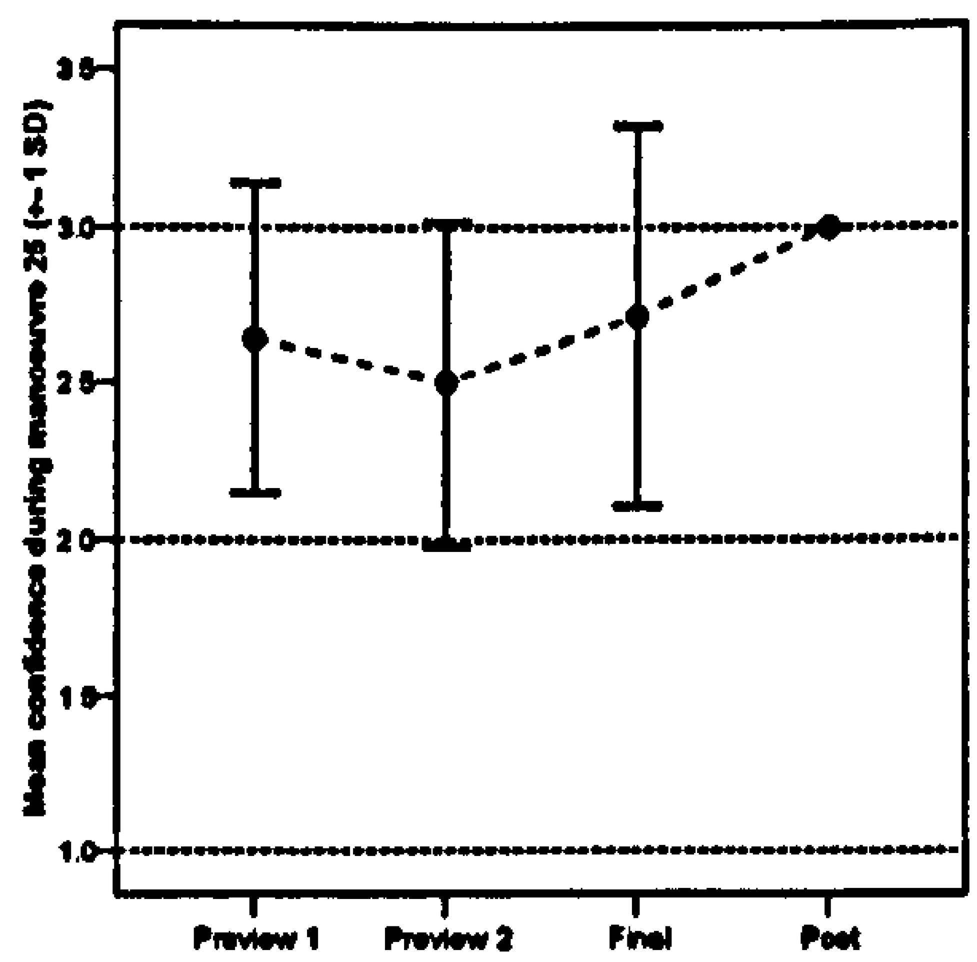
Changes in confidence during M23

N = 16, $\chi^2(2) = .500$, p = .779 (ns)



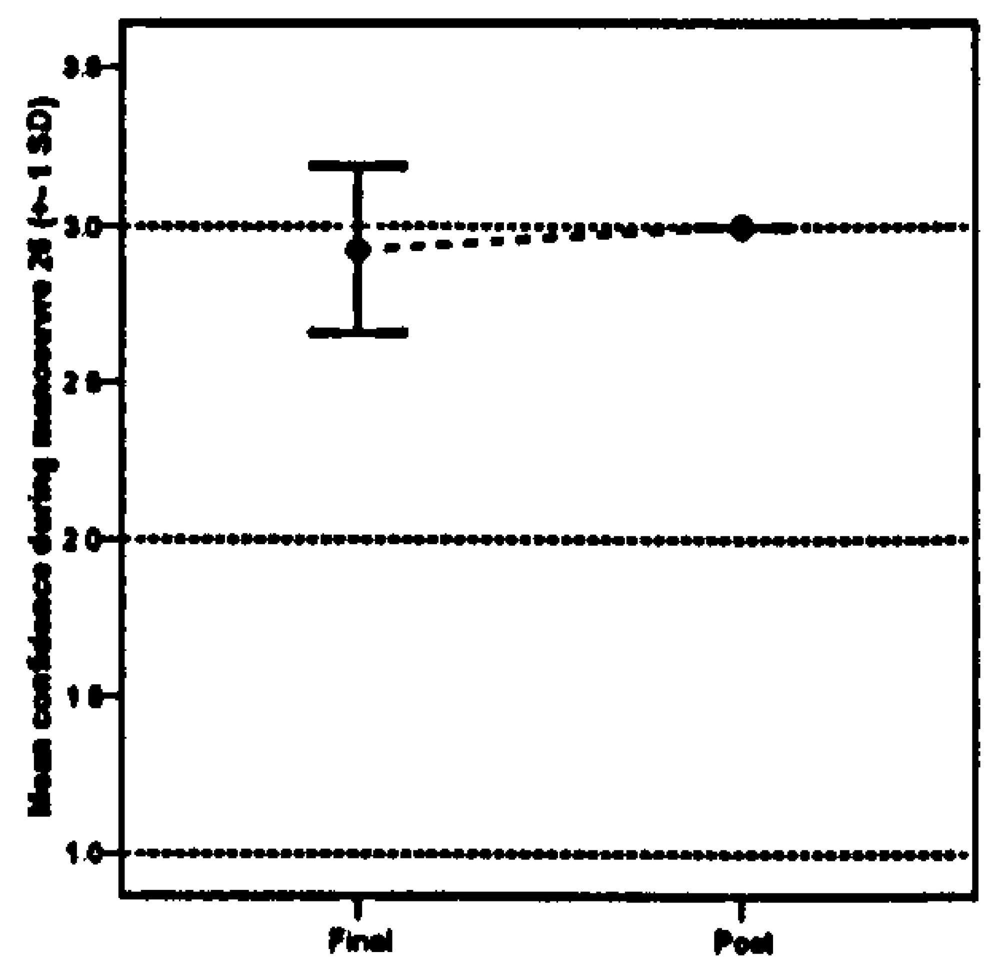
Changes in confidence during M24

N = 15, $\chi^2(3) = .600$, p = .896 (ns)



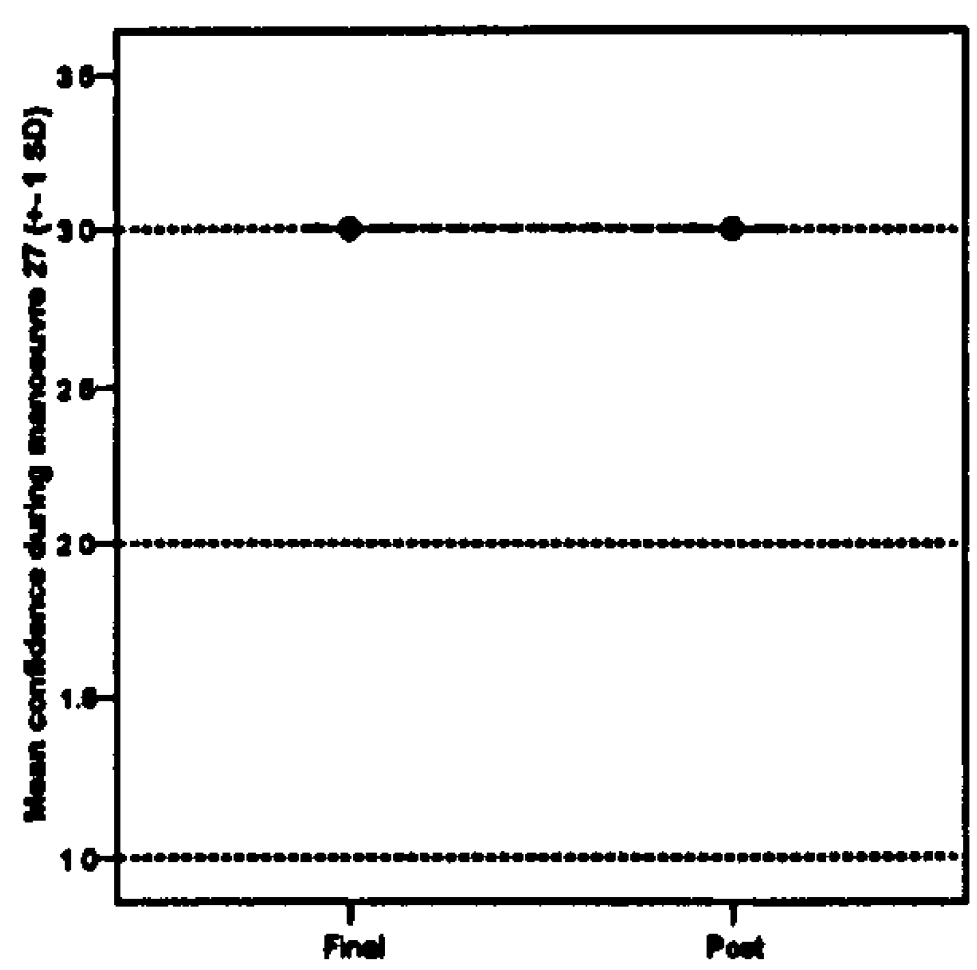
Changes in confidence during M25

N = 14, $\chi^2(3) = 11.816$, p = .008 [redacted]



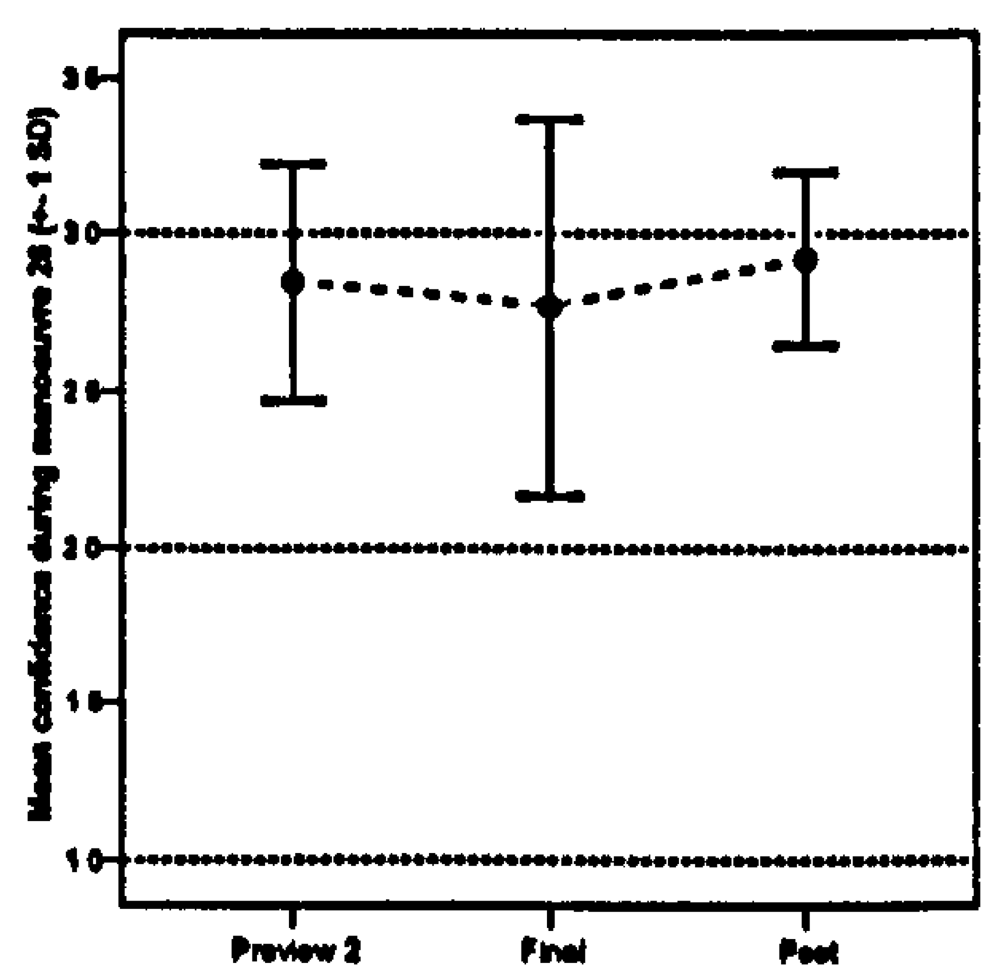
Changes in confidence during M26

N = 14, $\chi^2(1) = 1.000$, p = .317 (ns)



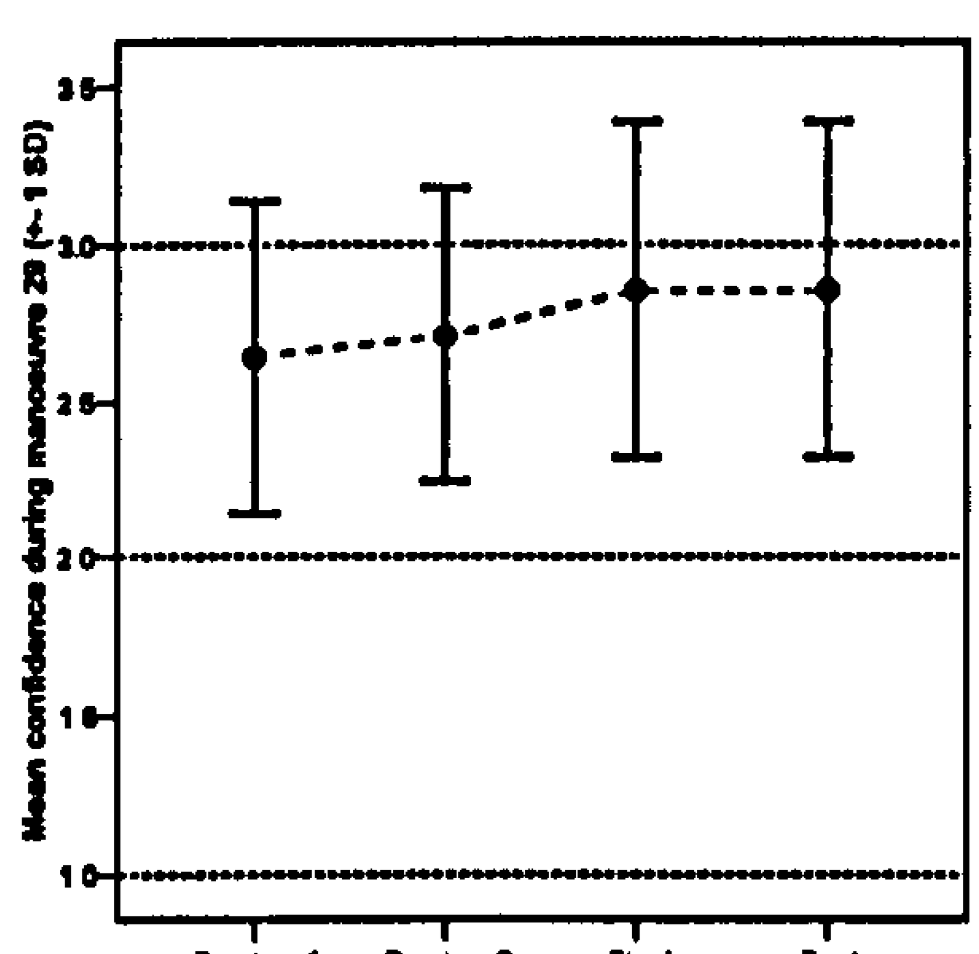
Changes in confidence during M27

N = 13, $\chi^2(1)$ = NA, p = NA



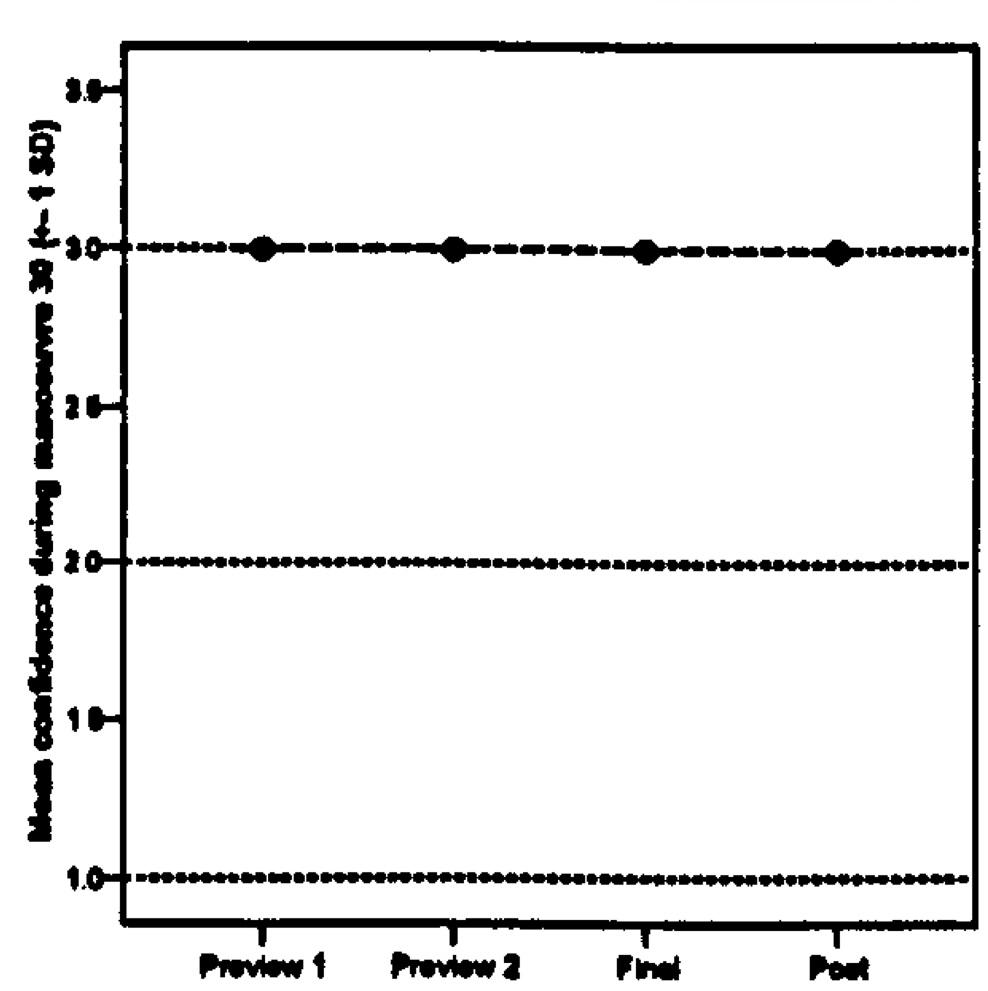
Changes in confidence during M28

N = 13, $\chi^2(2) = 1.000$, p = .607 (ns)



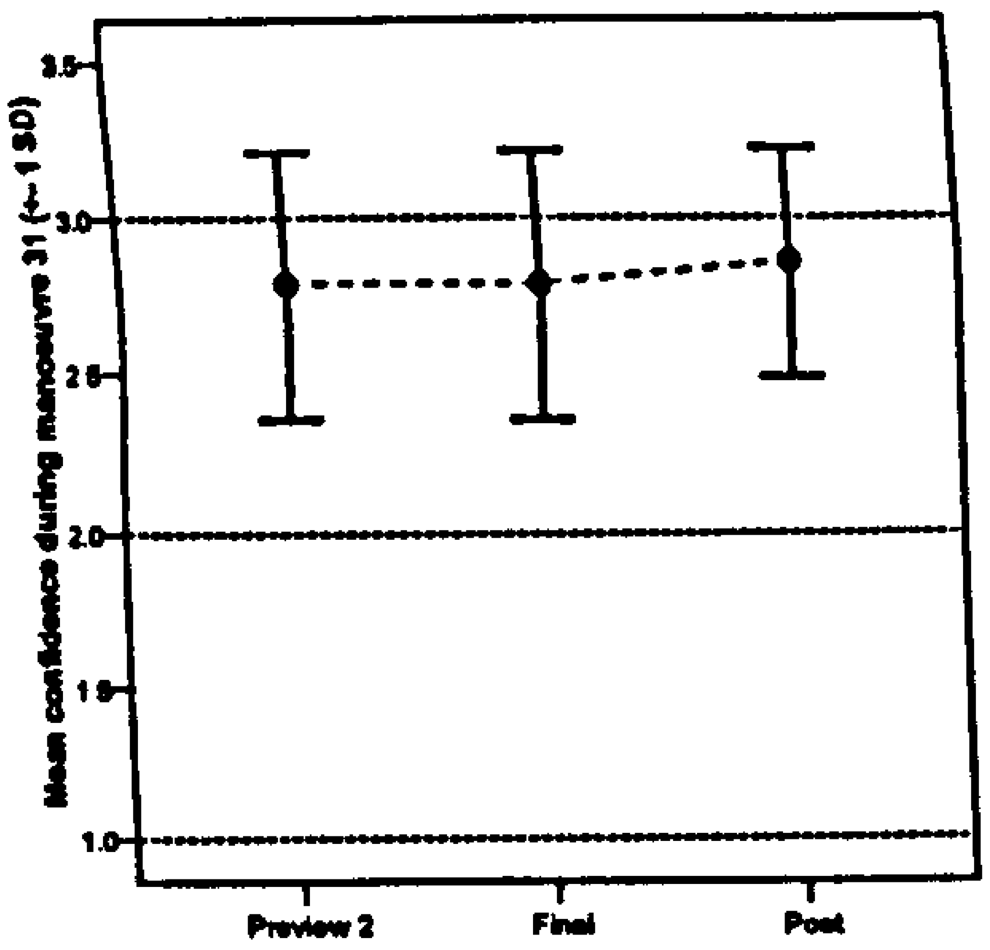
Changes in confidence during M29

N = 14, $\chi^2(3) = 4.263$, p = .234 (ns)



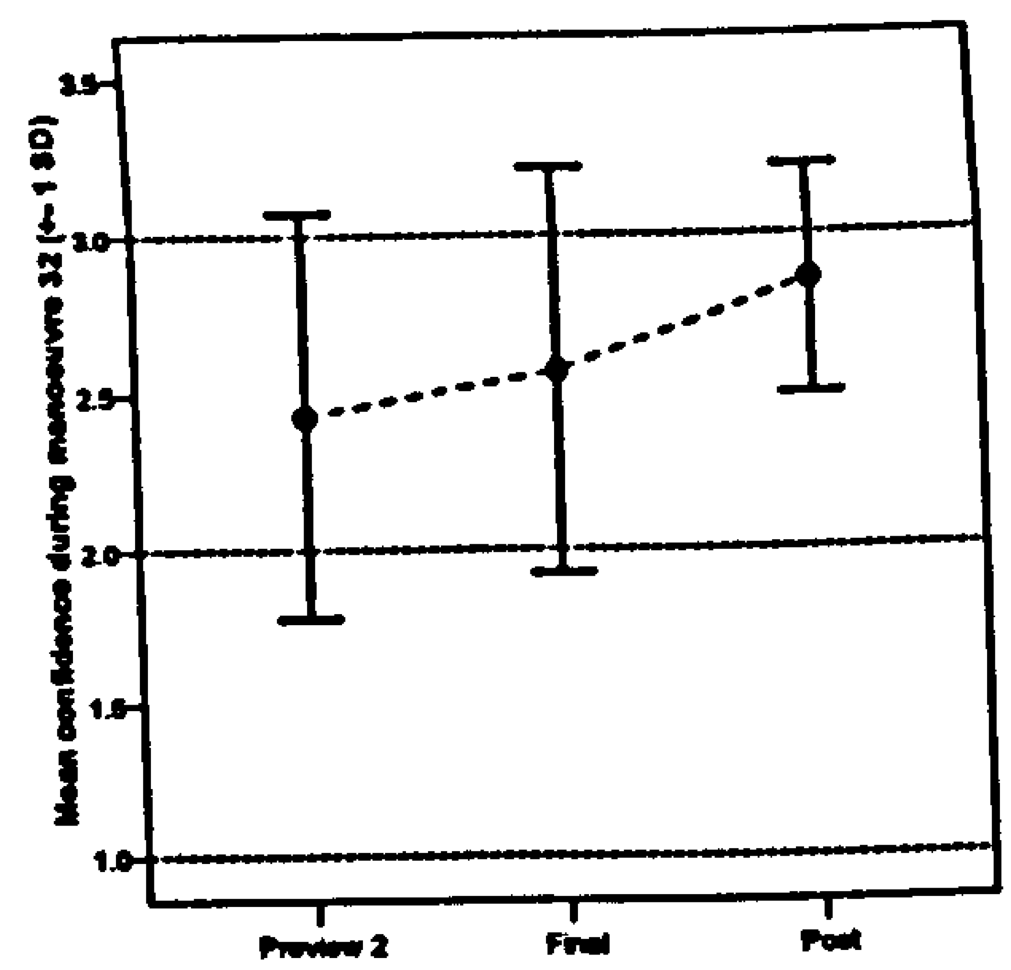
Changes in confidence during M30

N = 16, $\chi^2(3)$ = NA, p = NA



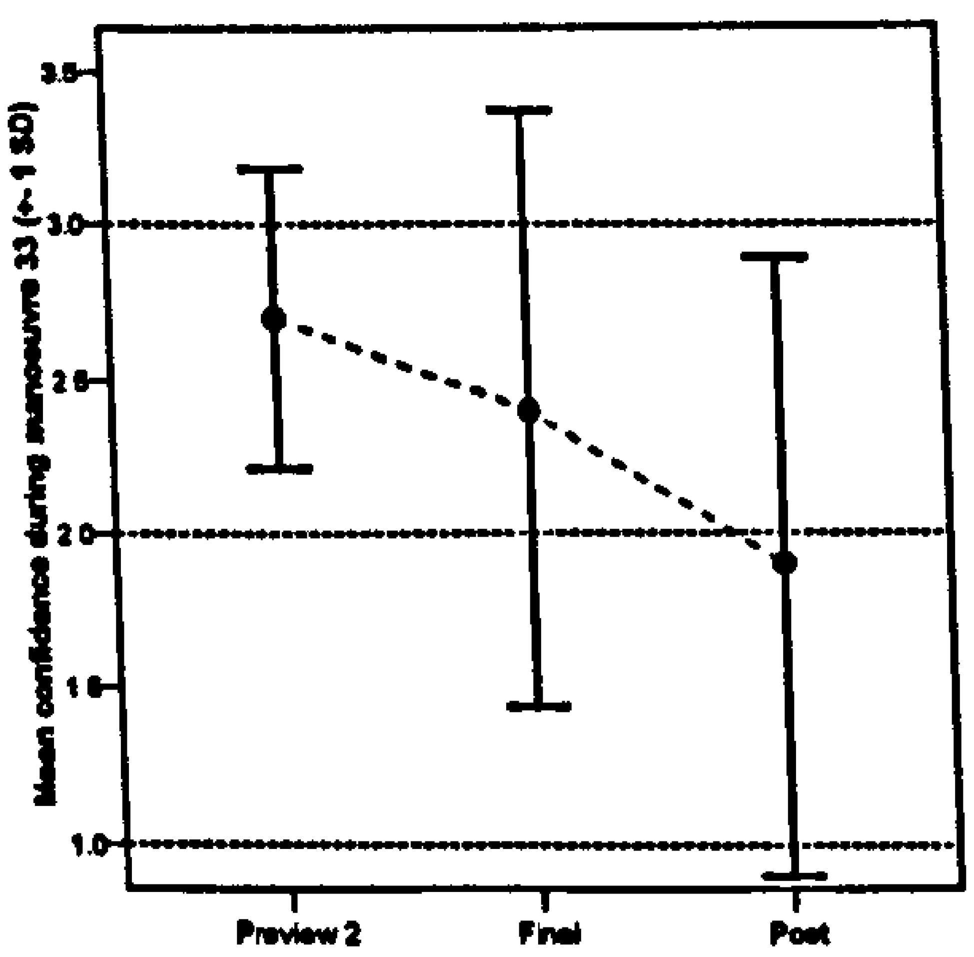
Changes in confidence during M31

N = 14, $\chi^2(2) = .667$, p = .717 (ns)



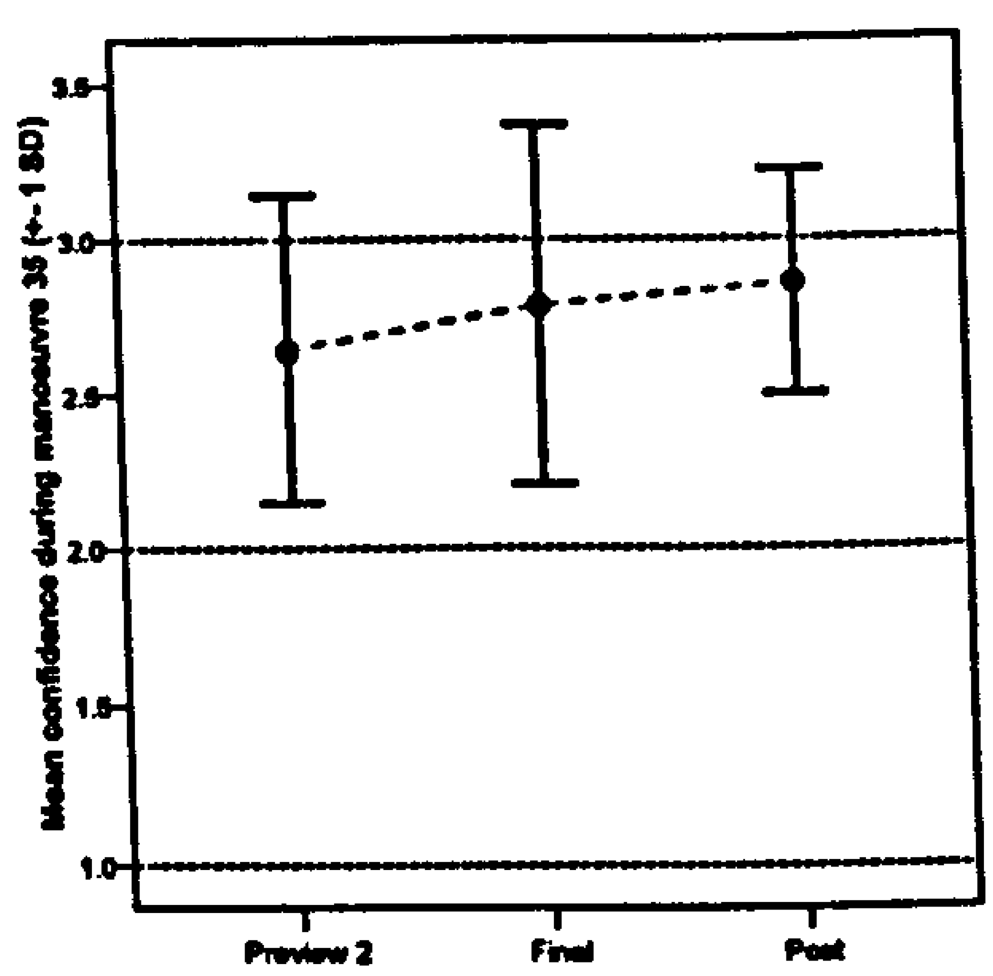
Changes in confidence during M32

N = 14, $\chi^2(2) = 6.500$, p = .039 [redacted]



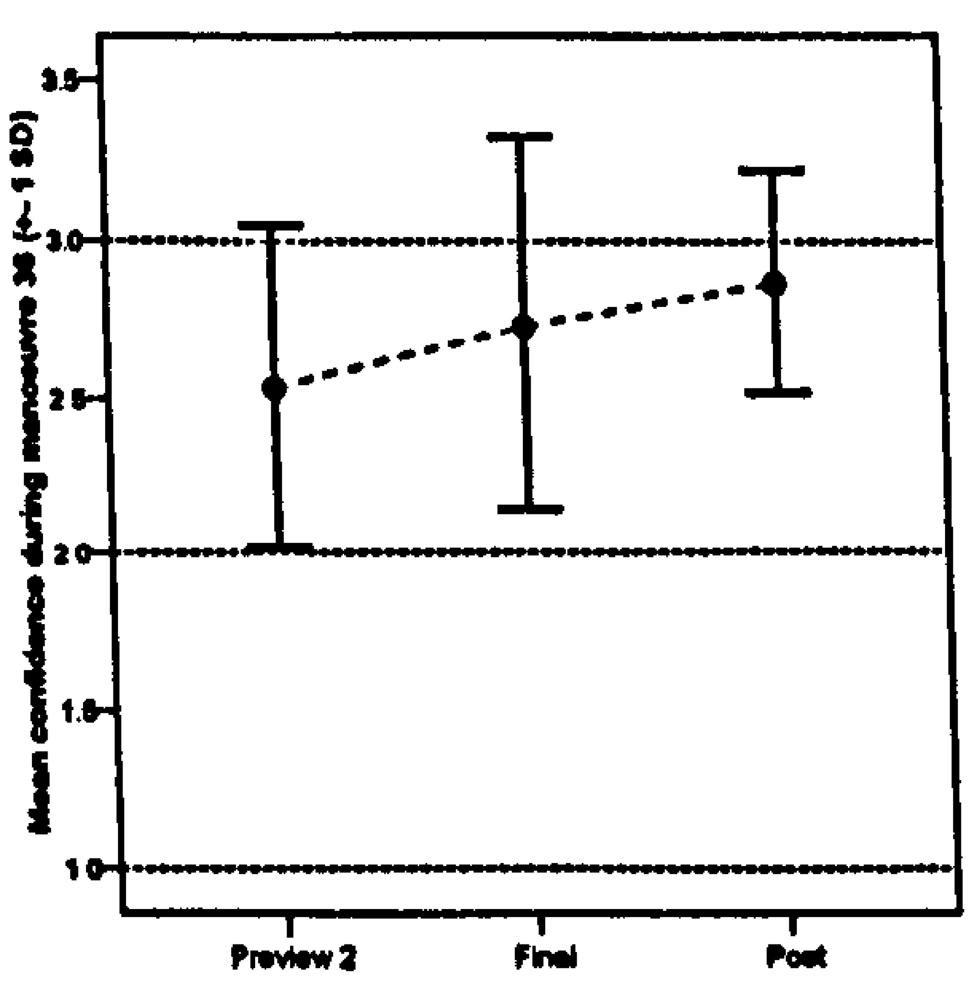
Changes in confidence during M33

N = 10, $\chi^2(2) = 5.429$, p = .066 (ns)



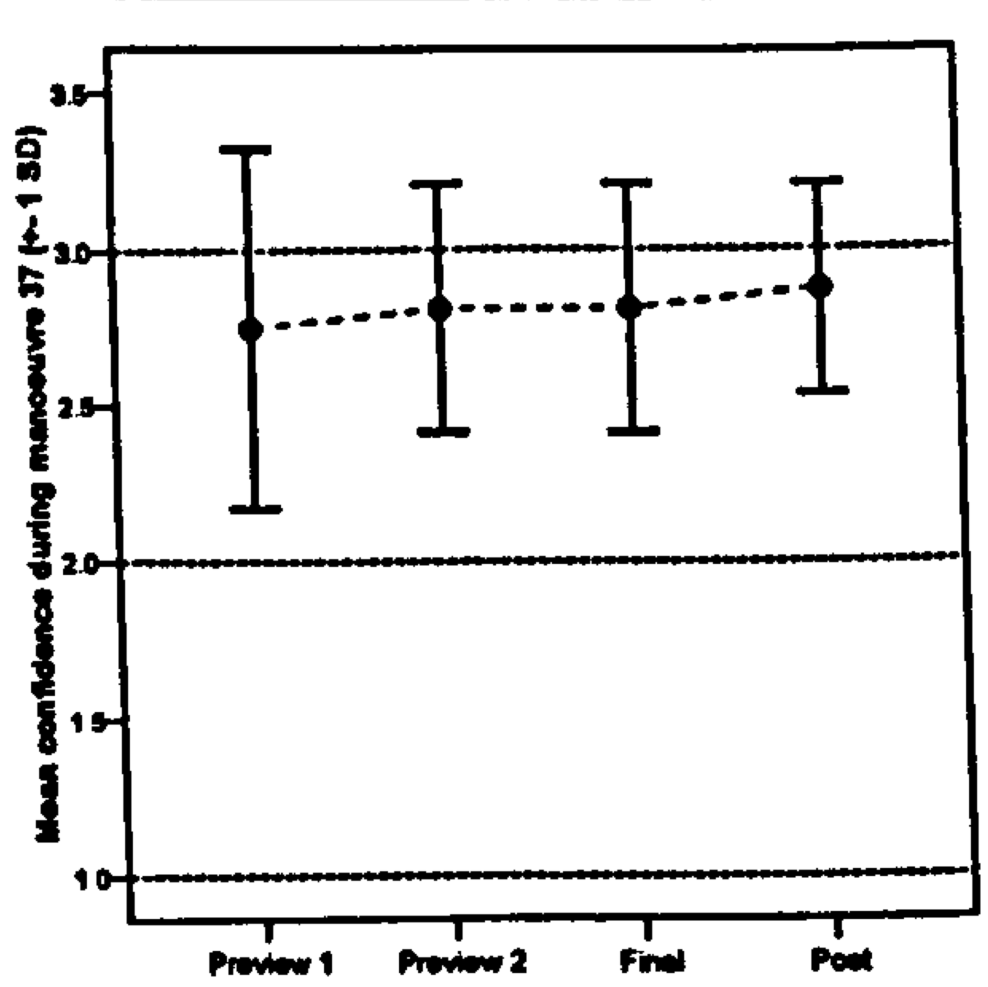
Changes in confidence during M35

N = 14, $\chi^2(2) = 3.500$, p = .174 (ns)



Changes in confidence during M36

N = 15, $\chi^2(2) = 6.091$, p = .048 [redacted]



Changes in confidence during M37

N = 16, $\chi^2(3) = .659$, p = .883 (ns)

Figure 8.3 Changes in driver confidence during each manoeuvre

8.5.2 Driving errors

Driving errors were assessed in six categories at each manoeuvre by the driving instructor who accompanied each participant. Errors were classified as minor, serious or dangerous and apportioned values of 1, 5 and 10 respectively to produce a total error score for each participant at each manoeuvre. The coding scheme and multipliers are described more fully in Section 8.4.6.1. Figure 8.4 shows how the error score (total for all participants), and division of error types varied according to manoeuvre. The *totals* for the (n=16) participants are shown due the relatively low levels of errors made by individual participants. As suggested by Figure 8.4, a Friedman test for related samples showed that the total driving error score was significantly impacted by the particular manoeuvre ($\chi^2(31) = 95.530$, $p < .001$).

8.5.3 Navigation performance

Navigation performance was assessed on the basis of participants committing actual or near navigation errors at each manoeuvre (see Section 8.4.6.2). The navigation errors committed at each manoeuvre en-route are shown in Figure 8.5 following. As above, the figure displays totals for all participants. A Cochran's Q test for related binary responses ('0' = no navigation error, '1' = actual or near navigation error at a manoeuvre) confirmed that the committal of navigation errors at manoeuvres by participants was significantly impacted by the manoeuvre they were undertaking ($\chi^2(31) = 292.098$, $p < .001$).

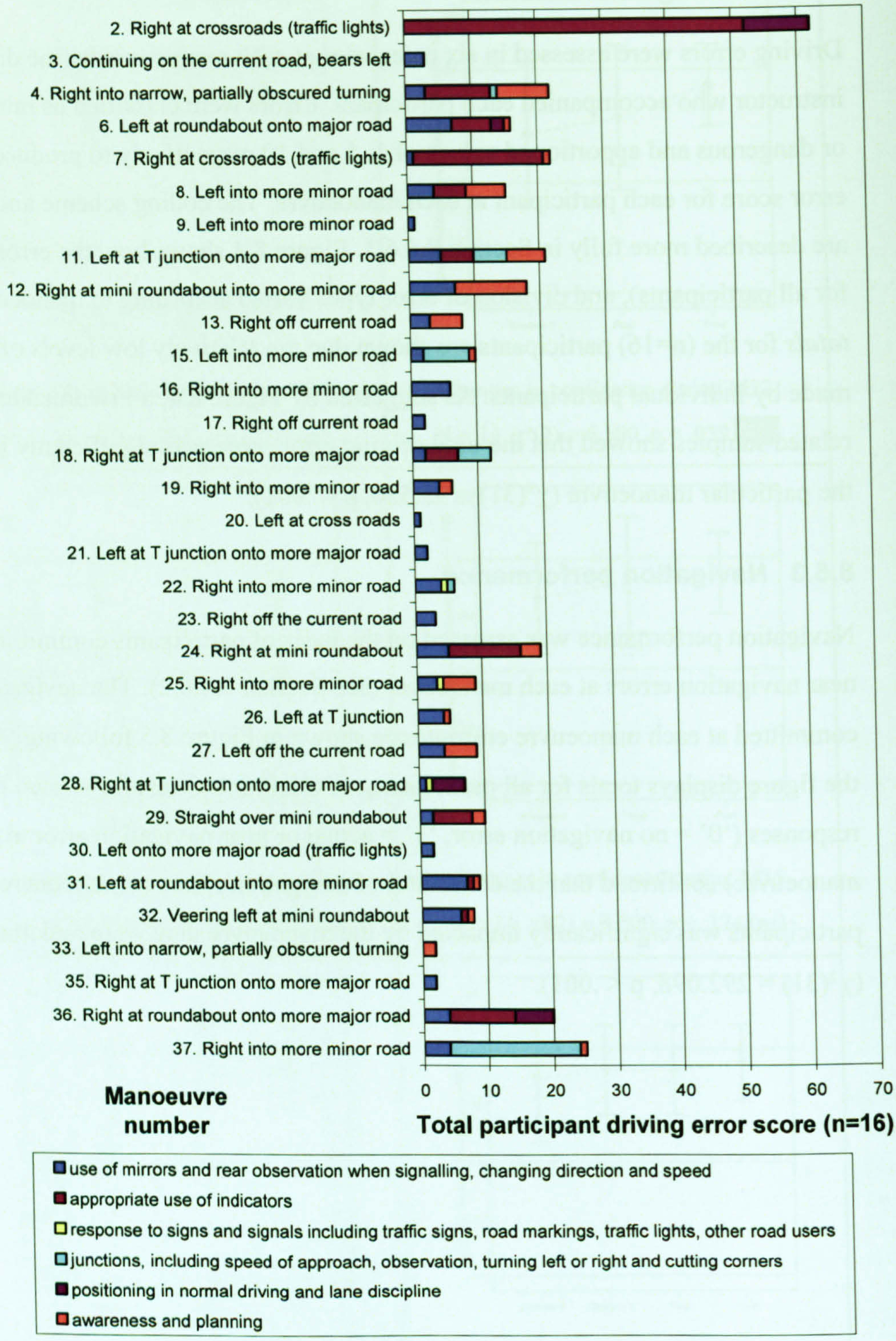


Figure 8.4 Total ***driving error*** **score (sum of all n=16 participants), and category split, at each manoeuvre en-route**

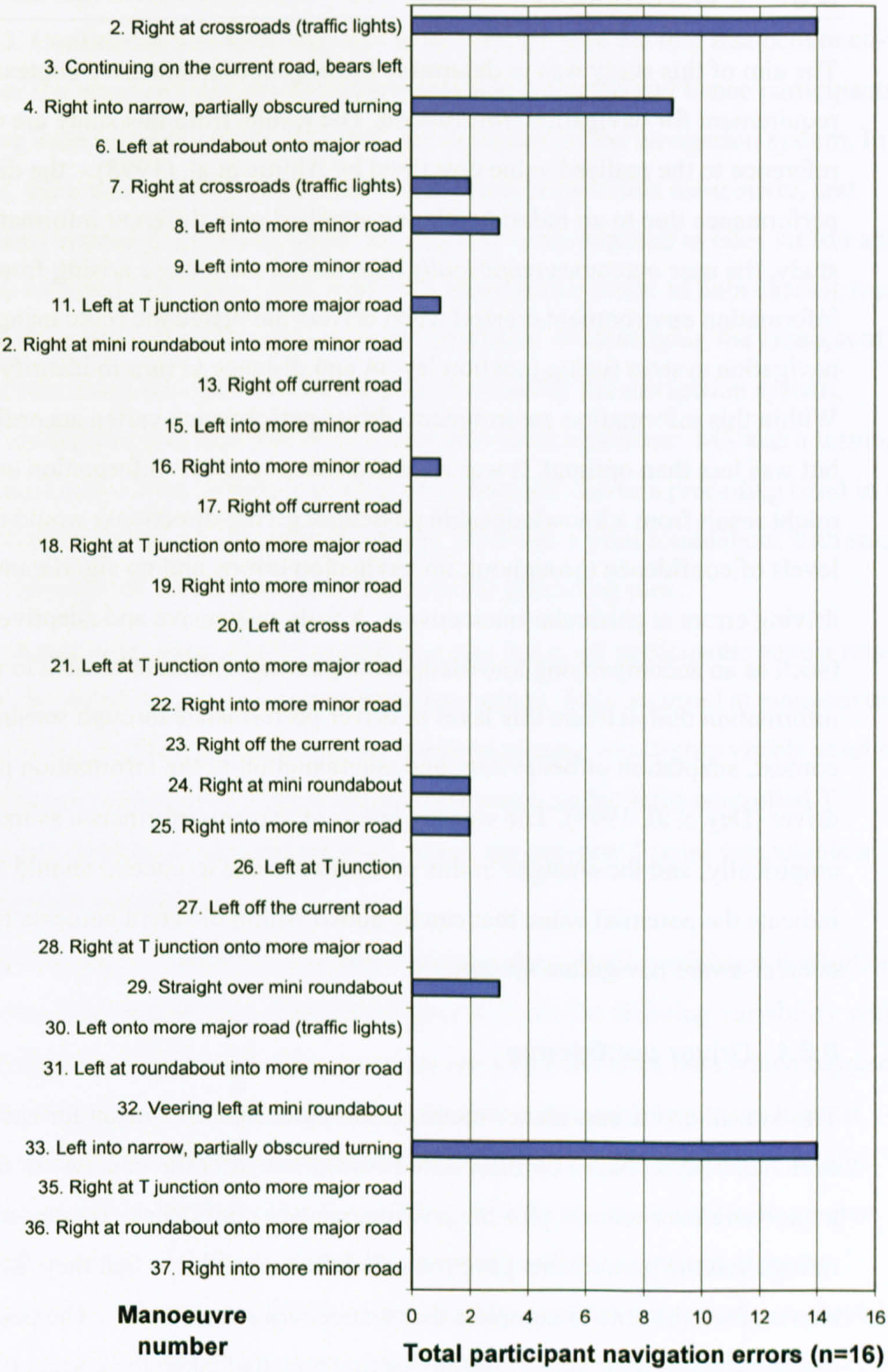


Figure 8.5 **Number of *navigation errors* (near or actual, sum of all n=16 participants) committed at each manoeuvre en-route**

8.6 Discussion

The aim of this study was to determine the impact of manoeuvre context on a driver's requirement for navigation information. The results from this study are discussed with reference to the realised value described by Ahituv et al. (1998) - the difference in performance due to an individual being supplied with different information sets. In this study, the user outcomes *empirically determined* were those arising from the information environment created when drivers navigated the route using a standard navigation system (using junction layout and distance to turn to identify manoeuvres). Within this information environment, driver performance varied according to context, but was less than optimal. It was assumed that a 'perfect' information environment (as might result from a knowledgeable passenger giving directions) would result in high levels of confidence throughout, no navigation errors, and no significant increases in driving errors at particular manoeuvres. A truly responsive and adaptive 'system' (such as an accompanying knowledgeable passenger) should be able to provide information that delivers this level of driver performance through sensing of relevant context, adaptation of behaviour, and augmentation of the information presented to the driver (Dey et al. 1999). The varying levels of driver performance as measured empirically, and the changes in this performance due to context should therefore indicate the potential value that can be added within different contexts by an effective, context-aware navigation system.

8.6.1 Driver confidence

The overall driver confidence measure was calculated as a mean for each participant at each manoeuvre, based on their stated confidence after the one, two or three pre-manoeuvre instructions, plus the post-manoeuvre confidence. The pre-manoeuvre ratings that the participants gave indicated their confidence that they 'know where to turn *and* will be able to complete that manoeuvre successfully'. The post-manoeuvre rating indicated their stated confidence that they had taken the correct turn. Figure 8.2 shows that the overall confidence levels of participant throughout the route were relatively high, although overall driver confidence during the various manoeuvres en-route did vary according to manoeuvre, as highlighted by the significance of the Friedman test for related samples.

There were only three manoeuvres where overall confidence was 2.5 or less: M2, M4 and M33. Confidence was relatively low at M2 since it was the first manoeuvre en-route (bar the practice manoeuvres) where data was collected and hence participants may have been relatively unfamiliar with the operation of the navigation system. In addition, there was a similar crossroads about 150m prior to this manoeuvre, and participants appeared unsure of which turning they were required to take. At M4 and M33, the required turn was a small road off a more major route: in both cases it was partially obscured and participants were not confident of identifying the location of the required turn using the distance information provided by the navigation system. Overall confidence was also relatively low at two other junctions: M8 was a turning off the more major route which was relatively obscured due to a preceding bend in the road, and preceded by a more major junction; M32 was a mini roundabout with two oblique turnings off, and this was also close to the preceding turn.

At two manoeuvres, mean overall confidence was 3, i.e. *all* participants gave a rating of 'high' for *all* of the pre and post-manoeuvre ratings. This occurred at manoeuvres M27 and M30. At these manoeuvres, the required turning was highly visible at all of the confidence rating points – for example M30 was a traffic light-controlled T junction preceded by a long straight road, where the preview 1 point was visible at 450m from the manoeuvre.

Not only was there a context-dependent impact on the overall confidence throughout a manoeuvre, what was also evident from Figure 8.2 was the differing variability within the participant group for each manoeuvre (as shown by the error bars which represent +/- 1 SD of the mean). At those manoeuvres where mean confidence was highest, there was also the lowest inter-subject variability. Lower mean confidence ratings occurring at manoeuvres M2, M4, M8, M32 and M33) are associated with greater inter-subject variability; this indicates the range of confidence ratings given by participants, but is also a factor of the range limitation of the rating scale employed. Participants were unable to rate higher than 3 (representing a confidence rating of 'high'), therefore the higher the mean rating, the less the scope for upward variation in this measure. Figure 8.3 isolates the confidence ratings produced at each manoeuvre, and plots, for each manoeuvre, the mean (across all participants) of the confidence ratings at each of the pre and post-manoeuvre points. It therefore shows how confidence ratings change throughout the course of each manoeuvre.

At most manoeuvres, there appeared to be similar levels of confidence at the Preview 1 point – in most cases the manoeuvre was not visible and driver confidence was purely based on expectations of the location and nature of the turning. The subsequent changes in confidence (as discussed below) were due to the extent to which the required turn became more visible (and navigational uncertainty reduced) on approach to the manoeuvre. The general trend shown within this figure is for driver confidence to increase on approach to a manoeuvre; this is to be expected due to the increased visibility of a turning, and the increasing ease with which distance-to-turn can be judged, as the turning is approached.

There were seven manoeuvres (M7, 9, 11, 16, 19, 32 and 36) where there was a significant ($p < .05$) increase in driver confidence on approach to the manoeuvre, and a further three (M3, 15, 17) where this increase was marginal ($.05 < p < .1$). At all of these manoeuvres, the intended turning was either partly obscured from a distance by buildings, road furniture and parked vehicles (and hence difficult to see until close to the turn), not visible from a distance due to the road geometry (e.g. just past a bend in the road) or was a complex roundabout where the intended turning was not apparent until close to the junction.

There were three manoeuvres where there were significant *reductions* in driver confidence on approach to the junction. At M13, driver confidence fell from Preview 1 to Preview 2, before rising at the Final preview point. This manoeuvre was a turning off a cluttered high street which was not visible after Preview 2 (~170m), but became highly visible at the Final preview point due to the lack of visual clutter at this point, and the siting of a petrol station on the corner of the road. At M25, driver confidence again fell from Preview 1 to Preview 2, then rose slightly at the Final preview point, before rising to a maximum possible at the Post manoeuvre point. This manoeuvre was a turning into a side road which was in close proximity (~30m) to other roads both before and after the turning. The confidence rating at 450m (Preview 1) was based on an assumption about the ease of locating a turning which could not yet be seen. After Preview 2 (~170m) the presence of multiple turnings in close proximity, and uncertainty of which turning was required, resulted in lower driver confidence. After Preview 3 (~30m), there was still uncertainty regarding the exact location of the turning, since the prior and subsequent turnings off the major road could be legitimate turns (they were not in fact as they were one-way streets, but this was not apparent until very close to them). Only after completing the turn could a driver be confident about having taken the correct turning since the street name was readily visible (all drivers gave a post-manoeuvre rating of 'high'). At manoeuvre M33 there was an indication (although non-significant) of a reduction in confidence throughout the manoeuvre: this was a small turning that was obscured by parked cars, and was followed by a larger and more visible junction. The mean Post-manoeuvre rating of less than 2 reflects the fact that many participants thought they had taken an incorrect turn. A similar effect was noted for M4, which was also a small turning off a more major road.

The final point of note from Figure 8.3 is that at some manoeuvres, driver confidence was high throughout the manoeuvre (e.g. M18, 20, 23, 26, 27, 30). At all of these manoeuvres, the junction was highly visible from each of the confidence rating points. The majority of these manoeuvres were T junctions where the end of the current road was visible from a distance.

8.6.2 Driving errors

The driving errors committed by participants en-route are shown in Figure 8.4; this figure gives the contribution to the overall error score (all participants) according to the six error categories of described in Section 8.4.6.1. Driving errors were significantly differentially impacted by different manoeuvres, and Figure 8.4 clearly demonstrates the problems that participants had at manoeuvre M2, with a disproportionately high error score at this manoeuvre. At this manoeuvre, participants employed inappropriate use of indicators and poor lane positioning/lane discipline, consistent with attempting to take the turn (via a filter lane) preceding that which was required. The other main findings regarding driver errors were:

- There was a low level of errors associated with mirrors and rear observation (category 1) throughout the route.
- There was inappropriate (late or not used) use of indicators at turns which were partially obscured, or those which could be confounded by possible preceding turnings, and some mini roundabouts.
- There was poor speed control at manoeuvre M37, which was a turning off a free flowing main road.

The main way in which driving errors could have been reduced was more effective identification of the location of turns; this would have enabled correct road positioning, timely use of indicators, and correct speed control on approach to the manoeuvre.

8.6.3 Navigation errors

Navigation errors were also significantly dependent on the particular manoeuvre that participants were undertaking. The location of errors as shown in Figure 8.5 is consistent with those manoeuvres where driver confidence was low (M2, 4 and 33) as shown in overall terms in Figure 8.2 and over the course of each manoeuvre in Figure 8.3. Navigation errors occurred where there were several turnings relatively close to each other, and particularly where the required turning was more minor than others close-by. A 'drawing in' effect appeared to occur where the driver's expectations were that they should take the more major road, consistent with the effect noted by Burnett (1998). Statistical analysis of navigation errors as a within-subjects effect was not possible due to the low error rate.

In order to reduce navigation errors, participants required additional information to highlight the required turning, especially where a turning was partially obscured due to street furniture and/or the layout of the approach. In other situations (e.g. where there were more prominent potential turnings close to that required), a more effective highlighting of the required turning should reduce the temptation for participants to be drawn towards these other manoeuvres.

8.6.4 Summary of contextual influences

The context of manoeuvres impacted on driving errors, navigation errors and driver confidence. A range of factors appeared to influence the ability of drivers to navigate the route successfully (and hence the potential to add value over and above that provided by basic distance and layout information). These are consistent with those proposed in Table 6.3 as either impacting on driver confidence and/or promoting the use of heuristics within navigation strategies.

The most obvious factor was the advance visibility of the junction, which may be obscured on approach by the road layout, street furniture or parked vehicles. In most cases, the manoeuvre itself was not visible at 500m when the Preview 1 instruction was given. Figure 8.3 shows how driver confidence generally increased on approach to the manoeuvre, as its visibility increased. Where manoeuvres were highly visible from a distance (e.g. M30), levels of confidence were high throughout approach. However, other factors over and above visibility were also clearly important. At some manoeuvres, driver confidence actually decreased on approach to a manoeuvre, particularly evident at M4, M13, M24 and M33. These were all turnings off a more major road, and at M4 and M33 (where confidence levels were relatively low and navigation errors also high), there was a more prominent turning in close proximity to the intended, i.e. the influences of expectations regarding the visual appearance of a turning and factors indicating a more major route as shown in Table 6.3.

As well as visibility per se, visual appearance, indicators of major routes etc, the affordances (Gibson 1979) of the road layout surrounding the manoeuvre were also important. These affordances could *enhance* the information environment (on a reduction of uncertainty basis) by providing cues that help reduce navigational uncertainty and facilitate desired driver behaviour. The best example of this was at M30, where the physical context of a large T junction provided highly visible cues to identify the location of a turning, and also required a driver to slow down on approach, thus reducing the likelihood of driving errors due to inappropriate speed control. The environmental affordances could also *degrade* the information environment by introducing cues that increase the driver uncertainty at a manoeuvre, or promote the incorrect application of heuristics as described in Section 6.7.

These results are not wholly consistent with the limited literature that deals with context or complexity within driver navigation. The potential to add value is clearly impacted by the number of decision choices and the clues available (Raubal and Egenhofer 1998) but appears poorly predicted by the (pedestrian rather than driving) model of Sugiyama (2001) which focuses on the geographical properties of the junction and does not take into account the visibility of the route, the affordances of the environment or the potential application of heuristics to support navigation decisions. The contextual influences on the value added by navigation information at manoeuvres appear to be better explained by the affordances of Gibson (1979) – including the *information* and *misinformation* that he describes - and a consideration of whether heuristic-driven decision making (e.g. a driver making an incorrect assumption to follow the major route) leads to navigation errors.

8.7 Design implications

8.7.1 Current navigation system design

Current navigation systems use a combination of graphics and text, and auditory verbal commands to provide information to the driver on approach to a manoeuvre. A typical visual display (as used in this study) is shown in Figure 8.1 at the beginning of this chapter. There is a range of information presented by the typical system that can help a driver locate a forthcoming turning with confidence: (1) the distance countdown bar, (2) the graphical display of distance to turn; (3) the movement of the current location indicator on the junction layout; (4) the name of the road being turning into and (5) the distance instructions presented verbally to the driver.

Systems *do* tailor information presentation according to the value it provides to drivers at potential navigation decisions: they make assumptions that drivers would normally continue past more minor turnings off the current road, and therefore that explicit visual and verbal instructions add little to the driver. At these locations, a single 'continue ahead' arrow is often shown. However, apart from the above basic distinction between manoeuvres and non-manoeuvres, navigation systems use little, if any notion of context at particular manoeuvres to tailor information presentation to the driver. Although the junction layout information display changes accordingly, the information presented visually and verbally to the driver on approach to a manoeuvre tends to be consistent from manoeuvre to manoeuvre and does not take into account where additional information would be useful to a driver, or where information presentation could be reduced to minimise visual distraction or the intrusiveness of verbal instructions. The variation in driver confidence, driver errors and navigation errors in this study, according to the context of a particular manoeuvre, suggests that there are opportunities for adding value with enhanced instruction at particular types of manoeuvres, and situations where information is not needed. These potential design improvements are summarised in the following section.

8.7.2 Recommendations arising from this study

The study reported in this chapter has provided empirical evidence that navigation value can be added to a driver navigating an unfamiliar route, over and above that provided by distance-to-turn and junction layout. However, this value-add depends on the context associated with a manoeuvre. Based on the results of the study, information can add value to the driver by better supporting some aspects of the *identification* (see Figure 6.5 and Figure 7.1) component of navigating. This can be achieved via a context-sensitive approach to information presentation:

Differentiation of proximate manoeuvres

Where a required turning is close to preceding or subsequent manoeuvres, greater differentiation can be made between the desired turning and others which are close by. The relatively poor distance judgement performance of humans (Böök and Gärling 1980) and potential inaccuracies in vehicle location can result in difficulty in using distance alone to identify the required turning. Alternative cues which may be used, such as street names, are often not present, or not visible until a driver is very close to the turn.

Identification of obscured manoeuvres

Where manoeuvres are wholly or partially obscured on approach by street furniture or geographical features such as a bend in the road, or brow of a hill, additional information can be provided to the driver to enable anticipation of the location of the turn which may not be visible until the driver is close the that turn. Driver confidence during this study was relatively low at the Preview 2 point (~150m from the turn) if the manoeuvre was not visible at that distance. The features that obscured the manoeuvre (e.g. geographical features, prominent buildings or even street furniture) can be used as relative reference points to enable the locating of a turning within a driver's cognitive map. This would mirror an instruction from a passenger of the form 'turn left after this bend', or 'turn right after that large pub'.

Highlighting of minor turnings

Participants displayed a tendency to be drawn towards more major turnings when being asked to take one which is more minor, particularly if the more minor turning was not visible from a distance. The minor turn needs to be emphasised; in addition the more major turns could also be displayed to the driver so that the turns they are *not* being asked to take are explicitly identified.

Raising confidence during manoeuvre approaches

Although the general trend shown in Figure 8.3 is for driver confidence to increase on approach to a turn, there were some manoeuvres where driver confidence at the

Preview 2 point (~150m) was still relatively low, and in some cases, less than that at the Preview 1 point (~450m). Driver confidence on approach to manoeuvres can be increased by referring to other cues present in the environment to (1) enable the driver to more easily judge progress towards a turn, and (2) visually locate the required turn that may be obscured on approach.

Minimising information presentation

The sections above have highlighted how information can add value (in relation to that provided by current navigation systems) in particular navigation contexts. However, there are also situations where it is possible to *minimise* the information presented to the driver and potentially reduce the distraction due to visual information, or the intrusiveness of verbal cues. This also increases the overall value of navigation systems by reducing the 'give' component.

The information presented by current navigation systems can be reduced where it adds no additional value to the driver. In particular, this occurs in the following situations:

- Environmental affordances are such that a turn is highly visible to an approaching driver
- The driver is required to stop or slow down at the manoeuvre
- There are no other turns in close proximity to the manoeuvre
- The driver is following the major traffic flow

Presenting landmarks to the driver

The sections above have highlighted the contexts where it is possible to add value to a driver, over and above that provided by distance and junction layout (i.e. the main information provided by current navigation systems). Consistent with the findings of the study in Chapter 7, - and research by Burnett (2000) and others, discussed more fully in Chapter 6, landmarks would appear to add value to drivers by addressing many of the requirements stated above:

- Where sited at junctions, they can be used to help identify which of a set of proximate turnings is the desired one.
- At junctions, they can help identify the location of turnings when the turning itself is wholly or partly obscured.

- Where landmarks are at or near required manoeuvres which are minor turns, they can be used to add prominence to that minor turn, and reduce the temptation for drivers to be drawn towards more major junctions.
- Landmarks sited on the approach to a turning can be used to increase the confidence of the driver (in a similar fashion to their use between manoeuvres as shown in Figure 7.8 in the previous chapter), and enable drivers to judge their progress to manoeuvres that may be obscured at the point at which a Preview 2 message is given by current systems (150-200m).
- Landmarks can also be used to minimise the information that systems present to drivers, by using them as key navigation cues instead of distance on approach to manoeuvres. By mirroring the types of instructions given by an informed passenger (e.g. 'turn left at the next set of traffic lights') within a piloting (Allen 1999) strategy, there is no longer the need for proceduralised, distance-based instructions on approach to a manoeuvre.

8.8 Critique of study

The aim of this study was to investigate how driving and navigation performance varied along the course of an unfamiliar route, when using basic navigation instructions (distance and junction layout) to indicate the location and type of manoeuvres. In particular, the study aimed to understand the extent to which additional navigation value (over and above that provided by current navigation systems) could be added according to the context associated with types of manoeuvre.

The study demonstrated that driver confidence, navigation errors and driving performance were differentially impacted at varying locations en-route. However, what was relatively unexpected was the lack of consistent impact due to the type of manoeuvre being undertaken. It was anticipated that driver confidence would be lowest for turnings off the major route. However it became apparent that the greatest determinant of driver confidence on approach to a manoeuvre was the visibility of the turn on approach, rather than the type of junction per se. In contrast, the pattern of driving and navigation errors did mirror that expected – these tended to occur at turnings off the major route, especially where the required turning was partially obscured or where there were other more prominent turnings in close proximity to the required turn.

8.8.1 Limitations to the study

The main methodological limitation to the study was the lack of control over the types of manoeuvres used en-route, and their associated context. The underlying rationale behind the study was to require drivers to navigate a real route in order to determine their actual behaviour. The limitations of driving a real route in a situated environment restricted the ability to select the range of manoeuvres as required, and the order with which they were encountered. In particular, it was not possible to randomize the presentation of manoeuvres to the participants i.e. they all navigated the manoeuvres in a set order. There may have been a learning effect encountered by participants; however, there was an attempt to minimise the incremental impact over the course of the route by incorporating the training sessions at the beginning of the trial. Visual inspection of the overall levels of driver confidence Figure 8.2 suggests that driver confidence tended to be lowest during the initial and final sections of the route, however there was no significant correlation between the mean participant confidence at a manoeuvre, and the number of the manoeuvre that they were undertaking (Spearman rho, $p = .547$, ns).

A second limitation to the study is the reliance on the information presented to the driver via a current navigation system. This was used to ensure consistent delivery of information to the driver, in terms of content, format and timing of delivery. The driver behaviour during the trial was therefore contingent on the design of the navigation system, and particularly the accuracy with which it (1) located the driver and (2) represented junction layouts. Since the aim was to have a benchmark of information delivery, against which added value could be assessed, it was assumed that the presentation of information to the driver at each manoeuvre was of a consistent quality level, e.g. that there was no differential in the location or representation accuracy experienced by drivers at the manoeuvres en-route.

A potential threat to reliability and validity arose from the multipliers used within the driving error score assessments. It was assumed that the identification of the *categories* and *severity* of errors was valid since they were based on a recognised schema used within the UK driving test examination. It was also assumed that these errors were reliably identified as a qualified and experienced driving instructor (who also held an advanced driving qualification) was used to record these. However no formal reliability checking (e.g. inter-rater or test-retest correlation of results) was undertaken, and this is recognised as a flaw. The main potential limitation arising from the driving error score assessments relates to the generation of a single driving error score metric based on the frequency and severity of driving errors identified by the driving instructor. Minor errors were given a score of 1, major errors scored 5 and dangerous errors scored 10. These were summed to give a total error score. This overall metric was proposed by the driving instructor, based on what would constitute a 'fail' within the UK driving test, and also what would, in his view, represent dangerous driving based on habitually committing minor driving errors.

Another potential limitation within the study relates to the validity of the driver confidence construct. Drivers were asked to provide three confidence ratings during the approach to each manoeuvre, and one confidence rating after having completed the manoeuvre. The pre-manoeuvre ratings were intended to capture confidence in relation to knowing where to turn and being able to complete that manoeuvre successfully. The post manoeuvre rating was used to indicate a driver's confidence that they had taken a correct turning. It could be argued that the confidence ratings provided during the trial merely represented an overall 'wellbeing' rating, i.e. that the confidence construct was poorly derived since it was based on a measure deemed to have ecological validity within a driving context, rather than a more theoretical derivation as would be the norm within the MIS literature. However the confidence ratings were consistent with the manoeuvres at which drivers also committed driving and navigation errors. Another limitation is the lack of a direct assessment of the resources expended at each manoeuvre and the use of the driver confidence metric as a surrogate – lack of a direct measure of the 'give' component within a value analysis. The level of mental demand on a driver is typically measured using a subjective driver workload tool such as that based on the NASA TLX (Hart and Staveland 1988). Since this requires deliberate assessment of multiple scales, and then scale ratings by the driver, it was felt this would introduce unnecessary additional demands on the driver within a safety-critical environment.

8.8.2 Potential improvements

There are several areas for improvement to the study. The first is the need to undertake a validation exercise for the driving error metric. The driving error metric was developed in close collaboration with a UK Advanced Driving Instructor, was based on established error severity levels and categories (as used in the UK driving test), and was piloted prior to the study. However, it would have led to more confidence in the results if this had been shown empirically to be a *reliable* measure. Some cross-correlation with more than one driving instructor, or on repeated data, should have been carried out.

The situated aspect of the study maximised the validity of the results, since they represented real driver outcomes. However, this also limited the ability to systematically vary the context (type of junctions, visibility on approach) associated with each manoeuvre, and explore the range of physical contextual factors that influenced value-add at different manoeuvres.

Finally, there were several logistical issues that hindered the study to some extent. It was not possible to programme the navigation system to direct participants around the route directly; instead a series of destinations and waypoints had to be used to ensure that the navigation system directed participants around the desired route. The destinations and waypoints were inputted using the remote control while the participant was driving (see Appendix 8D). An ability to directly programme the routing employed by the navigation system would have resulted in slightly more natural route following.

8.8.3 Future work

There are several recommendations for future work, based on the premise of a navigation system being an MLS whose role is to provide, to a driver, the right information at the right time in the right format (Hollnagel 1988) in order to satisfy navigation objectives.

The main theoretical recommendation is to explore more fully the aspects of context which are the key determinants of adding value at manoeuvres. The literature has tended to focus on pedestrians, rather than drivers, and the geometrical properties of manoeuvres (Sugiyama et al. 2001) rather than the wider range of influences on driver behaviour at manoeuvres. It is the impact of these wider influences that creates potential value from navigation instructions by enabling confident and correct navigation decisions to be made, whilst also minimising information provision to the driver. These factors include: those related to environmental affordances (e.g. layout of the junction), external explicit (e.g. signposts) and implicit (e.g. major traffic flows) cues available, previous instructions that may still be valid (e.g. see Section 7.7.2), existing knowledge of routes or sections of routes, and personal preferences for information.

At a fundamental level, basic research needs to determine the concepts that future navigation systems should employ, e.g. whether future navigation systems should continue to be based on proceduralised turn-by-turn instructions of a piloting form (Allen 1999), or instead, a dynamic, resource managing 'travel assistant' providing the active contextual adaptation described by Dey et al. (1999) and Chen and Kotz (2000). Future navigation systems could undertake a much higher level of contextual sensing and contextual augmentation. For example they could use dynamic entities (e.g. other traffic) as information cues, by instructing a driver to 'follow that bus'. They could also supplement information cues with personal or dynamic augmentation, such as providing additional lane support for particular drivers, or providing lane change instructions according to current traffic levels.

Of more near-term relevance, is the need to *demonstrate*, for drivers, within a real environment, the actual benefits of landmarks, assuming that for a driver undertaking a piloting strategy within an unfamiliar area, they comprise the 'right' (Hollnagel 1988) information. As navigation cues, their 'quality', i.e. that which impacts on their relevance within a dynamic context of use (Barry and Schamber 1998), varies considerably, and it is necessary to explore the link between the quality of a cue and their realistic or revealed value (Ahituv et al. 1994).

8.9 Conclusions

There is potential to provide additional value to a driver of an unfamiliar route, over and above that provided by distance-to-turn information, and junction layout. In addition, this added value depends considerably on the physical context associated with manoeuvres, and particularly the affordances of the road layout and the existence of other external information cues.

There are opportunities for improving driver confidence on approach to manoeuvres, reducing *navigation* errors (or near errors) at manoeuvres, and also reducing the number of *driving* errors committed whilst negotiating manoeuvres on an unfamiliar route. This can be done by supporting the driver in the following situations:

- Differentiating between proximate manoeuvres.
- Identifying the location of obscured manoeuvres.
- Highlighting where drivers may be drawn erroneously towards more major turnings.
- Using landmarks at or on approach to a manoeuvre.

There is also opportunity to reduce the amount of information presented to a driver, consistent with the views of Jackson (1998). A typical situation would be the approach to a highly visible T junction or set of crossroads, where the environmental affordances clearly identify the location of the junction and the need to slow or stop, and navigational uncertainty is low due to a simple left or right decision.

The overall conclusion from this study is that navigation systems would benefit from being more context-aware, consistent with the observation by Richter and Klippel (2004). Systems should move towards the model of an informed passenger providing context-relevant navigation information to the driver when it adds value to the driver, and *not* providing information when it is unnecessary – the contextual adaptation of behaviour described by Dey et al. (1999).

By simply being more aware of the situated environment (e.g. the location of landmarks and prominent geographical and road features), and either presenting this information or using this contextual sensing to govern information presentation to the driver, navigation systems can be designed to present information that is more relevant to drivers, in those situations where (and only where) they need it.

9 THE VALUE-ADD OF LANDMARK INFORMATION

Research questions addressed in this chapter:	
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	What is user 'value' in the context of mobile location services?
4	**How can a specific mobile location service (driver navigation) be enhanced using a value perspective?**
5	What general recommendations can be made for mobile location services research and design?

9.1 Introduction

As discussed previously, navigation systems are one category of MLS that is being adopted by the general public. To add value, they must maximise their effectiveness and minimise the human (and financial) resources needed to use them successfully. OEM navigation systems, and those based on portable devices, promote and support a piloting strategy for travel to a specified destination – a 'quest' (Allen 1999) - through the provision of turn-by-turn navigation instructions.

Human navigation using piloting strategies involves the use of landmarks, and a body of research has identified the benefits they provide in supporting driver navigation. In addition, the study reported in Chapter 7 has shown how particular landmarks are often used in a primary, as opposed to secondary information role and have particular potential to add value as navigation cues. This study has also highlighted that some landmarks such as traffic lights are consistently 'good' cues, whilst others, such as public houses (which are anecdotally used as navigation cues within the UK), may be relatively 'poor' landmarks.

In general terms, Kantowitz et al. (1997) highlight the importance of the accuracy of route guidance information. More specifically, Burnett and Porter (2002) highlight the potential impact of using landmarks of variable quality. Despite the literature on human navigation and the potential for landmarks within vehicle navigation systems, there is a lack of empirical evidence demonstrating how the intrinsic qualities of a landmark (i.e. whether it is a 'good' or 'poor' landmark) impacts on the value provided to a driver navigating an unfamiliar route.

The study reported in this chapter was an empirical investigation of the value-adding potential of a navigation MLS that included landmarks within its turn-by-turn instructions to a driver. In particular, this study investigated how the distinction between a 'good' and 'poor' landmark influenced the value provided by that cue, and how the value provided by good and poor landmarks compared to that provided by distance information. If landmarks are to add value over and above the distance and junction layout information used in current navigation systems, and to maximise their relevance (Barry and Schamber 1998), it is likely that the realised benefits will be dependent on the quality of that information cue.

9.2 Aims

The aim of this study was to investigate, within a real driving environment, the impact on driving and navigating performance of providing landmark information of varying quality within drivers' navigation instructions. In particular, this study assessed:

- The potential value of using landmarks (as opposed to distance information) as the key auditory navigation information used to locate a forthcoming manoeuvre in an unfamiliar area.
- The impact of the 'quality' of a landmark when navigating and driving a complex, unfamiliar route.
- The impact of the context of the manoeuvre on the value adding capacity of landmarks.

It was anticipated that providing good landmarks in verbal turn instructions would result in safer driving and better navigation performance than either poor landmarks or distance to turn information. However, it was not evident the extent to which performance may be degraded with the use of relatively poor landmarks. This study therefore aimed to provide empirical evidence of the value of providing landmarks within a navigation instructions, and design recommendations for future navigation systems.

9.3 Study rationale

9.3.1 Choice of methodology

This study had the characteristics of a classical deductive approach (Gill and Johnson 2002): (1) the testing of causal relationships between variables; (2) the collection of quantitative data; (3) the application of controls; and (4) a structured approach to enable replication. This study was based on the assertion that landmarks are a value-adding cue for drivers following an unfamiliar route, and this value-add will depend on the quality of the cue and the context of the manoeuvre.

The basic relationship being tested in this study was that between information design and realised behaviour. To enable empirical testing and generalisation of results, task scenarios and independent and dependent variables were operationalised as below.

9.3.2 Task scenario and variable definition

Turnings off the major road are situations where navigation information has the potential to provide substantial value to the driver. A driver's most likely outcome without effective information is to continue past a more minor turning off the major road – therefore the value-adding potential of information to support turning off the major road is high.

Since a key feature of 'value' is the impact on an outcome within a situated context (i.e. what happens to a real person in a real world situation), the study was designed as a road-based trial, involving real navigation decisions by participants driving an unfamiliar route. The independent variable within the study was the nature of the information provided to a driver in order to locate a turning and took three forms:

1. A good landmark at or near the required manoeuvre in order to identify the position of the turning – representing those information cues which potentially offer the greatest benefit to the driver.
2. A poor landmark at or near the required manoeuvre in order to identify the position of the turning – those which could be incorporated into systems, but potentially representing a poor design solution (and also enabling a direct comparison of information based on the qualities of the object, rather than the nature of the cue).

3. Distance to turn information being provided to the driver on approach to the manoeuvre – representing the information that is currently used by most navigation systems to pinpoint the location of manoeuvres to the driver.

The dependent variables related to the potential benefits or disbenefits to the driver in terms of the outcome (navigation, driving performance and driver confidence) and the resources used to generate these outcomes (physical and cognitive effort and visual demand). In their totality, they represent the 'gives' and 'gets' from a functional value perspective (Sheth et al. 1991). The independent and dependent variables are described in more detail in Section 9.4.6.

9.3.3 Boundary conditions

The boundary conditions employed within the study (i.e. those criteria that define the limits of applicability of the results) are shown below in Table 9.1.

Users	**Constrained by specifying participants:** All fulfilled the following criteria: aged 21+, normal vision, clean driving licence, regular drivers, unfamiliar with the area, no previous experience with navigation systems. **Balanced on the following criteria:** Age, gender, navigation ability, distance judgment ability.
Tasks and context	**Constrained by specifying the experimental task:** The driving of an unfamiliar route using a turn by turn strategy with a navigation system. The turning off a major road into a more minor turning. **Constrained by specifying the information environment within the requirements study:** The unfamiliar urban environment. The presence of good and poor landmarks. The availability of the navigation system as the single additional information sources (i.e. paper maps, passengers, passers-by could not be accessed). **Varied by the location-dependent context:** The characteristics of each (N=8) target manoeuvre. The information environment (availability of different information cues within the environment).

Table 9.1 Boundary conditions placed on the study

9.4 Method

9.4.1 Overview

This study comprised a road-based trial to assess the value-adding potential of differing navigation cues when using a modified vehicle navigation system that included landmarks within its instructions. Three different groups of participants used the navigation system to navigate around a complex urban route using navigation instructions which included either (1) 'good' landmarks, (2) 'poor' landmarks or (3) distance information within the auditory information presented to a driver. A range of dependent measures were collected, including visual glance data, driving errors, driver workload, navigation errors and driver navigation confidence.

9.4.2 Participants

As described in Section 8.4.2, 48 participants were recruited from the general public via web notice boards, local newspaper advertisements and posters. They were all over 21 with self-reported normal or corrected-to normal vision, held a clean driving licence, had driven regularly for at least three years, not previously used a navigation system, and did not know the area where the study took place. A pre-screening exercise enabled potential participants in three independent groups to be balanced for factors shown to potentially influence navigation performance, driving behaviour and/or information preferences:

- Age (Burns 1998; Walker et al. 1991)
- Gender (Burns 1998; Ward et al. 1986)
- Self-reported navigation ability (Allerton 2000; Streeter and Vitello 1986)

In addition, participants were also matched on self-reported distance judgment ability, since this skill was fundamental in interpreting the distance countdown bar on the display, has been shown to vary considerably within the population (Fine and Kobrick 1983), and be negatively impacted by concurrent task demands (Bocock and Gaerling 1978). Participants were then randomly allocated to one of the three between-subjects experimental conditions. They were paid £20 for their participation.

9.4.3 Apparatus

A Land Rover Freelander™ with a state of the art, DVD-based satellite navigation system was used to present visual and verbal turn instructions, and map overview information, to enable a driver to navigate to one or more specified destinations. This is described more fully in Section 8.4.3 in the previous chapter.

For the purposes of this study, landmarks were broadly defined as external reference points which were potentially useful to a driver as navigation cues, in line with the discussion of landmarks in Section 6.6.5.1. Four main constructs were assumed to be key determinants of the effectiveness of a landmark as a navigation cue: its visibility to an approaching driver, its familiarity to a typical driver, its uniqueness in terms of being dissimilar to other nearby objects, and the usefulness of its location when being integrated within other environmental information in order to support navigation at driver decision points.

In order to incorporate landmark information within the voice instructions, three sets of auditory prompts were recorded that either included 'good' landmarks, 'poor' landmarks or distance to turn information. The selection of 'good' and 'poor' landmarks was based on the assessment of potentially available landmarks against the attributes above which determine their suitability (quality in use) for navigation purposes: visibility, familiarity, uniqueness and location.

With respect to the latter three attributes, landmarks were selected which were all: familiar and relatively permanent features of the built environment, unique such that they would not be confused with other instances of the same object, or other similar objects, and located at or within 20m of the relevant junction. In addition, they were all common, easily recognisable objects such as petrol stations, as opposed to being unique objects such as individual restaurants, to prevent the need for memorisation of new information cues. The differentiation between 'good' and 'poor' landmarks was based on the distance at which they became visible and recognisable to an approaching driver on a clear day. This visible distance assessment was undertaken for each landmark independently by three raters with normal or corrected to normal eyesight, whilst driving the route in fine weather, and the median rating from these assessments used. The 'good' landmarks at the eight target manoeuvres were visible at a mean distance of 212 (SD = 83) m; the 'poor' landmarks at those same target manoeuvres were visible at a mean distance of 103 (SD = 46) m. Typical 'good' landmarks were traffic lights, pedestrian lights and petrol stations. Typical 'poor' landmarks were bus stops, post boxes and phone boxes. These are listed in Table 9.2 below.

The recorded auditory prompts were triggered and played to the driver in lieu of the auditory output generated automatically by the navigation system, to enable participants to navigate the trial route. The messages consisted of up to three verbal prompts as follows: a Preview 1 message given at the earlier of 500 m or the completion of a prior manoeuvre (this was omitted if subsequent manoeuvres were closer than 300 m); a Preview 2 message given at the earlier of 200 m or the completion of a prior manoeuvre; a Final auditory tone (beep) given at 50 m to the manoeuvre. This presentation strategy is typical of that employed by current vehicle navigation systems presenting turn-by-turn instructions. A typical auditory message that included a landmark was 'turn right after the Texaco™ petrol station', i.e. it included no distance-to-turn information.

To preserve face validity, where landmarks were present at incidental manoeuvres, they were presented to the driver at these locations; however these landmarks were not defined as 'good' or 'poor' and this data was not analysed. Where landmarks were not present at incidental manoeuvres, verbal distance to turn information was given for all participants. Visual distance to turn information was given for all participants at all manoeuvres, as shown in Figure 8.1 in the previous chapter.

9.4.4 Experimental route

The route used in this study is described in the previous chapter (Section 8.4.4) and included eight target manoeuvres (numbers 2, 7, 8, 9, 15, 19, 22 and 37) that met the following criteria: a left or right turn off the main route; other potential turns nearby (i.e. a requirement for information to precisely locate the manoeuvre); a good and a poor landmark that could be used to identify the turn; preferably at least a 500 m approach to allow for the presentation of three auditory messages. The eight target manoeuvres, plus accompanying good and poor landmarks are summarised in Table 9.2 below. Within this study, the other 25 manoeuvres were incidental, and merely served to link the target manoeuvres. Participants were unaware that there were target and non-target manoeuvres.

#	Manoeuvre	Good landmark	Poor landmark
2.	Right turn off a dual carriageway	Traffic lights at the turn	A distinctive sculpture (height 3m)
7.	Right turn off a dual carriageway	Petrol station	Public house, terraced, set back 4m from the carriageway
8.	Left turn off a single carriageway	Pedestrian lights*	Bus stop
9.	Left turn off a single carriageway	Public house, distinctive, detached	Bus stop
15.	Left turn off a single carriageway	Pedestrian lights*	Post box
19.	Right turn off a single carriageway	Pedestrian lights*	Bridge on the current road (to travel *over*)
22.	Right turn off a single carriageway	Pedestrian lights*	Post box
37.	Right turn off a single carriageway	Pedestrian lights*	Telephone box

* Of similar appearance to traffic lights

Table 9.2 Summary of target manoeuvres and accompanying landmarks

9.4.5 Experimental Design

A between-subjects experimental design was necessary, since a repeated navigation of a single route would undoubtedly cause a confounding learning effect. It was not possible to find three matched routes. In addition, the length of time that a participant would have to spend driving three equivalent routes meant that a repeated measures design was impractical. One group received 'good' landmarks in their auditory instruction, a second received 'poor' landmarks, and the third participant group received distance information in place of a landmark.

A secondary factor influencing the experimental design was the need to account for contextual differences between each manoeuvre. Although manoeuvres were chosen where explicit navigation instructions are needed (turnings off the main road), it was also desirable to identify whether the value derived from the different sets of navigation instructions was impacted by contextual factors that varied from manoeuvre to manoeuvre and could not be controlled empirically. An 8-level within subjects variable was incorporated that represented the set of eight target manoeuvres that the participant was completing.

The experimental design was therefore a 3 (Information) x 8 (Manoeuvre) mixed design. Information was a between subjects factor representing the nature of the verbal information provided to a participant, i.e. whether the auditory component of the navigation instructions incorporated: (a) distance-to-turn information (as per current navigation systems), (b) good landmarks, or (c) poor landmarks (instead of distance information) to locate a turning. Manoeuvre was a within subjects factor representing the eight target manoeuvres en-route, thereby enabling investigation of driver behaviour due to the variability of the context of individual manoeuvres.

Due to the constraints of driving an actual route with a real navigation system, it was not possible to randomise or balance the within-subjects factor, i.e. all participants completed the eight target manoeuvres in a set order. All trials took place mid morning or mid afternoon as described in Section 8.4.5.

9.4.6 Dependent variables

The dependent variables were those described in Chapter 8, with the addition of visual glance behaviour which was analysed for this study only (i.e. eight target manoeuvres instead of all 33 manoeuvres en-route), due to the effort involved in this analysis, and driver workload. The following measures/metrics were used within the study:

Measure	Metric
Driving safety	Visual glances to the in-vehicle display on the approach to each manoeuvre Driving errors whilst undertaking each manoeuvre
Navigation performance	Actual or potential navigation errors at each manoeuvre
Driver confidence	Driver confidence throughout each manoeuvre
Cognitive resources	Subjective post-trial driver workload

Table 9.3 The measures and metrics used in the study

Data was collected during the trial at all (33) manoeuvres for all participants for two reasons: to enable the analysis described in Chapter 8, and to ensure participants could not differentiate between target and non-target manoeuvres by differential data collection. These dependent variables are described below.

9.4.6.1 Primary task impact - driving safety

Visual glance behaviour was the main analysis that was carried out for this study, over and above that undertaken for the study that assessed value-add over the entire route (Chapter 8). This recognises the critical role that vision plays during driving, the impact of in-vehicle systems on driver visual allocation and the role that visual distraction can play in potentially unsafe driving behaviour (Lansdown 2001). Visual glance behaviour was measured via video capture in order to determine the number and duration of glances to the in-vehicle visual display during the 500m approach to each target manoeuvre. The time that each participant spent moving and spent stationary on approach to a manoeuvre (e.g. whilst queuing in traffic) was determined for each participant from the video analysis. The stationary glances (comprising less than 10% of the total) were not included in subsequent analysis as their mean duration was 65% higher than the moving glances, and some very long stationary glances were made (maximum 4.2 s). The percentage moving time metric was used to account for the speed variations in the approach to particular manoeuvres: the total moving time, upon which this metric was based, was measured separately for each participant at each manoeuvre. Correspondingly, the percentage moving time metric was calculated for each participant for each manoeuvre as the total duration of the glances to the display whilst moving, divided by the total time spent moving during the approach to that manoeuvre.

Driving errors were assessed at each manoeuvre as per the previous study (Section 8.4.6.1 in the previous chapter).

9.4.6.2 Secondary task impact – navigation performance

Navigation errors were recorded for each target manoeuvre as described in Section 8.4.6.2 in the previous chapter.

9.4.6.3 Driver confidence

Driver confidence was recorded as for each target manoeuvre as per Section 8.4.6.3 in the previous chapter.

9.4.6.4 Resources

To obtain an overall indication of the resources expended by the driver, mental workload was assessed on completion of the experimental route using a slightly modified version of the NASA TLX (Task Load Index), a subjective workload assessment tool originally developed by Hart and Staveland (1988) and extensively tested and considered to be a robust measure (Noyes and Bruneau 2007). The modified version computes the Raw TLX (RTLX), an unweighted sum of the sub-scale values (the original version uses paired comparisons to derive weights for the sub-scales of the TLX). Byers et al. (1989) have shown that the RTLX scores can give an even better account of perceived workload than traditional TLX values. An additional sub-scale of 'perceived distraction' was added to the RTLX as a result of the work of Fairclough (1991) to adapt the TLX for the driving task. Although initially developed nearly 20 years ago, the NASA TLX (or variants thereof) is still used to measure driver workload, a recent example being Lansdown et al. (2004). The sheet used to explain the NASA RTLX, and record driver ratings is shown in Appendix 9A.

9.4.7 Procedure

On arrival, participants were introduced to the study and signed consent forms. After familiarising themselves with the vehicle controls, the participants completed a mixed-road familiarisation drive lasting approximately 25 minutes. They then drove for about 10 minutes using the vehicle navigation system, receiving approximately eight navigation instructions during this period, and then undertook a practice session lasting a further 10 minutes where they drove using the navigation system and gave confidence ratings at five manoeuvres. All participants were able to complete this familiarisation process successfully and without requesting additional practice time, which was offered in all cases.

After familiarisation and training (lasting approximately 45 minutes), the participants drove the trial route using the navigation system with simulated auditory output, giving the three pre- and one post-manoeuvre confidence ratings at each manoeuvre; they were occasionally prompted if necessary. During the approach to each manoeuvre, the nature and severity of any driving errors were recorded by the driving instructor, and navigation errors were recorded. After undertaking the final manoeuvre, the participant completed the modified NASA RTLX and was debriefed and paid.

9.5 Analysis and results

9.5.1 Visual behaviour

Visual glance analysis was undertaken for the eight target manoeuvres where there were good and poor landmarks that could be used by a driver to locate the turning. Figure 9.1 shows the mean (across all eight target manoeuvres) number of glances to the navigation display during the 500m approach to a manoeuvre, according to whether participants used auditory navigation instructions employing good landmarks, poor landmarks or distance information to locate a turn. As discussed in Section 9.4.6.1, these exclude all glances made while stationary. Figure 9.2 shows the mean duration of those glances (across all eight target manoeuvres). Figure 9.3 shows the mean (across the target manoeuvres) of the percentage moving time metric (total time spent glancing to the display while moving, as a percentage of the time spent moving). Figure 9.4 to Figure 9.6 are equivalent graphs, showing the differentiation in the data according to each target manoeuvre. Error bars represent +- 1 SD of the mean.

Figure 9.7 is a boxplot of the data shown in Figure 9.4, to give a more effective indication of the range and distribution of the number of glances made by participants on approach to each manoeuvre. In this figure, the shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers which are shown separately. A solid line across the box indicates the median. A dashed reference line is drawn to show zero glances on the ordinate axis.

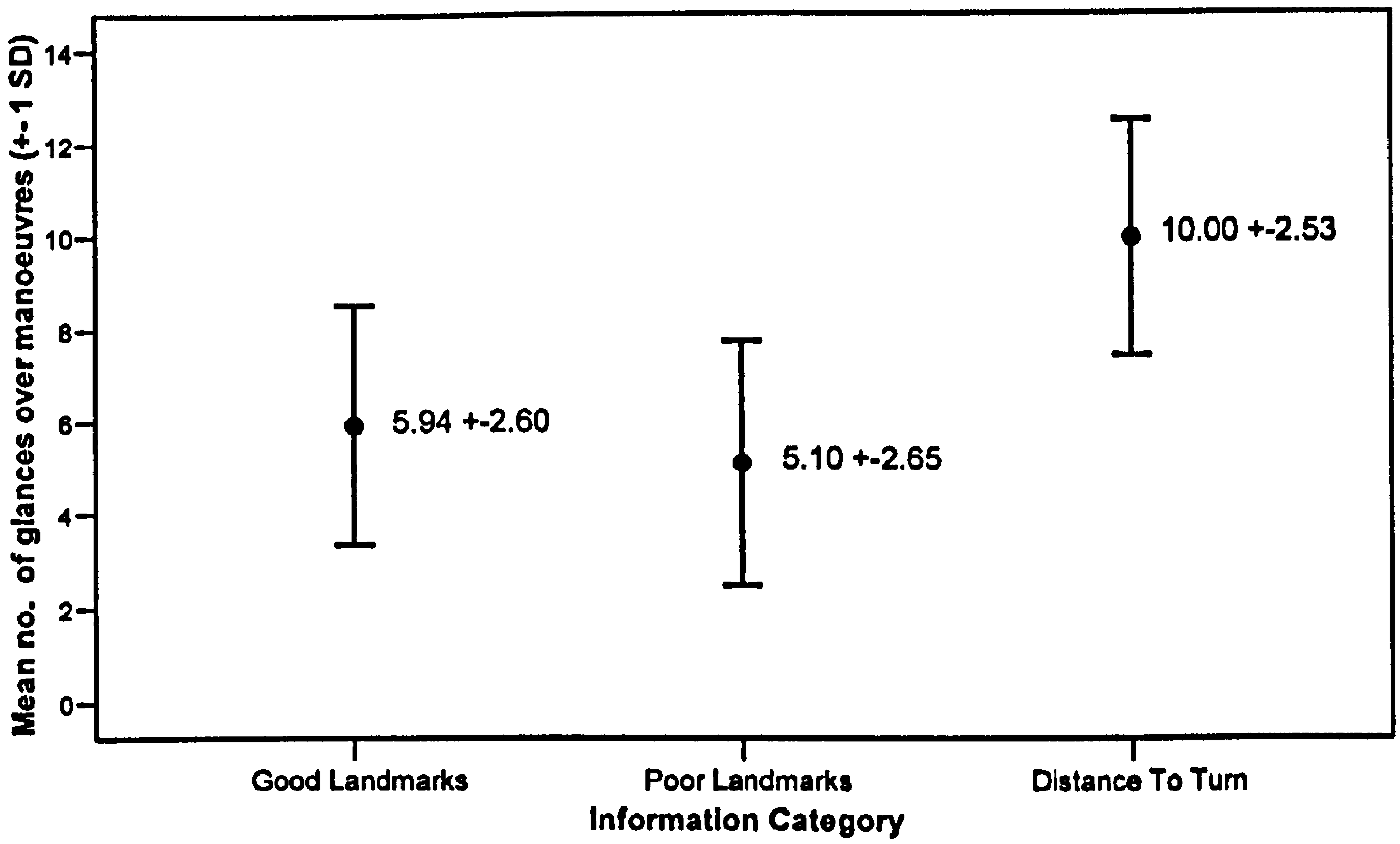


Figure 9.1 The effect of information category on the mean number of glances made to the display during the approach to a manoeuvre

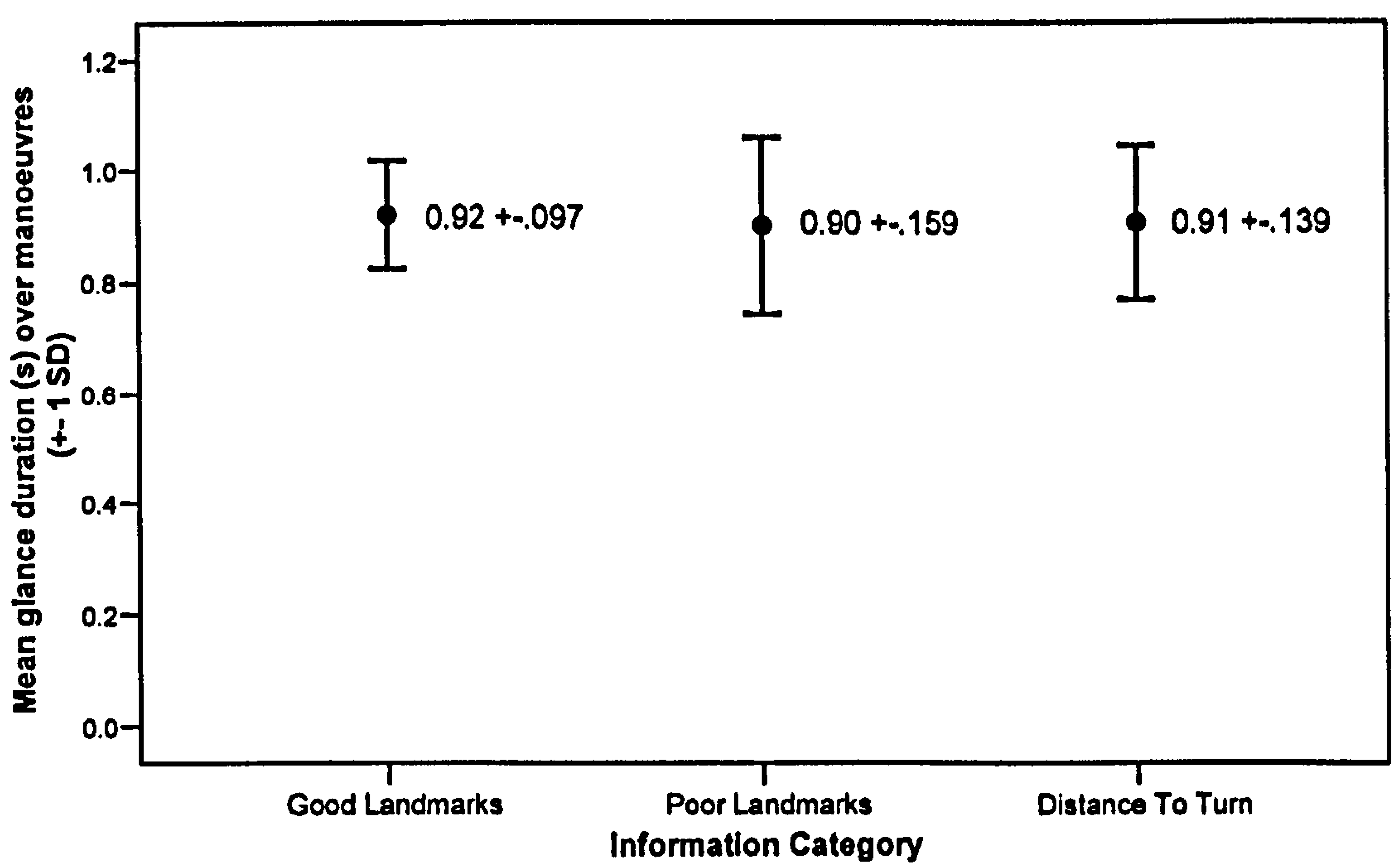


Figure 9.2 The effect of information category on the mean duration of glances made to the display during the approach to a manoeuvre

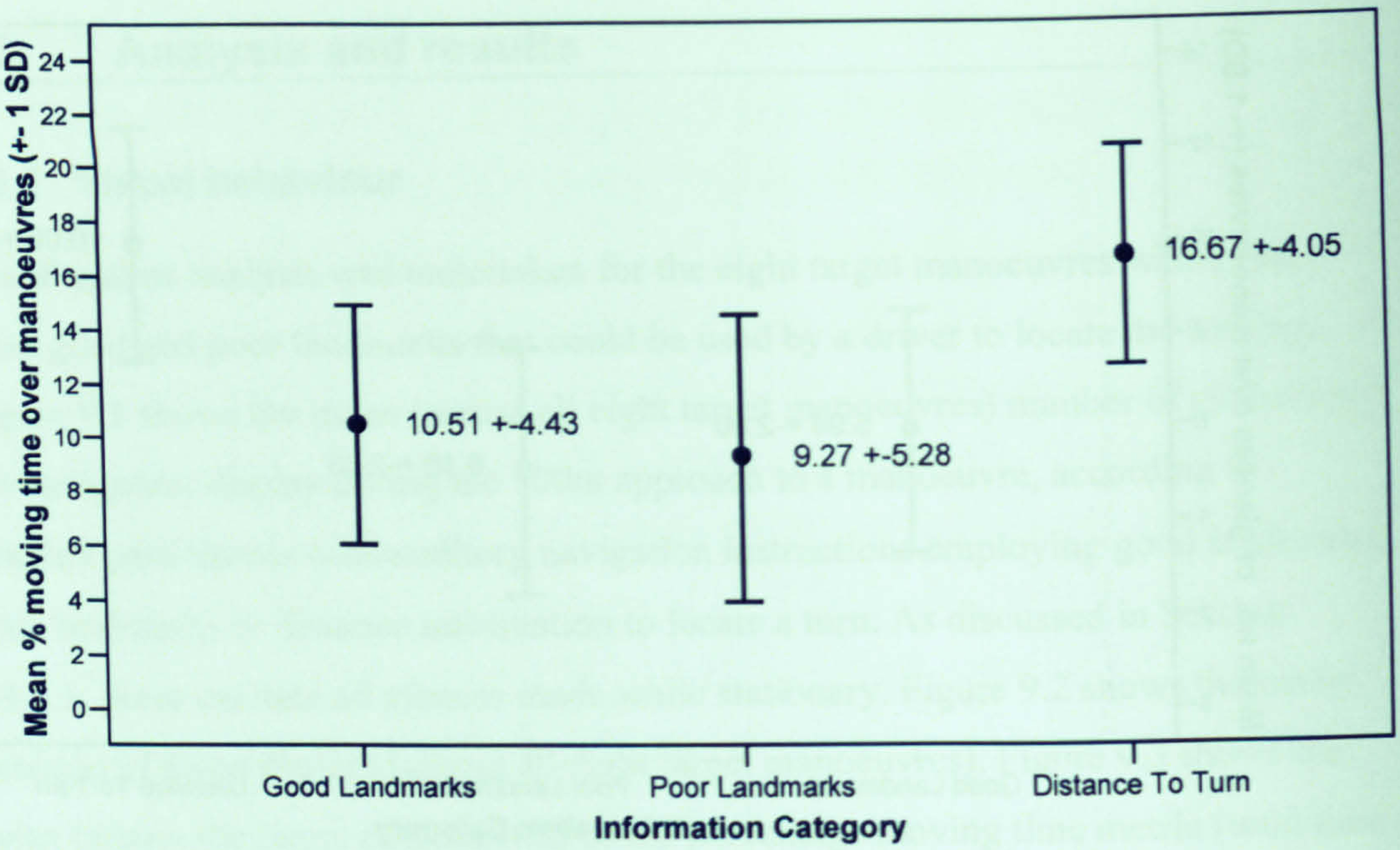


Figure 9.3 The effect of information category on % moving time spent glancing to the display during the approach to a manoeuvre

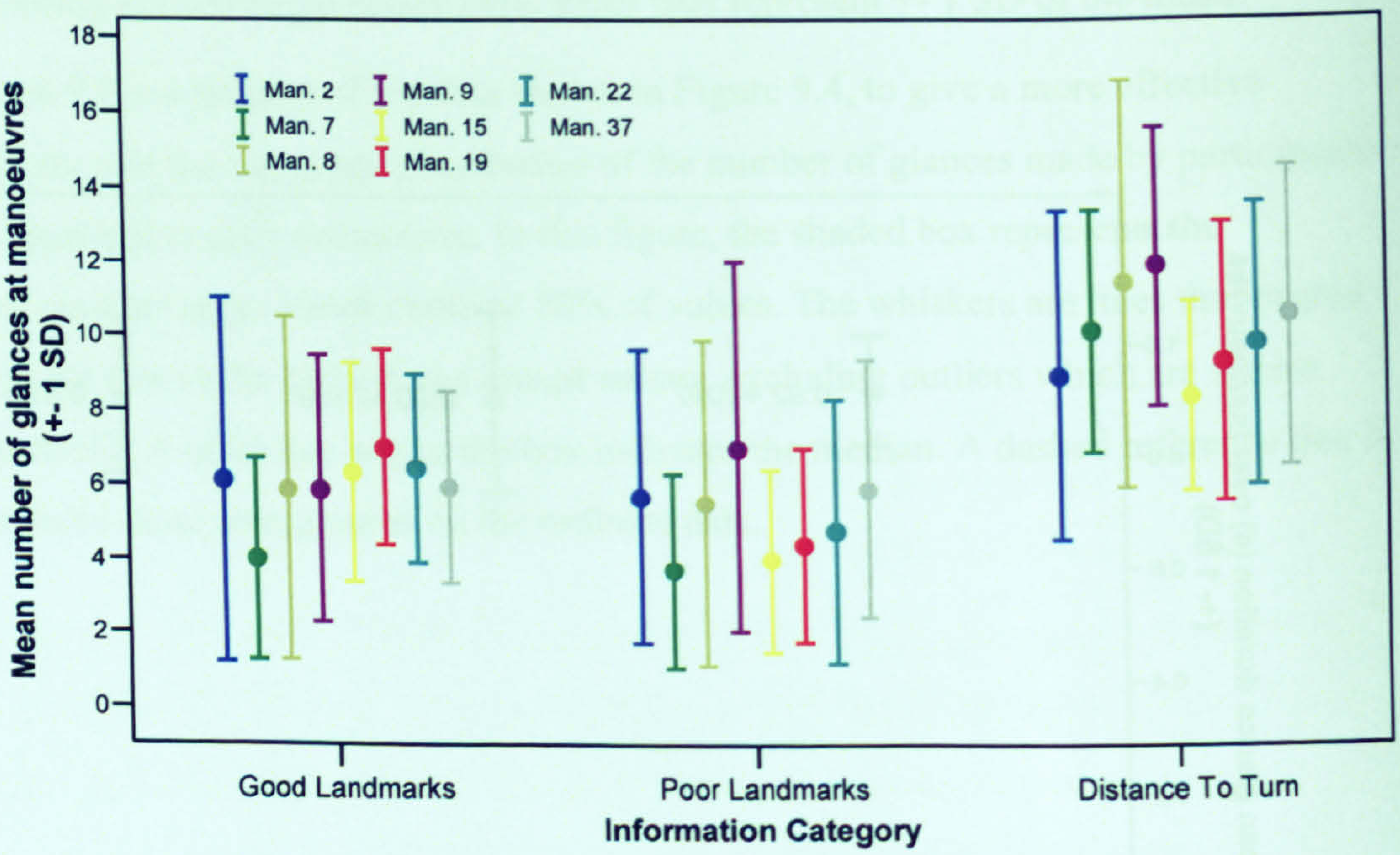


Figure 9.4 The effect of information category, and manoeuvre number, on the mean number of glances to the display during the approach to each target manoeuvre

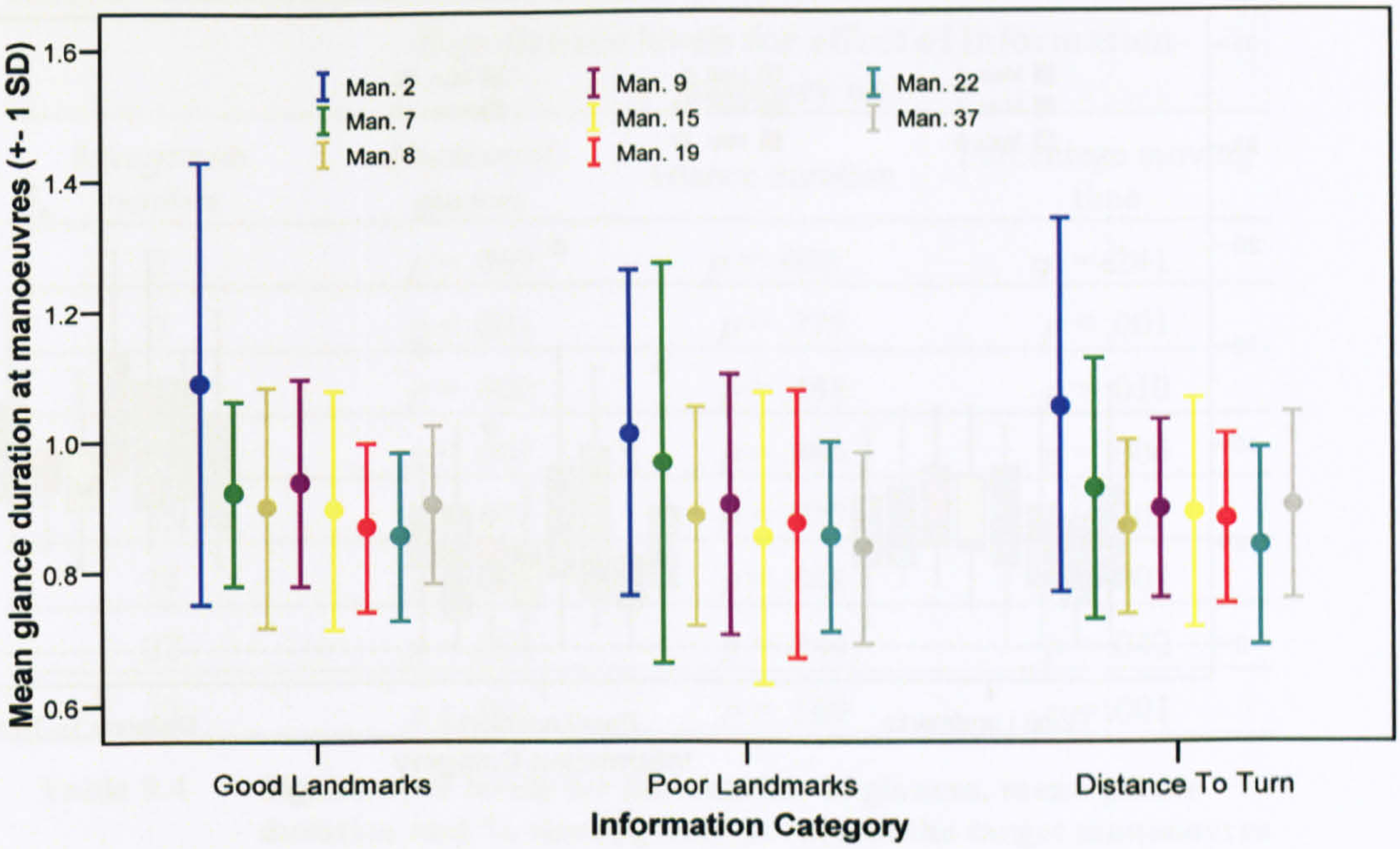


Figure 9.5 **The effect of information category, and manoeuvre number, on the mean duration of glances made to the display during the approach to each target manoeuvre**

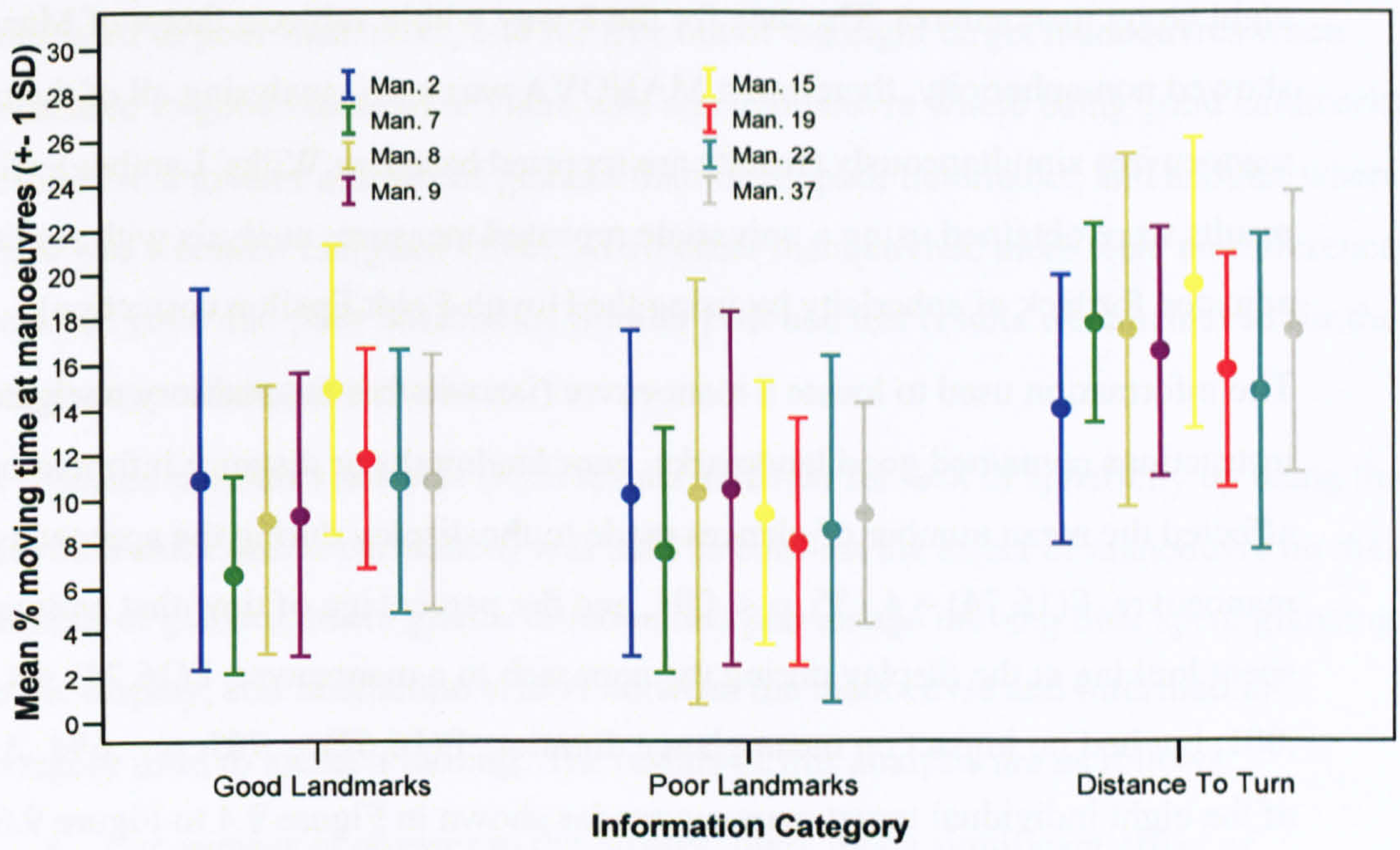


Figure 9.6 **The effect of information category, and manoeuvre number, on % moving time spent glancing to the display during the approach to a manoeuvre**

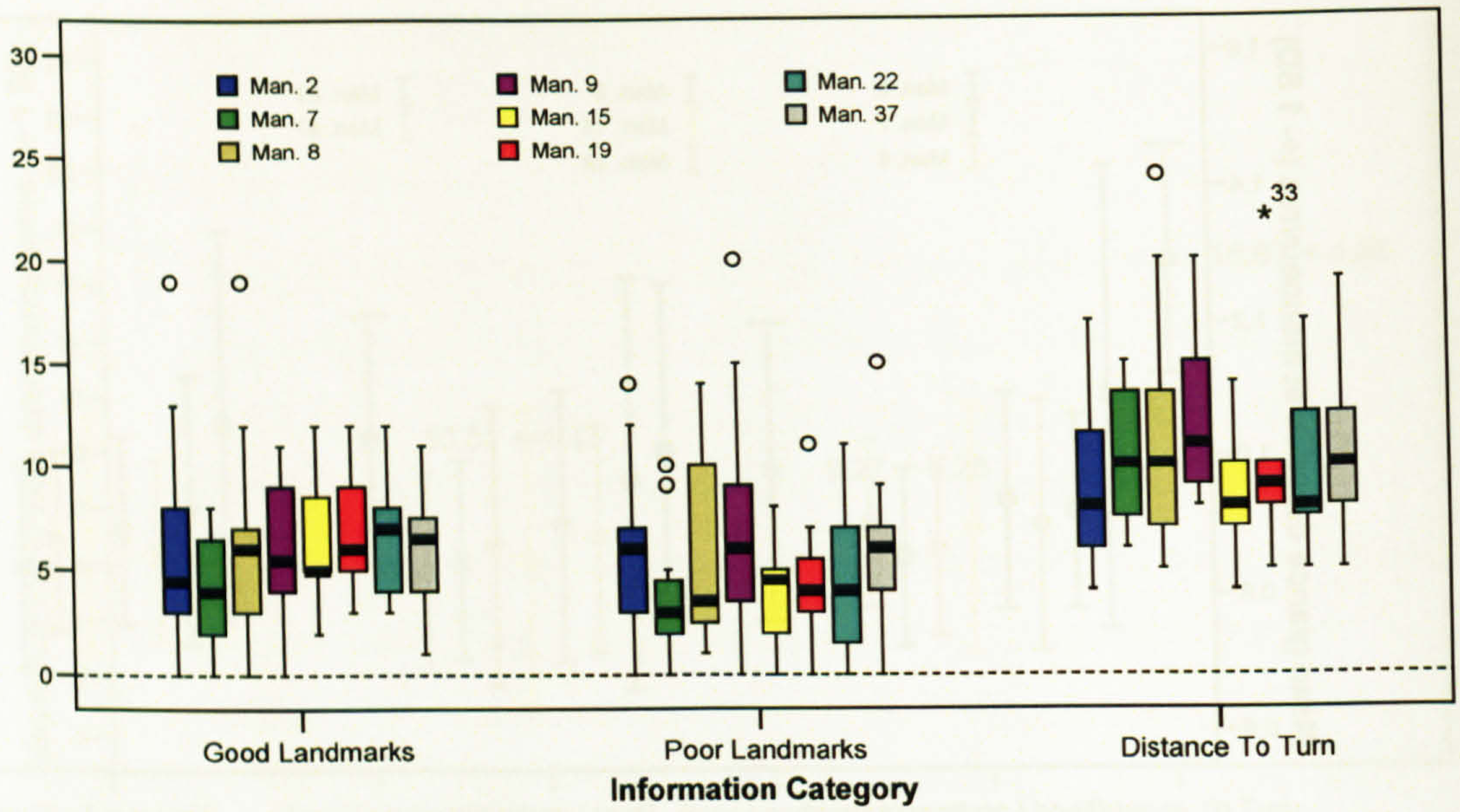


Figure 9.7 Boxplot showing distribution of [number of glances to the display for participants], according to information category and manoeuvre number

The experimental design comprised a within subjects component that represented the eight target manoeuvres. The data for the 8-way within subjects factor of Manoeuvre showed non-sphericity, therefore a MANOVA was used, analysing all of the target manoeuvres simultaneously (results are reported based on Wilks' Lambda). (Similar results were obtained using a univariate repeated measures analysis with results adjusted for lack of sphericity by using the Huynh-Feldt Epsilon correction).

The information used to locate a manoeuvre (i.e. whether the auditory navigation instructions contained good landmarks, poor landmarks or distance information) affected the mean number of glances made to the display during the approach to the manoeuvre, $F(16,74) = 4.135$, $p < .001$, and the percentage of time that participants spent looking at the display during the approach to a manoeuvre, $F(16,74) = 4.393$, $p < .001$, but had no impact on mean glance duration, $F(16,62) = .787$, $p = .694$. Analysis of the eight individual target manoeuvres (as shown in Figure 9.4 to Figure 9.6) indicated significant effects (at $p < .05$) of information category on: the number of glances made to the display and the percentage moving time spent looking at the display for all eight target manoeuvres bar the first one as shown in Table 9.4 below.

	Significance levels for effect of information category on:		
Manoeuvre number	Number of glances	Glance duration	Percentage moving time
2	$p = .069$	$p = .600$	$p = .241$
7	$p < .001$	$p = .775$	$p < .001$
8	$p = .002$	$p = .488$	$p = .010$
9	$p < .001$	$p = .896$	$p = .006$
15	$p < .001$	$p = .927$	$p < .001$
19	$p < .001$	$p = .948$	$p = .001$
22	$p < .001$	$p = .844$	$p = .042$
37	$p < .001$	$p = .169$	$p = .001$

Table 9.4 **Significance levels for the number of glances, mean glance duration and % moving time at each of the target manoeuvres**

Tukey HSD post hoc tests (α =.05) showed that using distance information to locate a turn resulted in a significantly greater number of glances being made to the display for seven out of the eight target manoeuvres (and a marginal effect for the 8th) when compared to poor landmarks, and for five out of the eight target manoeuvres when compared to good landmarks. There was one manoeuvre where using good landmarks resulted in a greater number of glances than using poor landmarks, and another where there was a similar marginal effect. At all other manoeuvres, there were no differences between good and poor landmarks. Similar post hoc test results were achieved for the *percentage moving time* measure.

A repeated measures analysis (with results adjusted for lack of sphericity by using the Huynh-Feldt Epsilon correction) was used to confirm the effect of manoeuvre on the number of glances, mean glance duration and percentage moving time spent glancing to the display, and interaction effects between the manoeuvre and information category used to locate a turning. The results of this analysis are as follows:

- For *number of glances* to the display, there was a significant effect of manoeuvre, $F(5.835) = 3.561, p = .002$, and a marginal interaction between manoeuvre and interaction category $F(11.671) = 1.760, p = .057$.
- For *mean glance duration*, there was a significant effect of manoeuvre, $F(5.920) = 7.719, p < .001$, and no interaction between manoeuvre and interaction category $F(11.840) = .807, p = .642$.

- For *percentage moving time* glancing to the display, there was a significant effect of manoeuvre, $F(5.756) = 2.640$, $p = .018$, and a significant interaction between manoeuvre and interaction category $F(11.511) = 1.961$, $p = .030$.

The associated profile plots are shown below in Figure 9.8 to Figure 9.10.

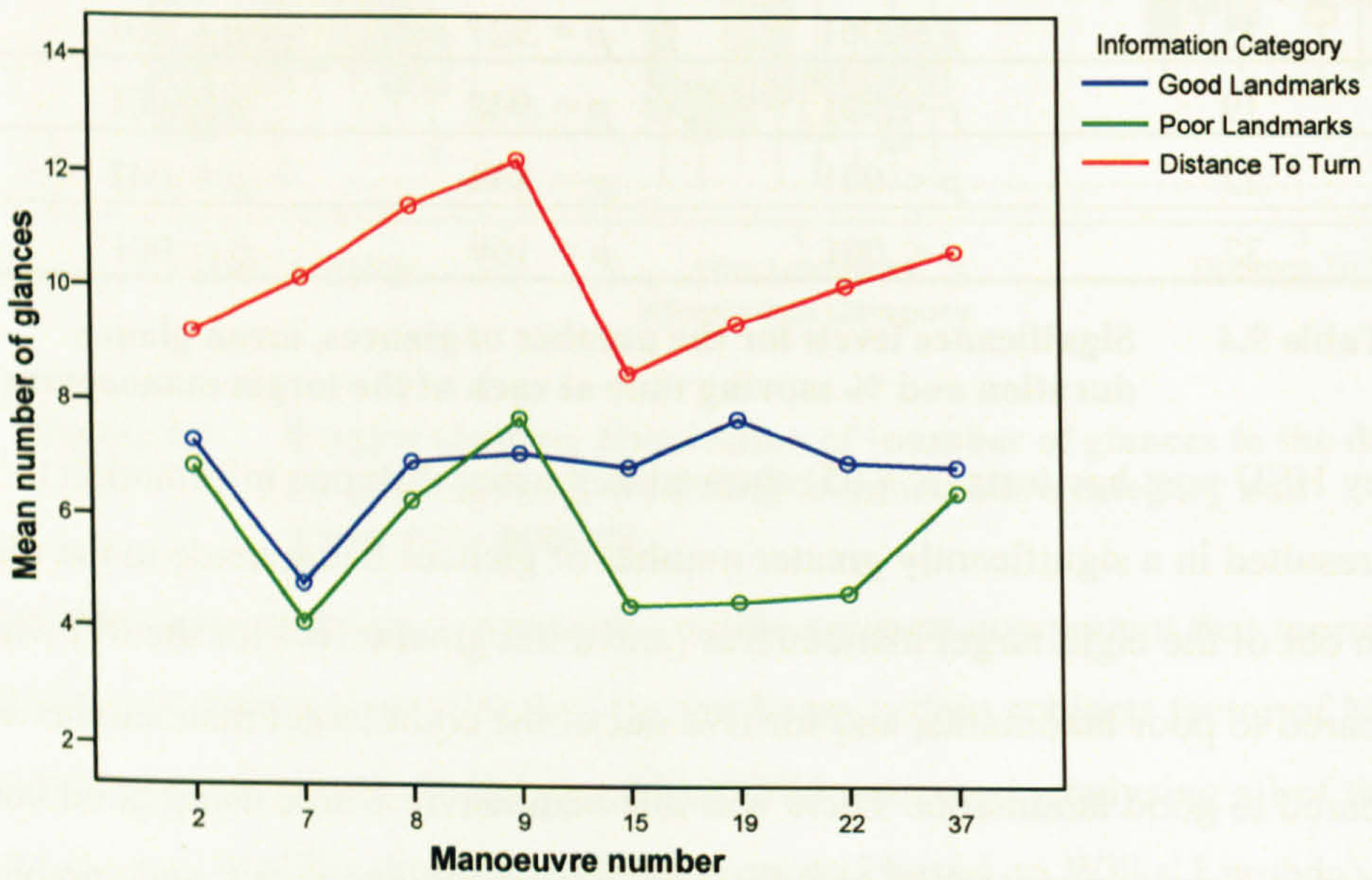


Figure 9.8 Interaction plot of estimated marginal means of the number of glances to the display, for information category and manoeuvre number

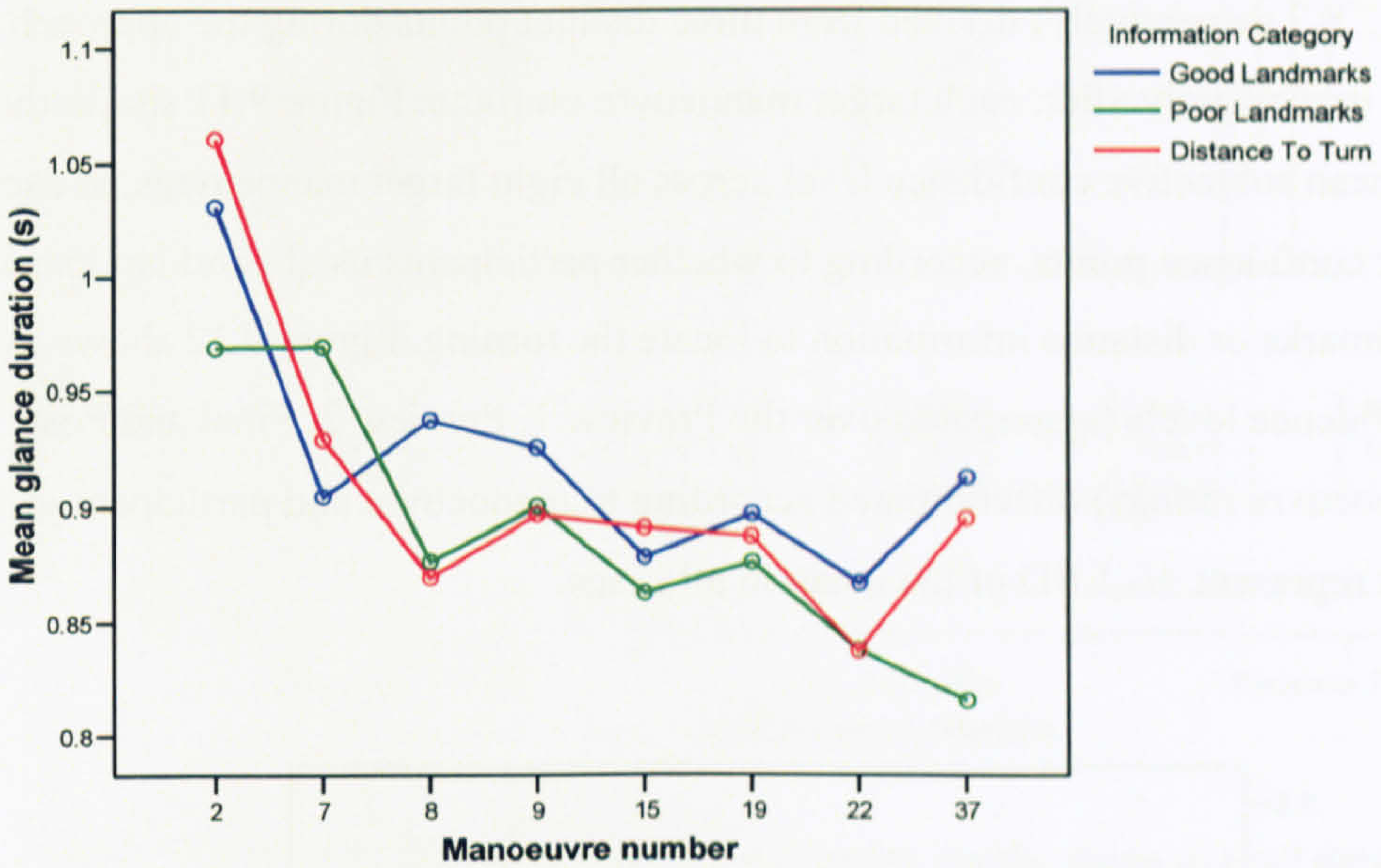


Figure 9.9 **Interaction plot showing estimated marginal means of the duration of glances to the display, for information category and manoeuvre number**

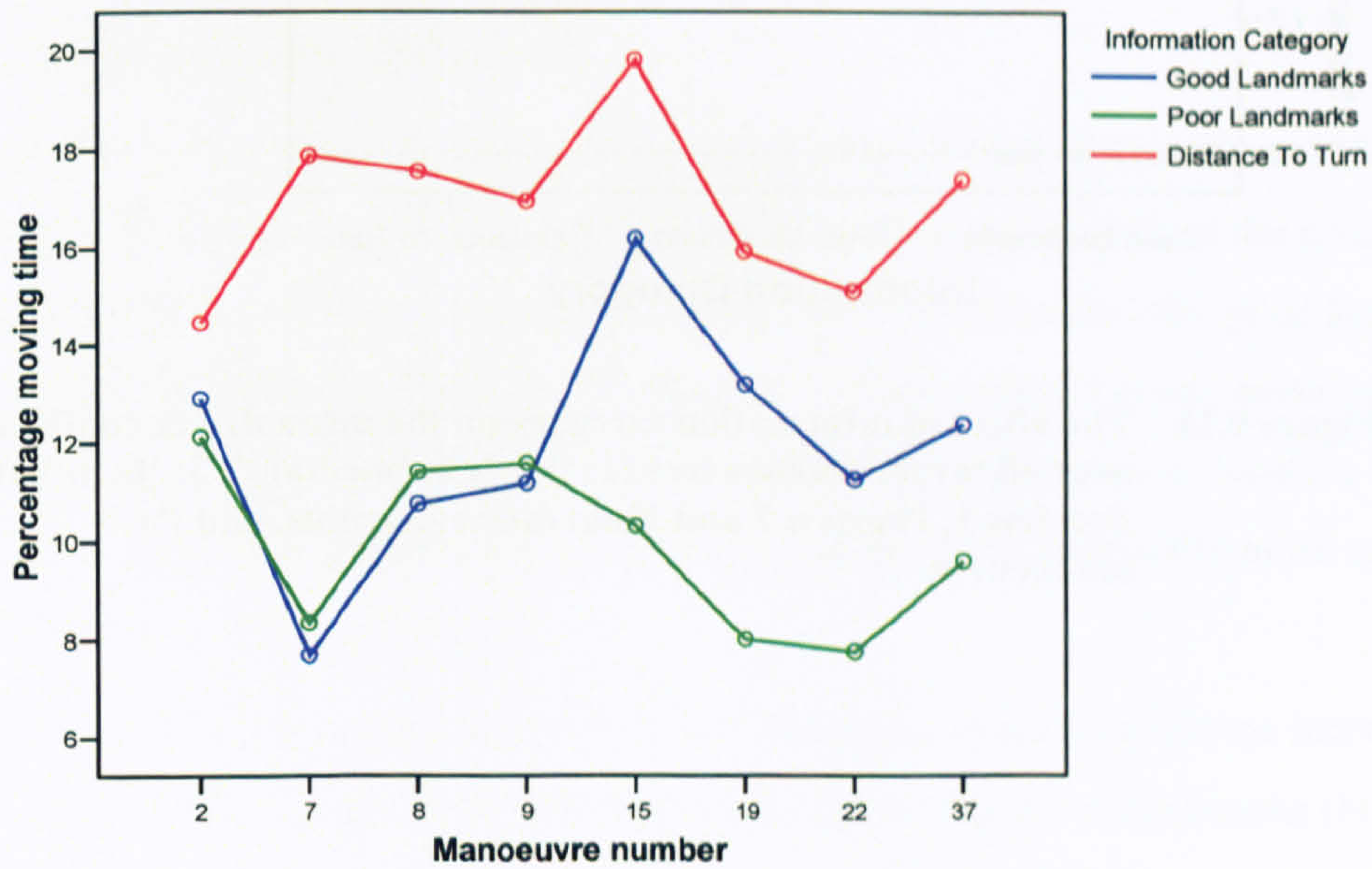


Figure 9.10 **Interaction plot showing estimated marginal means of the percentage moving time spent glancing to the display, for information category and manoeuvre number**

9.5.2 Driver confidence

The empirical data consisted of four confidence ratings of low, medium or high (coded as 1, 2, 3 respectively) derived from three distinct points during the approach to, and one immediately after, each target manoeuvre on route. Figure 9.11 shows the change in mean subjective confidence level across all eight target manoeuvres, at each of the four confidence points, according to whether participants used good landmarks, poor landmarks or distance information to locate the turning. Figure 9.12 shows overall confidence levels (aggregated over the Preview 1, Preview 2, Final and Post manoeuvre ratings) differentiated according to manoeuvre and participant group. Error bars represent +/- 1 SD of the mean in all cases.

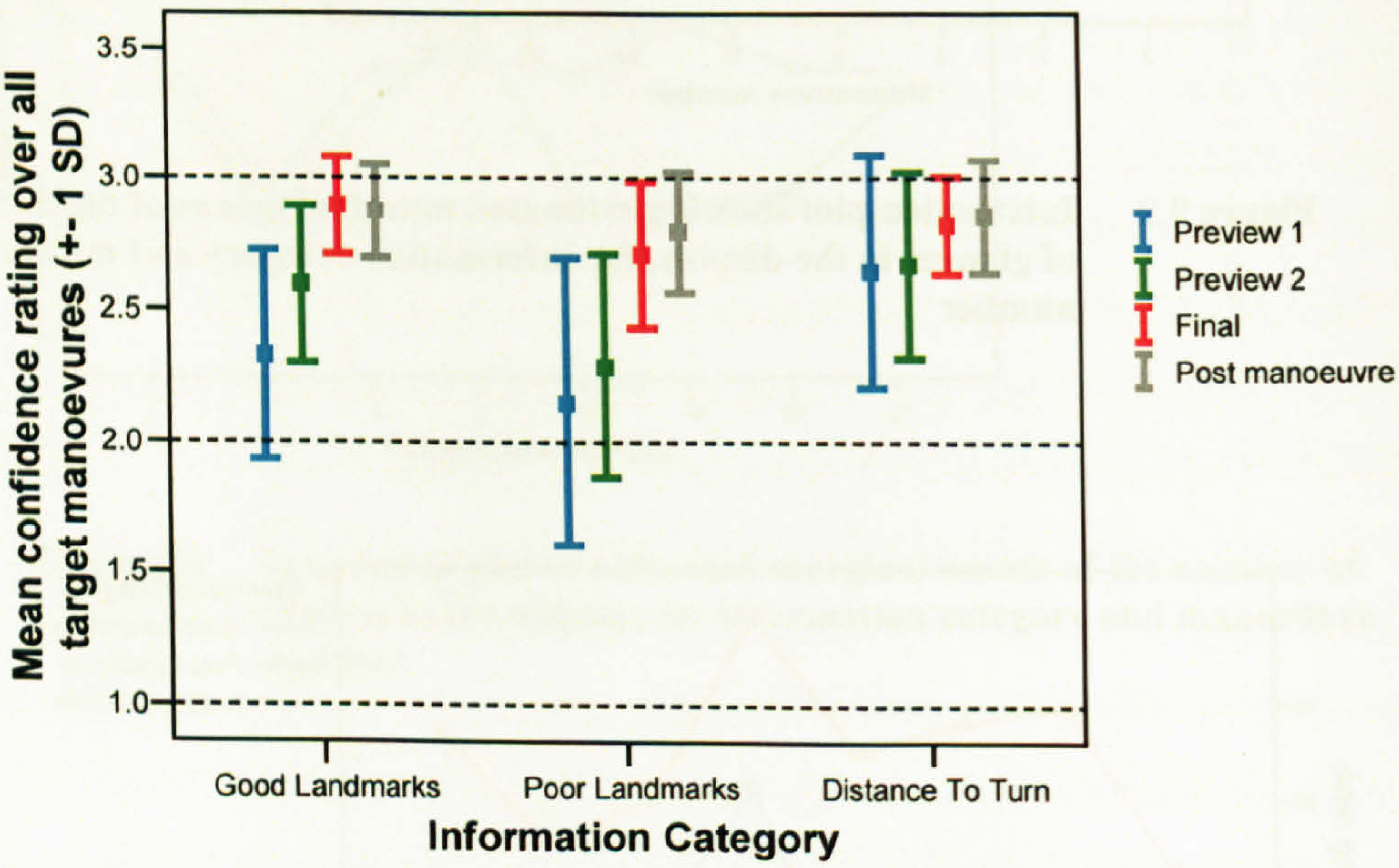


Figure 9.11 The effect of information category on the mean driver confidence over all target manoeuvres (1: 'low'; 2: 'medium'; 3: 'high') at the Preview 1, Preview 2 and Final message points, and Post-manoeuvre

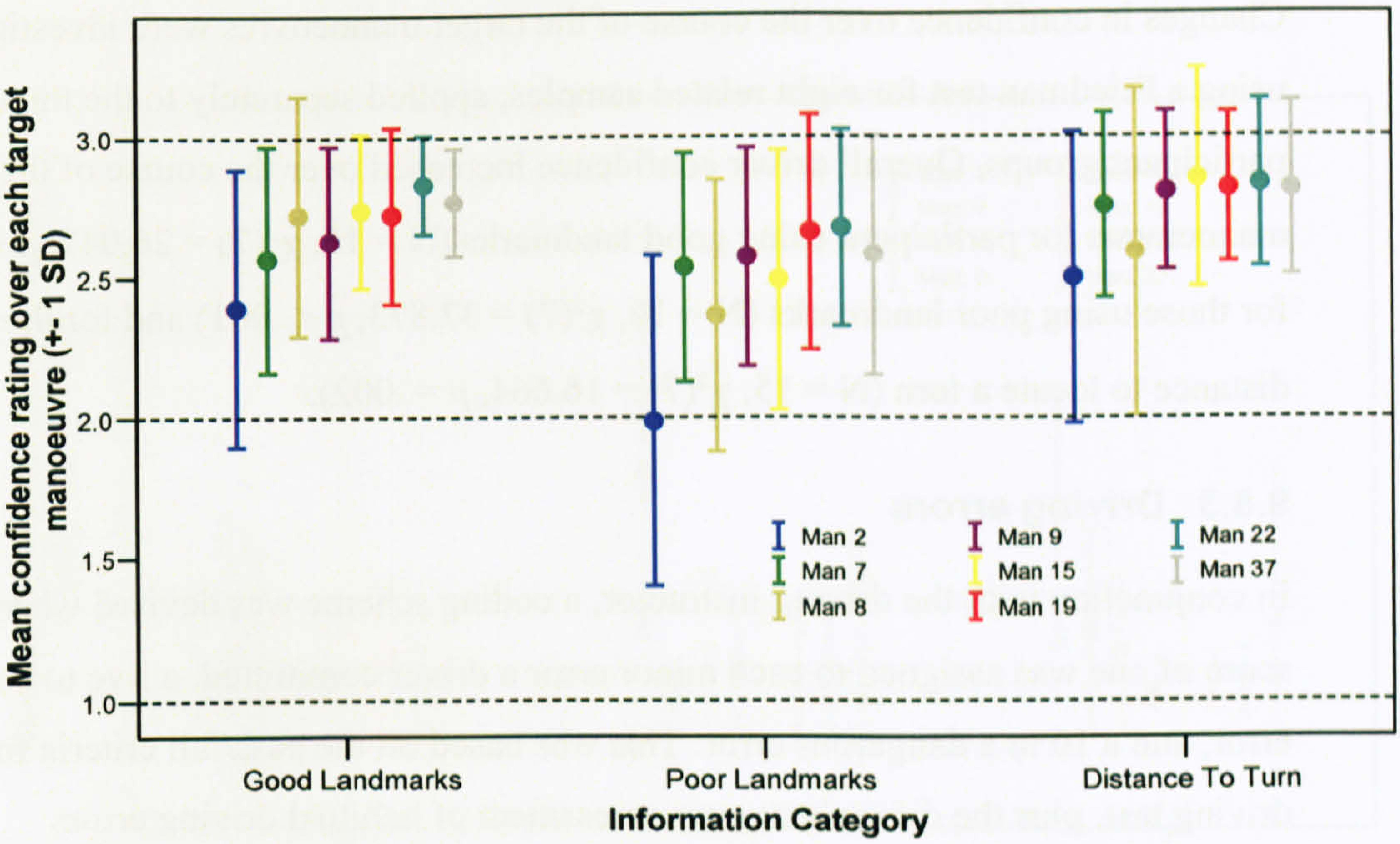


Figure 9.12 The effect of information category on the mean overall driver confidence at each target manoeuvre (1: 'low'; 2: 'medium'; 3: 'high')

A Kruskal-Wallis test for three independent samples showed that the information used to locate a turning had a significant impact on the confidence of the driver at the Preview 1 point, $\chi^2(2) = 8.484$, p = .014, the Preview 2 point, $\chi^2(2) = 8.049$, p = .018, and a marginal impact at the Final point ($\chi^2(2) = 5.856$, p = .053, but no impact on driver confidence post-manoeuvre.

Multiple independent sample paired comparisons (Siegel & Castellan, 1988, p. 213), (α =.05) were undertaken to compare driver confidence at each of the confidence rating points, dependent on whether drivers used good landmarks, poor landmarks or distance to locate a turning. At the Preview 1 and Preview 2 point, participants using distance were more confident than those using poor landmarks to locate a turning. At the Final preview point, the good landmark group were marginally more confident than the poor landmark group.

Based on a Friedman test for three related samples, driver confidence increased during the approach to a manoeuvre for the participants using good landmarks (N = 16, $\chi^2(2) = 19.6$, $p < .001$) and poor landmarks (N = 16, $\chi^2(2) = 19.966$, $p < .001$) to locate a turning. There was no significant increase in confidence when using distance information to locate a turn.

Changes in confidence over the course of the target manoeuvres were investigated using a Friedman test for eight related samples, applied separately to the three participant groups. Overall driver confidence increased over the course of the 8 target manoeuvres for participant using good landmarks (N = 15, $\chi^2(7) = 26.047, p < .001$), for those using poor landmarks (N = 16, $\chi^2(7) = 37.873, p < .001$) and for those using distance to locate a turn (N = 15, $\chi^2(7) = 16.664, p = .002$).

9.5.3 Driving errors

In conjunction with the driving instructor, a coding scheme was devised whereby a score of one was assigned to each minor error a driver committed, a five to a serious error, and a 10 to a dangerous error. This was based on the pass/fail criteria for the UK driving test, plus the driver instructor assessment of habitual driving errors representing dangerous driving (and is described in more detail in Section 8.6.2).

Driving errors were aggregated for each participant over all eight target manoeuvres. Figure 9.13 shows, for each participant group, the contribution of each level of error to the total score, aggregated across target manoeuvres, according to whether participants were using good landmarks, poor landmarks or distance information to locate a turn. Figure 9.14 shows how the driving error score varied according to the manoeuvre and the information being used to locate a turning (i.e. participant group).

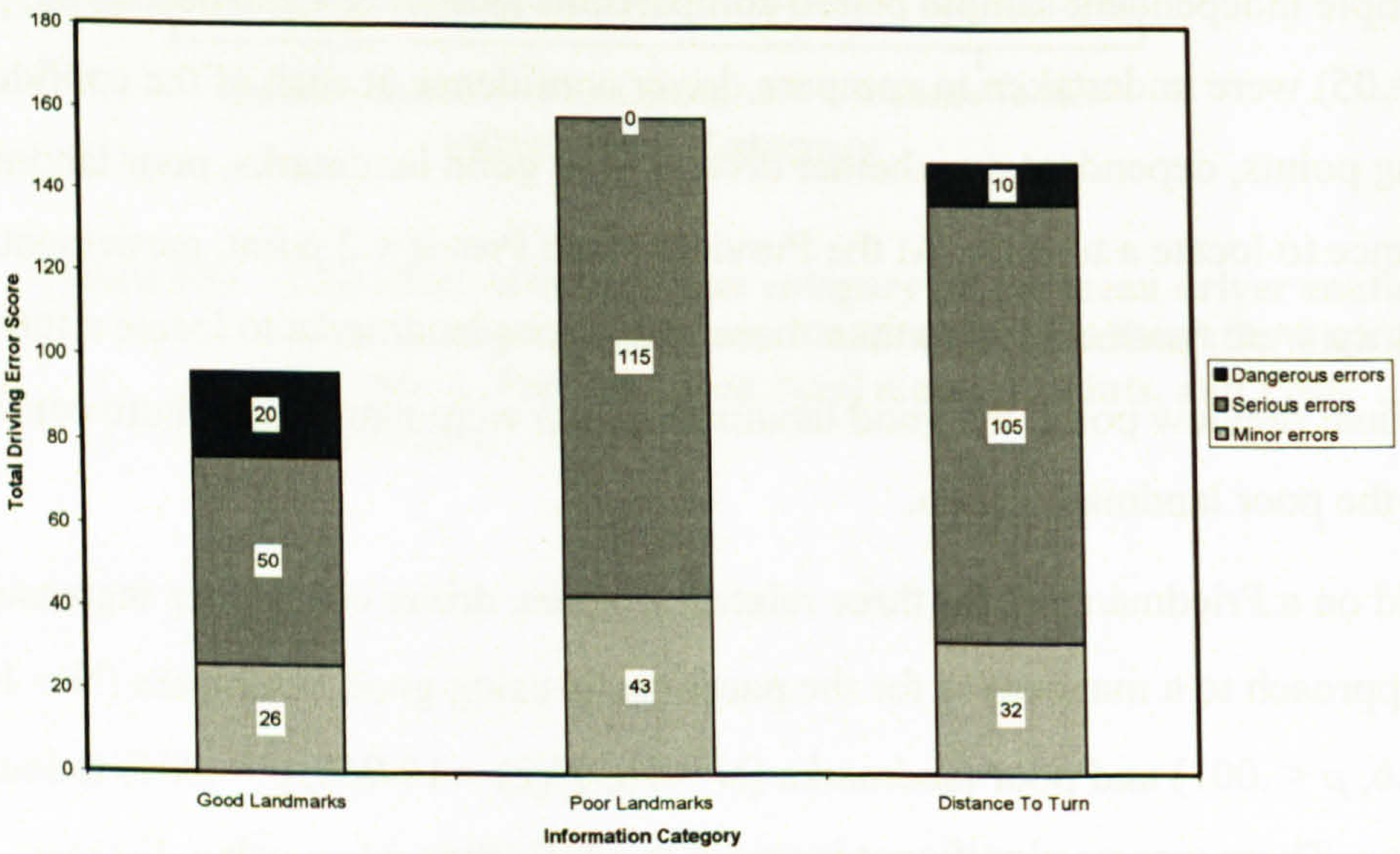


Figure 9.13 The effect of information category on the severity of errors and total driving error score per participant group (n=16, 16, 16)

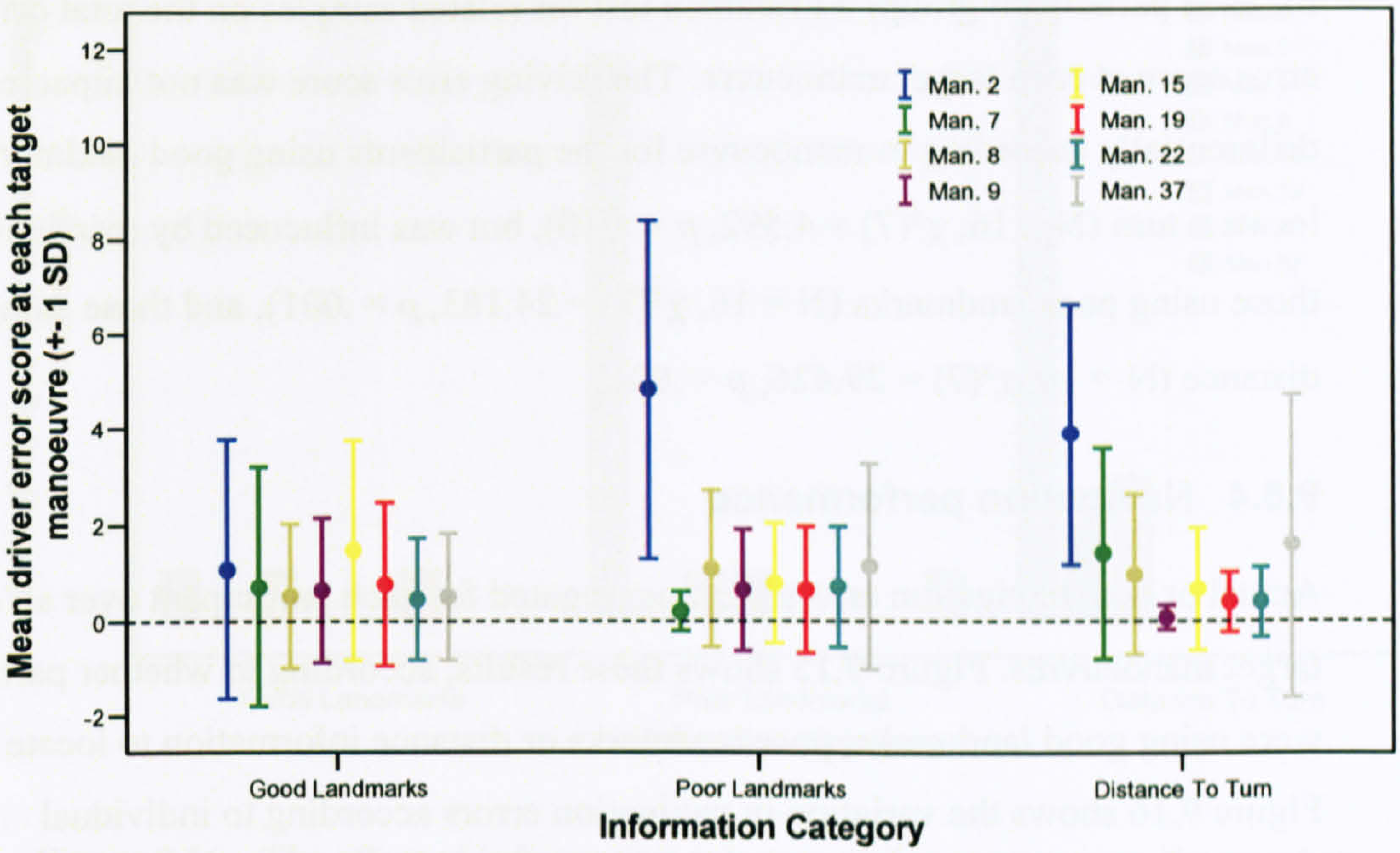


Figure 9.14 The effect of information category and manoeuvre on the total driving error score

A Kruskal-Wallis test for three independent samples showed that the information used to locate a turn had a significant impact on the *total* driving error scores ($\chi^2(2) = 7.337$, $p = .026$). Multiple independent sample paired comparisons (Siegel and Castellan 1988), (α =.05) indicated that participants using good landmarks produced a lower total driving error score than those who used poor landmarks. An analysis of the minor, serious and dangerous error scores showed that the information used to locate a turn had a significant impact on the *serious* error scores ($\chi^2(2) = 10.173$, $p = .006$), with no statistically significant differences for the *minor* or *dangerous* error categories.

An analysis was undertaken on each of the six individual driving error categories: observation; use of indicators; response to signs and signals; performance at junctions; vehicle positioning; awareness and planning (described more fully in Section 8.4.6.1 in the previous chapter). A significant effect was found for Indicator error score, $\chi^2(2) = 13.309$, $p = .001$; the above multiple comparison technique indicated that participants using good landmarks achieved a significantly lower indicator error score than those using poor landmarks and those using distance to locate a turn. No statistically significant differences were found for other driving error categories.

The effect of manoeuvre on driving errors was investigated by undertaking (separately for each participant group) a Friedman test for related samples on the total driving error score at each target manoeuvre. The driving error score was not impacted differentially according to manoeuvre for the participants using good landmarks to locate a turn (N = 16, $\chi^2(7) = 4.592, p = .710$), but was influenced by manoeuvre for those using poor landmarks (N = 16, $\chi^2(7) = 24.183, p = .001$), and those using distance (N = 16, $\chi^2(7) = 29.426, p < .001$).

9.5.4 Navigation performance

Actual or near navigation errors were aggregated for each participant over all eight target manoeuvres. Figure 9.15 shows these results, according to whether participants were using good landmarks, poor landmarks or distance information to locate a turn. Figure 9.16 shows the variation in navigation errors according to individual manoeuvres and the information that participants were using to locate turnings.

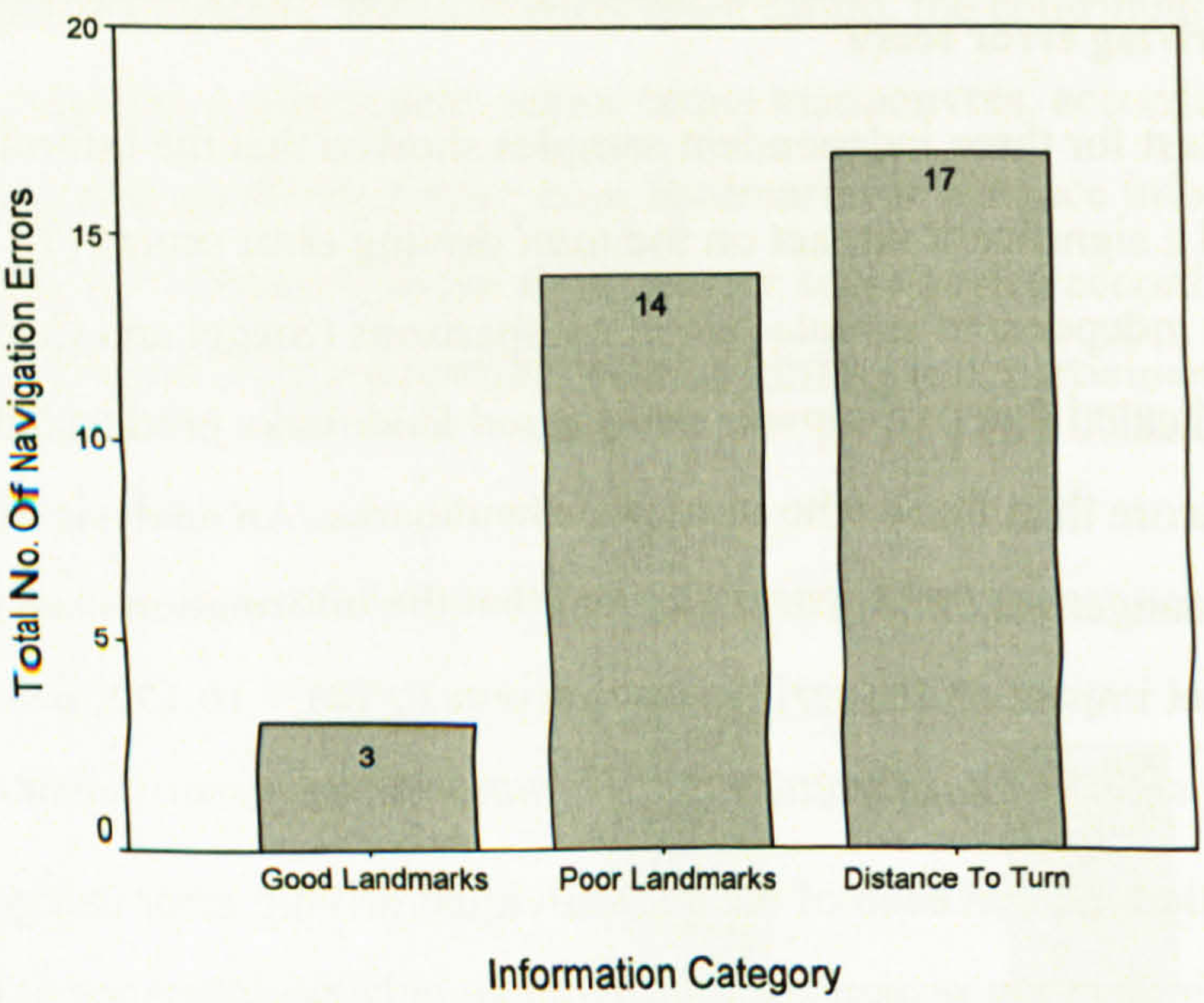


Figure 9.15 The effect of information category on the total of navigation errors made, per participant group (good landmarks: n=16, poor landmarks: n=16, distance to turn: n=16)

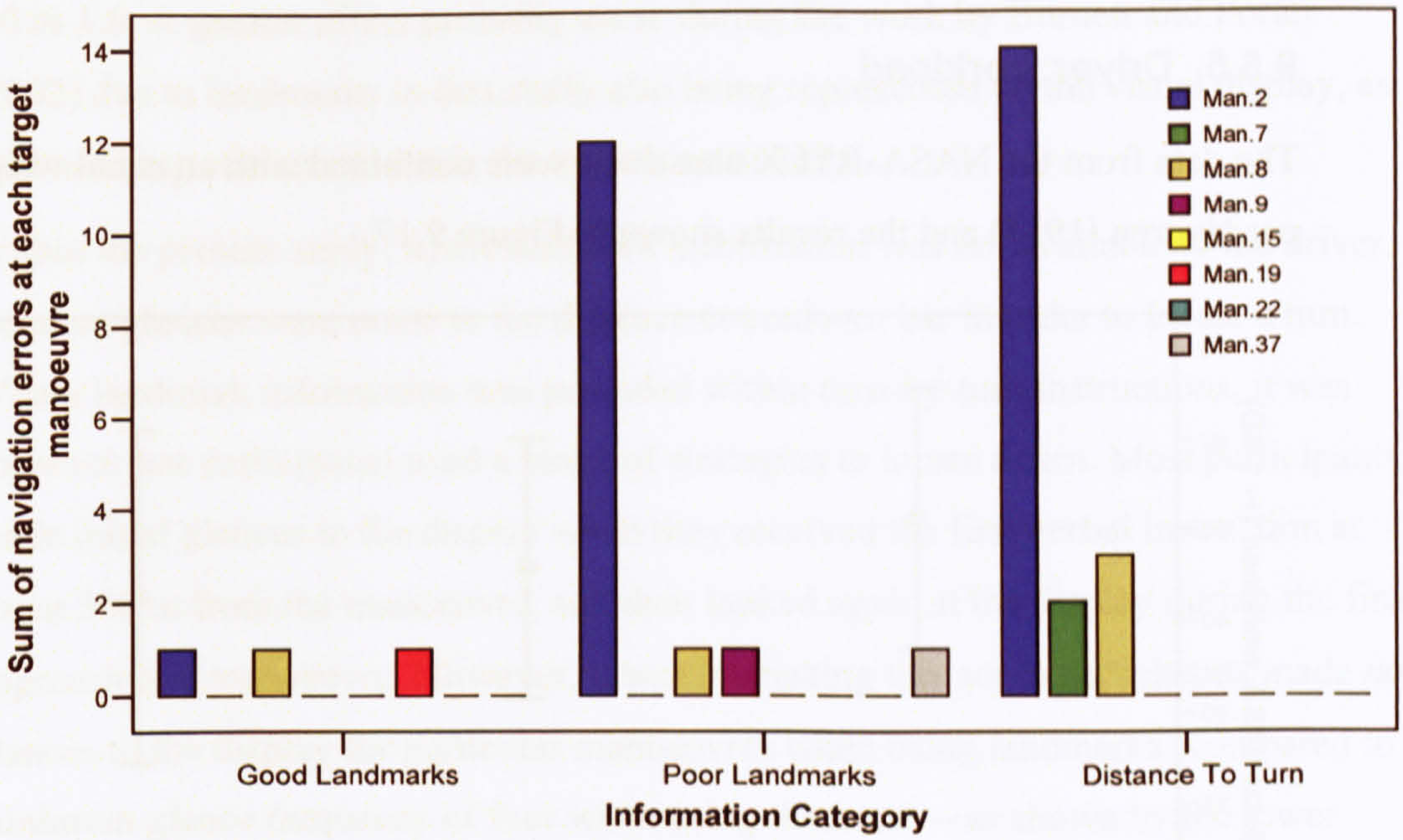


Figure 9.16 The effect of information category and manoeuvre on the number of navigation errors made at each target manoeuvre

A Kruskal-Wallis test for three independent samples showed that the information used to locate a turn had a significant impact on the number of navigation errors made ($\chi^2(2) = 18.749, p < .001$). The multiple paired comparison technique described by Siegel and Castellan (1988) ,p.213 (α =.05) indicated that participants using good landmarks committed fewer [actual or near] navigation errors than those using poor landmarks or distance information to locate a turn.

A Cochran's Q test for related binary responses ('0' = no navigation error, '1' = navigation error at a manoeuvre) indicated that the committal of navigation errors was not impacted by manoeuvre for those participants using good landmarks to locate a turning ($\chi^2(7) = 5.526, p = .596$), but was significantly impacted by manoeuvre by those using poor landmarks ($\chi^2(7) = 67.242$, p < .001) and those using distance to locate a turning ($\chi^2(7) = 73.416$, p < .001).

9.5.5 Driver workload

The data from the NASA-RTLX constructs were combined with an equal weighting as per Nygren (1991) and the results shown in Figure 9.17.

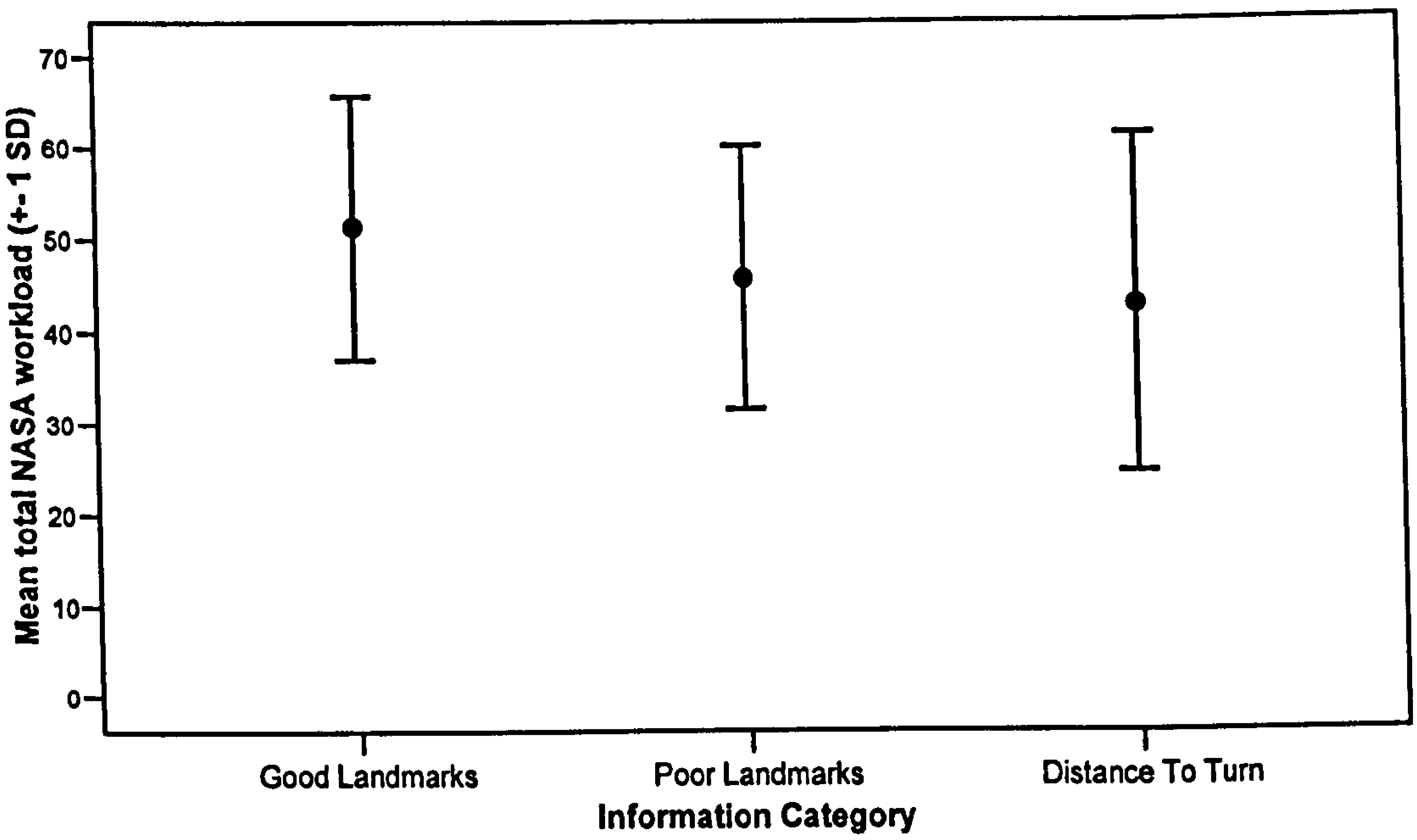


Figure 9.17 The effect of information category on the overall NASA workload rating

Based on a univariate analysis of the aggregated totals, the information used to locate a turning made no difference to the perceived total driver workload, $F(2) = 1.182, p = .316$. A similar result was achieved using a multivariate analysis to combine the six individual constructs.

9.6 Discussion

9.6.1 Visual glance behaviour

Incorporating landmarks within the verbal navigation instructions resulted in a 40% decrease in the number of glances made to the display during the approach to the target manoeuvres (Figure 9.1), with a reduction in glances occurring at all eight target manoeuvres (Figure 9.4). This reduction in the number of glances whilst using landmarks was consistent with the results of Burnett and Porter (2002) who found that emphasising landmarks (as opposed to distance) within a vehicle navigation system resulted in a reduction of glances during the approach to a manoeuvre from a mean of

5.0 to 1.6. A greater effect probably arose during the work by Burnett and Porter (2002) due to landmarks in that study also being represented on the visual display, as well as being contained within the verbal instructions.

Within the present study, when landmark information was not available to the driver, frequent glances were made to the distance countdown bar in order to locate a turn. Where landmark information was provided within turn-by-turn instructions, it was apparent that participants used a range of strategies to locate a turn. Most participants made initial glances to the display when they received the first verbal instruction at about 500 m from the manoeuvre, and then looked again at the display during the final approach to a manoeuvre. However, it was interesting that some participants made *no* glances to the display for particular manoeuvres when using landmarks (compared to a minimum glance frequency of four when using distance) – as shown by the lower whiskers in the boxplot of Figure 9.7. This underlines the *potential* for vehicle navigation systems that place minimal reliance on provision of information via a visual display, as noted by Yang and Fricker (2001).

One of the most obvious indicators of the safety implications of an in-vehicle display is the total amount of time spent looking at that display. Figure 9.3 shows that using landmarks to locate a turn reduced the percentage of time spent looking at the in-vehicle display by approximately 40 %, due to the reduction in the number of glances made to the display. There was no effect of Information category on mean glance durations; this is as expected as the visual information presented to participants was constant for the three participant groups. The mean durations as shown in Figure 9.2 and Figure 9.5 are consistent with findings from similar trials, such as those summarised by Burnett (1998), who additionally suggested that a display with a simple representation of a landmark could result in shorter glance frequencies due to the reduced level of visual demand.

An interesting finding was that a larger number of glances were made to the display when using good landmarks as opposed to poor landmarks to locate a turn. This could potentially question the definition of landmarks as 'good' or 'poor' since it indicates less eyes-on-road time for good external information cues as opposed to poor ones. However since there was no visual representation of the landmarks on the visual display, a likely explanation for this unexpected result is that demand-driven (but resource-limited) visual search behaviour resulted in participants directing greater visual attention to the roadside when searching for poor landmarks (*good* landmarks were easier to see), with subsequent reduction in attention to the visual display. In effect, since the display was not *needed* for those drivers using landmarks, participants searching for poor landmarks were too visually engaged with the external road scene to look at the visual display.

The mean glance duration reduced over the course of the eight target manoeuvres, for all three participant groups (Figure 9.5 and Figure 9.9), indicating a potential training effect over the course of the experiment. As well as this temporal reduction, visual glance behaviour was differentially impacted at the target manoeuvres according to the type of information presented to the driver, highlighted by Figure 9.10 which shows the interaction of information category and manoeuvre number on the percentage moving time metric. At five manoeuvres there was a significant increase in the number of glances when using distance to locate the turn (compared with good and poor landmarks); at three manoeuvres there was a significant reduction in the number of glances when using poor landmarks to locate the turn (compared with good landmarks or distance information). Although difficult to interpret with certainty, the relative increase in visual glances when using distance information occurred at those turns which were partially obscured, and hence difficult to locate via visual search without reference to a landmark. In contrast, the reduction in glances with poor landmarks occurred at turns where the turn itself was relatively visible, but the poor landmark was particularly difficult to locate, with greater exterior visual search being required (and hence a compensatory reduction in glances to the display). In practice the visual glance behaviour, and differential impact of information provision to the driver will be contextually dependent on a range of factors such as the visibility of the manoeuvre, speed of traffic, drivers expectations (of where the next manoeuvre is likely to be) and the nature and location of the landmark.

In this study, the visual component of the information provision was kept constant throughout the study in order to prevent a confounding of the display-induced visual demand on the driver. However this then resulted in an inconsistency of information display to the driver when using landmarks (visual distance and verbal landmarks). This is likely to have reduced the differential effect of the independent variable: a graphical representation of landmarks would have increased the ease of visually identifying the landmark, and further reduced the need to refer to distance on the visual display. In reality, the visual complexity of a landmark-featured navigation system could be reduced, with a concomitant decrease in the visual demand induced by such a system.

9.6.2 Driver confidence

Driver confidence during the *initial* stages (at approximately 450m) of an approach to a manoeuvre was higher when *good* as opposed to *poor* landmarks were used to locate the turn, but in general, lower than when distance information was used instead. This is shown in Figure 9.11, which also clearly shows the increase in confidence over the approach to a manoeuvre for good and poor landmarks, and the less transient confidence levels for the participants using distance information to locate a turn.

Alm et al. (1992) have found landmarks to improve driver confidence regarding where to turn. However the present study additionally investigated *changes in confidence* over the approach to a manoeuvre. Due to the urban driving environment (with complex road geometries, roadside furniture, parked cars etc), in most cases the landmark being used to locate a turn was not visible at the Preview 1 message point which was typically given at 450-500 m from the manoeuvre (the average distance from the turn at which the good landmarks were visible was 212m; for the poor landmarks, this was only 103m). The type of information, and the quality of any landmark used (as operationalised within this study), therefore appear to have a direct impact on a driver's confidence on approaching a manoeuvre. There was no differential impact post-manoeuvre: in most cases the street name was present and visible and participants were able to use the visual display to confirm that they had taken the correct turn.

There was an overall increase in confidence over the course of the eight target manoeuvres for all three participant groups (Figure 9.12). The temporal changes in confidence indicate that a learning effect was still occurring during the first half of the trial. Although potentially confounding, this effect did appear to be present for all three participant groups. The learning-induced effect is potentially confounding when interpreting driver confidence as a function of manoeuvre (i.e. it is questionable to compare levels of confidence at M2 with those at M37). However it is more valid to compare the differential impact of information on overall confidence at a particular manoeuvre according to different information categories. Figure 9.12 also highlights the low levels of confidence when participants were using a poor landmark to identify the turning at M2. Both the context of the manoeuvre and the characteristics of the poor landmark served to lower driver confidence at M2 – the relatively inconspicuous nature of the poor landmark against a cluttered retail background, and the proximity of a preceding major turning which required accurate distance judgement to locate it correctly.

9.6.3 Driving errors

The *aggregated* driving error scores showed that auditory instructions employing good landmarks resulted in a significantly lower total error score than using either poor landmarks or distance to locate a turn (Figure 9.13). Results regarding the inappropriate use of signals (i.e. turn indicators), are consistent with other studies that have looked at the effect on driving errors of including landmarks in navigation instructions (Bengler et al. 1994; Philips 1999). No statistically significant differences were found for other driving error categories; however the results suggest the potential safety benefits of using good landmarks to locate turns, since the highest score in each of the error categories always arose as a result of using either poor landmarks or distance to locate a turn. Analysis of the differences in the error severity (i.e. minor, serious or dangerous) contributing to the overall error score indicated that it was the error score arising from 'serious' errors which differed according to the information presented to the driver. This suggests that differences in the total error score were not merely due to differing driving styles (e.g. braking late for manoeuvres or rarely using turn indicators), as this would have resulted in disproportionate 'errors' within the minor error category.

Two main results are apparent from the analysis of driving errors at each manoeuvre, split by participant group (Figure 9.14). Manoeuvre 2 presented particular difficulties for the participants who were *not* using good landmarks to locate the turning. While the good landmark group were able to complete this manoeuvre safely, the participants using poor landmarks or distance-to-turn committed driving errors due to the confounding of a preceding major junction. Also apparent is the higher number and increased variation in errors at manoeuvre 37. These largely resulted from inappropriate speed on approach to the manoeuvre; this did not occur for the good landmark group.

9.6.4 Navigation errors

The participant group that used good landmarks to locate a turning made far fewer (actual or near) navigation errors than those using either poor landmarks or distance information to locate a manoeuvre, as can be seen in Figure 9.15. Taking into account the total number of target manoeuvres undertaken (i.e. those manoeuvres where a distinction was made between landmarks and distance information), the percentages of navigational errors made were: good landmarks (2%), poor landmarks (11%) and distance information (13%). The potential navigation benefit of good landmarks mirrors the results of other studies investigating landmarks including Alm et al. (1992) and Bengler et al. (1994), although these studies did not explicitly differentiate between good and poor landmarks. In practice, the *absolute* error rates reported in this study are unlikely to be as high within a real-use context, since the experimental route employed was deliberately chosen to be challenging, and participants were chosen who had no prior experience of using navigation systems (they were therefore more representative of first-time rather than experienced navigation system users).

Manoeuvre 2 was particularly problematic for the reasons highlighted in Section 9.6.2. In addition, the higher navigation error rate at manoeuvre 2 was probably exacerbated by it being the first target manoeuvre that participants undertook. Figure 9.16 breaks down the errors according to manoeuvre, and shows how the committal of navigation errors was highly dependent on the manoeuvre for those participants using distance or poor landmarks to locate a turn. In contrast, the error rate using good landmarks was lower, with less variation over the route. This indicates the potential for good landmarks to consistently add value to a driver following an unfamiliar route.

9.6.5 Driver workload

The results for perceived driver workload failed to detect any differences according to whether drivers were using good landmarks, poor landmarks or distance information to locate a turn. The NASA-RTLX has been successfully employed within driving research to demonstrate effects due to a range of independent variables such as form or modality of information presentation (Lee et al. 2001), and early navigation studies (Alm et al. 1992) have shown that drivers' mental workload was lower when including landmarks in navigation instructions. There are several potential explanations as to why no differences in driver workload were detected in *this* study: (1) to ensure face validity, a manipulation of the independent variable (and therefore expected differences in workload) only occurred at those manoeuvres where landmarks were present, whereas the NASA-RTLX was completed at the end of the route taking into account *all* manoeuvres; (2) unlike previous studies, the visual information was held constant across the independent variable manipulation, therefore the variation in cognitive demand arising from the independent variable was likely to be less; (3) any minor effects on workload were likely to be masked by isolated traffic incidents due to the situated context of the study. It was likely that the verbal confidence rating process that the drivers undertook at each manoeuvre increased their mental workload, in addition to the navigation task they were undertaking. Although this was a potential confounding factor, there was no reason why this should have differentially impacted on any one of the participant groups.

9.6.6 Summary of contextual influences

There were two main sets of contextual influences on the value added by landmarks at turnings off the more major route. Contextual influences generated a *need* for good information cues at turnings, and this is discussed in Chapter 8. In the present study, the impact of contextual influences was limited by selecting target manoeuvres of a similar nature (turnings off a more major road), and in particular where the affordances (Gibson 1979) of the road structure do not act to control driver speed. However, other (physical) contextual factors also helped determine the effectiveness of the cues, in addition to the intrinsic qualities of the landmarks. Their location in relation to other physical objects and the driver's direction of visual attention helped determine the extent to which they could be seen.

This highlights the importance of factors that influence the ability of landmarks to add value within a navigation system:

- The intrinsic qualities of a landmark at a particular location
- Their relationship with other physical objects in the environment
- Their relationship with the physical structures they are sited within
- The relationship with the actions of the drivers navigating the route

In a broad sense, this is compatible with descriptions of context that include location and spatial relationships, activity and time (Dey et al. 2001). Also influential are the more subtle environmental cues that are used for navigation (Burns 1997) and the environmental affordances as discussed in Chapter 8.

9.7 Design implications

9.7.1 Recommendations arising from this study

The study reported in this chapter has provided empirical evidence that good landmarks add greater value than distance information in situations where there is a lack of other relevant cues to indicate the location of a turning. By way of contrast, it is likely that if the study was replicated using turnings at T-junctions, there would be little if any difference between the value added by distance information or by landmarks due to the additional cues available and the affordances of the navigation context (a driver would see the end of the road approaching, and would stop at the junction anyway).

The chief design recommendation that arises from this study is therefore that navigation systems are developed that do not *require* that a driver uses distance-to-turn information to locate a forthcoming manoeuvre, and that good landmarks are used as key navigation cues where these are available. Good landmarks are particularly useful when the turning is wholly or partly obscured to an oncoming driver. However, good landmarks do not universally outperform distance information, since driver confidence on the initial approach to a manoeuvre was higher when distance information was being used to locate the turning. This was probably due to landmarks at a manoeuvre not being visible during the initial stages of the approach to that manoeuvre (e.g. after the Preview 1 point of Figure 9.11 at approximately 450m from the turning). In addition, the differential impact of information type (i.e. good landmarks, poor landmarks or distance information) at different manoeuvres provides evidence that the value added by different cues also depends on the context associated with a manoeuvre (even within a specific category of manoeuvres, i.e. turnings off the major road). Although difficult to interpret, this differential effect appeared to indicate that both factors to do with the quality of the landmark, and factors describing the attributes of a turning, impacted on the value added by particular cues at manoeuvres.

A hybrid approach to navigation system design may be most beneficial, where distance to turn information is used to create driver confidence during the initial approach to a manoeuvre (e.g. at 500m from the turning), and good landmarks used to help locate the turning when they become clearly visible to the driver. The visibility assessment of landmarks must to be situated – it needs to take into account the intrinsic characteristics of the landmark, plus the context associated with the turning, e.g. whether the turn is just after a bend in the road, or is partly obscured by road furniture, or inconspicuous against a cluttered background. By way of example, an initial or preview instruction to a driver may take the form 'turn left at traffic lights in 500 metres'. A final instruction could be thus: 'turn left at the traffic lights'. Since the traffic lights (or other relevant landmark) may not be visible at 500m, a distance reference such as '500 metres' provides an *indication* of the proximity of the next turning. As soon as the traffic lights are visible, they are an effective cue to identify the location of the turning, and distance information is likely to add no additional value to the navigation instruction.

In terms of information adding value (producing an outcome improvement) through enhanced design of navigation systems, good landmarks clearly added greater value than either poor landmarks or distance information. However, in order for good landmarks to be incorporated into future navigation systems, there must be a way of distinguishing between good and poor landmarks based on key attributes such as their permanence, visibility, uniqueness, location and familiarity. There must also be a means of representing these qualities on the navigable databases that vehicle navigation systems use to represent geographical space and generate directions.

One solution is for navigable databases to be populated with a wide range of landmarks, of which the best one is selected at a particular location and presented to the driver. This dynamic information selection could take into account contextual factors that would impact on the value added by the landmark. Recognition could be aided by presenting landmarks that are familiar to the individual (Kaplan 1976). In addition, some landmarks would be far more effective from a particular direction of travel (they may be wholly or partly obscured from one direction of travel). Similarly, factors such as time of day will greatly influence the effectiveness of landmarks: a landmark (e.g. a particular building) may be relatively indistinct during the daytime, but illuminated and highly visible at night. In contrast, a building that is not illuminated at night time may be much more visible during the day.

An optimum navigation system would therefore select the landmark that is most appropriate within a given context and present this landmark to the driver – the contextual sensing and adaptation of content presentation described by Dey et al. (1999) and (2001). However, this scenario (involving adaptation to context) is unlikely to happen within next-generation navigation systems due to several reasons:

- It would require extensive population of navigable databases with a diverse range of available landmarks.
- The factors that influence the effectiveness of a landmark would need to be developed into quantifiable metrics that can be used to represent landmark effectiveness.
- A set of rules would be needed that would predict the optimum landmark in any particular context (e.g. incorporating time of day and direction of travel)
- The inherent difficulty in determining the contextual factors that influence the effectiveness of a particular landmark in a specified location. However, as discussed by Bellotti and Edwards (2001), the non-human aspects of context (e.g. junction topologies and location of physical entities) may be dealt with more successfully by computers.

Due to the scale of effort required in order to populate and maintain navigable databases, and the methodological steps required to develop selection rules and quantifiers of 'effectiveness', a more likely scenario for future navigation system development is the incorporation of landmarks that are consistently relatively 'good' landmarks, irrespective of any influencing factors such as time of day and personal preferences. Landmark presentation would therefore be based on presenting, when appropriate, those that have been added to the navigable database rather than selecting the optimum from a range of potential candidates.

A final comment regarding the design implications arising from this study relates to the business models for including landmarks within navigable databases. These are key to the success of MLS, with successful revenue sharing helping to explain the success of i-Mode (Fasol 2004). In order for landmarks to be included in these databases (and therefore available as potential navigation cues), they must satisfy several key criteria:

- They must be usable for more than one purpose, since the commercial viability of developing navigable databases depends on these databases being sold to a wide variety of customers, for navigation, other MLS, town planning, highway maintenance etc.
- The data must be easily obtainable and maintainable, preferably without requiring field visits to collect information. Field visits are costly and are only undertaken when absolutely necessary (van Duren 1997). Ideally, landmarks would have a low information quality decay rate. By way of example, petrol stations have been proposed by several authors – e.g. Green et al. (1995) - as relatively good landmarks but they are liable to change ownership or use, impacting directly on their use as landmarks (May et al. 2002). Commercial alliances between information providers and systems developers could help ensure the currency of 3rd party data.

9.8 Critique of study

The aims of the study were to assess:

- The potential value of using landmarks (as opposed to distance information) as the key auditory navigation information used to locate a forthcoming manoeuvre in an unfamiliar area
- The impact of the 'quality' of a landmark when navigating and driving a complex, unfamiliar route
- The impact of context on the value added by different forms of navigation information

The study demonstrated the differing value-add of landmarks and distance information and in general demonstrated the benefits of good landmarks wrt. to a range of key outcome measures. However there were some unexpected results: (1) that fewer glances were made to the display when using poor as opposed to good landmarks (Figure 9.1); (2) the relatively stable levels of confidence on approach to a manoeuvre when using distance to locate a turning (Figure 9.11); and (3) the interaction effects of manoeuvre and information category (e.g. Figure 9.10 and Figure 9.14).

9.8.1 Limitations to the study

There were several potential limitations to the study. Where applicable to the previous study (Chapter 8), they are discussed in more detail in Section 8.8.1.

This road study suffered from the typical lack of experimental control. Within a real-road environment, it was possible to minimise, but not eliminate potentially confounding factors. Trials were undertaken mid-morning and mid-afternoon in order to minimise the impact of traffic conditions on the study (or more strictly, minimise the likely *variability* in traffic conditions between participants who were completing the study). Assumptions were made about traffic levels based on experience gained through piloting, although no formal measurement of traffic levels was undertaken.

There was a potential lack of reliability and validity with the multipliers using for the driving error score assessments, since these were new measures developed specifically for this study. This is discussed in Section 8.8.1 in the previous chapter.

There were also potential limitations with the validity of the driver confidence construct. As discussed in Section 8.8.1, it could be argued that this represented an overall 'wellbeing' rating by the driver. However, the confidence ratings given by the participants were consistent with the visibility of the landmark that they were using to identify the location of the turning. In addition, it is likely that requiring the driver to provide confidence ratings increased their workload, with this being reflected in the subjective workload ratings given at the end of the study. However, since confidence ratings were obtained for all three levels of the main independent variable (information category), the incremental workload should have been equivalent across the independent variable. As long as this incremental workload was relatively insignificant compared with the main experimental impact on workload, (as it should have been due to the demanding nature of the navigation task), it should not have unduly influenced the ability to detect overall differences in perceived workload due to the main independent variable.

The study incorporated several key balancing variables in order to match participants across the main between subjects factor (whether they received good landmarks, poor landmarks or distance information in the verbal instructions). This increased the confidence in the analysis of the impact of the main independent variable. However, since the balancing variables of navigation ability and distance judgement were only self-reported, they were not analysed as independent variables in their own right. It is recommended that future studies of this nature might objectively quantify these variables in order to assess their impact on driving and navigational performance.

There was also some evidence that the training period was at the beginning of the trials was insufficient, since behavioural adaptation (e.g. a reduction glance durations) occurred during the trials. Although potentially confounding the within-subjects factor (i.e. the particular manoeuvre), this should have impacted equally across the between-subjects factor of information type.

9.8.2 Potential improvements

There were several potential improvements that could have improved the study:

- The objective quantification of the balancing variables used in the study, rather than a reliance on self-reported values.
- A validation exercise for the driving error metric as discussed in Section 8.8.1 in the previous chapter, in order to assess its reliability.
- An ability to directly programme the routing employed by the navigation system, in order to overcome the need to enter a series of destinations and waypoints so that participants could be directed around the route. This is also discussed in Section 8.8.1.
- A longer training and familiarisation period to reduce the effect of behavioural adaptation during the trials.

9.8.3 Future work

Although the potential benefits of good landmarks have been demonstrated, there are several fundamental issues that must be addressed before they can be successfully incorporated within next generation navigation systems:

- As discussed in Section 8.8.3, basic research needs to determine the concepts that future navigation systems are based on. Future systems could move away from proceduralised information delivery, and could adapt to the availability of particular navigation cues such as landmarks and direction signs, and tailor the delivery of navigation instructions based on the need for explicit new instructions at driver decision points. A future navigation system could therefore use a combination of turn-by-turn instructions which may include landmarks as key locators, as well as using a less paced delivery of navigation instructions based on following road signs, where routes or sections of routes are clearly signposted. In this latter case, landmarks may be relatively superfluous.

- The theory and construct behind a landmark, as relevant within a driving context, needs to be better understood. Although there has been much discussion of what landmarks are, how they are defined, and the role they play in navigation strategies, there has been relatively little research into how they are defined and operationalised as effective cues within a driving context, a point made by Burnett (2000).
- The design of context sensitive navigation systems, consistent with the literature discussed in Sections 2.6.3 to 2.6.6. As discussed in this study, a range of factors relating to the quality in use of landmarks (e.g. their visibility and location relative to a turn) and the context of a particular turn (e.g. whether it is partly obscured) influence the value that landmarks add at manoeuvres. In practice these factors, and their interactions, will influence greatly the usefulness of landmarks within future navigation systems, and need to be better understood.
- The pragmatic design of such context-dependent systems, e.g. how the factors relating to context of use and information quality are measured or predicted, ambiguities resolved, and how these are incorporated into system algorithms.
- The content, depth and accuracy of information that is needed in navigable map databases in order to present landmarks to drivers, and the implications for collating, maintaining and enhancing this data.

9.9 Conclusions

Navigation systems are a category of MLS that capitalise on their key enabling properties - location and time relevance - to provide functional value (Sheth et al. 1991) to the driver. Greater contextual awareness, and adaptation in terms of system behaviour and information presentation, are key opportunities for these systems to maximise the benefits they provide, whilst minimising the resources needed to use them.

At manoeuvres where high value-add is possible (such as turning off the major route), good landmarks are value-adding navigation cues. When good landmarks (as opposed to poor landmarks or distance information) are used to locate forthcoming manoeuvres, they have the potential to increase navigation performance at the manoeuvre, increase driving performance throughout the manoeuvre, and increase driver confidence immediately preceding the turning. However, distance information may still have a useful role within a turn-by-turn navigation scenario as it promotes driver confidence during the early stage of an approach to a manoeuvre (e.g. at approximately 500m from the turn). Distance information can therefore be used to provide an indication of the proximity of forthcoming manoeuvres, but should not be the sole means of identifying the exact location of that manoeuvre.

In comparison to good landmarks, poor landmarks result in low driver confidence and increased navigation and driving errors. It is therefore critical to distinguish between good and poor landmarks, and to only use 'good' landmarks as navigation cues.

Good landmarks add particular value in the following situations: (a) where a manoeuvre is obscured during the approach to that manoeuvre; (b) where support is required for the control of vehicle speed control on approach to the manoeuvre; (c) where there are other major junctions close to the desired turn.

Although there are useful models that describe the dimensions that influence the effectiveness of landmarks, e.g. Burnett et al. (2001a), further work is needed to assess their relative importance and operationalise actual or surrogate effectiveness metrics within a driving context. This is required to enable an effectiveness attribute to be embodied within navigable databases, or calculated on the fly by navigation systems, using key object attributes and spatial data.

Next generation navigation systems can add maximum value via turn-by-turn instructions by employing a hybrid approach to the provision of information to the driver. Preview instructions (as are currently given at about 500m from a manoeuvre) should include distance to provide an *indication* of the proximity of the manoeuvre. Final turn instructions (as are typically given at about 200m and 50m) should use good landmarks such as traffic lights to locate the turning.

Landmarks are a natural component within human navigation strategies. However, they will only be beneficial if they are *good* landmarks, taking into account their:

visual characteristics; the perception of them by potential users; their location in relation to the road network; and the physical properties of the built and traffic environment, such that drivers can see, recognise and use them as navigation cues. The incorporation of poor landmarks within navigation systems is likely to be worse than not using them at all.

10 OVERVIEW AND SYNTHESIS

Research questions addressed in this chapter:	
1	Which theoretical perspectives are useful for enhancing the user-focussed design of mobile location services?
2	How are mobile location services fairing in the current consumer marketplace?
3	What is user 'value' in the context of mobile location services?
4	How can a specific mobile location service (driver navigation) be enhanced using a value perspective?
5	**What general recommendations can be made for mobile location services research and design?**

10.1 Introduction

This thesis set out to tackle the research questions shown above. To this end, this thesis has described two literature reviews and five empirical studies focussed on the user-centred design of mobile location services (MLS). Chapters 2 and 3 focused on theoretical and methodological perspectives. Chapters 4 and 5 had an explorative slant and considered MLS in general. In order to arrive at design recommendations for specific services, Chapters 6 to 9 then focused on a particular location-aware application: driver navigation systems.

This chapter summarises and synthesises the main findings from the thesis. There were six main outputs, relating to the above research questions (RQ1 – 5) as follows:

- A discussion of user value, including the contribution of various theoretical perspectives relevant to mobile applications [RQ1, RQ3]
- An assessment of the current marketplace for MLS, via a survey that investigated demographic characteristics of early adopters, user behaviour and awareness and attitudes with regard to MLS [RQ2]
- Some insights into a user's willingness to pay for mobile information access.
- Recommendations for the design of future vehicle navigation systems, including identification of the navigation cues that add greatest value to a driver in an unfamiliar environment, and the impact of the context associated with a manoeuvre [RQ4]

- Empirical evidence of the need to differentiate between good and poor landmarks to add value to a driver following an unfamiliar route [RQ4]
- Wider recommendations for designing MLS to add value to consumers [RQ5]

Each of these outputs is summarised in turn below.

10.2 A multidisciplinary view of 'value'

A simple, broad working definition of value was used throughout the thesis thus:

'Value is the actual, net benefit, that an individual derives from a service'

This definition therefore places an emphasis on *user outcomes* associated with the use of an MLS. It is by definition an expression of the situated interaction between a user and a service, and not a set of service qualities that can be measured independently of a user, or a particular context of use. For example, a service that offers location-tailored train times could be described in terms of service quality attributes (e.g. being up to date, location relevant) but cannot be described as value-adding without consideration of the user's needs, their existing knowledge, the ability to genuinely augment (with that service) the existing information environment, and the differences in outcomes that result.

It was clear that the literature offered many different views on 'value'. Consumer perspectives described value as comprising multiple components – e.g. functional, emotional, social (Sheth et al. 1991; Sweeney and Soutar 2001), plus a conditional factor. Value was also typically described as having 'get' and 'give' components – benefit arising through the expenditure of resources. The most interesting insights from a marketing perspective associated value with 'new freedoms', and the possibility of overcoming the limits imposed by the structures or constraints of life (Keen and Mackintosh 2001). From a marketing perspective, value was also described in terms of the qualities of information being presented to a mobile user via a service (Lindgren et al. 2002), or as a more general set of attributes that also include the relevance to the activities of the user (Couzens 2001) – see Section 2.6.1. In other cases, e.g. May (2001), value is implied by the reference to the location and time responsiveness of services, plus the importance of the user activity. These definitions all to some extent recognise the highly transient nature of 'value', particularly when

May (2001) describes how 'windows of opportunity open and close and are consumed by time'.

In contrast, the theoretical perspectives described in Section 2.4 were generally found to be lacking with respect to mobile computing. There is a huge literature on models based on technology acceptance such as TAM (Davis et al. 1989) and derivatives. In general, the following limitations can be identified for these models with respect to mobile computing (although it is accepted that this is somewhat a generalisation):

- Some were developed for fixed computing in the workplace, and are being applied to mobile computing contexts which are very different.
- They are narrowly focused from a single discipline, for example there is very little cross reference to other academic domains – although this is starting to change, for example Zhang et al. (2004).
- They tend to focus on usage *intentions*, rather than *actual* behaviour.
- They are often based on cross-sectional rather than longitudinal studies, with convenience samples of students who may not be representative of the population that generalisation is intended for.
- There is undue attention on sophisticated statistical analysis from a hypothesis testing perspective, rather than trying to understand the phenomena of interest.
- There may be limited relevance in the real world, for example studies may replicate unrealistic usage scenarios, or try to limit the influence of 'real' behaviour.
- There is often little or no consideration of the context of use, and the impact this has on user behaviour.

There are of course exceptions, a notable one being the study by Venkatesh and Brown (2001). This was relatively unique as it used a general guiding theoretical framework, but allowed the data to determine the constructs (i.e. an inductive element) rather than theory being used purely as a convenient reference theory. In addition, the study was longitudinal, and was able to determine what people *did*, not just what people said they *would do*. Another exception to the limitations listed above was Dillon and Morris (1999) who were one of the few to attempt a cross-disciplinary approach, but only performed limited testing of the model they proposed. In addition, Kaasinen (2005), in developing Davis' TAM (1989) recognised the need for value, not featurism, and that there are other factors particularly important within a mobile setting. She incorporated value, trust and ease of adoption into the original TAM model.

A problem with some of the technology adoption research appears to be the promoting of perceived rigour over and above research relevance, a point made by Clarke (2002). In addition, since these theories generally consider basic underlying influences, they operate at too gross a level to be able to explain or predict mobile computing behaviour within a highly dynamic usage context. By reference to the study in Chapter 5, some of the influences on users' information seeking desires (and hence their potential motivation for using services that supplement their information environment) were very short lived, and highly dependent on context (e.g. external 'resources' available), situational affordances, and other subtleties that would not be captured by general constructs.

The most insightful approaches from a user-centred design approach are possibly those from an ecological interface perspective, e.g. Flach et al. (1998), although these have traditionally been used within a work rather than consumer setting. The ecological approach takes into account the 'wider view' of interaction, the enablers and constraints within an interaction setting, and the requirements for provision of *meaning* rather than *information* via an interface. It would be interesting to see these approaches applied to settings outside of the military or process control. In contrast, standard usability approaches still (and sometimes necessarily) focus on the interaction with the interface, and not the overall impact on the individual. Much research into MLS still focuses on interface usability, rather than the wider impact on the individual, and how this may vary according to their context - as starting to be discussed by authors such as Cockton (2004b; 2006).

Information science provided one of the most useful perspectives, since it pointed towards different means of assessing value for a MLS that provides information to an end user, e.g. a normative, revealed or subjective value (Ahituv et al. 1994). It also highlighted how value-add can be described as a comparative concept based on outcomes resulting from different information environments (e.g. the difference due to augmentation via a MLS). In particular, an information value view demonstrated the need to provide benefit over and above the information sources (of whatever nature) already available, and the descriptions of information relevance and information costs highlighted the dynamic nature of these constructs and the way in which they are traded off against each other.

It is felt that a multidisciplinary perspective incorporating many of the above concepts provides the best opportunity for enhancing the design of MLS from a user's perspective. At present, there is little cross over between disciplines (e.g. as evidenced by the lack of cross-disciplinary referencing within research articles). In addition, the human factors/HCI literature often lacks the theoretical underpinning and rigour of information or management science, but this more theoretically rigorous literature may in turn lack the real world relevance and external validity of some of the work undertaken within human factors. It is suggested that future mobile research attempts to incorporate a range of theoretical perspectives, in terms of formulating the research approaches, designing the instruments to be used, and explaining the results that are achieved.

10.3 The market for location-aware services

The survey in Chapter 4 provided evidence that although consumers may adopt mobile locations services the market place must improve its efforts in terms of designing services, marketing them and making them easily accessible. This web-based survey was completed by a total of 1270 individuals; responses were then segregated based on user groups identified by Lindgren et al. (2002) in order to focus specifically on potential early adopters of technology.

These groups tended to display the following characteristics:

- Ownership of at least one mobile phone and regular use of the internet via a PC at home and/or work.
- A highly mobile lifestyle, borne out by work and non-work travel patterns.
- A general willingness to 'try out' new technology, i.e. early adopter behaviour as characterised by Rogers (2003).
- The use of a range of static and mobile ICT, but a lack of use of advanced features on mobile phones.

This latter result confirms the findings by Kaasinen (2005) that the use of mobile phones is still largely based on voice and SMS, and that the more advanced features (including mobile location services) are not widely used.

Although there was a low level of usage of mobile location services (and varying levels of awareness), respondents' overall attitudes were positive towards most of these services. The survey also identified clear negative attitudes to location-based advertising, and mixed attitudes to 'friend-finder' and safety camera services, and location-based games. These results highlighted the role played by a wide range of issues such as privacy, trust, individual versus societal values and lack of understanding of services. Table 10.1 lists, in descending order, the percentage positive attitudes to services, with corresponding levels of usage. No differentiation is made between groups since attitudes were similar for the 'young social' and 'older professional' groups, although there were some relatively minor variations according to group in terms of levels of *usage*.

Type of mobile location service	Percentage who were positive/negative towards the service	Percentage who had used/were aware of/had never heard of the service
Local phone numbers	92.9 / 7.1	26.6 / 55.2 / 18.1
Public transport information	92.7 / 7.3	18.4 / 55.7 / 25.9
Roadside assistance	92.5 / 7.5	6.4 / 52.3 / 41.4
Nearest services	88.2 / 11/8	13.4 / 62.0 / 24.6
Traffic information	88.0 / 12.0	17.8 / 65.9 / 17.1
Mobile booking/paying	86.4 / 13.6	8.9 / 44.7 / 46.4
Walking directions	84.5 / 15.5	7.5 / 43.1 / 49.4
Safety/security information	82.7 / 17.3	1.0 / 30.1 / 68.9
City guides	81.4 / 18.6	6.6 / 56.0 / 37.4
Driving directions	81.2 / 18.8	10.2 / 48.7 / 41.1
Local weather	77.6 / 22.4	14.2 / 71.0 / 14.8
Friend finder	66.1 / 33.9	1.1 / 25.5 / 73.4
Safety camera information	65.5 / 34.5	2.6 / 36.0 / 61.5
Location based games	55.5 / 44.5	1.9 / 19.6 / 78.5
Location based advertising	20.2 / 79.8	4.5 / 40.2 / 55.3

Table 10.1 Consumers' overall attitudes to, and awareness of, different mobile location services

A cross-tabulation analysis of attitudes according to whether respondents were merely aware of a service, or had actually used it, showed that a higher proportion of those who had *used* a service tended to be positive rather than negative towards that service. This lends some support to views - e.g. Schiller (2004) - that mobile location services may be due for a comeback, since those who have used services have not dismissed them outright. However, MLS in general have not been adopted widely by consumers.

There appear to be two main issues with mobile location services. On the one hand, their marketing appears to have been poor, resulting in a lack of awareness of many services. In addition, the lack of adoption as evidenced by this survey is also likely to be due to services failing to provide the perceived relative advantage and compatibility described by Rogers (2003). Although not directly verifiable from the survey, many services seem to fail the 'press the button' test – they are either not accessible, or are not perceived as adding value within mobile lifestyles, i.e. being 'better than the alternatives' discussed by Lindgren et al. (2002) when quoting Solveig Wikström.

The limitations of this market analysis are recognised, and discussed more fully in Chapter 5. In particular, it was not possible to determine the cause of the positive and negative attitudes reflected in Table 10.1 or the reasons for use or non-use. However, the combination of the lifestyle demographics, patterns of ICT use, and overall attitudes and levels of awareness relating to different location aware services are quite revealing. The results suggest the need to better understand the role of technology within mobile lifestyles, and the need to address fundamental issues such as privacy and intrusiveness before some MLS will be used by the consumer.

10.4 Willingness to pay

The investigation of a customers' 'willingness to pay' (WTP) has not been the main emphasis of this thesis. There was only a superficial review of the literature in this area, and a WTP aspect was only explicitly included in one of the studies undertaken (structured interviews described in Chapter 5). However, the generation of revenue from mobile services is critical for the commercial organisations within the mobile business models, and discussions with telecom network operators and third-party application developers have invariably led to a consideration of what consumers are willing, or not willing to pay for when accessing mobile services, and what the WTP decision is based on. There emerged from this study a wide range of factors that promoted, or lessened a WTP, as shown in Table 5.3. These were categorised under four headings: (1) financial; (2) internal; (3) information-based; and (4) outcome-based motivators. There appeared to be a wider range of motivators present than in the 'value research' described by Smith and Nagle (2002). In particular, many subtle factors only became apparent when the situated nature (Dourish 2001b) of the individual's behaviour was taken into account. A consistent theme that emerged was the need for potential information sources to add value to the consumer, i.e. do something for them, with the 'get' component outweighing the 'give' component. This was both in relation to *realised* value (i.e. based on the potential for improved behavioural outcomes), but also a comparative judgement of value (being 'better' than the alternatives out there.

An opportunity, but also a challenge for personal mobile services, is the clearly temporal nature of WTP; it can either increase as the perceived need increases, or decrease as other ways of satisfying information needs become apparent, or the perceived importance of that need decreases. An interesting conclusion regarding WTP in general was that value was a *prerequisite for*, but not a sufficient *determinant of*, willingness to pay.

It is worth noting that the study in Chapter 5 was undertaken from an exploratative viewpoint, and looked at WTP in relation to, and drew conclusions from, critical information needs rather than regular usage scenarios. It is therefore aligned with goal-driven behaviour, e.g. the 'mission' of May (2001), rather than the seamless meshing of mobile services within lifestyles, as described within a Japanese context by Fasol (2004).

10.5 Design of more effective vehicle navigation systems

Navigation systems are one of the few mobile location services that are currently being adopted by the public. Several factors have contributed to this including the emergence of portable solutions that run on PDAs/Smart Phones, reduced software and hardware costs and continuing navigable map enhancements. They are an example of successful context-aware computing, since they adapt their behaviour and information presentation to context (i.e. location), and can create functional value for an unfamiliar traveller, dependent on the extent to which other information sources (e.g. roadsigns) are useful.

The design of navigation systems for use within vehicles is challenging due to the need to present real-time information to the driver during a time and safety critical task. Due to the resource-limited nature of the driver (Yang and Fricker 2001), there can be an adverse impact on safety due to the attentional/perceptual demands (e.g. glancing to a display), the information processing demands (e.g. interpreting a route graphic in relation to the layout of a junction), or due to the driver behaviour induced by the navigation system (e.g. a sudden lane change or other manoeuvre). To enable a driver to follow an unfamiliar route, there is clearly a need to present the 'right information' to the driver at the 'right time' in the 'right format', to paraphrase Hollnagel (1988).

The study described in Chapter 7 has highlighted how information provision to a driver needs to focus on that which enables them to identity the location of manoeuvres, as well as supporting lane positioning on approach to multi-lane junctions, findings also noted by Burnett (1998) and several others. Although information *between* manoeuvres also plays a role in supporting navigation (by maintaining driver confidence), the need for this information is limited in comparison to that needed at or on the approach to manoeuvres.

A value-adding (rather than simple frequency of usage-based) analysis of navigation instructions generated for the unfamiliar driver has shown clear differences in the usefulness of different navigation cues. Taking into account their availability and the variability of value-add present within a category (and hence their potential practical effectiveness), those cues that add greatest value to a driver are junction descriptions, landmarks such as traffic lights and major bridges over the current road, and road signs, particularly those to major routes. Other specific landmarks such as petrol stations and large superstores are also potentially useful cues since they are designed to be highly visible, although may not be usefully sited *at* manoeuvres. These results confirm the survey findings of Burns (1997), but also show how those objects which are anecdotally used for navigation (e.g. public houses) are not the most effective cues, as they tend to be used in a redundant role within navigation instructions.

There is a mismatch between the information perceived as being of most value within a navigation context and that which is provided by current vehicle navigation systems, a point highlighted by Burnett (2000) and others. Current systems tend to rely on distance to turn as the predominant means of identifying the location of a manoeuvre.

The results of this study, as well as other evidence – e.g. Philips (1999), Burnett and Porter (2002) - indicate that the design of vehicle navigation systems can be enhanced by using alternative navigation cues, for example by incorporating *effective* landmarks within the information provided by vehicle navigation systems. A good first step would be to incorporate landmarks such as traffic lights within navigation systems, since they are widely available as information cues in urban environments, and as a category, consistently add value within a driving context.

Consistent with a 'realised value' perspective (Ahituv et al. 1994), the actual benefit of information to a driver following an unfamiliar route varies considerably according to the type of manoeuvre the driver is undertaking, their direction of travel, and indications of the direction of the more major route. As these factors influence the extent to which a driver is likely to make a navigation error, or suffer low navigation confidence, they also determine the benefits of navigation information at specific driver decision points. Given the need to minimise the amount of information presented to the driver, navigation systems can use the concepts of value-add (i.e. a tradeoff of 'gets' versus 'gives') to tailor the presentation of navigation instructions, as opposed to using a more rigid procedural approach to information presentation as is currently used by systems. This current lack of contextual adaptation is highlighted by Richter and Klippel (2004). This will help manage the information load on the driver, and also potentially increase the acceptability of systems as well as promoting driver confidence on approach to manoeuvres and minimising driving and navigating errors. The particular opportunities for navigations systems to add value to the driver are to (1) differentiate between potential manoeuvres which are close together, (2) clearly identify manoeuvres which are obscured on approach, and (3) highlight where the driver is required to take a turn which is not the major route. However, the success of this contextual adaptation will be limited by the challenges described by Brown and Randell (2004), Bellotti and Edwards (2001), and Greenberg (2001): that both relevant context is difficult to define and measure, and appropriate system behaviour may not be describable.

The main constraint facing designers of navigation systems is that navigation performance must be maximised while the obtrusiveness and distraction of information presentation is minimised. By incorporating greater adaptation within systems, this tradeoff can be managed more successfully. Various interface solutions can be employed in those situations where the value-add to drivers is high, for example greater pre-notification of manoeuvres, repetition of information, use of multiple information cues, and redundancy of visual and auditory output modes. Where value-add is low (e.g. continuing over a mini-roundabout), a simple visual straight on indication may be sufficient.

There is also considerable scope for new navigation system concepts to support a more natural mode of navigation. Most published research (and that within this thesis) is based on drivers using turn-by-turn information to follow a 'piloting' strategy (Allen 1999). More advanced concepts could further reduce the reliance on in-vehicle interfaces, and also mitigate the potential de-skilling consequences of current systems - an example being the reduction in the levels of cognitive awareness of environments, a problem discussed by Jackson (1998). These future research/design issues are highlighted in Section 11.3.

10.6 The need for *effective* landmarks

Previous research, e.g. Alm et al. (1992); Burnett (2000), and the study described in Chapter 7 have highlighted how landmarks are potentially useful to drivers navigating in an unfamiliar area. The study described in Chapter 7 has shown how landmarks are often used as *primary* information cues within 'optimum' turn by turn navigation instructions (although the description as 'optimum' is potentially misleading, as discussed in Section 7.10.1). Therefore landmarks are information cues that can potentially offer real value to drivers based on the realistic or revealed information value perspectives described by Ahituv et al. (1994).

The incorporation of landmarks within the instructions given by a navigation system has been recommended by a number of authors including Burnett (2000). However, their value to the driver depends on two main factors: their context of use, and the qualities associated with the landmark (i.e. extrinsic *and* intrinsic factors). The context of use is critical in determining the extent to which landmarks actually add value to the driver. The presence of other cues (such as clear roadsigns), or environmental affordances (e.g. those that force a driver to stop at a manoeuvre) potentially reduce the impact that landmarks have in terms of increasing driver confidence, enabling correct navigation errors to be made, or maintaining promoting driver safety such as correct speed control on approach to a manoeuvre. The *variation* in the need for additional information (over and above the distance-to-turn and junction layouts currently employed by systems) was highlighted in Chapter 8. A challenge for navigation systems is therefore to determine those contexts of use where landmarks actually add value to a driver, and to promote their presentation to the driver in those situations.

As well as the extrinsic or contextual factors described above, the intrinsic qualities of cues such as landmarks are key determinants of the extent to which they add value to a driver. Burnett and Porter (2002) highlight the *potential* impact of using landmarks which are less than optimal (e.g. confused with others, or partially obscured). A limitation of the requirements study described in Section 7 and the literature on the benefits of landmarks as driver navigation cues, has been a lack of analysis of the extent to which landmarks have to be 'good' landmarks in order to add value to a driver at manoeuvres. The study in Chapter 9 has compared the impact of 'good' landmarks against both 'poor' landmarks, and distance information (which is what most current navigation systems rely on for identifying the location of a forthcoming manoeuvre).

When good landmarks (as opposed to poor landmarks or distance information) are used to locate forthcoming manoeuvres, they have the following benefits:

- An increase in navigation performance at the manoeuvre.
- Reduction in driving errors (e.g. inappropriate speed control or incorrect use of indicators) on the approach to the manoeuvre.
- Increase in driver confidence immediately preceding the turn.

The impact of landmark *quality* on the driver is relatively clear cut – 'good' landmarks are better than 'poor' landmarks, and it is important that poor landmarks are not incorporated within navigation instructions since they will result in reduced driver confidence and an increase in navigation and driving errors.

In order to differentiate between good and poor landmarks, the following criteria can be used, in line with the more theoretically-derived factors proposed, but not tested, by Burnett et al. (2001a). Suggestions are given for the operationalisation of the criteria, although it is stressed that no formal validation of these has been completed:

Criteria	Potential operationalisation of this criteria
A permanent object	The object would be expected to be present in the same visual format at that location one year later
A familiar object	The recognition of the object by at least 90% of a random sample of the UK population
Unique at that location	An observer would not potentially confuse the object with other similar looking things at the same location
Usefully located	Located within 20m of the junction, or such that it is readily associated with that junction, and not with other potential turns. Where several manoeuvres are close together, landmarks will need to be more tightly coupled to individual turns; in other cases they can still be useful if they are sited further from junctions.
Visible on approach	Visible and recognisable at least 200m from the junction based on a clear approach to manoeuvre (when a driver's speed is likely to be high). This may be made speed-dependent, using the approach taken by Ross et al. (1994).

Table 10.2 Potential criteria for selection of 'good' landmarks

Good landmarks in the UK are typically; traffic lights, pedestrian lights, major bridges over the current road, petrol stations and large supermarkets or hyperstores. Traffic lights are particularly good since they are familiar and visible objects, both during the day and at night time, and are located at junctions.

Although good landmarks add value to drivers navigating an unfamiliar route, distance to turn information is still useful to drivers since it promotes driver confidence during the early stages of an approach to a manoeuvre (when a landmark may not be visible) and can give an indication of when to expect a forthcoming manoeuvre. Distance-to-turn information can help a driver locate a forthcoming manoeuvre independently of the visibility of the manoeuvre, or the visibility of landmarks associated with that manoeuvre.

Although it is possible to describe navigation cues such as landmarks in terms of their attributes in Table 10.2, in practice it is not possible to differentiate these from external factors such as their context of use. For example, the visibility of an object depends on the topology of the road infrastructure and the presence of road furniture. The uniqueness depends on the presence or absence of other similar objects. The familiarity depends on the previous experiences of the driver, and so on. Navigation systems may also be able to measure or predict those contextual influences on other characteristics (e.g. visibility impacted by obscuration due to road geometry, or the presence of buildings).

10.7 Delivering value with mobile location services

Much design of mobile services (including those incorporating location) is still driven by technological development and user interface design. Although technology and application developers are increasingly interested in an end user perspective (e.g. see Appendix 1A) there is still insufficient effort spent understanding how to create value for mobile users of IT. Without value, users will reject (at least in the longer term) new mobile technology, as highlighted by Lindgren et al. (2002) and Kaasinen (2005). Value can be delivered to the consumer by drawing on the contributions from the multiple disciplines discussed in this thesis.

There are two key prerequisites for delivering this value to mobile consumers, roughly equivalent to the motivational and action aspects of the user experience described by Kankainen (2002). The first is to understand the aspect of a mobile lifestyle that is potentially enhanced or enabled by new mobile technology. This mirrors the position of Keen and Mackintosh (2001) who underline the need to deliver 'new freedoms' to the user, rather than mere conveniences or technological features. New freedoms may be thought of as new enablers within a lifestyle, outside of the limits of what is currently possible. To underline this point, they describe how many early mobile services were merely trying to replicate the WWW, rather than deliver the information that is available on the WWW in a way that actually makes a difference to the user and is compatible with their mobile lifestyle. Similarly, the 'day in the future' scenarios which were common - and which Keen and Mackintosh (2001) are critical of - usually merely add multiple conveniences to the consumer. Mobile services must tap into basic human needs and prove themselves to be *worthy* of use (Cockton 2006) at a motivational level: the safety of self and others important to the individual, to be informed and empowered, to belong to social networks while maintaining privacy, and so on. The basic philosophy behind a service must align with one or more of these, such that a service is missed if taken away.

A MLS must also add value at an interaction level, by augmenting and enhancing the information environment, enabling decisions and actions to be undertaken that could not be achieved without that service, and ultimately resulting in improved outcomes within a given context. This component of value is dependent on the underlying concept behind a service as described above. However it also requires that, within a given context, a service 'enables' the user i.e. can result in improved outcomes (however they may be described) at a specific moment in time.

The cost benefit ratio of the mobile method must be better than any other means of potentially achieving the same goal. This determines the design of services for specific usage contexts, and generally cannot be assessed at a overall service level, since it is highly contextual, depending on the specifics of the situation the individual finds themselves in. For example, navigation systems potentially offer new freedoms to some groups of consumers (or at least *perceived* new freedoms). However, their usefulness in specific situations (e.g. during a regular commute, or at particular manoeuvres) will depend on how much they enhance that activity (i.e. make a real difference), how much financial, physical and cognitive effort is required to use them, and crucially, what other (mobile and non-mobile) sources are available that can be used instead. If the local radio gives up to date and useful travel information, then the mobile solution has to do better than this, and be as cheap, easy to access and easy to understand etc. Similarly, if an individual can ask a colleague where the nearest cashpoint is, or can follow clear signs to the train station, they are going to be extract little value from a mobile service that gives directions to the nearest cashpoint or train station - unless that location information is integrated with other information that then provides something new to the consumer. A consumer may still use a mobile service (that adds limited value) if the resources required are low enough. Regular users of navigation systems may keep them running in the background without expending effort to enter destinations (Linfoot 2005).

Mobile location services are likely to be successful if they either operate on location directly, or can use location in a *robust* manner as a surrogate for context. Drawing on navigation as an example, navigation instructions, including the presentation of landmarks are clearly using location directly to trigger and display content. However, within navigation applications, a fundamental factor that determines the extent to which the information provided adds value (i.e. the changes in outcomes produced by providing navigation instructions to that driver) is the level of familiarity the driver has with an area (Frank 2003). A driver's familiarity with an area cannot be automatically measured or computed; however a mapping of the areas that a driver has visited may be a relatively effective proxy for mapping levels of familiarity, and therefore adapting the presentation of navigation information based on familiarity.

Where the contextual factors that determine the value-add of an MLS are more varied and/or less predictable or determinable, it is likely that MLS will not be able to adapt their behaviour in a sufficiently accurate way, the point made by several authors including Brown and Randell (2004) and Bellotti and Edwards (2001). Even a simple application will fail if the contextual factors are diverse and subtle – an example being a location-based presence application that tailors a phone's ringing behaviour according to location, such as that described by Brown and Randell (2004). Location is insufficient to prescribe how a phone should behave – it will 'get it wrong' much of the time. A key success factor for MLS is therefore likely to be the simplicity with which context can be effectively incorporated, irrespective of the simplicity of the application itself. If location is a relatively direct and unique determinant of desired system behaviour, it can be used directly for system adaptation. A good example of this is described by Benford (2005), who states that 'location-based experiences could indeed introduce significant benefits for education'. Based on location-specific data delivery and capture for later use in the classroom: location is being used in a simple, and direct way. If the role of location is more subtle, then MLSs need to be designed to operate in a supporting role, i.e. acting as an assistant, deferring action to the user (Bellotti and Edwards 2001) and presenting suggestions or options based on location attributes.

A final point to make is that mobile services must capitalise fully on the *mobile* aspect of the user. Unless the capability offered is something that is *required* when the user is mobile, the mobile service adds little value compared to other sources. This is the key point made by May (2001) when he states that 'rather than focusing on the perceived limitations of the current generation of mobile devices, let's look at where the mobile platform clearly wins out over the fixed Internet'.

A good example of this is pre-trip travel information. If this is readily available via the fixed WWW (e.g. a traveller can print off an itinerary), this may offer a less effort solution than mobile provision, with the advantages of security of medium and ease of use. Of course, if travel plans change, then mobile solutions start to offer value, as demonstrated in Chapter 5. The context of the user is fundamental to understanding how a mobile solution may add value. It plays a key role in determining: (1) what a user needs are at a particular time; (2) the potential for bringing about improved outcomes; and (3) the potential constraints for interacting with a mobile device. It has long been recognised that there is 'more to context than location' (Schmidt et al. 1999b); however location can play a key role in providing value. Applications such as navigation (Chapters 6 to 9) use it directly to trigger information. However, a range of other services can use it as an *enabler* to more effective or more accessible applications by changing the depth or scope of the information world that the user interacts with. Simple examples would be the presentation of localised and personalised travel information, or historical information and networking opportunities associated with a specific habitat.

A theme that emerged over the course of the thesis (but was not investigated explicitly) was that users weren't actually that interested in location: they were more interested in the meaning attached to that location, the implications of being in that location within the wider context of their mobility, or the information that was useful to them at that location. This is consistent with the views of Timpf (2002) who identifies one of the main research challenges being the intelligent integration of information – i.e. that users are interested in the wider implications, rather than location in itself.

10.8 Design recommendations

The work undertaken in this thesis has led to a number of outputs which have been summarised above. Some outputs are related to a specific mobile location service - driver navigation - where design recommendations have been made. Other outputs have relevance to the design of mobile location services more generally. It is possible to propose a range of design recommendations for MLS – they should:

- Enable new freedoms either by overcoming existing barriers or providing new possibilities within a lifestyle.

- Address basic individual, group and societal needs rather than provide technological features.
- Be better than alternatives (of whatever form or source) that are available.
- Capitalise on the *mobile* aspect of the individual, otherwise they are merely poor replications of fixed information sources.
- Use location as an enabler to understanding information and interaction requirements, rather than it being an attribute that consumers are necessarily interested in.
- Focus on those applications where context (including simple location attributes) can reliably determine desired system behaviour (i.e. where it is not likely to 'get it wrong').
- Take into account the likelihood of 'getting it wrong' and where this may occur, be designed as an 'assistant' that supports and informs the user, without assuming control.
- Be considered in relation to the wider context of an activity (i.e. a 'use centred' perspective), reflecting the nature of mobile activities generally being integrated within a wider work or life context.

11 THESIS CONCLUSIONS AND FURTHER WORK

11.1 Introduction

This final short chapter concludes the thesis. It outlines the main contributions that have emerged from the thesis, and identifies further research issues that have arisen as a result. This section also indicates where results in the thesis have been published in academic journals.

11.2 Contribution to knowledge

11.2.1 A snapshot of the market for mobile location services

The large scale survey described in Chapter 4 presented a snapshot of the relevant demographics, behaviour and attitudes of three sets of UK early adopter groups in relation to mobile location services. Since the survey was exploratory, and used to set the context for the remainder of the thesis, there was no attempt to design the survey around constructs comprising multiple items and proposed causal links in order to test models. The survey indicated a range of potential *enablers* in the early adopter groups studied - e.g. mobile lifestyles, use of mobile technology and relative acceptance of new technology. In addition, analysis of the levels of awareness or usage of difference types of services, and overall attitudes to services, was quite revealing. It showed positive overall attitudes to most services, but a lack of usage and in many cases an additional lack of awareness of mobile location services. Where services *had been used*, this was associated with a higher rate of positive attitudes towards them. The implications from the survey were that the marketing, accessibility and design of services needed to be improved. A limitation of the survey was that there was no attempt to determine *why* positive or negative attitudes towards services were stated. This was omitted to limit the effort required to complete the questionnaire, but with hindsight should have been included.

A subset of the results from this study was published in a peer reviewed journal:

> May, A., Bayer, S. H., & Ross, T. (2007). A survey of 'young social' and 'professional' users of location-based services in the UK. *Journal of Location Based Services* (1), 1 - 21.

11.2.2 Value of navigation information to a driver

The results described in Chapters 7, 8 and 9 demonstrated the type of navigation cues, and the types of manoeuvres, where navigation value is provided to the driver. A wide range of studies undertake some years ago have identified the basic navigation information used by drivers when navigating an unfamiliar route; for a summary see Burnett (2000). However, relatively little research has used a value-based approach identifying the need at a particular manoeuvres, and the contribution made by different navigation cues. The studies reported in Chapters 7, 8 and 9 have provided additional insights into the impact of the context of the manoeuvre, including the physical context and affordances that act to influence navigation behaviour. These help determine the value of providing additional information to the driver as described by Frank (2003). In addition, the analysis of those cues used to support driver navigation, explicitly differentiated between those used as *primary* navigation cues, and those used in a *redundant* nature. This analysis has not been seen in the research literature, and provides greater insights for content selection and HMI presentation than recommendations based on frequency of usage alone.

A basic analysis of data from Chapter 7 was published in a peer reviewed journal:

> May, A. J., Ross, T., & Bayer, S. H. (2003). Drivers' Information Requirements when Navigating in an Urban Environment. *Journal of Navigation*, 56(1), 89-100.

11.2.3 The value of *effective* landmarks

Empirical evidence was presented that demonstrated how a particular mobile location service (driver navigation) can be enhanced through more effective information provision - the 'right' information as described by Hollnagel (1988). Landmarks were shown to offer significant benefits over the distance-based information that current vehicle navigation systems are based on. This in itself is not a new contribution, since several authors, e.g. Alm et al.(1992) and Burnett (2000), have long since commented on the benefits that landmarks offer within a navigation context. However the study reported in Chapter 9 offered greater ecological validity, and more insights than many of the previous studies, due to the use of a real driving context, a driving instructor to assess driving errors, and the determination of the temporal impact on driver confidence on approach to and throughout a manoeuvre. Burnett and Porter (2002) highlight the potential impact of using landmarks which are less than optimal (e.g. confused with others, or partially obscured), but did not set out to test this hypothesis.

An explicit *new contribution* was the empirical investigation of how the quality of the information cue (landmark) affected the value provided to the driver. If landmarks are to be incorporated into navigation instructions, this consideration is crucial, due to the widely varying nature of available landmarks, and the need to manage information presentation to the driver in order to minimise additional mental (and particularly visual) demand (Lansdown 2000). Incorporating good landmarks in navigation instructions added value over using distance-to-turn information; however presenting poor landmarks to the driver was detrimental compared to the use of distance to locate a turning.

The findings reported in Chapter 9 were published in two peer reviewed journals:

> May, A., & Ross, T. (2006). Presence and quality of navigational landmarks: effect on driver performance and implications for design. *Human Factors*, 48(2), 346-361.
>
> May, A., Ross, T., & Osman, Z. (2005). The design of next generation in-vehicle navigation systems for the older driver. *Interacting with Computers*, 17, 643-659.

11.2.4 The benefits of multidisciplinarity

Discipline	Contribution
Consumer marketing and retailing	Components of value that influence consumption decisions; a focus on functional value
User centred and ecological design	The emphasis on the user; a wider context of use; usability
Context aware computing	Contextual discovery, adaptation and information augmentation
Models of technology adoption	The importance of relative advantage, ease of use, user-task match
Information value	An outcome measure of information value; importance of information relevance and costs
Mobile location services	Freedoms not features; location and time responsiveness
Application-specific literature (navigation)	The strategies and information used for navigation; the potential enhancements

Table 11.1 The multidisciplinary contributions

It is hoped that this thesis demonstrates the benefits of employing a multidisciplinary perspective to a user-focused design of MLS. This multidisciplinarity is recommended by Rasmussen (2000) and Stay (2001) but is rarely seen in published research. Table 11.1 above summarises the contributions of the different bodies of literature discussed in this thesis.

User centred design was used as a guiding philosophy throughout the thesis. However, at an overall level, the multidisciplinary perspective enabled a focus on those MLS which (1) potentially add value within mobile lifestyles by being consistent with the 'new freedoms' described by Keen and Mackintosh (2001) and (2) can potentially use location successfully due to a direct link between location and desired application behaviour, as well as a relative lack of impact of additional contextual influences. Few published studies explicitly consider the overall benefits to a user, i.e. whether the concept for a service potentially adds value within a mobile lifestyle. There is a clear dichotomy between mobile consumer and mobile work research, since mobile work applications must generally *demonstrate* tangible benefits to the end-user and organisation, whereas the benefits of mobile *consumer* applications are generally less quantifiable.

Most HCI studies of mobile information systems do not highlight the information providing role of these services – i.e. that they supplement or enhance the information environment of the mobile user. It is rare to find *any* references to information value within the HCI literature. At a more detailed empirical level, information value perspectives influenced the experimental designs and analysis undertaken in this thesis, and in particular:

- A 'revealed value' (Ahituv et al. 1994) perspective based on determining user outcomes.
- A comparative analysis, based on outcomes derived from exposure to different information environments.

In addition, both an 'information value' and a 'context aware computing' approach highlighted the highly contextual nature of the interaction with mobile services based on the situated nature of human actions (Dourish 2001b).

The main theoretical benefit of a multidisciplinary approach has been highlighting the need for more effective models for explaining and predicting the use of mobile services by users, based on the premise that they will only be used if they add value within a particular context of use. Empirical studies of mobile services based on TAM (Davis et al. 1989) are still being seen in the literature, despite the fact that they are often extremely poor in predicting levels of *actual* use - e.g. Hung and Chang (2005). TAM was originally designed for a work-based use of static ICT, where the context of use is relatively definable and static, user actions during use are focused on single goals, and there are relatively few constraints on successful interaction with ICT. In contrast, mobile interaction usually occurs within a multitasking and dynamic environment, with 'windows of opportunity' for adding value, and a range of usage constraints. A multidisciplinary approach has helped identify the need for new models (perhaps based on Figure 5.2) that address both the bigger theme of 'making a difference' and the micro-level situational influences on the individual. These should provide greater insights and help define what 'right' means as described by Hollnagel (1988).

11.2.5 The highly contextual and multidimensional nature of value

The exploratory study in Chapter 5 demonstrated the highly contextual nature of the value that could be derived from a mobile information service. This also showed that although location plays a key role in determining the value of information to users, it is by itself insufficient. It has long been recognised that 'there is more to context than location' (Schmidt et al. 1999b), and that context is highly dynamic and multidimensional (Greenberg 2001). However few studies have been seen which attempt to describe access and use of information in relation to the multiple influences within a mobile context of use. This study highlighted a range of barriers to information acquisition and use, and a set of influences on willingness to pay, expanding on those described by Smith and Nagle (2002). An interesting finding was that added-value was a necessary, but insufficient prerequisite for a willingness to pay.

In addition, this study attempted to summarise the key influences on 'value' for a mobile consumer, as shown in Figure 5.2. The study also suggested a set of opportunities and challenges for the successful design of mobile services, including those based on location. Although the results were interesting, this study had several limitations: it was small scale, retrospective, and relied on a single source of data (self-reports).

11.3 Future work

A range of potential avenues for further research has come out of this thesis. These are outlined below.

11.3.1 Theory development

There is a need for development and validation of theoretical frameworks that can drive the user-centred research and development of value adding mobile services. There are many established models such as TAM (Davis et al. 1989), TPB (Ajzen 1991) and TTF (Goodhue 1995), and later developments including integration of models. These models generally fail to take into account the mobile aspect and contextual interdependence of many mobile services, and are not necessarily appropriate for 'mobile' research. Usability approaches focus more on the usability of services, rather their usefulness, and motivation to use, a point made by Dillon and Morris (1999) several years ago when suggesting that a combined MIS and usability approach may be useful.

Lurie (2004) has stated the crucial importance of understanding how information-rich environments affect consumer decision making. A cognitive consumer decision-making model is described by Peter and Olson (1999). This describes how external (e.g. seeing a restaurant) and/or internal (e.g. feeling hungry) stimuli initiate a cognitive process consisting of interpretation and integration. The *interpretation* process consists of attention (the selection of stimuli for interpretation by the cognitive system) and comprehension (how cognitive representations are created that represent subjective meaning of the information contained within those stimuli). The *integration* process describes how consumers use different types of knowledge to form overall evaluations of products, other objects and behaviours, and to make choices among alternative behaviours. The key processes at the integration stage are the formation of consumer attitudes and intentions. These are impacted by the knowledge, meanings and beliefs held by the consumer, and ultimately lead to decisions or choices concerning consumer behaviour. Rather than using these types of models in relation to *brands*, it may be possible to adapt them so they are applicable to the choice of *channels*, i.e. to explain how a mobile service competes with other sources to satisfy users' needs.

Alternatively, development of models such as that used by Wang and Soergel (1998) – see Figure 2.8- could incorporate the major contextual factors that influence value judgements and decisions. These could be used in a descriptive (explaining behaviour), or prescriptive (design-focussed) manner, as discussed in Section 5.6.

Kaasinen (2005) shown in Figure 5.2 took an interesting first step in adapting an existing model of technology acceptance to the mobile arena. She recognised that adoption models derived within a work context are insufficient for mobile consumer services. New models such as this need to be tested to determine their effectiveness in a mobile context. The independent variables in such models would include key aspects of context that, if manipulated, would influence the degree to which a service would add value to the individual (e.g. potentially provide new freedoms). The dependent variables should be actual usage, and willingness to pay for services. A challenge to such theory development (and one that may be insurmountable) is that the potentially influential aspects of context are highly diverse, potentially unbounded, and not necessarily quantifiable or computational (Bellotti and Edwards 2001). However, for any given mobile service, it should be possible to determine the over-riding factor(s) that influence the value provided by a service. An example for navigation services would be the level of familiarity with a given environment – hence any attempt to design value-adding navigation services should take this key influence into account.

11.3.2 The role that location plays

Some services use location as a direct input to specifying how applications should behave. Navigation is an obvious example, where the user location in relation to environmental features determines the presentation of navigation instructions. Services that incorporate location attributes were originally marketed as 'location-based' services, highlighting this technological capability. However, it is increasingly recognised that users are not interested in location, rather the implications for what that location means to them, or what they need to do at that location. This is a similar observation to that made by Menou (1995a) when he states that 'people do not use information, they just take care of their business'.

There may be three roles that location can play within mobile service design:

1. A direct triggering of information or service behaviour at a specific location

2. As a surrogate for detecting changes in context and altering interactions accordingly
3. As a general means of increasing the relevance of services offered to the user, based on the notion that all user actions are situated (Dourish 2001b) and therefore the information needed to support those actions is to some extent location-dependent.

It is relatively straight forward for future research to investigate point 1 above within a range of application domains, based on a user (or 'use') centred design process. Future research should also investigate point 2 above – Bellotti and Edwards (2001) - although it is likely that even accurate location determination will in many cases prove insufficient for describing context in a way that can lead to enhanced services.

Point 3 above potentially enables location tracking within mobile phones to benefit many mobile services. Indeed, during a UK fact finding visit to Japan (DTI 2005), it was 'made very clear that the operators and content providers see 'location' as one of the cornerstones of future services'. Location can potentially alter the information that a user 'sees', for example reducing the size of the 'information world' that they must interact with when performing active information search. Future research should investigate how location can operate in the background to lead to services which are easier to use for the individual. This should also investigate the extent to which location should be transparent to the individual, without the need to market services as 'location-based'. In addition, research should investigate ways of integrating these services within the wider user experience. Rather than a series of distinct applications, services should reflect the multitasking nature of mobile lifestyles instead of the need to support a series of distinct user tasks.

11.3.3 Applying value-based design approaches

Although Section 10.7 provided some pointers towards how value may delivered by mobile (location) services, this is currently little more than a framework, or a set of guidelines. In addition to the need for situated inductive and deductive research highlighted in this chapter, there needs to be greater application of value-adding perspectives within product design. Value-based product evaluations (based on whether they 'make a difference' within a given context of use) would both highlight the limitations of many mobile offerings, and also demonstrate the lack of insights generated by standard usability assessments. By way of example, assessment of a mobile map application in this way quickly led to the conclusion that it was relatively well designed, but of virtually no use within the specific context of use. Why would you wait for and pay for information when you can simply ask passers-by for directions? The application was technically impressive and usable, but not useful. It simply didn't 'do enough' for that set of users within that usage context.

Value-based design approaches would identify where real benefits are achievable for different groups in varying usage contexts, and also take into account affordances (task-related, social, physical etc) to add value within dynamic environments. Note that 'affordance' is used in the widest sense of the term to mean those extrinsic factors that offer opportunities, constraints, or otherwise direct the future activities of the individual within a given environment.

11.3.4 Understanding willingness to pay

The investigation of willingness to pay was not an explicit objective of this thesis. However, it was apparent that the determinants of willingness to pay within a mobile usage context are still not understood and are more wide ranging than those described by Smith and Nagle (2002). Although a service needed to provide value to an end-consumer, this in itself was shown to be insufficient to generate a willingness to pay. Future research needs to be undertaken to better understand the motivators for willingness to pay, the impact of individual and contextual influences, and the implications for mobile service design and delivery.

11.3.5 Future design of vehicle navigation systems

There are various avenues for research which can improve the design of vehicle navigation systems (see also Sections 7.10.3, 8.8.3, and 9.8.3). In order to incorporate landmarks within the instructions presented to drivers, more research is needed to understand how to operationalise (i.e. measure or predict) the factors that describe the effectiveness of landmarks (e.g. their visibility, familiarity and uniqueness) and develop the algorithms needed to incorporate these factors in the generation of navigation instructions. In addition, since some of these factors are not purely intrinsic factors (e.g. visibility depends on the road geometry, presence of road furniture and parked cars, background, weather conditions etc), there is a range of environmental and contextual information that is needed to determine the effectiveness of landmarks. It is necessary to understand the content, depth and accuracy of information needed on navigable databases, and the implications for collation, maintenance and transformation of this data.

In addition, there is opportunity to develop new concepts for navigation systems that move away from the proceduralised, turn-by-turn mode of operation based on piloting strategies (Allen 1999). Future systems could be based on the model of a resource managing 'travel assistant' that increases the context-dependent relevance (and hence cost-benefit ratio) of information presented to the driver. It may be possible to develop totally new concepts for navigation, for example an interconnected network of vehicles may enable a 'follow that blue van' concept, where the navigation task becomes one of interaction with the environment, rather than interaction with an in-vehicle HMI.

Whatever future concepts are developed, the following issues need to be addressed:

- The need to develop more natural 'heads up' interaction modes, including those that are purely auditory-based.
- Design of navigation concepts that enhance, rather than limit the development of local knowledge (Jackson 1998).
- The potential for treating navigation as a means to an end, and an enabler within a mobile lifestyle, rather than an activity in itself. This implies integrating navigation within other functions, such that the navigation function itself becomes less overt.

11.4 Conclusions

The main conclusion of this thesis is that much greater emphasis needs to be placed on understanding user value within a context of use and developing mobile solutions that provide this. A multidisciplinary approach is highly beneficial, since it can draw upon the wide range of views which are useful in understanding how users interact with, and gain benefit from, technology.

Terms such as 'mobile location service' or 'location-based service' are not necessarily very useful and may hinder the uptake of services that incorporate an element of location. Consumers aren't interested in location – they are interested in 'getting on with their lives'. Location can therefore be used as an enabler to help provide meaning via an interface to a user, based on placing the user at the centre of their own world.

Irrespective of what mobile service is being designed, to be truly successful, the concept behind a service must add real value to the consumer, and the interactions with the service must be based on a positive cost-benefit ratio to the user within a specific context. Ensuring usability and optimising interface design will not by themselves be sufficient to ensure successful services.

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13 APPENDICES

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APPENDIX 1A (CHAPTER 1): USER ISSUES FROM A MOBILE HANDSET MANUFACTURER

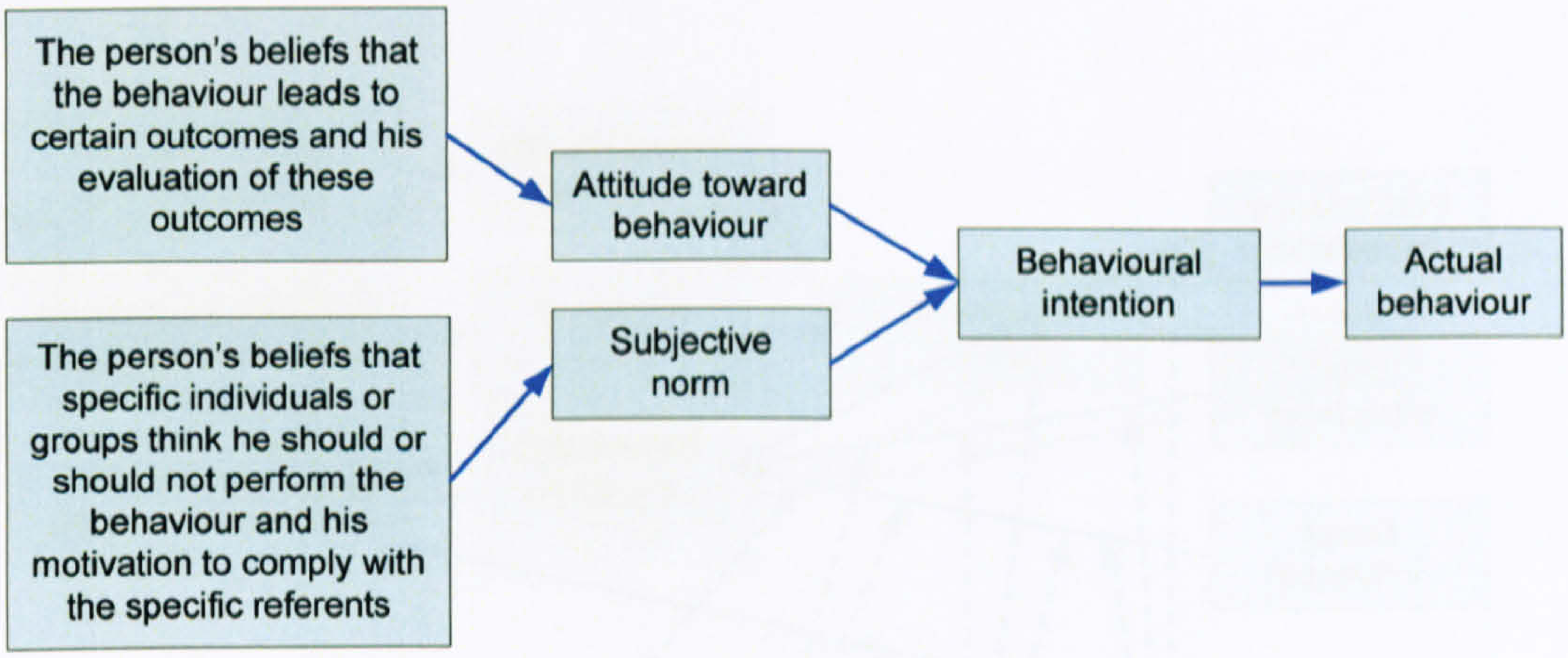
This Appendix lists the main issues raised by a handset manufacturer seeking to find relevance in human factors research undertaken at ESRI (Personal Communication):

1. What are the key issues that drive adoption of new services (e.g. price, community of users, convenience, other lifestyle issues, fashion etc etc)?
2. What are the key issues that inhibit the adoption of new services (e.g. price, poor usability, don't understand the benefits etc etc)?
3. What themes have emerged as the types of services that users might find useful and valuable?
4. What were the surprises, if any in terms of conclusions and findings?

APPENDIX 2A (CHAPTER 2): THEORY OF REASONED ACTION

This figure shows the Theory of Reasoned Action (TRA):

Ajzen, I., & Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall.



A person's behaviour is determined by their intention to perform that behaviour, which is jointly determined by their attitude and subjective norm concerning the behaviour.

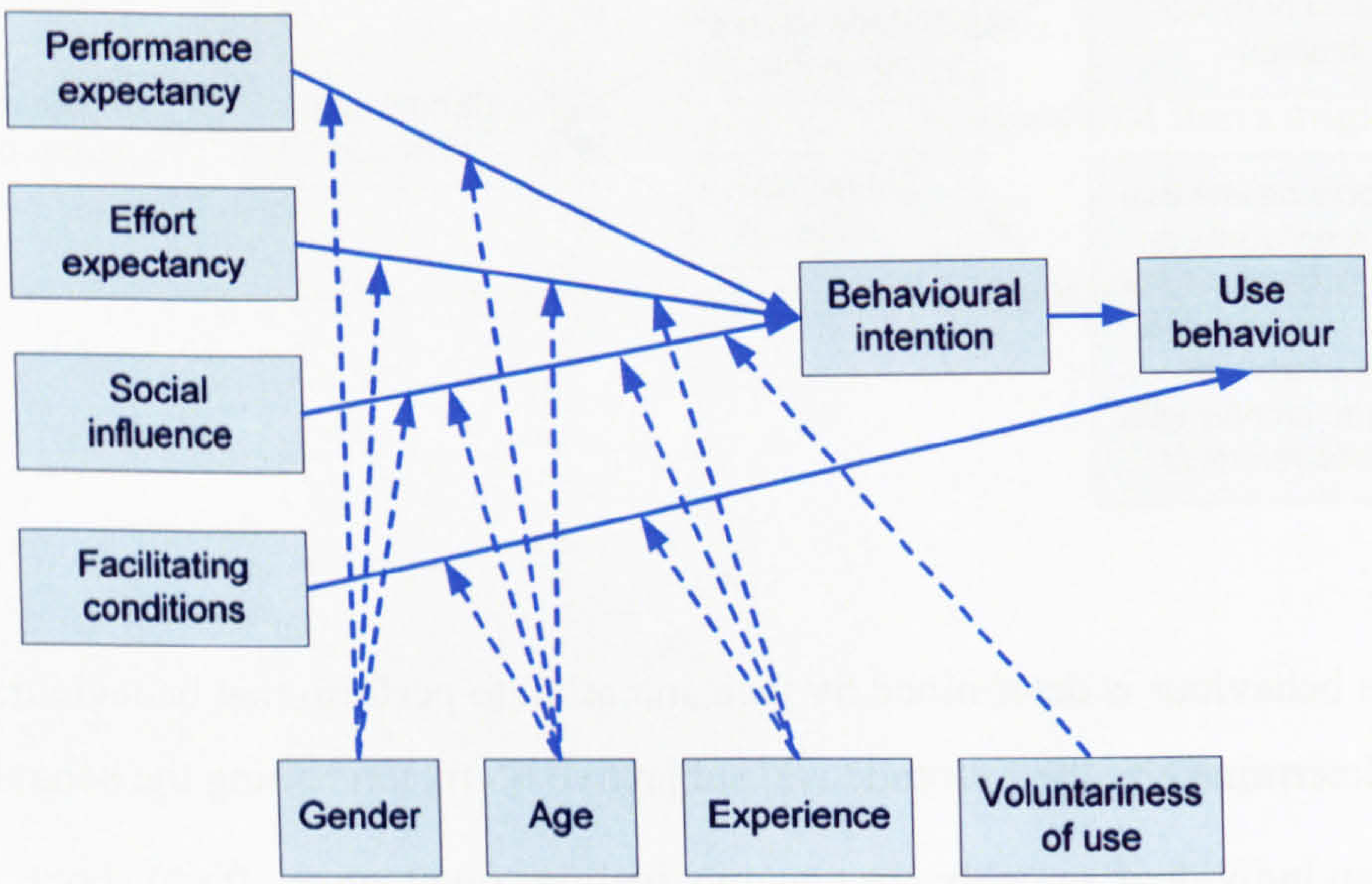
Attitude: an individual's positive or negative feelings (evaluative affect) about performing the target behaviour. A person's attitude toward a behaviour is determined by their salient beliefs about consequences of performing the behaviour, multiplied by the evaluation of those consequences.

Subjective norm: the person's perception that most people who are important to them think they should or should not perform the behaviour in question. Subjective norm is determined by a multiplicative function of their normative beliefs (perceived expectations of specific reference individuals or groups, and their motivation to comply with those expectations.

APPENDIX 2B (CHAPTER 2):

UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT)

This figure shows the Unified Theory of Acceptance and Use of Technology: Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

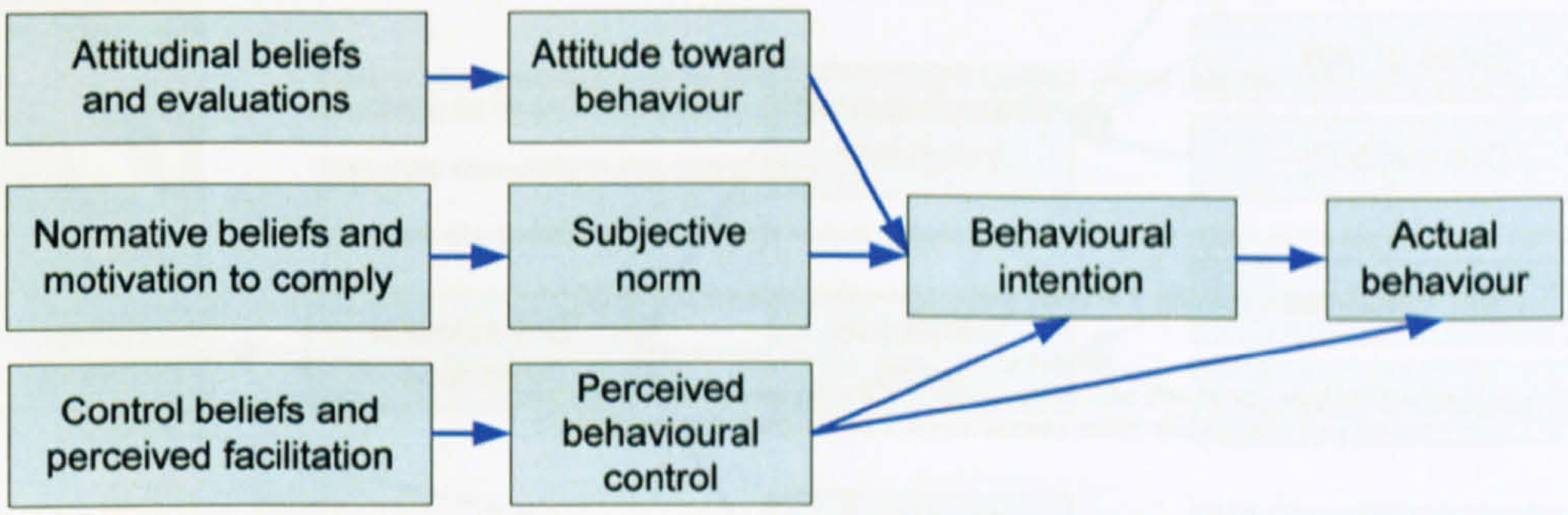


This includes four core determinants of intention and usage (performance expectancy, effort expectancy, social influence and facilitating conditions) and up to four moderators of these influences (gender, age, experience and voluntariness).

APPENDIX 2C (CHAPTER 2): THEORY OF PLANNED BEHAVIOUR (TPB)

This figure shows the Theory of Planned Behaviour:

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.



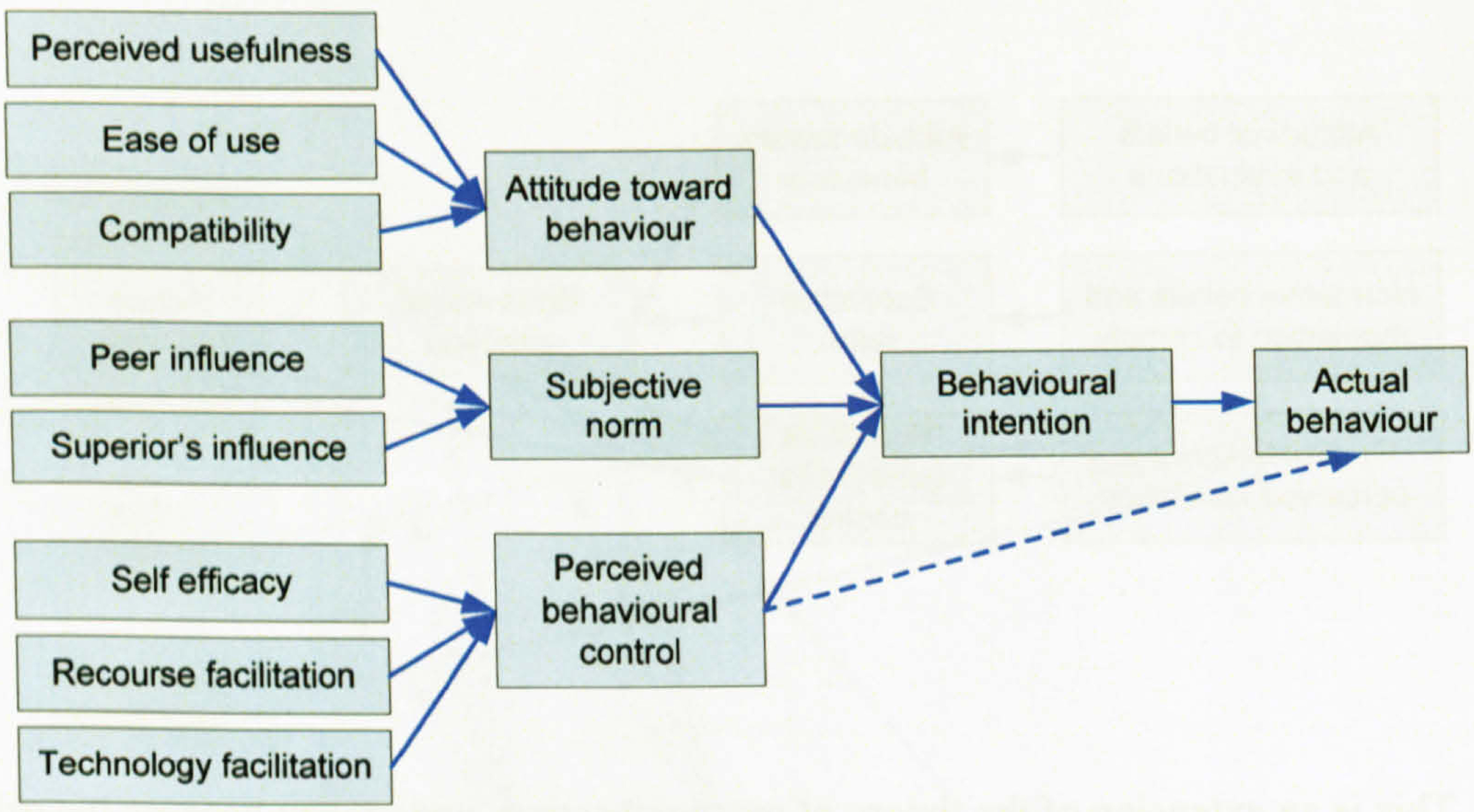
This is an extension of the theory of reasoned action, undertaken because the original model did not take into account behaviours over which people have incomplete volitional control (i.e. perceived behavioural control shown above). Perceived behavioural control refers to 'people's perception of the ease or difficulty of performing the behaviour of interest'.

Intentions are assumed to describe the motivational factors that influence behaviour – how hard people are willing to try in order to perform the behaviours. An intention can only result in behaviour if the behaviour is under volitional control – the person can decide at will to perform or not perform the behaviour. Most behaviours depend on motivational factors such as opportunities and resources (e.g. time, money, skills, cooperation of others).

APPENDIX 2D (CHAPTER 2)
DECOMPOSED THEORY OF PLANNED BEHAVIOUR

This figure shows the Decomposed Theory of Planned Behaviour:

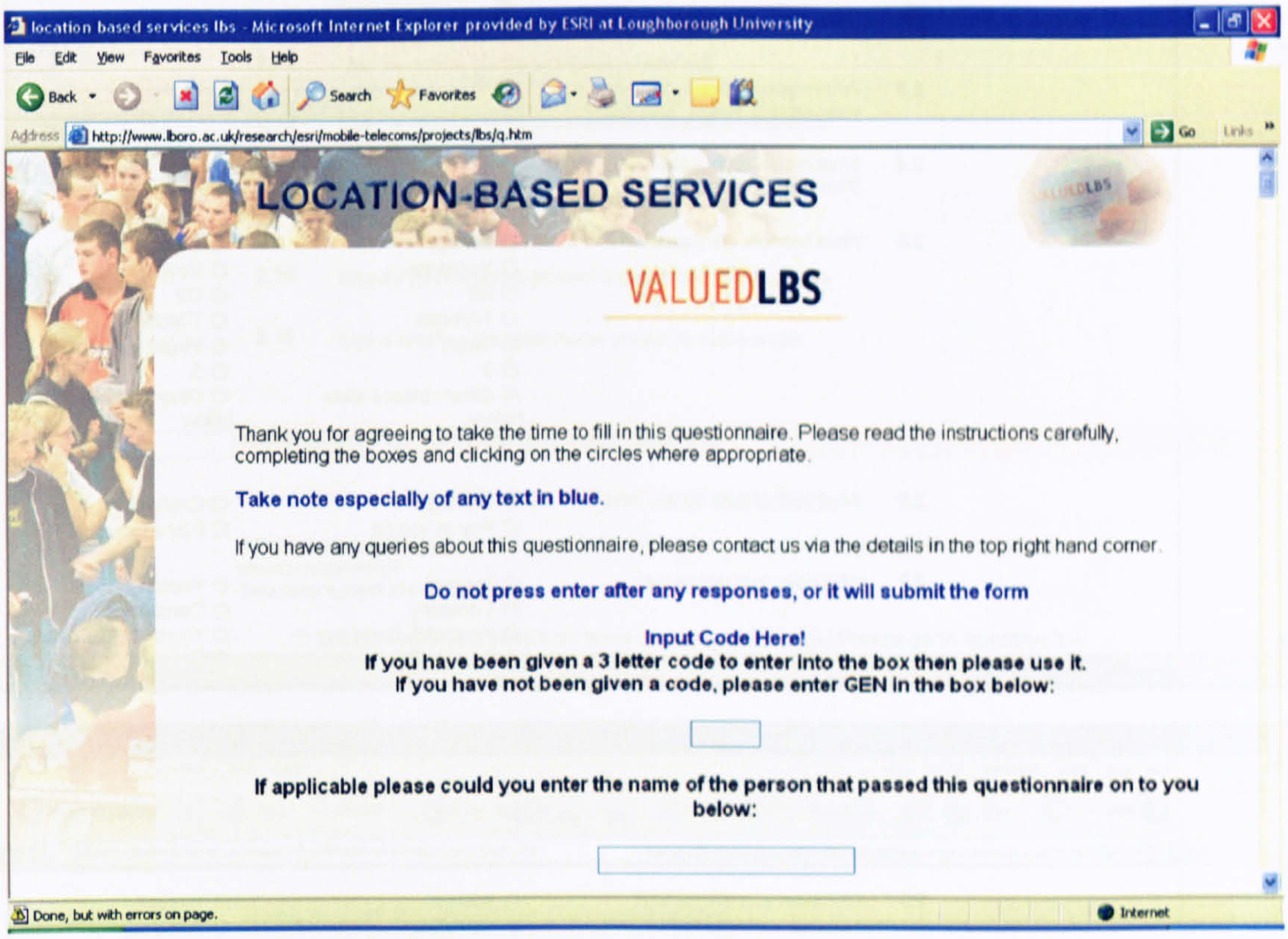
Taylor, S. A., & Todd, P. A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Info Systems Research, 6*(2), 144-176.



The decomposed TPB further decomposes attitudes, subjective norm and perceived behavioural control. Self efficacy refers to the individual's judgement of whether they possess the skills necessary to undertake designated types of performance.

APPENDIX 4A (CHAPTER 4)
QUESTIONNAIRE SCREENSHOTS

This appendix contains screenshots of the web questionnaire for Chapter 4.



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Address http://www.lboro.ac.uk/research/esri/mobile-telecoms/projects/lbs/q.htm Go Links

LOCATION-BASED SERVICES

VALUEDLBS

Thank you for agreeing to take the time to fill in this questionnaire. Please read the instructions carefully, completing the boxes and clicking on the circles where appropriate.

Take note especially of any text in blue.

If you have any queries about this questionnaire, please contact us via the details in the top right hand corner.

Do not press enter after any responses, or it will submit the form

Input Code Here!
If you have been given a 3 letter code to enter into the box then please use it.
If you have not been given a code, please enter GEN in the box below:

If applicable please could you enter the name of the person that passed this questionnaire on to you below:

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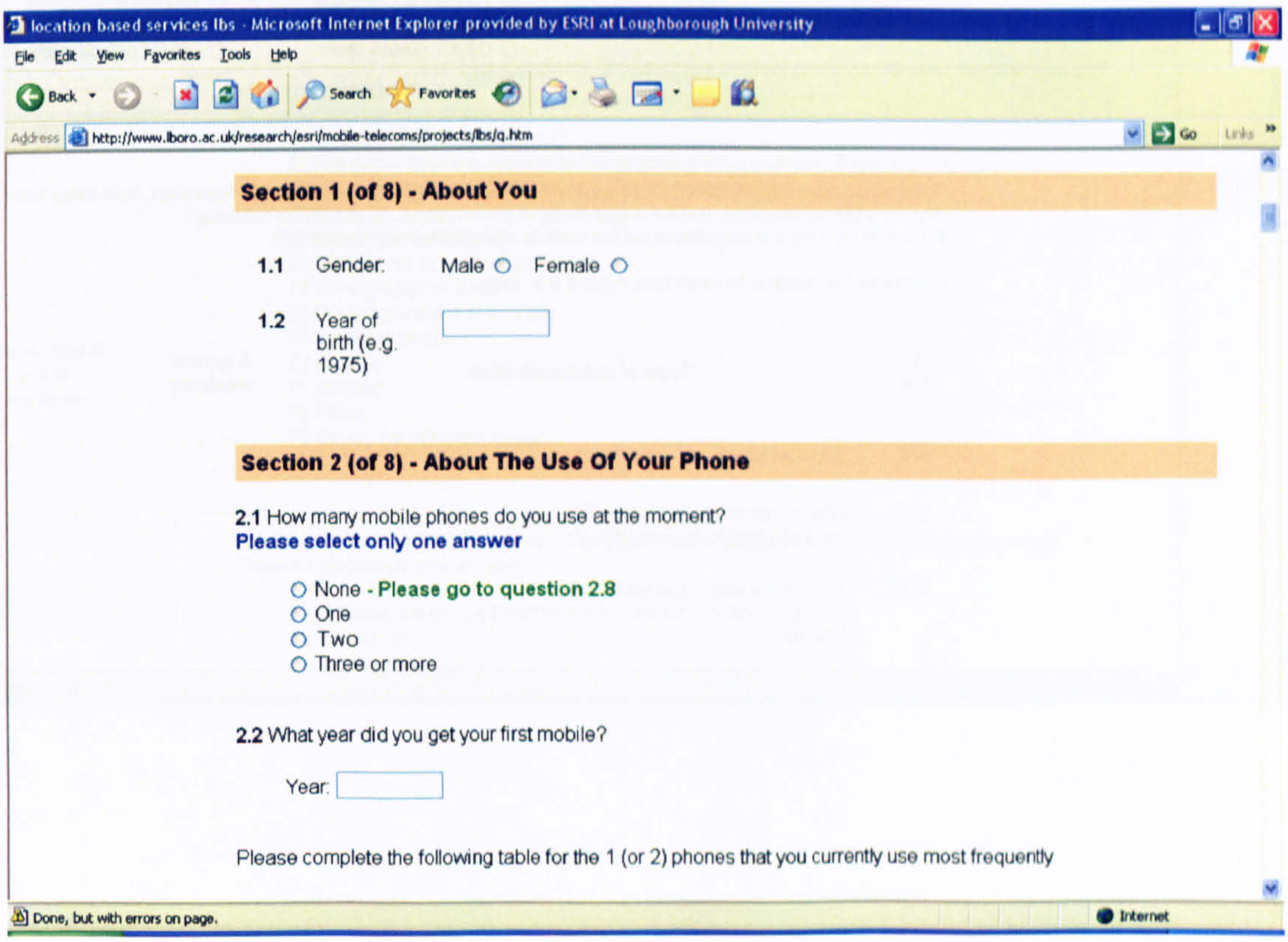

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Section 1 (of 8) - About You

1.1 Gender: Male ○ Female ○

1.2 Year of birth (e.g. 1975)

Section 2 (of 8) - About The Use Of Your Phone

2.1 How many mobile phones do you use at the moment?
Please select only one answer

○ None - Please go to question 2.8
○ One
○ Two
○ Three or more

2.2 What year did you get your first mobile?

Year:

Please complete the following table for the 1 (or 2) phones that you currently use most frequently

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Please complete the following table for the 1 (or 2) phones that you currently use most frequently

Q. No.	Question	Phone 1 (most frequently used)	Phone 2
2.3	What make of mobile phone(s) do you own (e.g. Nokia, Siemens)?	[ ]	[ ]
2.4	What model is your phone(s)? **If known.**	[ ]	[ ]
2.5	What network are you with?	○ Orange ○ Vodafone ○ O2 ○ T-Mobile ○ Virgin ○ 3 ○ Other - please state below: [ ]	○ Orange ○ Vodafone ○ O2 ○ T-Mobile ○ Virgin ○ 3 ○ Other - please state below: [ ]
2.6	What kind of tariff do you have?	○ Contract ○ Pay as you go	○ Contract ○ Pay as you go
2.7	Who pays your phone bill?	○ Yourself ○ Company ○ Yourself & Company	○ Yourself ○ Company ○ Yourself & Company

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Q. No.	Question	Phone 1	Phone 2
2.7	Who pays your phone bill?	○ Yourself ○ Company ○ Yourself & Company ○ Parents/Relation ○ Other - please state below: [ ]	○ Yourself ○ Company ○ Yourself & Company ○ Parents/Relation ○ Other - please state below: [ ]

Think about communication with friends, family or work colleagues, or accessing information. How many times a day, on a typical weekday, and for a typical day at the weekend, do you do the following?
If it is less than once a day please put the number and duration e.g. 3x a month

Please put a number in each box even if it is zero.

Q. No.	Type of communication	A typical weekday	A typical day at the weekend
2.8	Send an email	[ ]	[ ]
2.9	Use instant messaging on a PC i.e. each session/conversation	[ ]	[ ]
2.10	Access the web / internet on a PC i.e. each time you access it for a different purpose e.g. buy a holiday	[ ]	[ ]

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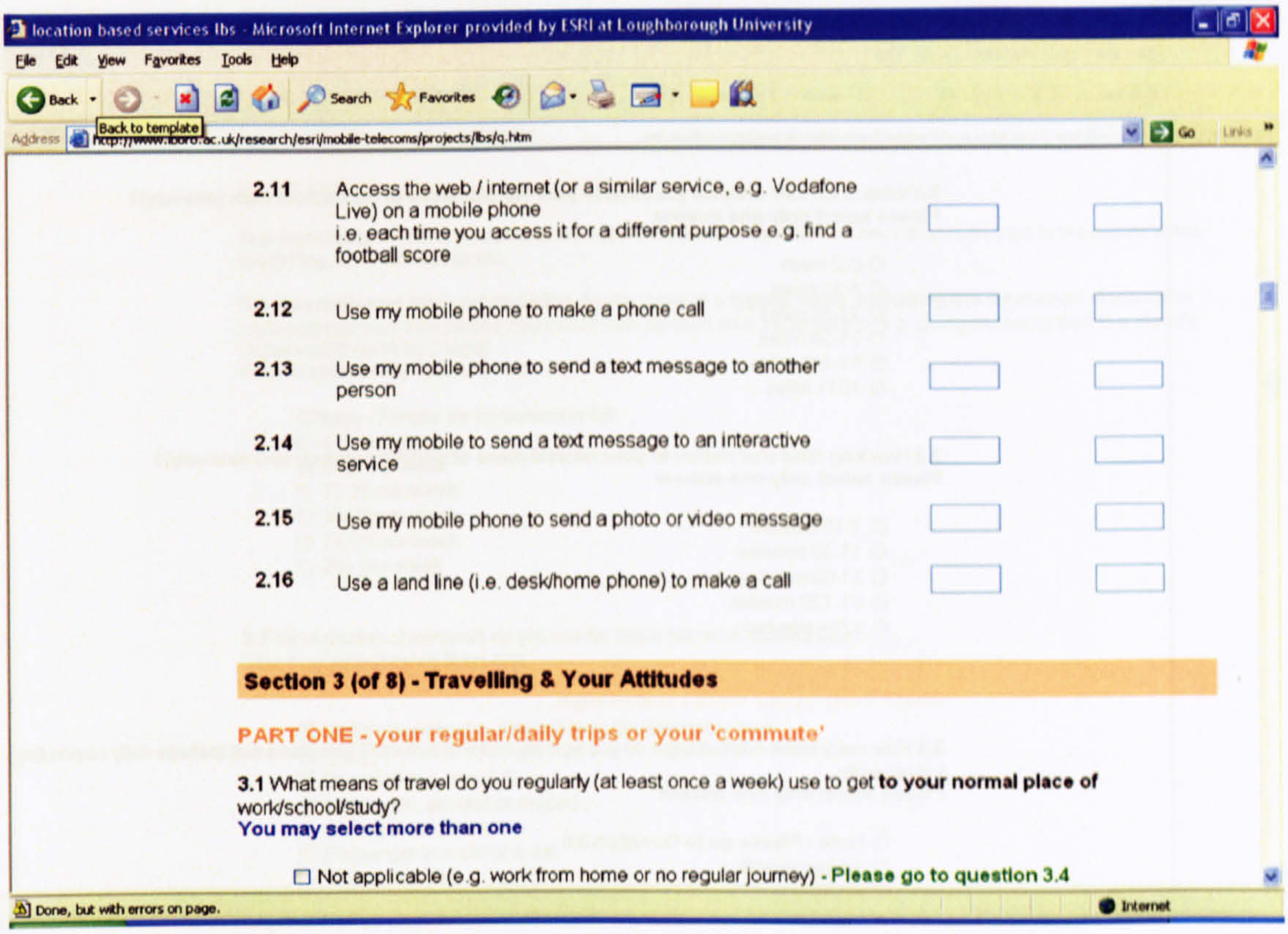

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2.11	Access the web / internet (or a similar service, e.g. Vodafone Live) on a mobile phone i.e. each time you access it for a different purpose e.g. find a football score		
2.12	Use my mobile phone to make a phone call		
2.13	Use my mobile phone to send a text message to another person		
2.14	Use my mobile to send a text message to an interactive service		
2.15	Use my mobile phone to send a photo or video message		
2.16	Use a land line (i.e. desk/home phone) to make a call		

Section 3 (of 8) - Travelling & Your Attitudes

PART ONE - your regular/daily trips or your 'commute'

3.1 What means of travel do you regularly (at least once a week) use to get **to your normal place of** work/school/study?
You may select more than one

☐ Not applicable (e.g. work from home or no regular journey) - **Please go to question 3.4**

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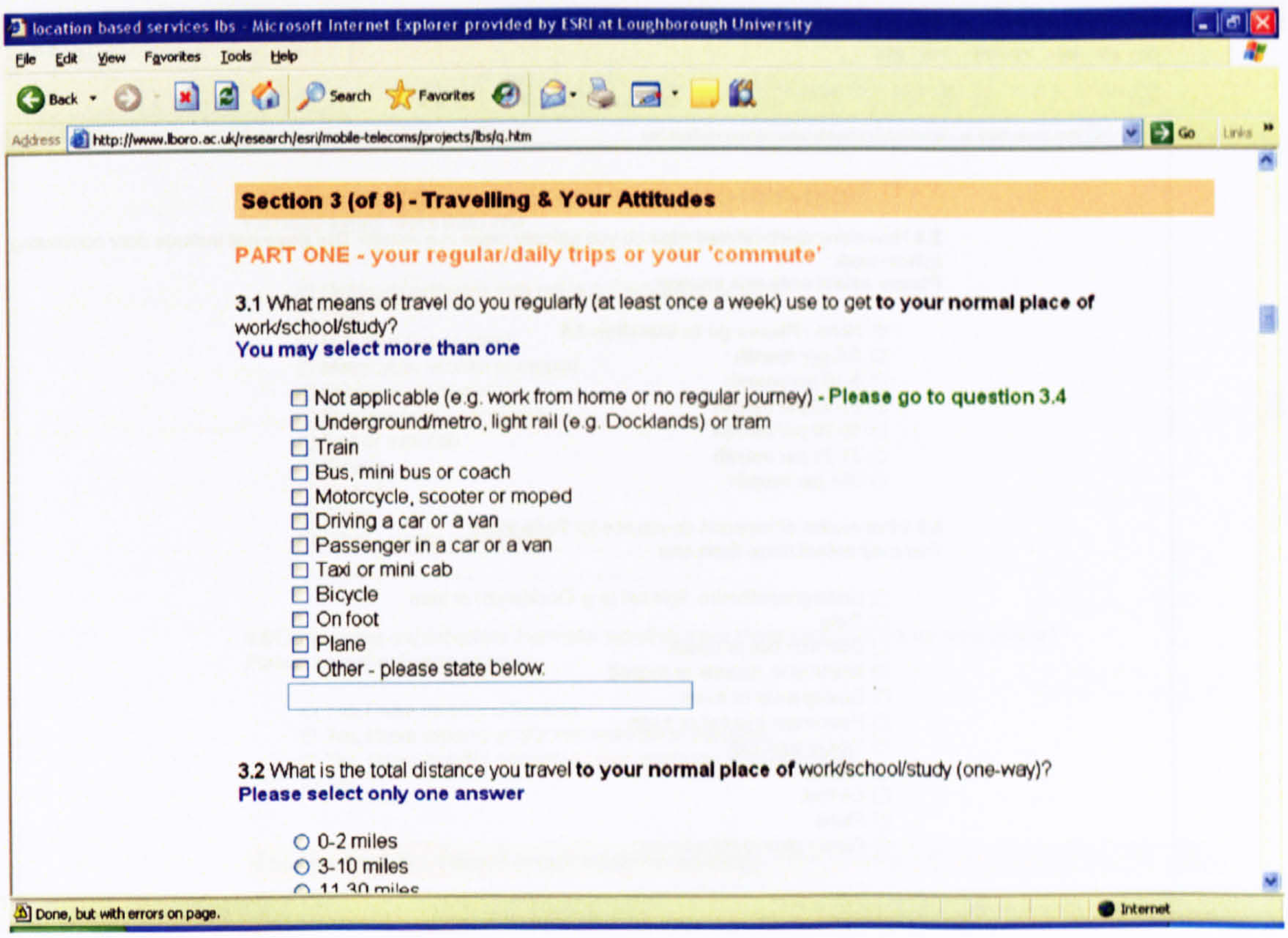

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Section 3 (of 8) - Travelling & Your Attitudes

PART ONE - your regular/daily trips or your 'commute'

3.1 What means of travel do you regularly (at least once a week) use to get **to your normal place of** work/school/study?
You may select more than one

- ☐ Not applicable (e.g. work from home or no regular journey) - **Please go to question 3.4**
- ☐ Underground/metro, light rail (e.g. Docklands) or tram
- ☐ Train
- ☐ Bus, mini bus or coach
- ☐ Motorcycle, scooter or moped
- ☐ Driving a car or a van
- ☐ Passenger in a car or a van
- ☐ Taxi or mini cab
- ☐ Bicycle
- ☐ On foot
- ☐ Plane
- ☐ Other - please state below:

3.2 What is the total distance you travel **to your normal place of** work/school/study (one-way)?
Please select only one answer

- ○ 0-2 miles
- ○ 3-10 miles
- ○ 11-30 miles

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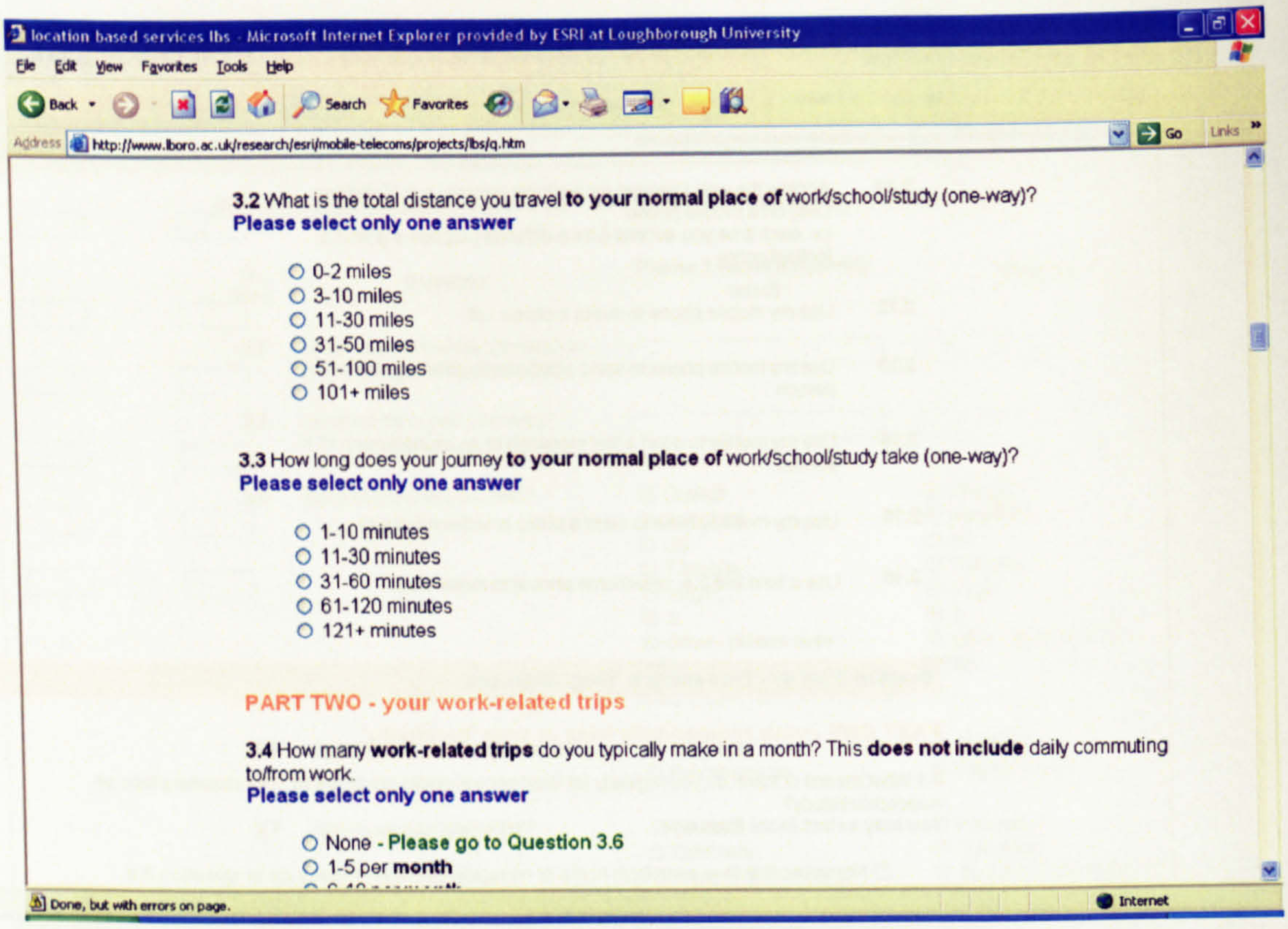


3.2 What is the total distance you travel **to your normal place of** work/school/study (one-way)?
Please select only one answer

- ○ 0-2 miles
- ○ 3-10 miles
- ○ 11-30 miles
- ○ 31-50 miles
- ○ 51-100 miles
- ○ 101+ miles

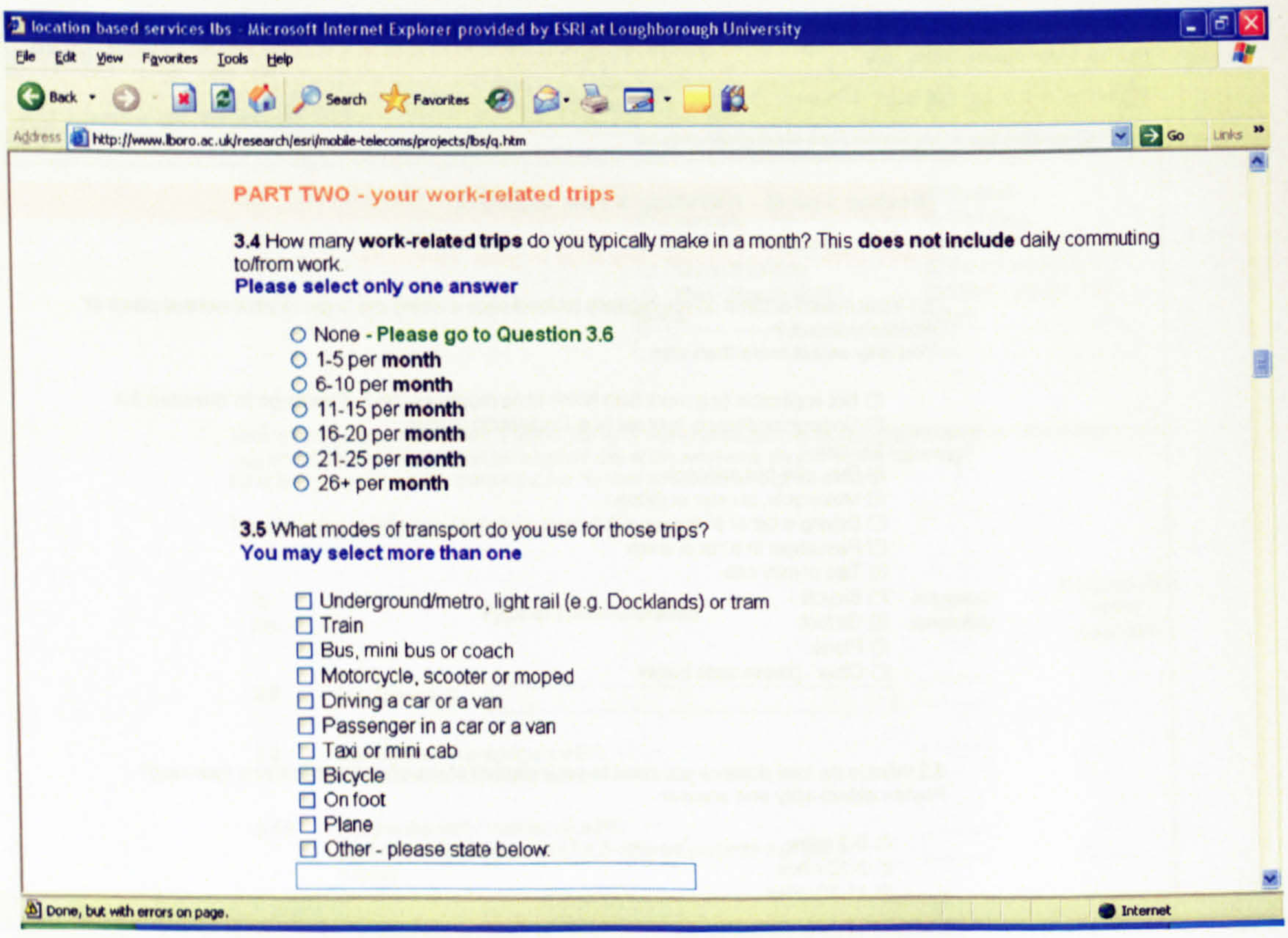
3.3 How long does your journey **to your normal place of** work/school/study take (one-way)?
Please select only one answer

- ○ 1-10 minutes
- ○ 11-30 minutes
- ○ 31-60 minutes
- ○ 61-120 minutes
- ○ 121+ minutes

PART TWO - your work-related trips

3.4 How many **work-related trips** do you typically make in a month? This **does not include** daily commuting to/from work.
Please select only one answer

- ○ None - **Please go to Question 3.6**
- ○ 1-5 per **month**



PART TWO - your work-related trips

3.4 How many **work-related trips** do you typically make in a month? This **does not include** daily commuting to/from work.
Please select only one answer

- ○ None - **Please go to Question 3.6**
- ○ 1-5 per **month**
- ○ 6-10 per **month**
- ○ 11-15 per **month**
- ○ 16-20 per **month**
- ○ 21-25 per **month**
- ○ 26+ per **month**

3.5 What modes of transport do you use for those trips?
You may select more than one

- ☐ Underground/metro, light rail (e.g. Docklands) or tram
- ☐ Train
- ☐ Bus, mini bus or coach
- ☐ Motorcycle, scooter or moped
- ☐ Driving a car or a van
- ☐ Passenger in a car or a van
- ☐ Taxi or mini cab
- ☐ Bicycle
- ☐ On foot
- ☐ Plane
- ☐ Other - please state below:

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PART THREE - your non-work trips

Non-work related means all trips that are not work/school/study related. They can include trips to the supermarket, swimming, a friend's house etc.

3.6 How many **non work-related trips** do you make in a **typical week, including the weekend?** (If you make multi-purpose trips then please count each new location as a separate trip, e.g. going shopping then to a friend's house would count as 2 trips)
Please select only one answer

- ○ None - **Please go to Question 3.8**
- ○ 1-5 per **week**
- ○ 6-10 per **week**
- ○ 11-15 per **week**
- ○ 16-20 per **week**
- ○ 21-25 per **week**
- ○ 26+ per **week**

3.7 What modes of transport do you use for these non work-related trips?
You may select more than one

- ☐ Underground/metro, light rail (e.g. Docklands) or tram
- ☐ Train
- ☐ Bus, mini bus or coach
- ☐ Motorcycle, scooter or moped
- ☐ Driving a car or a van
- ☐ Passenger in a car or a van
- ☐ Taxi or mini cab

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3.7 What modes of transport do you use for these non work-related trips?
You may select more than one

- ☐ Underground/metro, light rail (e.g. Docklands) or tram
- ☐ Train
- ☐ Bus, mini bus or coach
- ☐ Motorcycle, scooter or moped
- ☐ Driving a car or a van
- ☐ Passenger in a car or a van
- ☐ Taxi or mini cab
- ☐ Bicycle
- ☐ On foot
- ☐ Plane
- ☐ Other - please state below

3.8 Do you have any difficulties that make travelling more challenging than it is for most people?
Please select only one answer

- ○ Yes, I have mobility difficulties
- ○ Yes, I have sensory and/or communication difficulties
- ○ Yes, I have mobility, sensory **and/or** communication difficulties
- ○ No

Section 4 (of 8) - Your Contact With Technology

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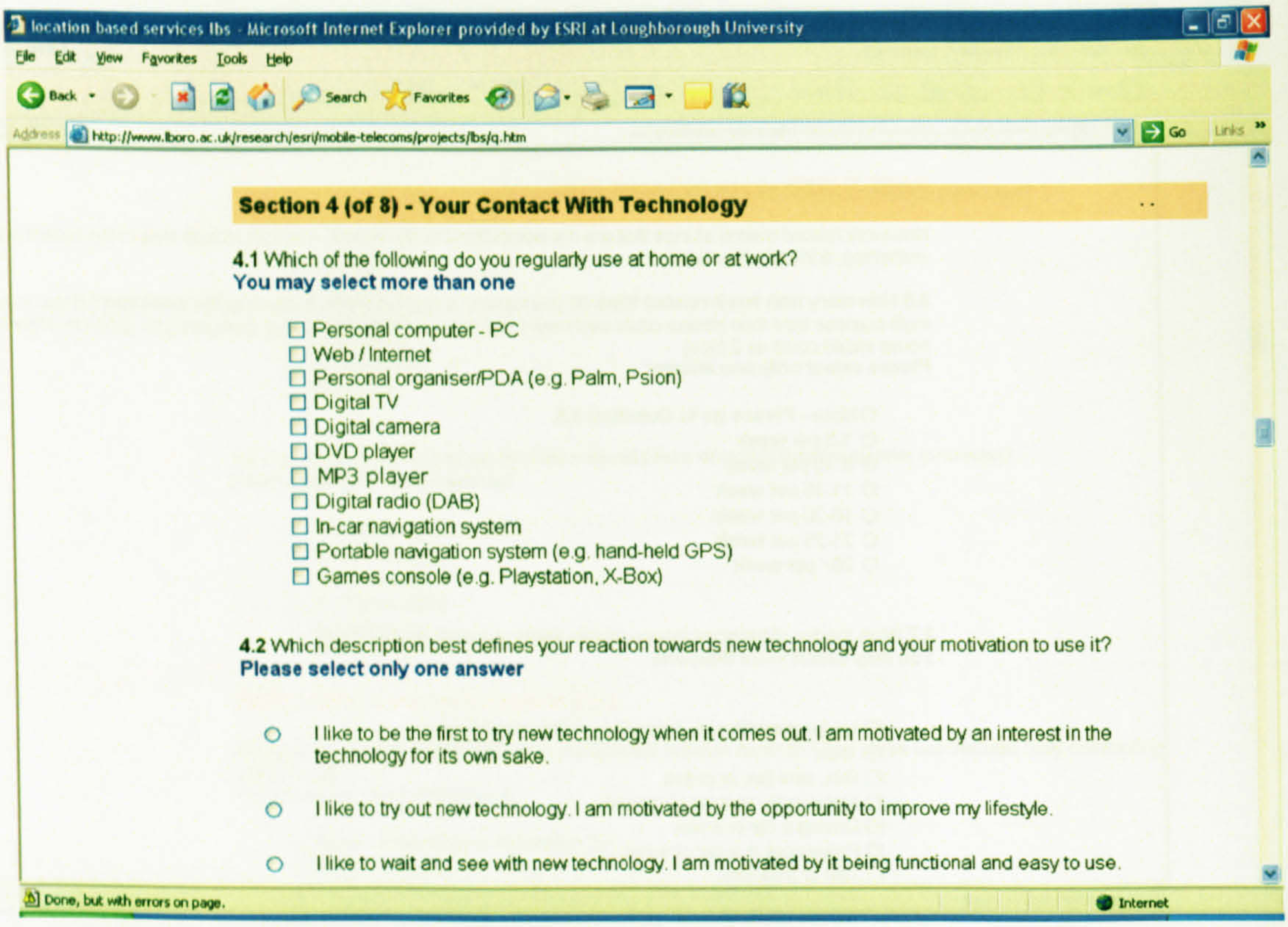

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Section 4 (of 8) - Your Contact With Technology

4.1 Which of the following do you regularly use at home or at work?
You may select more than one

- ☐ Personal computer - PC
- ☐ Web / Internet
- ☐ Personal organiser/PDA (e.g. Palm, Psion)
- ☐ Digital TV
- ☐ Digital camera
- ☐ DVD player
- ☐ MP3 player
- ☐ Digital radio (DAB)
- ☐ In-car navigation system
- ☐ Portable navigation system (e.g. hand-held GPS)
- ☐ Games console (e.g. Playstation, X-Box)

4.2 Which description best defines your reaction towards new technology and your motivation to use it?
Please select only one answer

- ○ I like to be the first to try new technology when it comes out. I am motivated by an interest in the technology for its own sake.
- ○ I like to try out new technology. I am motivated by the opportunity to improve my lifestyle.
- ○ I like to wait and see with new technology. I am motivated by it being functional and easy to use.

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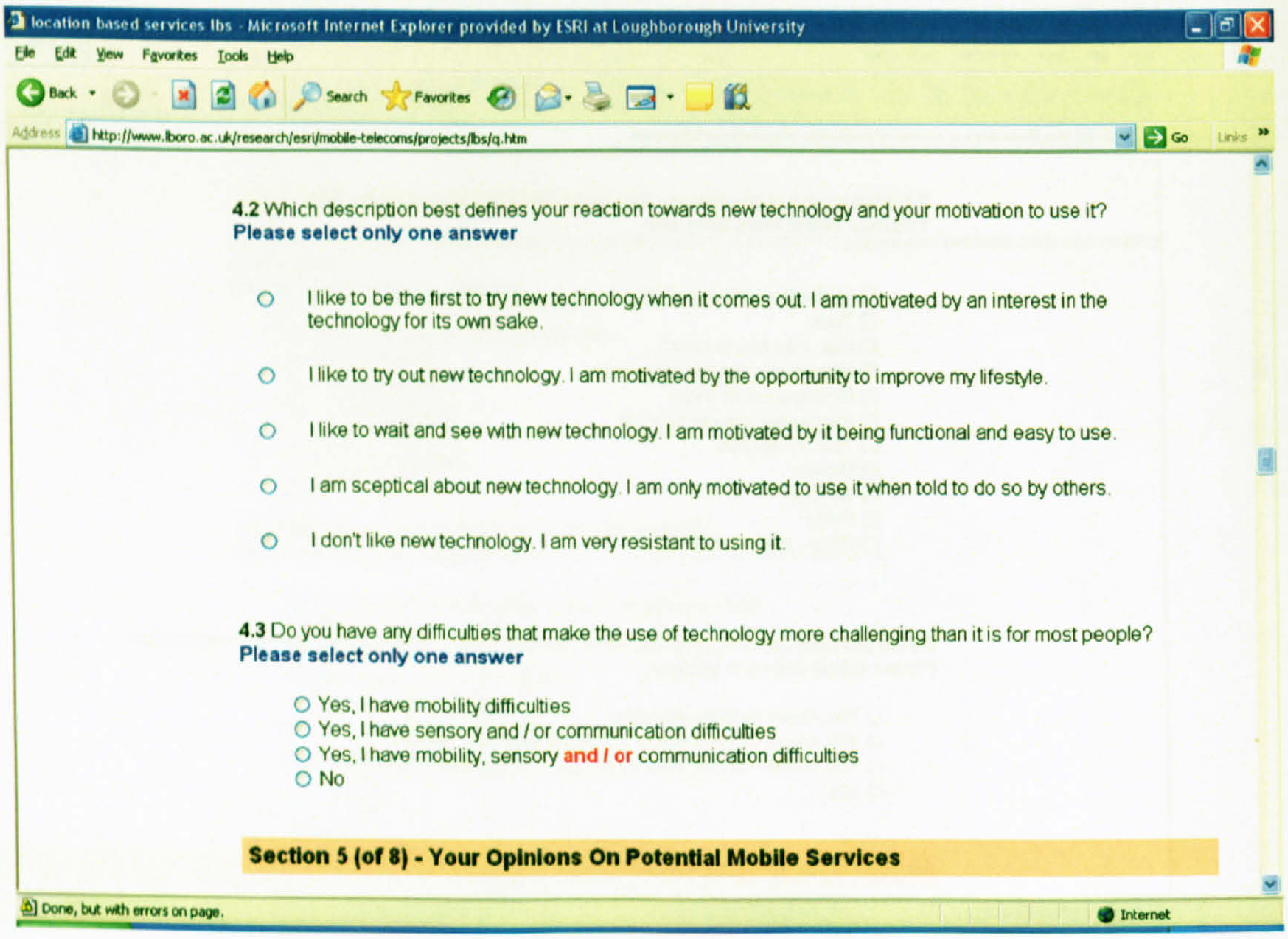

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4.2 Which description best defines your reaction towards new technology and your motivation to use it?
Please select only one answer

- ○ I like to be the first to try new technology when it comes out. I am motivated by an interest in the technology for its own sake.
- ○ I like to try out new technology. I am motivated by the opportunity to improve my lifestyle.
- ○ I like to wait and see with new technology. I am motivated by it being functional and easy to use.
- ○ I am sceptical about new technology. I am only motivated to use it when told to do so by others.
- ○ I don't like new technology. I am very resistant to using it.

4.3 Do you have any difficulties that make the use of technology more challenging than it is for most people?
Please select only one answer

- ○ Yes, I have mobility difficulties
- ○ Yes, I have sensory and / or communication difficulties
- ○ Yes, I have mobility, sensory **and / or** communication difficulties
- ○ No

Section 5 (of 8) - Your Opinions On Potential Mobile Services

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Section 5 (of 8) - Your Opinions On Potential Mobile Services

What is your opinion on the following potential services available through your mobile phone using text, mobile internet or similar? Some of these services are already available, some are proposed for the future.

They do not include phoning a helpline and talking to a person so please do not include these types of services when you are answering the question.

Also remember they do not include services you would use on a PC

Please select your two responses for each service e.g. 'Used it' & 'I am mostly positive towards it'.

5.1	**Nearest services on your mobile** e.g. you can find out where the nearest cash-point, chemist or cinema is	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.2	**Local weather on your mobile** e.g. what the weather will be like in your current location	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it

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5.3	**City guides on your mobile** e.g. on-the-spot tourist attractions, events when you visit a new place	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.4	**Local phone numbers on your mobile** e.g. taxi company, cinema, restaurant	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.5	**Walking directions on your mobile** e.g. a map or directions of the best way to walk somewhere from where you are now	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.6	**Driving directions on your mobile** e.g. a map or directions of the best way to drive somewhere from where you are now	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it

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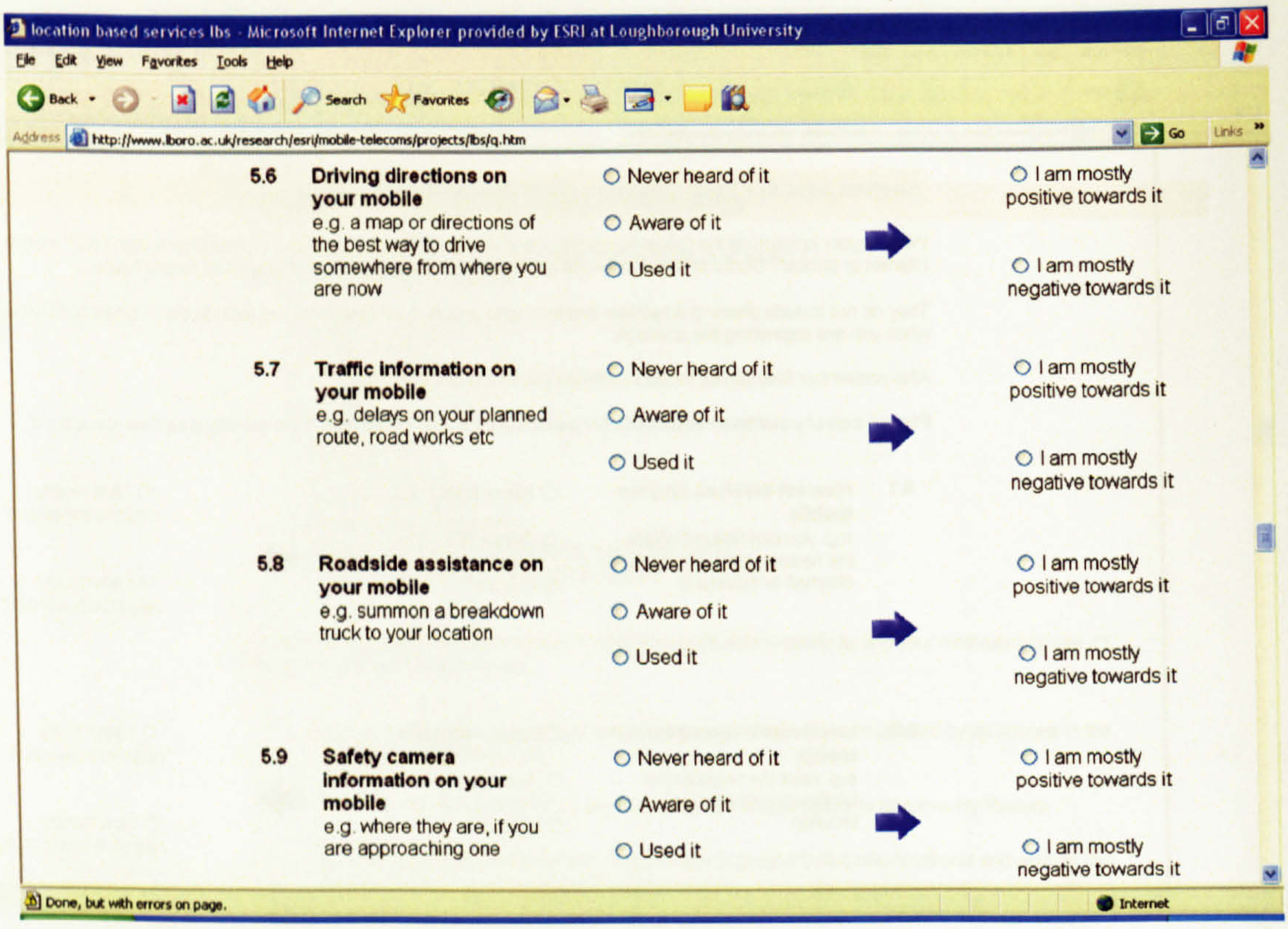
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Go Links
5.6 Driving directions on your mobile
e.g. a map or directions of the best way to drive somewhere from where you are now
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.7 Traffic information on your mobile
e.g. delays on your planned route, road works etc
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.8 Roadside assistance on your mobile
e.g. summon a breakdown truck to your location
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.9 Safety camera information on your mobile
e.g. where they are, if you are approaching one
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
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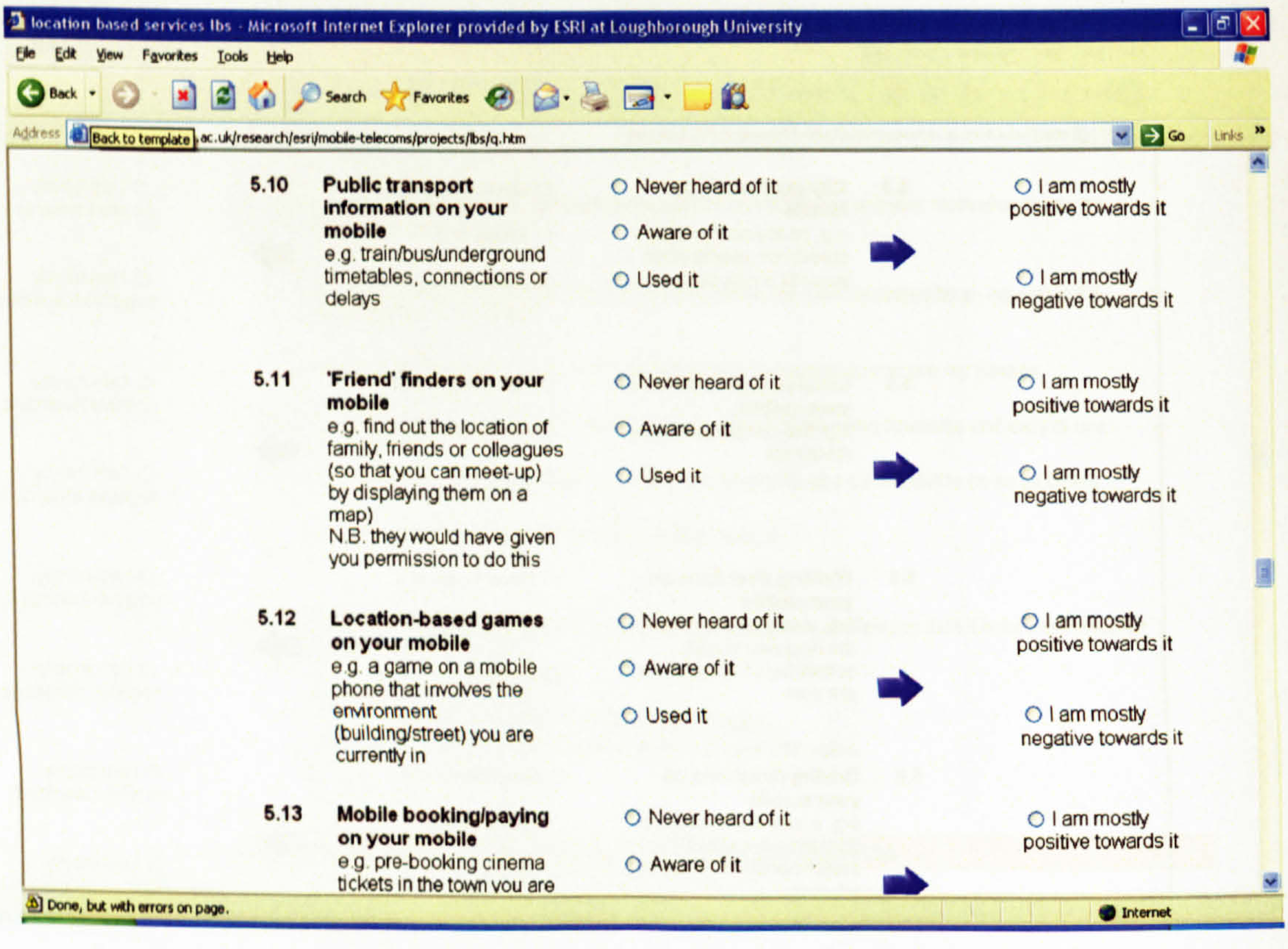
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5.10 Public transport information on your mobile
e.g. train/bus/underground timetables, connections or delays
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.11 'Friend' finders on your mobile
e.g. find out the location of family, friends or colleagues (so that you can meet-up) by displaying them on a map)
N.B. they would have given you permission to do this
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.12 Location-based games on your mobile
e.g. a game on a mobile phone that involves the environment (building/street) you are currently in
Never heard of it
Aware of it
Used it
I am mostly positive towards it
I am mostly negative towards it
5.13 Mobile booking/paying on your mobile
e.g. pre-booking cinema tickets in the town you are
Never heard of it
Aware of it
I am mostly positive towards it
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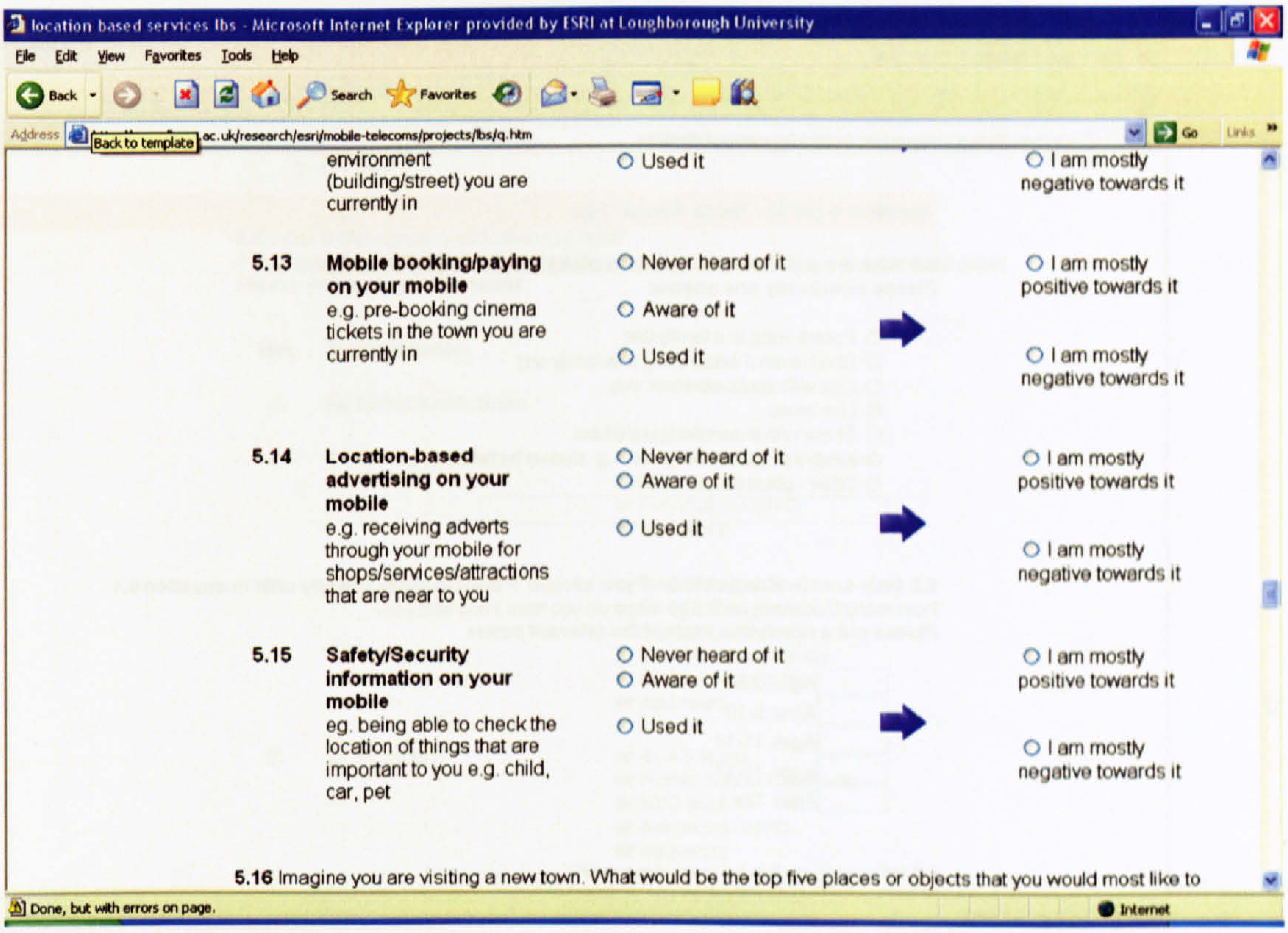

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	environment (building/street) you are currently in	○ Used it		○ I am mostly negative towards it
5.13	**Mobile booking/paying on your mobile** e.g. pre-booking cinema tickets in the town you are currently in	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.14	**Location-based advertising on your mobile** e.g. receiving adverts through your mobile for shops/services/attractions that are near to you	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it
5.15	**Safety/Security information on your mobile** eg. being able to check the location of things that are important to you e.g. child, car, pet	○ Never heard of it ○ Aware of it ○ Used it	➡	○ I am mostly positive towards it ○ I am mostly negative towards it

5.16 Imagine you are visiting a new town. What would be the top five places or objects that you would most like to

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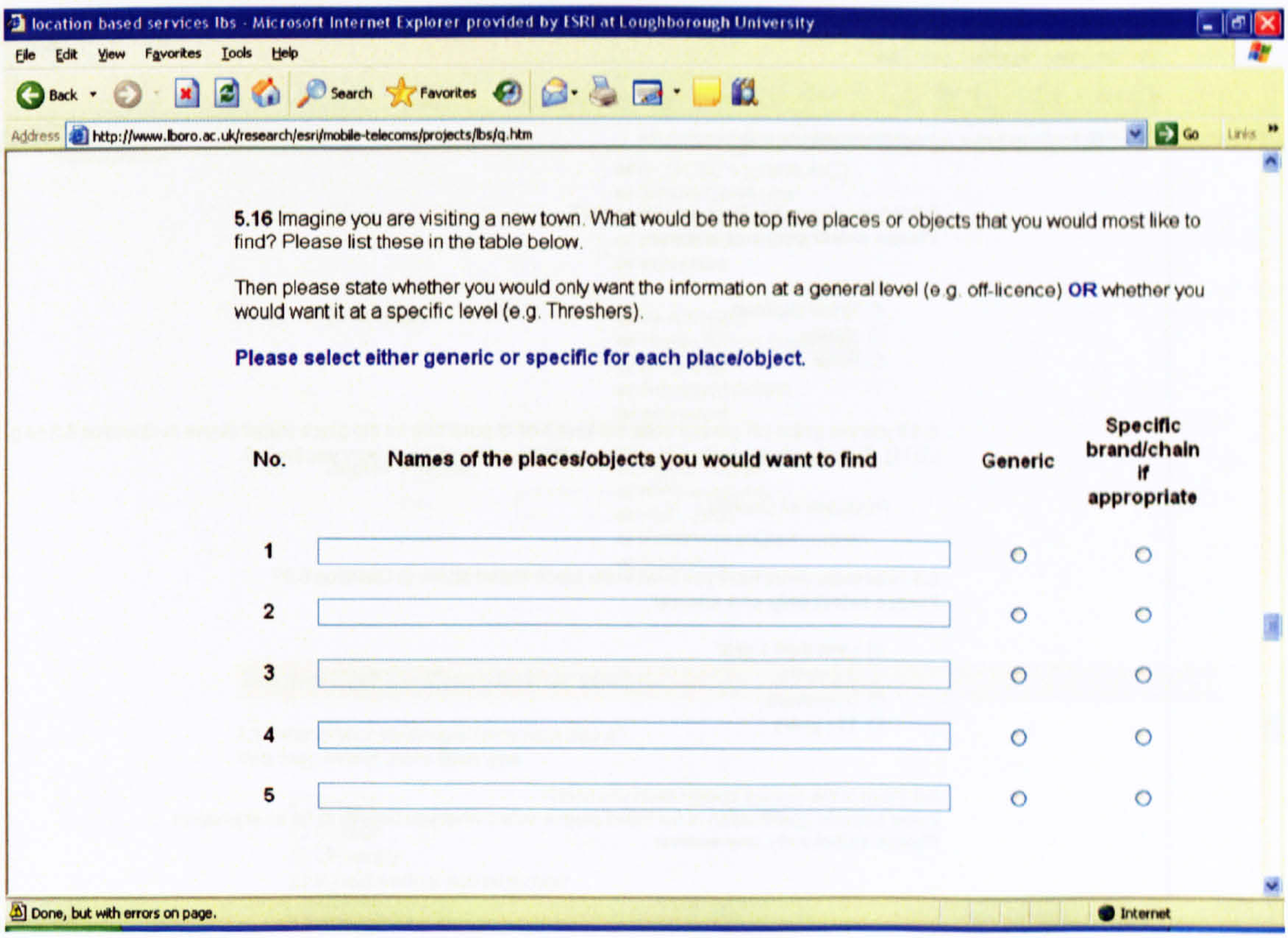

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5.16 Imagine you are visiting a new town. What would be the top five places or objects that you would most like to find? Please list these in the table below.

Then please state whether you would only want the information at a general level (e.g. off-licence) **OR** whether you would want it at a specific level (e.g. Thresher).

Please select either generic or specific for each place/object.

No.	Names of the places/objects you would want to find	Generic	Specific brand/chain if appropriate
1		○	○
2		○	○
3		○	○
4		○	○
5		○	○

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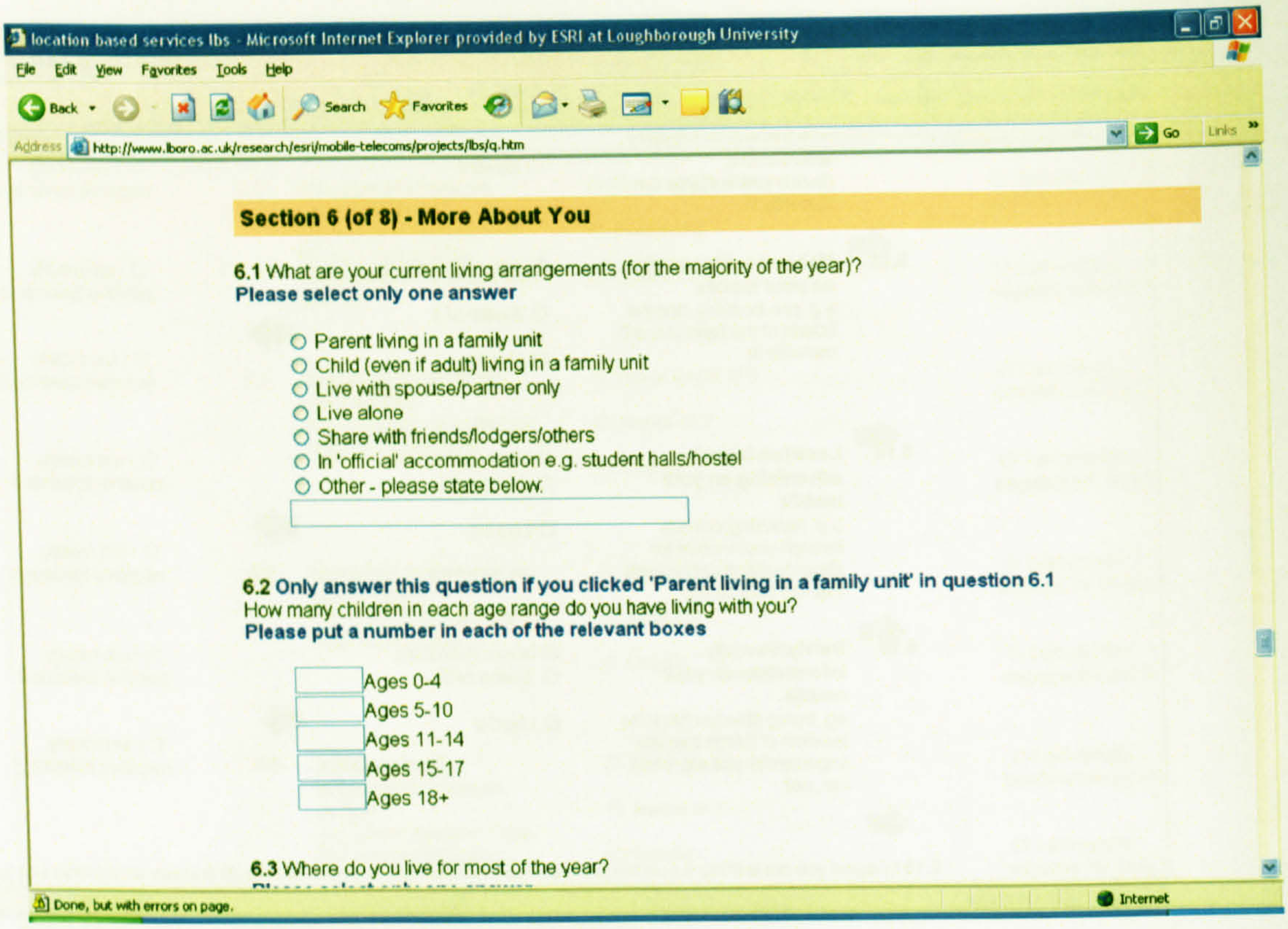


Section 6 (of 8) - More About You

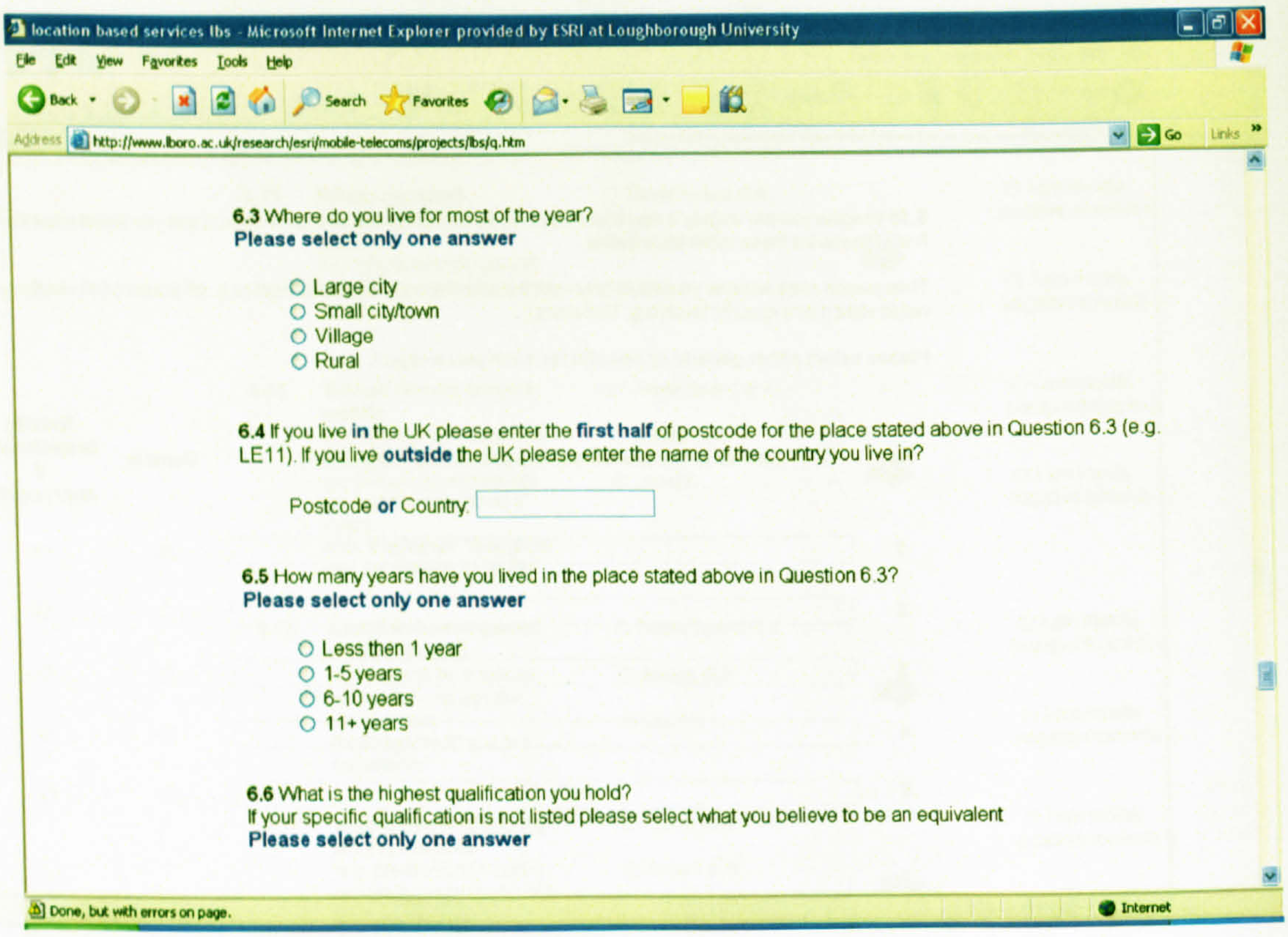
6.1 What are your current living arrangements (for the majority of the year)?
Please select only one answer

- ○ Parent living in a family unit
- ○ Child (even if adult) living in a family unit
- ○ Live with spouse/partner only
- ○ Live alone
- ○ Share with friends/lodgers/others
- ○ In 'official' accommodation e.g. student halls/hostel
- ○ Other - please state below:

6.2 Only answer this question if you clicked 'Parent living in a family unit' in question 6.1
How many children in each age range do you have living with you?
Please put a number in each of the relevant boxes

- Ages 0-4
- Ages 5-10
- Ages 11-14
- Ages 15-17
- Ages 18+

6.3 Where do you live for most of the year?



6.3 Where do you live for most of the year?
Please select only one answer

- ○ Large city
- ○ Small city/town
- ○ Village
- ○ Rural

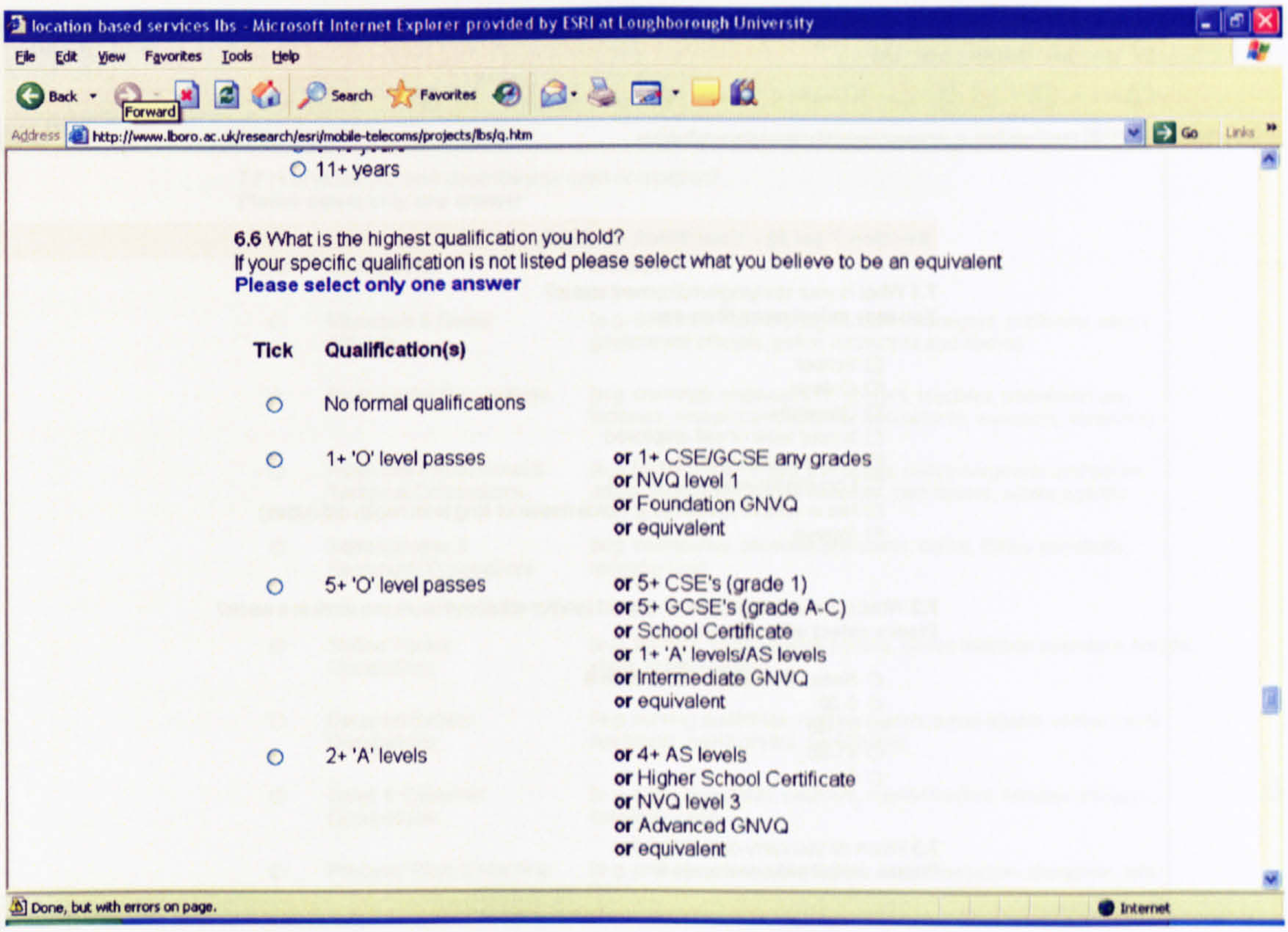
6.4 If you live **in** the UK please enter the **first half** of postcode for the place stated above in Question 6.3 (e.g. LE11). If you live **outside** the UK please enter the name of the country you live in?

Postcode **or** Country:

6.5 How many years have you lived in the place stated above in Question 6.3?
Please select only one answer

- ○ Less then 1 year
- ○ 1-5 years
- ○ 6-10 years
- ○ 11+ years

6.6 What is the highest qualification you hold?
If your specific qualification is not listed please select what you believe to be an equivalent
Please select only one answer



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○ 11+ years

6.6 What is the highest qualification you hold?
If your specific qualification is not listed please select what you believe to be an equivalent
Please select only one answer

Tick	Qualification(s)	
○	No formal qualifications	
○	1+ 'O' level passes	**or** 1+ CSE/GCSE any grades **or** NVQ level 1 **or** Foundation GNVQ **or** equivalent
○	5+ 'O' level passes	**or** 5+ CSE's (grade 1) **or** 5+ GCSE's (grade A-C) **or** School Certificate **or** 1+ 'A' levels/AS levels **or** Intermediate GNVQ **or** equivalent
○	2+ 'A' levels	**or** 4+ AS levels **or** Higher School Certificate **or** NVQ level 3 **or** Advanced GNVQ **or** equivalent

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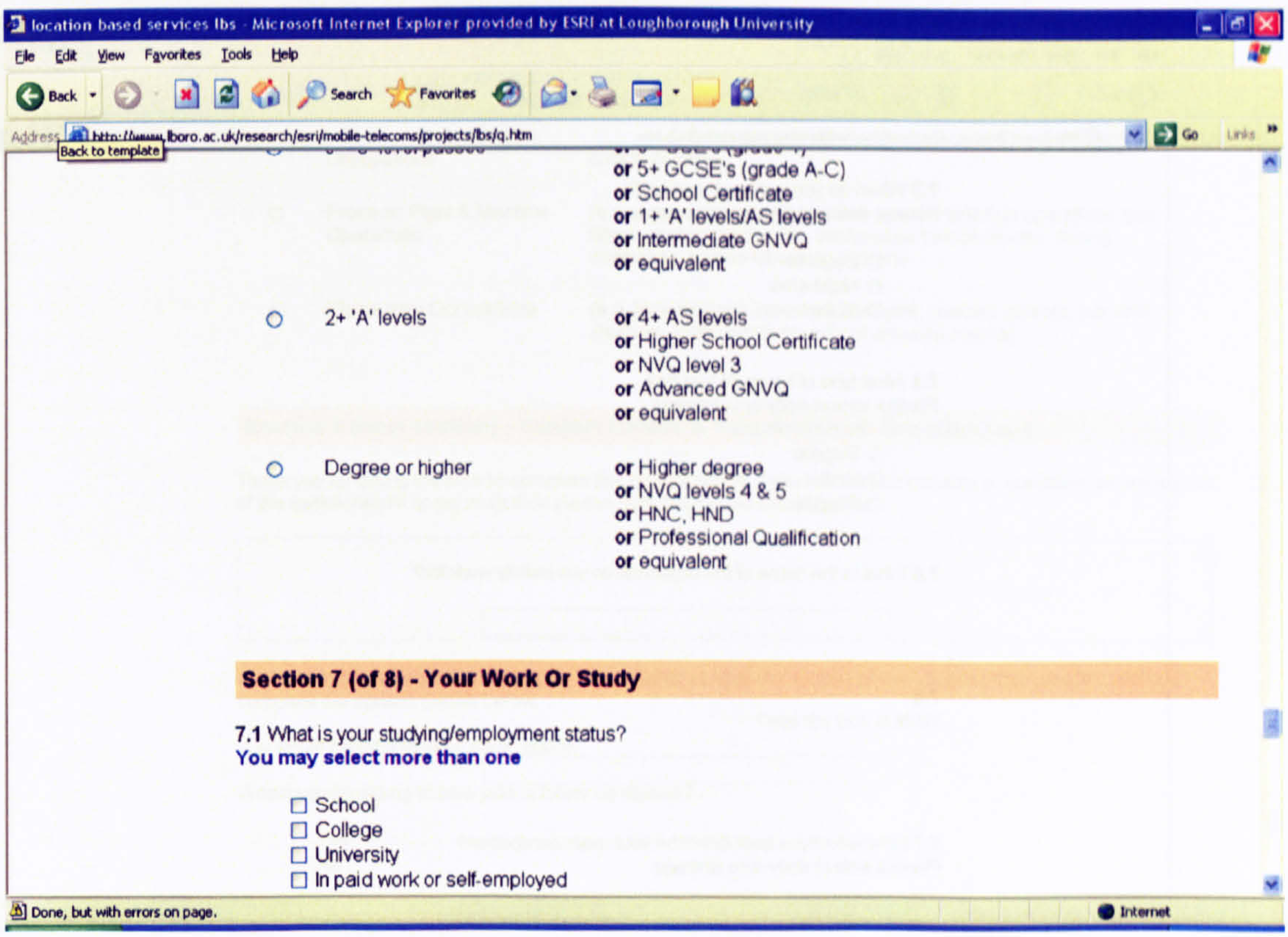

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		or 5+ GCSE's (grade A-C) **or** School Certificate **or** 1+ 'A' levels/AS levels **or** Intermediate GNVQ **or** equivalent
○	2+ 'A' levels	**or** 4+ AS levels **or** Higher School Certificate **or** NVQ level 3 **or** Advanced GNVQ **or** equivalent
○	Degree or higher	**or** Higher degree **or** NVQ levels 4 & 5 **or** HNC, HND **or** Professional Qualification **or** equivalent

Section 7 (of 8) - Your Work Or Study

7.1 What is your studying/employment status?
You may select more than one

☐ School
☐ College
☐ University
☐ In paid work or self-employed

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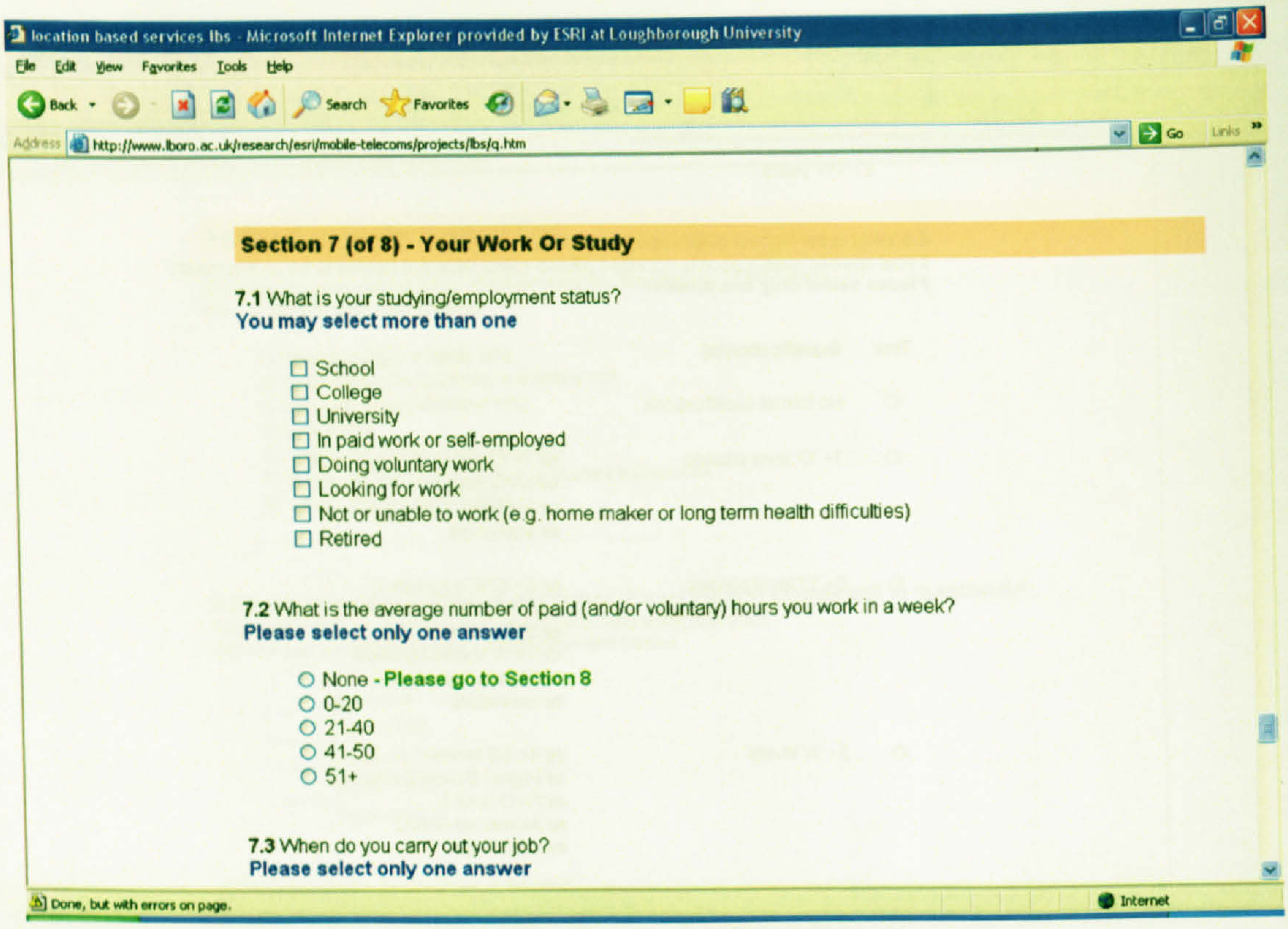

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Section 7 (of 8) - Your Work Or Study

7.1 What is your studying/employment status?
You may select more than one

- ☐ School
- ☐ College
- ☐ University
- ☐ In paid work or self-employed
- ☐ Doing voluntary work
- ☐ Looking for work
- ☐ Not or unable to work (e.g. home maker or long term health difficulties)
- ☐ Retired

7.2 What is the average number of paid (and/or voluntary) hours you work in a week?
Please select only one answer

- ○ None - **Please go to Section 8**
- ○ 0-20
- ○ 21-40
- ○ 41-50
- ○ 51+

7.3 When do you carry out your job?
Please select only one answer

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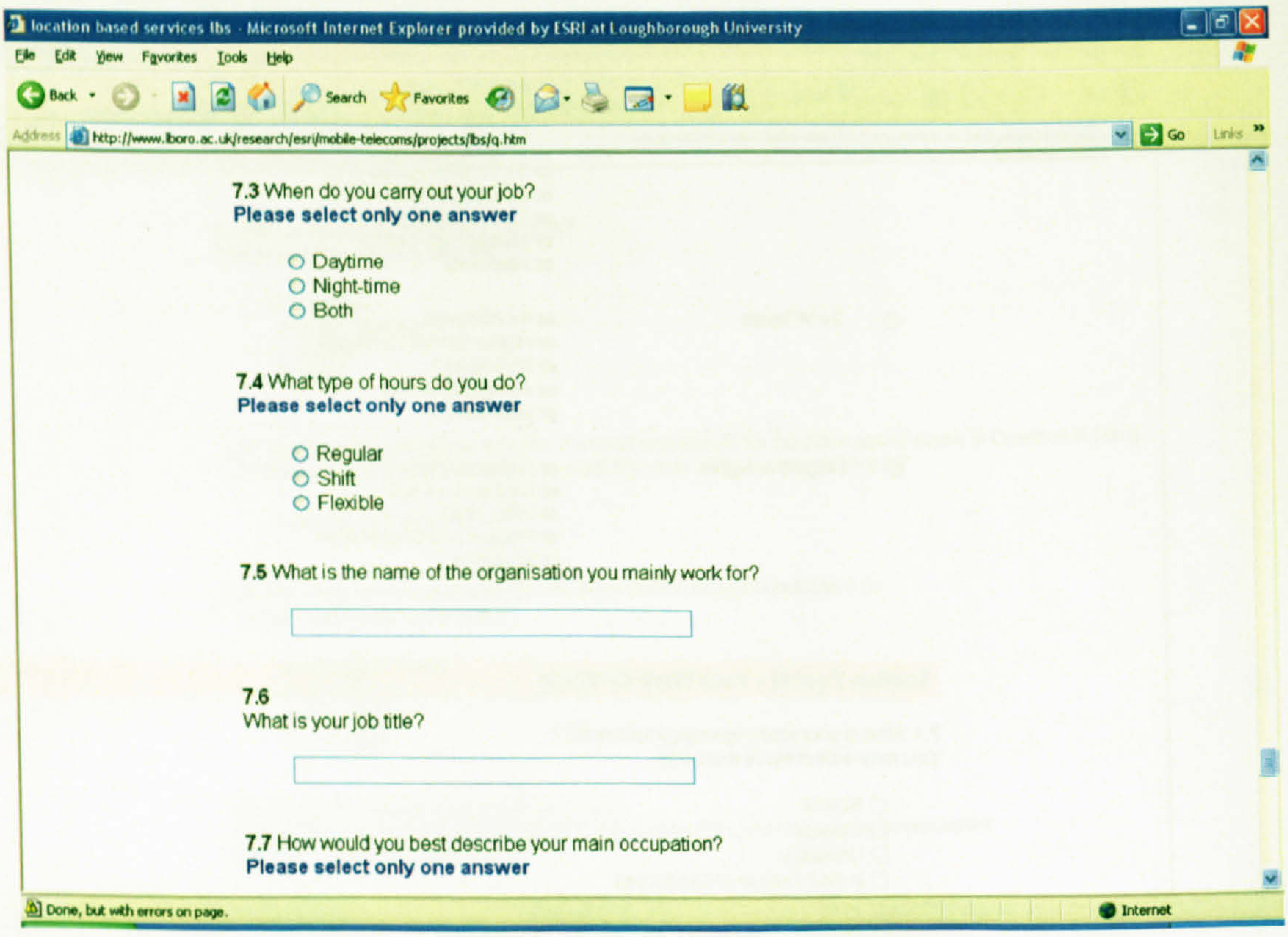

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7.3 When do you carry out your job?
Please select only one answer

- ○ Daytime
- ○ Night-time
- ○ Both

7.4 What type of hours do you do?
Please select only one answer

- ○ Regular
- ○ Shift
- ○ Flexible

7.5 What is the name of the organisation you mainly work for?

7.6
What is your job title?

7.7 How would you best describe your main occupation?
Please select only one answer

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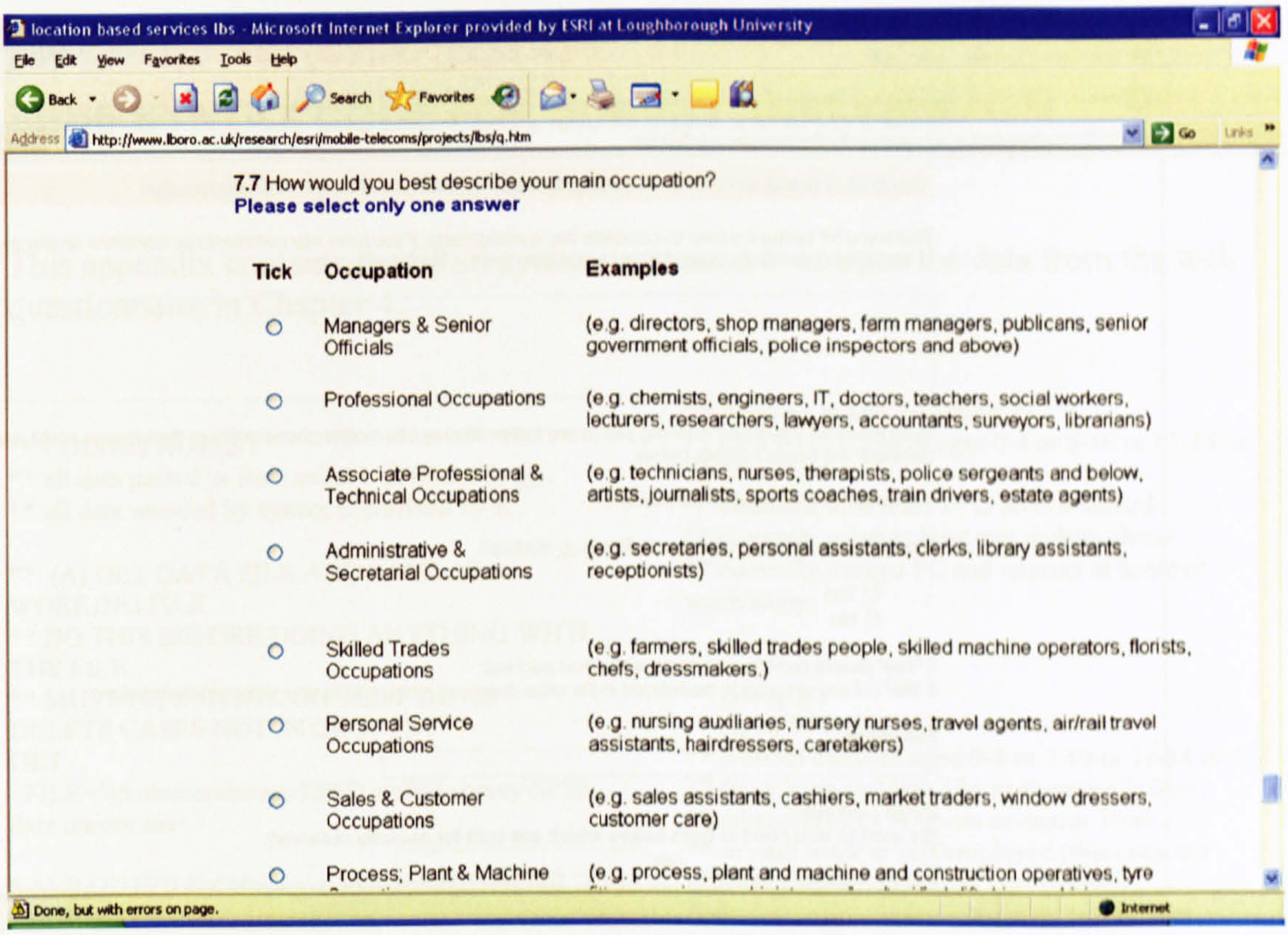

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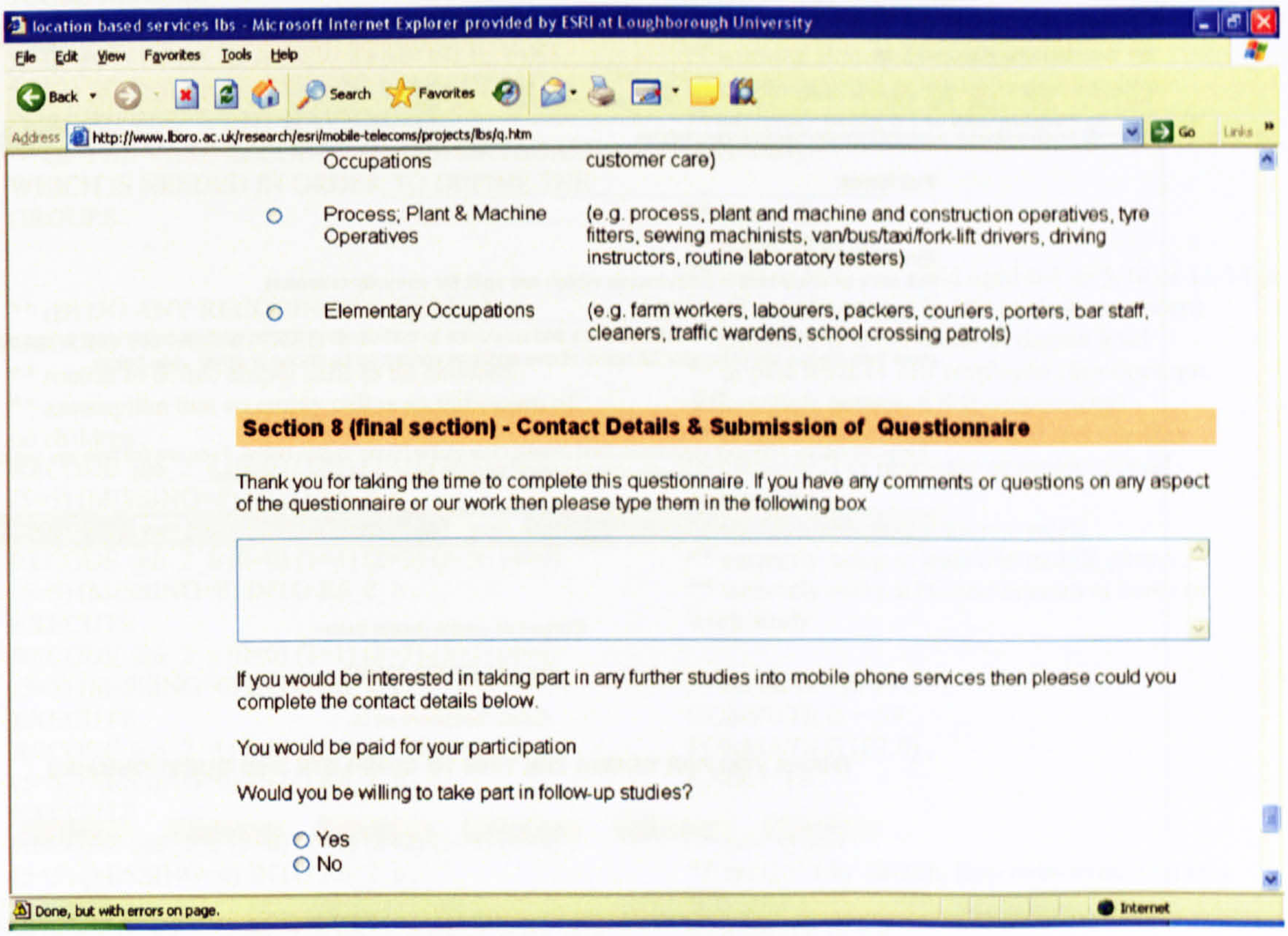
7.7 How would you best describe your main occupation?
Please select only one answer

Tick	Occupation	Examples
○	Managers & Senior Officials	(e.g. directors, shop managers, farm managers, publicans, senior government officials, police inspectors and above)
○	Professional Occupations	(e.g. chemists, engineers, IT, doctors, teachers, social workers, lecturers, researchers, lawyers, accountants, surveyors, librarians)
○	Associate Professional & Technical Occupations	(e.g. technicians, nurses, therapists, police sergeants and below, artists, journalists, sports coaches, train drivers, estate agents)
○	Administrative & Secretarial Occupations	(e.g. secretaries, personal assistants, clerks, library assistants, receptionists)
○	Skilled Trades Occupations	(e.g. farmers, skilled trades people, skilled machine operators, florists, chefs, dressmakers.)
○	Personal Service Occupations	(e.g. nursing auxiliaries, nursery nurses, travel agents, air/rail travel assistants, hairdressers, caretakers)
○	Sales & Customer Occupations	(e.g. sales assistants, cashiers, market traders, window dressers, customer care)
○	Process, Plant & Machine	(e.g. process, plant and machine and construction operatives, tyre

Done, but with errors on page.



location based services lbs - Microsoft Internet Explorer provided by ESRI at Loughborough University

Address http://www.lboro.ac.uk/research/esri/mobile-telecoms/projects/lbs/q.htm

Tick	Occupation	Examples
	Occupations	customer care)
○	Process, Plant & Machine Operatives	(e.g. process, plant and machine and construction operatives, tyre fitters, sewing machinists, van/bus/taxi/fork-lift drivers, driving instructors, routine laboratory testers)
○	Elementary Occupations	(e.g. farm workers, labourers, packers, couriers, porters, bar staff, cleaners, traffic wardens, school crossing patrols)

Section 8 (final section) - Contact Details & Submission of Questionnaire

Thank you for taking the time to complete this questionnaire. If you have any comments or questions on any aspect of the questionnaire or our work then please type them in the following box

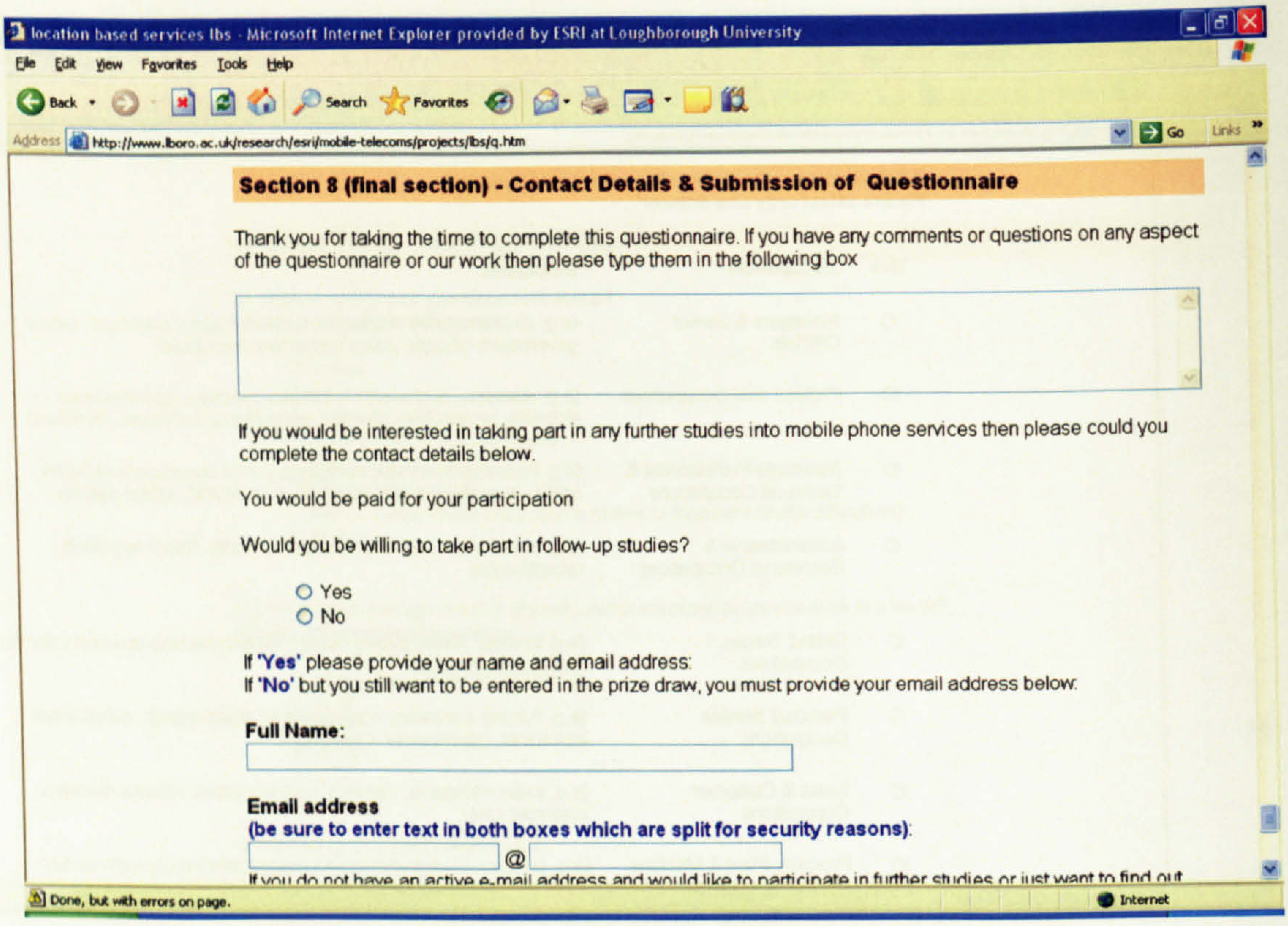
If you would be interested in taking part in any further studies into mobile phone services then please could you complete the contact details below.

You would be paid for your participation

Would you be willing to take part in follow-up studies?

○ Yes
○ No

Done, but with errors on page.



Section 8 (final section) - Contact Details & Submission of Questionnaire

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You would be paid for your participation

Would you be willing to take part in follow-up studies?

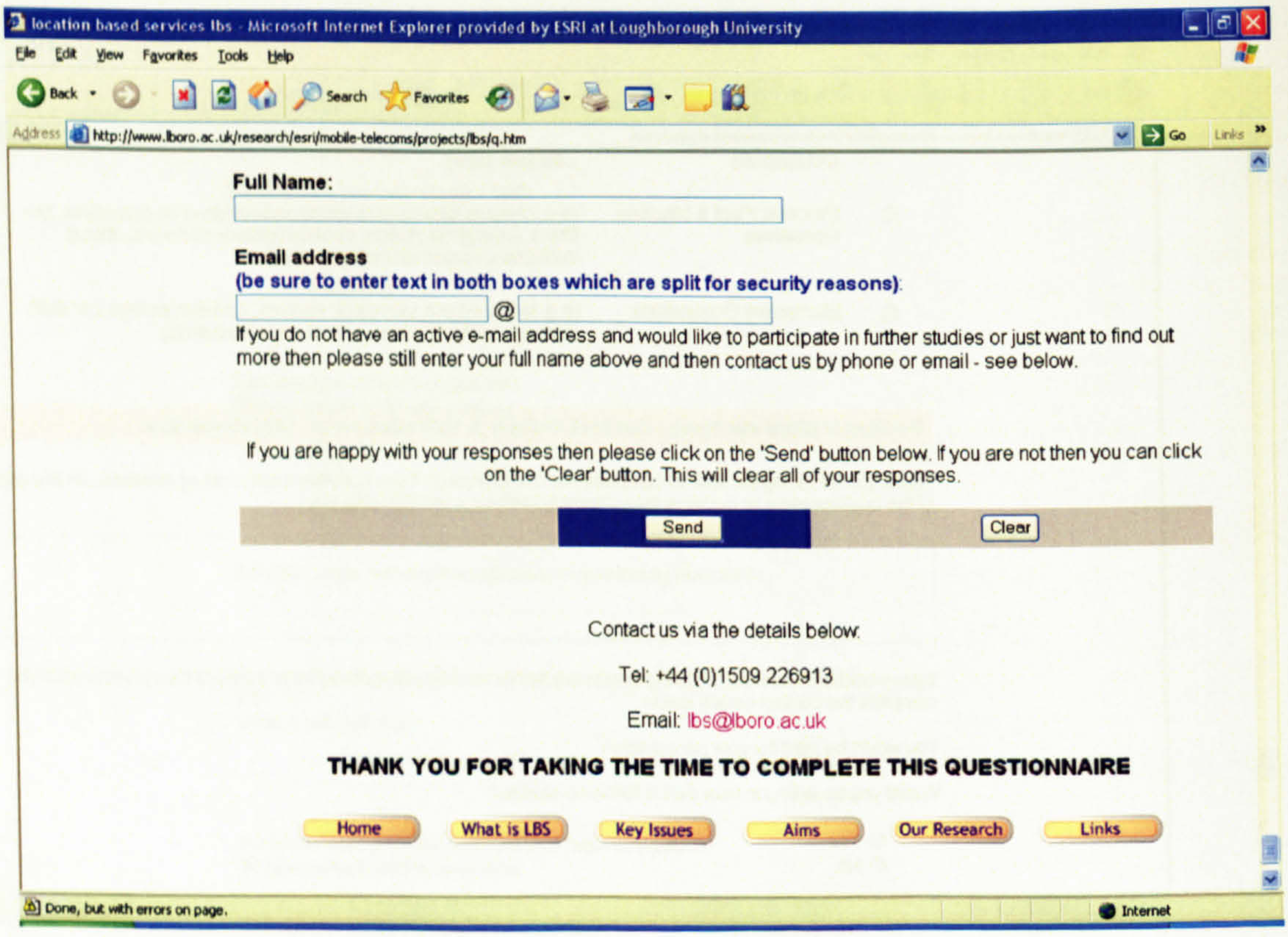
- ○ Yes
- ○ No

If **'Yes'** please provide your name and email address:
If **'No'** but you still want to be entered in the prize draw, you must provide your email address below:

Full Name:

Email address
(be sure to enter text in both boxes which are split for security reasons):

@



Full Name:

Email address
(be sure to enter text in both boxes which are split for security reasons):

@

If you do not have an active e-mail address and would like to participate in further studies or just want to find out more then please still enter your full name above and then contact us by phone or email - see below.

If you are happy with your responses then please click on the 'Send' button below. If you are not then you can click on the 'Clear' button. This will clear all of your responses.

Send | Clear

Contact us via the details below:

Tel: +44 (0)1509 226913

Email: lbs@lboro.ac.uk

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Home | What is LBS | Key Issues | Aims | Our Research | Links

APPENDIX 4B (CHAPTER 4)

SPSS SYNTAX CODE FOR SURVEY ANALYSIS

This appendix contains the SPSS syntax code used to analyse the data from the web questionnaire in Chapter 4.

```
** CODING NOTES .
** all data pasted in from excel is prefixed by @ .
** all data recoded by syntax is prefixed by R .

** (A) GET DATA FILE AND SAVE AS A WORKING FILE .
** DO THIS BEFORE DOING ANYTHING WITH THE FILE .
** MUST DO SYNTAX ON TEMP DB AS DELETE CASES NOT IN GROUPS .
GET
 FILE='\\fusion\andrewm$\PhD stuff\2 survey\SPSS data master.sav'.

SAVE OUTFILE='\\fusion\andrewm$\PhD stuff\2 survey\lbs temp.sav'
 /COMPRESSED.

** IF YOU CREATE A NEW TEMP FILE, YOU NEED TO RUN THROUGH FILE AGAIN FROM HERE AS YOU WONT HAVE SOME .
** OF THE VARS RECODED IN THE DATABASE WHICH IS NEEDED IN ORDER TO DEFINE THE GROUPS .

** (B) DO ANY RECODING TO ENABLE GROUPS TO BE DEFINED .
** recode to define empty cells as no children .
** assumption that an empty cell is an indication of no children .
RECODE @6_2_a (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (MISSING=0) INTO R6_2_a .
EXECUTE .
RECODE @6_2_b (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (MISSING=0) INTO R6_2_b .
EXECUTE .
RECODE @6_2_c (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (MISSING=0) INTO R6_2_c .
EXECUTE .
RECODE @6_2_d (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (MISSING=0) INTO R6_2_d .
EXECUTE .
RECODE @6_2_e (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (MISSING=0) INTO R6_2_e .
EXECUTE .
FORMATS R6_2_a R6_2_b R6_2_c R6_2_d R6_2_e (F2.0) .

** (C) DEFINE GROUPS ACCORDING TO LINDGREN .
USE ALL.
** Group 1 .
** Aged up to and including 29 .
** with no children of ages 0-4 or 5-10 or 11-14 or 15-17 or 18+ .
** educated to at least 5+ O level standard .
** currently using at least one mobile phone .
** currently using a PC and internet at home or work/study.

** Group 2 .
** Aged 30 to 50 .
** without children aged 0-4 or 5-10 or 11-14 or 15-17 (may have children 18+ as these are indep) .
** educated to 2+ A levels or degree level .
** in paid work or self employed (this does not differentiate betweeen diff occupations) .
** in [associate professional and technical] or [professional] or [manager or senior offical] occupations .
** working at least 21 hours a week.
** currently using at least one mobile phone .
** currently using a PC and internet at home or work/study.

** Group 3 .
** Aged 30 to 50 .
** with at least one child aged 0-4 or 5-10 or 11-14 or 15-17 (not interested in 18+ as these are indep) .
** educated to 2+ A levels or degree level .
** in paid work or self employed (this does not differentiate betweeen diff occupations) .
** in [associate professional and technical] or [professional] or [manager or senior offical] occupations .
** working at least 21 hours a week.
** currently using at least one mobile phone .
** currently using a PC and internet at home or work/study.

** set all G = to 99 .
COMPUTE G = 99 .
FORMATS G (F2.0) .
EXECUTE .

** new syntax .
** set G = 4 by default, then over-write with new definitions .
COMPUTE G = 4 .
FORMATS G (F2.0) .
EXECUTE .

** group 1 - mobile kids with lots of friends MOKLOFS .
 IF ( (@1_2 GE 1976)
```

```
   AND (R6_2_a=0 AND R6_2_b=0 AND
R6_2_c=0 AND R6_2_d=0 AND R6_2_e=0)
   AND (R6_6 ge 3)
   AND (R2_1=2 OR R2_1=3 OR R2_1=4)
   AND (R4_1_a=1 and R4_1_b=1) )
G = 1.
EXECUTE .

** group 2 young urban professinals with lack of
time.
 IF ( (@1_2 < 1976 AND @1_2 ge 1955)
   AND (R6_2_a=0 AND R6_2_b=0 AND
R6_2_c=0 AND R6_2_d=0)
   AND (R6_6 ge 4)
   AND (R7_1_d =1)
   AND (R7_7 = -3 OR R7_7 = -2 OR R7_7 = -1)
   AND (R7_2 = 3 OR R7_2 = 4  OR R7_2 = 5)
   AND (R2_1=2 OR R2_1=3 OR R2_1=4)
   AND (R4_1_a=1 and R4_1_b=1) )
 G = 2.
 EXECUTE .

** group 3 - as group 2 but with kids YUPPLOTS .
 IF ( (@1_2 < 1976 AND @1_2 ge 1955)
   AND (R6_2_a >0 OR R6_2_b>0 OR R6_2_c>0
OR R6_2_d>0)
   AND (R6_6 ge 4)
   AND (R7_1_d =1)
   AND (R7_7 = -3 OR R7_7 = -2 OR R7_7 = -1)
   AND (R7_2 = 3 OR R7_2 = 4  OR R7_2 = 5)
   AND (R2_1=2 OR R2_1=3 OR R2_1=4)
   AND (R4_1_a=1 and R4_1_b=1) )
 G = 3.
 EXECUTE.

** define 99 as missing values, so dont plot any cases
that dont fall into G = 1 or 2 or 3 .
MISSING VALUES G (99) .

VARIABLE LABEL G ' Sub group' .
VALUE LABEL G
 1 'Young social'
 2 'Prof. without children'
 3 'Prof. with children'
 4 'other' .

FREQUENCIES
 VARIABLES=G
 /ORDER=  ANALYSIS .

** (D) DELETE THE CASES THAT DONT FALL
INTO G= 1 OR 2 OR 3 .

FILTER OFF.
USE ALL.
SELECT IF(G = 1 OR G = 2 OR G = 3).
EXECUTE .

FREQUENCIES
 VARIABLES=G
 /ORDER=  ANALYSIS .

** 1 ABOUT YOU .
** 1_1 GENDER .

GRAPH
 /PIE=PCT BY @1_1
 /TEMPLATE='D:\do not delete\LBS 200w by 200h
pie.sgt' .

USE ALL .
CROSSTABS
 /TABLES=@1_1  BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(STACKED)=COUNT BY G BY @1_1
 /TEMPLATE='D:\do not delete\LBS vertical bars
count half page.sgt'.

** 1_2  AGE  .

FREQUENCIES
 VARIABLES=@1_2
 /BARCHART  NONE
 /ORDER=  ANALYSIS .

** all subs .
** GRAPH
 /BAR(SIMPLE)=PCT BY @1_2
 /TEMPLATE='D:\do not delete\LBS 400w by 300h
bars DOB.sgt'.

GRAPH
 /BAR(SIMPLE)=PCT BY @1_2 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
year of birth.sgt'.

** 2  ABOUT THE USE OF YOUR PHONE .
** 2_1 HOW MANY MOBILE PHONES YOU USE.

RECODE @2_1  ('None'=1) ('One'=2) ('Two'=3)
('Three'=4) (' '=99)  INTO R2_1 .
FORMATS R2_1 (F2.0) .
VARIABLE LABEL R2_1 'Number of mobile
phones' .
VALUE LABEL R2_1
1  'None'
2 'One'
3 'Two'
4 'Three or more'
99 'Did not answer'  .
execute .

USE ALL .
CROSSTABS
 /TABLES=R2_1  BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R2_1 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 2_2 WHAT YEAR YOU GOT YOUR FIRST
MOBILE PHONE .
```

```
VARIABLE LABEL @2_2 'Date of getting their first
mobile phone' .
FREQUENCIES
 VARIABLES=@2_2
 /BARCHART PERCENT
 /ORDER= ANALYSIS .

** 2_8 - 16 INFO ACCESS AND COMMS .
VARIABLE LABEL @2_8_a 'Send an email' .
VARIABLE LABEL @2_9_a 'Use instant messaging
on a PC' .
VARIABLE LABEL @2_10_a 'Access the web on a
PC' .
VARIABLE LABEL @2_11_a 'Access the web on
your mobile phone' .
VARIABLE LABEL @2_12_a 'Use your mobile
phone to make a call' .
VARIABLE LABEL @2_13_a 'Text another person' .
VARIABLE LABEL @2_14_a 'Text an interactive
service' .
VARIABLE LABEL @2_15_a 'Send a photo or
video message' .
VARIABLE LABEL @2_16_a 'Make a landline call'.

VARIABLE LABEL @2_8_b 'Send an email' .
VARIABLE LABEL @2_9_b 'Use instant messaging
on a PC' .
VARIABLE LABEL @2_10_b 'Access the web on a
PC' .
VARIABLE LABEL @2_11_b 'Access the web on
your mobile phone' .
VARIABLE LABEL @2_12_b 'Use your mobile
phone to make a call' .
VARIABLE LABEL @2_13_b 'Text another person' .
VARIABLE LABEL @2_14_b 'Text an interactive
service' .
VARIABLE LABEL @2_15_b 'Send a photo or
video message' .
VARIABLE LABEL @2_16_b 'Make a landline call'.
** dont do boxplots with the examine command - too
messy .
** show whether symmetric or skewed, if skewed
then plot medians.

FORMATS @2_8_a @2_8_b @2_9_a @2_9_b
@2_10_a @2_10_b @2_11_a @2_11_b @2_12_a
@2_12_b
  @2_13_a @2_13_b @2_14_a @2_14_b @2_15_a
@2_15_b @2_16_a @2_16_b (F2.0) .

DESCRIPTIVES
 VARIABLES= @2_8_a @2_8_b @2_9_a @2_9_b
@2_10_a @2_10_b @2_11_a @2_11_b @2_12_a
@2_12_b
  @2_13_a @2_13_b @2_14_a @2_14_b @2_15_a
@2_15_b @2_16_a @2_16_b
 /STATISTICS=STDDEV SEMEAN SKEWNESS .

** combine groups 2 and 3 into one, so new variable
G2 has two values, 1 and 2.
IF G=1 G2 = 1.
IF G=2 OR G=3 G2 = 2.
EXECUTE .
FORMATS G2 (F2.0) .

GRAPH
 /BAR(SIMPLE)= MED(@2_8_a) MED(@2_9_a)
MED(@2_10_a) MED(@2_11_a) MED(@2_12_a)
 MED(@2_13_a) MED(@2_14_a) MED(@2_15_a)
MED(@2_16_a) BY G
/MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
median ICT use.sgt'.

GRAPH
 /BAR(SIMPLE)= MED(@2_8_b) MED(@2_9_b)
MED(@2_10_b) MED(@2_11_b) MED(@2_12_b)
 MED(@2_13_b) MED(@2_14_b) MED(@2_15_b)
MED(@2_16_b) BY G
/MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
median ICT use.sgt'.

* non para for 2 indep groups to compare differences
between younger and older ..
NPAR TESTS
 /M-W= @2_8_a @2_8_b @2_9_a @2_9_b
@2_10_a @2_10_b @2_11_a @2_11_b @2_12_a
@2_12_b @2_13_a @2_13_b @2_14_a @2_14_b
@2_15_a
 @2_15_b @2_16_a @2_16_b  BY G2(1 2)
 /MISSING ANALYSIS.

** check for skewness and kurtosis .
** SORT CASES BY G .
** SPLIT FILE
 LAYERED BY G .

** FREQUENCIES
 VARIABLES=@2_10_a @2_10_b @2_11_a
@2_11_b @2_12_a @2_12_b @2_13_a @2_13_b
@2_14_a @2_14_b @2_15_a @2_15_b @2_16_a
@2_16_b
 /STATISTICS=MEAN MEDIAN MODE
SKEWNESS SESKEW KURTOSIS SEKURT
 /HISTOGRAM NORMAL
 /ORDER= ANALYSIS .

** 3  TRAVELLING AND ATTITUDES .
** 3_1 REGULAR COMMUTE - TYPE OF
TRANSPORT .

** make sure 99 set to define missing in db .

RECODE @3_1_a ('at home'=1) (' ' = 99) INTO
R3_1_a .
VARIABLE LABEL R3_1_a 'Work from home / no
regular journey' .
EXECUTE .

RECODE @3_1_b ('underground'=1) (' ' = 99)
INTO R3_1_b .
VARIABLE LABEL R3_1_b 'Underground, metro,
light rail, tram' .
EXECUTE .

RECODE @3_1_c ('train'=1) (' ' = 99)  INTO
R3_1_c .
VARIABLE LABEL R3_1_c 'Train' .
EXECUTE .

RECODE @3_1_d ('bus'=1) (' ' = 99)  INTO R3_1_d.
VARIABLE LABEL R3_1_d 'Bus, minibus, coach' .
```

```
EXECUTE .

RECODE @3_1_e ('motrocycle'=1) (' ' = 99)  INTO
R3_1_e .
VARIABLE LABEL R3_1_e 'Motorcycle, scooter,
moped' .
EXECUTE .

RECODE @3_1_f ('driving car'=1) (' ' = 99)  INTO
R3_1_f .
VARIABLE LABEL R3_1_f 'Driving a car or van' .
EXECUTE .

RECODE @3_1_g ('passenger car'=1) (' ' = 99)
INTO R3_1_g .
VARIABLE LABEL R3_1_g 'Passenger in a car or
van' .
EXECUTE .

RECODE @3_1_h ('taxi'=1) (' ' = 99)  INTO
R3_1_h.
VARIABLE LABEL R3_1_h 'Taxi' .
EXECUTE .

RECODE @3_1_i ('bicycle'=1) (' ' = 99)  INTO
R3_1_i .
VARIABLE LABEL R3_1_i 'Bicycle' .
EXECUTE .

RECODE @3_1_j ('foot'=1) (' ' = 99)  INTO R3_1_j .
VARIABLE LABEL R3_1_j 'On foot' .
EXECUTE .

RECODE @3_1_k ('plane'=1) (' ' = 99)  INTO
R3_1_k .
VARIABLE LABEL R3_1_k 'By plane' .
EXECUTE .

RECODE @3_1_l ('other'=1) (' ' = 99)  INTO R3_1_l
.
VARIABLE LABEL R3_1_l 'Other' .
EXECUTE .

** R3_1_m is set to 1 if someone has not answered
any of a to k so can plot this.
** set to 1 initially, then set to 99 if they have
answered any of the prev questions .

COMPUTE R3_1_m = 1 .
VARIABLE LABEL R3_1_m 'Did not answer' .
EXECUTE .

DO IF  (R3_1_a = 1) OR (R3_1_b = 1) OR (R3_1_c
= 1) OR (R3_1_d = 1) OR (R3_1_e = 1) OR (R3_1_f
= 1) OR (R3_1_g = 1) OR (R3_1_h = 1)
OR (R3_1_i = 1) OR (R3_1_j = 1) OR (R3_1_k = 1)
OR (R3_1_l = 1) .
COMPUTE R3_1_m = 99 .
END IF .
EXECUTE .

** plot them all on the same graph, using no of cases .
** dont do BY G, as graph too messy.

FORMATS R3_1_a R3_1_b R3_1_a R3_1_c R3_1_d
R3_1_e R3_1_f R3_1_g R3_1_h R3_1_i R3_1_j
R3_1_k R3_1_l (F2.0) .

** plot count .
MISSING VALUES R3_1_a R3_1_b R3_1_c
R3_1_d R3_1_e R3_1_f R3_1_g R3_1_h R3_1_i
R3_1_j R3_1_k R3_1_l (99) .
GRAPH
 /BAR(SIMPLE)= N(R3_1_a) N(R3_1_b)
N(R3_1_c) N(R3_1_d) N(R3_1_e) N(R3_1_f)
N(R3_1_g) N(R3_1_h)
 N(R3_1_i) N(R3_1_j) N(R3_1_k) N(R3_1_l)
N(R3_1_m) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS 400w by 300h
bars.sgt'.

** plot percentage less than 99 - ie empty value .
MISSING VALUES R3_1_a R3_1_b R3_1_c
R3_1_d R3_1_e R3_1_f R3_1_g R3_1_h R3_1_i
R3_1_j R3_1_k R3_1_l () .
GRAPH
 /BAR(SIMPLE)= PLT(99)(R3_1_a)
PLT(99)(R3_1_b) PLT(99)(R3_1_c)
PLT(99)(R3_1_d) PLT(99)(R3_1_e)
PLT(99)(R3_1_f)
  PLT(99)(R3_1_g) PLT(99)(R3_1_h)
PLT(99)(R3_1_i) PLT(99)(R3_1_j)
PLT(99)(R3_1_k) PLT(99)(R3_1_l) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page rhs key.sgt.'

** 3_2 REGULAR COMMUTE - TOTAL
DISTANCE TO WORK SCHOOL STUDY .

RECODE @3_2
('0-2 miles'=1)
('3-10 miles'=2)
('11-30 miles'=3)
('31-50 miles'=4)
('51-100 miles'=5)
('101+ miles'=6)
(' '=99)  INTO R3_2 .
VALUE LABEL R3_2
1 '0 - 2 miles'
2 '3 - 10 miles'
3 '11 - 30 miles'
4 '31 - 50 miles'
5 '51 - 100 miles'
6 '101 + miles'
99 'DNA'   .
EXECUTE   .
FORMATS R3_2 (F2.0) .

CROSSTABS
 /TABLES=R3_2  BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R3_2 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 3_3 TOTAL TIME TO WORK SCHOOL
STUDY.
```

```
RECODE @3_3 ('1-10 minutes'=1) ('11-30
minutes'=2) ('31-60 minutes'=3) ('61-120 minutes'=4)
('121+ minutes'=5) (' '=99) INTO R3_3 .
VARIABLE LABEL R3_3 'Duration of regular trip to
work/study' .
VALUE LABEL R3_3
1 '1 - 10 minutes'
2 '11 - 30 minutes'
3 '31 - 60 minutes'
4 '61 - 120 minutes'
5 '121 + minutes'
99 'Did not answer' .
EXECUTE .
FORMATS R3_3 (F2.0) .

CROSSTABS
 /TABLES=R3_3 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R3_3 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 3_4 NUMBER OF WORK RELATED TRIPS .
** make sure 99 set to define missing in db .

RECODE @3_4 ('none'=1) ('1-5 trips'=2) ('6-10
trips'=3) ('11-15 trip'=4) ('16-20 trips'=5) ('21-25
trips'=6) ('26+ trips'=7) (' '=99) INTO R3_4 .
VARIABLE LABEL R3_4 'Number of work-related
trips per month' .
VALUE LABEL R3_4
1 'None'
2 '1 - 5 trips'
3 '6 - 10 trips'
4 '11 - 15 trips'
5 '16 - 20 trips'
6 '21 - 25 trips'
7 '26 + trips'
99 'Did not answer' .
EXECUTE .
FORMATS R3_4 (F2.0) .

CROSSTABS
 /TABLES=R3_4 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R3_4 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 3_5 MODE OF TRANSPORT FOR WORK
RELATED TRIPS .

RECODE @3_5_a ('underground'=1) (' ' = 99) INTO
R3_5_a .
VARIABLE LABEL R3_5_a 'Underground, metro,
light rail, tram' .
EXECUTE.

RECODE @3_5_b ('train'=1) (' ' = 99) INTO
R3_5_b .
VARIABLE LABEL R3_5_b 'Train' .
EXECUTE.

RECODE @3_5_c ('bus'=1) (' ' = 99) INTO R3_5_c.
VARIABLE LABEL R3_5_c 'Bus, minibus, coach' .
EXECUTE.

RECODE @3_5_d ('motrocycle'=1) (' ' = 99) INTO
R3_5_d .
VARIABLE LABEL R3_5_d 'Motorcycle, scooter,
moped' .
EXECUTE.

RECODE @3_5_e ('driving car'=1) (' ' = 99) INTO
R3_5_e .
VARIABLE LABEL R3_5_e 'Driving a car or van' .
EXECUTE.

RECODE @3_5_f ('passenger car'=1) (' ' = 99)
INTO R3_5_f.
VARIABLE LABEL R3_5_f 'Passenger in a car or
van' .
EXECUTE.

RECODE @3_5_g ('taxi'=1) (' ' = 99) INTO R3_5_g
.
VARIABLE LABEL R3_5_g 'Taxi' .
EXECUTE.

RECODE @3_5_h ('bicycle'=1) (' ' = 99) INTO
R3_5_h .
VARIABLE LABEL R3_5_h 'Bicycle' .
EXECUTE.

RECODE @3_5_i ('foot'=1) (' ' = 99) INTO R3_5_i .
VARIABLE LABEL R3_5_i 'On foot' .
EXECUTE.

RECODE @3_5_j ('plane'=1) (' ' = 99) INTO
R3_5_j .
VARIABLE LABEL R3_5_j 'By plane' .
EXECUTE.

RECODE @3_5_k ('other'=1) (' ' = 99) INTO
R3_5_k .
VARIABLE LABEL R3_5_k 'Other' .
EXECUTE.

** R3_5_l is set to 1 if someone has not answered any
of a to k so can plot this.
** set to 1 initially, then set to 99 if they have
answered any of the prev questions .
COMPUTE R3_5_l = 1 .
VARIABLE LABEL R3_5_l 'Did not answer' .
EXECUTE .

DO IF (R3_5_a = 1) OR (R3_5_b = 1) OR (R3_5_c
= 1) OR (R3_5_d = 1) OR (R3_5_e = 1) OR (R3_5_f
= 1) OR (R3_5_g = 1) OR (R3_5_h = 1)
OR (R3_5_i = 1) OR (R3_5_j = 1) OR (R3_5_k = 1) .
COMPUTE R3_5_l = 99 .
END IF .
EXECUTE .
```

```
FORMATS R3_5_a R3_5_b R3_5_c R3_5_d R3_5_e
R3_5_f R3_5_g R3_5_h R3_5_i R3_5_j
R3_5_k R3_5_l (F2.0) .

** dont do BY G, as graph too messy.
** plot the number of cases, need to state 99 as
missing so these values are not counted .
** plot counts.
MISSING VALUES R3_5_a R3_5_b R3_5_c
R3_5_d R3_5_e R3_5_f R3_5_g R3_5_h R3_5_i
R3_5_j
R3_5_k R3_5_l (99) .
GRAPH
 /BAR(SIMPLE)= N(R3_5_a) N(R3_5_b)
N(R3_5_c) N(R3_5_d) N(R3_5_e) N(R3_5_f)
N(R3_5_g) N(R3_5_h)
 N(R3_5_i) N(R3_5_j) N(R3_5_k) N(R3_5_l) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS 400w by 300h
bars.sgt'.

** plot the percentages, need to state 99 not missing,
so can plot % less than 99 .
MISSING VALUES R3_5_a R3_5_b R3_5_c
R3_5_d R3_5_e R3_5_f R3_5_g R3_5_h R3_5_i
R3_5_j
R3_5_k R3_5_l () .
GRAPH
 /BAR(SIMPLE)= PLT(99)(R3_5_a)
PLT(99)(R3_5_b) PLT(99)(R3_5_c)
PLT(99)(R3_5_d) PLT(99)(R3_5_e)
PLT(99)(R3_5_f)
  PLT(99)(R3_5_g) PLT(99)(R3_5_h)
PLT(99)(R3_5_i) PLT(99)(R3_5_j)
PLT(99)(R3_5_k) PLT(99)(R3_5_l) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page rhs key.sgt'.

** 3_6 NUMBER OF NON - WORK RELATED
TRIPS .

** make sure 99 set to define missing in db .
RECODE @3_6 ('none'=1) ('1-5 trips'=2) ('6-10
trips'=3) ('11-15 trips'=4) ('16-20 trips'=5) ('21-25
trips'=5) ('26+ trips'=5) (' '=99) INTO R3_6 .
VARIABLE LABEL R3_6 'Number of non work-
related trips per week' .
VALUE LABEL R3_6
1 'None'
2 '1 - 5 trips'
3 '6 - 10 trips'
4 '11 - 15 trips'
5 '16 - 20 trips'
6 '21 - 25 trips'
7 '26 + trips'
99 'Did not answer' .
EXECUTE .

CROSSTABS
 /TABLES=R3_6 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R3_6 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 3_7 MODE OF TRANSPORT FOR NON -
WORK RELATED TRIPS .

RECODE @3_7_a ('underground'=1) (' ' = 99) INTO
R3_7_a .
VARIABLE LABEL R3_7_a 'Underground, metro,
light rail, tram' .
EXECUTE .

RECODE @3_7_b ('train'=1) (' ' = 99) INTO
R3_7_b .
VARIABLE LABEL R3_7_b 'Train' .
EXECUTE .

RECODE @3_7_c ('bus'=1) (' ' = 99) INTO R3_7_c.
VARIABLE LABEL R3_7_c 'Bus, minibus, coach' .
EXECUTE .

RECODE @3_7_d ('motrocycle'=1) (' ' = 99) INTO
R3_7_d.
VARIABLE LABEL R3_7_d 'Motorcycle, scooter,
moped' .
EXECUTE .

RECODE @3_7_e ('driving car'=1) (' ' = 99) INTO
R3_7_e .
VARIABLE LABEL R3_7_e 'Driving a car or van' .
EXECUTE .

RECODE @3_7_f ('passenger car'=1) (' ' = 99)
INTO R3_7_f .
VARIABLE LABEL R3_7_f 'Passenger in a car or
van' .
EXECUTE .

RECODE @3_7_g ('taxi'=1) (' ' = 99) INTO
R3_7_g.
VARIABLE LABEL R3_7_g 'Taxi' .
EXECUTE .

RECODE @3_7_h ('bicycle'=1) (' ' = 99) INTO
R3_7_h .
VARIABLE LABEL R3_7_h 'Bicycle' .
EXECUTE .

RECODE @3_7_i ('foot'=1) (' ' = 99) INTO R3_7_i .
VARIABLE LABEL R3_7_i 'On foot' .
EXECUTE .

RECODE @3_7_j ('plane'=1) (' ' = 99) INTO
R3_7_j .
VARIABLE LABEL R3_7_j 'By plane' .
EXECUTE .

RECODE @3_7_k ('other'=1) (' ' = 99) INTO
R3_7_k .
VARIABLE LABEL R3_7_k 'Other' .
EXECUTE .

** R3_7_l is set to 1 if someone has not answered any
of a to k so can plot this.
```

```
** set to 1 initially, then set to 99 if they have
answered any of the prev questions .

COMPUTE R3_7_l = 1 .
VARIABLE LABEL R3_7_l 'Did not answer' .
EXECUTE .

DO IF (R3_7_a = 1) OR (R3_7_b = 1) OR (R3_7_c
= 1) OR (R3_7_d = 1) OR (R3_7_e = 1) OR (R3_7_f
= 1) OR (R3_7_g = 1) OR (R3_7_h = 1)
OR (R3_7_i = 1) OR (R3_7_j = 1) OR (R3_7_k = 1) .
COMPUTE R3_7_l = 99 .
END IF .
EXECUTE .

** plot them all on the same graph, using no of cases .
** dont do BY G, as graph too messy.
FORMATS R3_7_a R3_7_b R3_7_c R3_7_d R3_7_e
R3_7_f R3_7_g R3_7_h R3_7_i R3_7_j
R3_7_k R3_7_l (F2.0) .

** plot count .
MISSING VALUES R3_7_a R3_7_b R3_7_c
R3_7_d R3_7_e R3_7_f R3_7_g R3_7_h R3_7_i
R3_7_j
R3_7_k R3_7_l (99) .
GRAPH
 /BAR(SIMPLE)= N(R3_7_a) N(R3_7_b)
N(R3_7_c) N(R3_7_d) N(R3_7_e) N(R3_7_f)
N(R3_7_g) N(R3_7_h)
  N(R3_7_i) N(R3_7_j) N(R3_7_k) N(R3_7_l) BY G
 /MISSING=VARIABLEWISE.

** plot percentages .
MISSING VALUES R3_7_a R3_7_b R3_7_c
R3_7_d R3_7_e R3_7_f R3_7_g R3_7_h R3_7_i
R3_7_j
R3_7_k R3_7_l () .
GRAPH
 /BAR(SIMPLE)= PLT(99)(R3_7_a)
PLT(99)(R3_7_b) PLT(99)(R3_7_c)
PLT(99)(R3_7_d) PLT(99)(R3_7_e)
PLT(99)(R3_7_f)
  PLT(99)(R3_7_g) PLT(99)(R3_7_h)
PLT(99)(R3_7_i) PLT(99)(R3_7_j)
PLT(99)(R3_7_k) PLT(99)(R3_7_l) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page rhs key.sgt'.

** 4 CONTACT WITH TECHNOLOGY .

** CONTACT WITH OTHER TECHNOLOGY .
** bars 4_1
** make sure 99 set to define missing in db .

RECODE @4_1_a ('pc'=1) (' '= 99) INTO R4_1_a .
VARIABLE LABEL R4_1_a 'PC' .
EXECUTE .

RECODE @4_1_b ('internet'=1) (' '= 99) INTO
R4_1_b .
VARIABLE LABEL R4_1_b 'Internet' .
EXECUTE .

RECODE @4_1_c ('pda'=1) (' '= 99) INTO R4_1_c.
VARIABLE LABEL R4_1_c 'PDA' .
```

```
EXECUTE .

RECODE @4_1_d ('digital tv'=1) (' '= 99) INTO
R4_1_d .
VARIABLE LABEL R4_1_d 'Digital TV' .
EXECUTE .

RECODE @4_1_e ('digital camera'=1) (' '= 99)
INTO R4_1_e .
VARIABLE LABEL R4_1_e 'Digital camera' .
EXECUTE .

RECODE @4_1_f ('dvd'=1) (' '= 99) INTO R4_1_f .
VARIABLE LABEL R4_1_f 'DVD' .
EXECUTE .

RECODE @4_1_g ('mp3'=1) (' '= 99) INTO
R4_1_g .
VARIABLE LABEL R4_1_g 'MP3' .
EXECUTE .

RECODE @4_1_h ('digital radio'=1) (' '= 99) INTO
R4_1_h .
VARIABLE LABEL R4_1_h 'Digital radio' .
EXECUTE .

RECODE @4_1_i ('car nav'=1) (' '= 99) INTO
R4_1_i .
VARIABLE LABEL R4_1_i 'In-car navigation' .
EXECUTE .

RECODE @4_1_j ('portable nav'=1) (' '= 99) INTO
R4_1_j .
VARIABLE LABEL R4_1_j 'Portable navigation' .
execute .

RECODE @4_1_k ('games'=1) (' '= 99) INTO
R4_1_k .
VARIABLE LABEL R4_1_k 'Games console' .
EXECUTE .

** R4_1_l is set to 1 if someone has not answered any
of a to k so can plot this.
** set to 1 initially, then set to 99 if they have
answered any of the prev questions .

COMPUTE R4_1_l = 1 .
EXECUTE .

DO IF (R4_1_a = 1) OR (R4_1_b = 1) OR (R4_1_c
= 1) OR (R4_1_d = 1) OR (R4_1_e = 1) OR (R4_1_f
= 1) OR (R4_1_g = 1) OR (R4_1_h = 1)
OR (R4_1_i = 1) OR (R4_1_j = 1) OR (R4_1_k = 1) .
COMPUTE R4_1_l = 99 .
END IF .
EXECUTE .

** id those who use at least 1 mobile phone .
IF (R2_1 = 2 OR R2_1 = 3 OR R2_1 = 4) R4_1_mob
= 1 .
EXECUTE .
VARIABLE LABEL R4_1_mob 'Mobile phone' .

** plot counts.
MISSING VALUES R4_1_mob R4_1_a R4_1_b
R4_1_c R4_1_d R4_1_e R4_1_f R4_1_g R4_1_h
R4_1_i R4_1_j
```

```
R4_1_k R4_1_1() .
GRAPH
 /BAR(SIMPLE)= PLT(99)(R4_1_mob)
PLT(99)(R4_1_a) PLT(99)(R4_1_b)
PLT(99)(R4_1_c) PLT(99)(R4_1_d)
PLT(99)(R4_1_e) PLT(99)(R4_1_f)
  PLT(99)(R4_1_g) PLT(99)(R4_1_h)
PLT(99)(R4_1_i) PLT(99)(R4_1_j)
PLT(99)(R4_1_k) PLT(99)(R4_1_l)
 /MISSING=VARIABLEWISE.
 /TEMPLATE='D:\do not delete\LBS 400w by 250h
bars.sgt'.

** plot them all on the same graph .
MISSING VALUES R4_1_mob R4_1_a R4_1_b
R4_1_c R4_1_d R4_1_e R4_1_f R4_1_g R4_1_h
R4_1_i R4_1_j
R4_1_k R4_1_1 (99) .
GRAPH
 /BAR(SIMPLE)= N(R4_1_mob) N(R4_1_a)
N(R4_1_b) N(R4_1_c) N(R4_1_d) N(R4_1_e)
N(R4_1_f) N(R4_1_g) N(R4_1_h)
  N(R4_1_i) N(R4_1_j) N(R4_1_k) N(R4_1_l) BY G
  /MISSING=VARIABLEWISE
  /TEMPLATE='D:\do not delete\LBS 400w by 250h
bars.sgt'.

** plot percentages .
MISSING VALUES R4_1_mob R4_1_a R4_1_b
R4_1_c R4_1_d R4_1_e R4_1_f R4_1_g R4_1_h
R4_1_i R4_1_j
R4_1_k R4_1_1() .
GRAPH
 /BAR(SIMPLE)= PLT(99)(R4_1_mob)
PLT(99)(R4_1_a) PLT(99)(R4_1_b)
PLT(99)(R4_1_c) PLT(99)(R4_1_d)
PLT(99)(R4_1_e) PLT(99)(R4_1_f)
  PLT(99)(R4_1_g) PLT(99)(R4_1_h)
PLT(99)(R4_1_i) PLT(99)(R4_1_j)
PLT(99)(R4_1_k) PLT(99)(R4_1_l) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page rhs key.sgt'.

** 4_2 OVERALL ATTITUDES TO
TECHNOLOGY .

RECODE @4_2 ('tech first'=1) ('tech second'=2)
('tech third'=3) ('tech fourth'=4 )('tech fifth'=5) (' ' =
99) INTO R4_2 .
VARIABLE LABEL R4_2 'Attitude to technology' .
VALUE LABEL R4_2
1 '1 \n Be the first'
2 '2 \n Try it out'
3 '3 \n Wait and see'
4 '4 \n Sceptical'
5 '5 \n Dont like it'
99 'Did not answer' .
EXECUTE .

** take out missing data for stats .
MISSING VALUES R4_2 (99) .
CROSSTABS
  /TABLES=R4_2 BY G
  /FORMAT= AVALUE TABLES
  /STATISTIC=CHISQ
  /CELLS= COUNT
  /COUNT ROUND CELL .

NPAR TESTS
 /K-W=R4_2 BY G(1 3)
 /MISSING ANALYSIS.

** can also do non-parametric test for unrelated
samples, based on ordinal data .
** put back in missing data for graphs .
MISSING VALUES R4_2 () .

GRAPH
 /BAR(STACKED)=COUNT BY R4_2 BY G .
** or .
GRAPH
 /BAR(SIMPLE)=PCT BY R4_2 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent overall attitudes.sgt'.


** 5 OPINIONS ON DIFFERENT SERVICES .
** 5_1 TO 5_15 a only LEVEL OF AWARENESS
OF SERVICES .

RECODE @5_1_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_1_a.
VALUE LABEL R5_1_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_2_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_2_a.
VALUE LABEL R5_2_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_3_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_3_a.
VALUE LABEL R5_3_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_4_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_4_a.
VALUE LABEL R5_4_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_5_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_5_a.
VALUE LABEL R5_5_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_6_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_6_a.
VALUE LABEL R5_6_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_7_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_7_a.
VALUE LABEL R5_7_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_8_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_8_a.
VALUE LABEL R5_8_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_9_a ('never'=1) ('aware'=2) ('used'=3)
(' ' = 99) INTO R5_9_a.
```

```
VALUE LABEL R5_9_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_10_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_10_a.
VALUE LABEL R5_10_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_11_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_11_a.
VALUE LABEL R5_11_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_12_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_12_a.
VALUE LABEL R5_12_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_13_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_13_a.
VALUE LABEL R5_13_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_14_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_14_a.
VALUE LABEL R5_14_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

RECODE @5_15_a ('never'=1) ('aware'=2) ('used'=3)
(' '=99) INTO R5_15_a.
VALUE LABEL R5_15_a 1 'Never heard of it' 2
'Aware of it' 3 'Have used it' 99 'Did not answer' .

VARIABLE LABEL R5_1_a 'Awareness of Nearest
Services' .
VARIABLE LABEL R5_2_a 'Awareness of Local
Weather' .
VARIABLE LABEL R5_3_a 'Awareness of City
Guides' .
VARIABLE LABEL R5_4_a 'Awareness of Local
Phone Numbers' .
VARIABLE LABEL R5_5_a 'Awareness of Walking
Directions' .
VARIABLE LABEL R5_6_a 'Awareness of Driving
Directions' .
VARIABLE LABEL R5_7_a 'Awareness of Traffic
Information' .
VARIABLE LABEL R5_8_a 'Awareness of Roadside
Assistance' .
VARIABLE LABEL R5_9_a 'Awareness of Safety
Camera Information' .
VARIABLE LABEL R5_10_a 'Awareness of Public
Transport Information' .
VARIABLE LABEL R5_11_a 'Awareness of Friend
Finder' .
VARIABLE LABEL R5_12_a 'Awareness of
Location-based Games' .
VARIABLE LABEL R5_13_a 'Awareness of Mobile
Booking/paying' .
VARIABLE LABEL R5_14_a 'Awareness of
Location-based Advertising' .
VARIABLE LABEL R5_15_a 'Awareness of
Safety/Security Information' .

** overall levels of awareness or use, no split
according to group.

FREQUENCIES
 VARIABLES=R5_1_a R5_2_a R5_3_a R5_4_a
R5_5_a R5_6_a R5_7_a R5_8_a R5_9_a R5_10_a
R5_11_a R5_12_a R5_13_a R5_14_a R5_15_a
 /BARCHART PERCENT
 /ORDER= ANALYSIS .

CROSSTABS
 /TABLES=R5_1_a R5_2_a R5_3_a R5_4_a R5_5_a
R5_6_a R5_7_a R5_8_a R5_9_a R5_10_a R5_11_a
R5_12_a R5_13_a R5_14_a R5_15_a BY
 G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

** levels of awareness split by group.
 GRAPH /BAR(SIMPLE) = PCT BY R5_1_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_2_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_3_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_4_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_5_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_6_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_7_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_8_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_9_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_10_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_11_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_12_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_13_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_14_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_15_a BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
```

```
** 5_1 TO 5_15 b only. POSITIVE OR NEGATIVE
TOWARDS SERVICES .

RECODE @5_1_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_1_b .
VALUE LABEL R5_1_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_2_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_2_b .
VALUE LABEL R5_2_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_3_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_3_b .
VALUE LABEL R5_3_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_4_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_4_b .
VALUE LABEL R5_4_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_5_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_5_b .
VALUE LABEL R5_5_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_6_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_6_b .
VALUE LABEL R5_6_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_7_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_7_b .
VALUE LABEL R5_7_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_8_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_8_b .
VALUE LABEL R5_8_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_9_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_9_b .
VALUE LABEL R5_9_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_10_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_10_b .
VALUE LABEL R5_10_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_11_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_11_b .
VALUE LABEL R5_11_b 1 'Positive  towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_12_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_12_b .
VALUE LABEL R5_12_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_13_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_13_b .
VALUE LABEL R5_13_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_14_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_14_b .
VALUE LABEL R5_14_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

RECODE @5_15_b ('positive'=1) ('negative'=2) (' ' =
99) INTO R5_15_b .
VALUE LABEL R5_15_b 1 'Positive towards it' 2
'Negative towards it' .
EXECUTE .

VARIABLE LABEL R5_1_b 'Attitude to Nearest
Services' .
VARIABLE LABEL R5_2_b 'Attitude to Local
Weather' .
VARIABLE LABEL R5_3_b 'Attitude to City
Guides' .
VARIABLE LABEL R5_4_b 'Attitude to Local
Phone Numbers' .
VARIABLE LABEL R5_5_b 'Attitude to Walking
Directions' .
VARIABLE LABEL R5_6_b 'Attitude to Driving
Directions' .
VARIABLE LABEL R5_7_b 'Attitude to Traffic
Information' .
VARIABLE LABEL R5_8_b 'Attitude to Roadside
Assistance' .
VARIABLE LABEL R5_9_b 'Attitude to Safety
Camera Information' .
VARIABLE LABEL R5_10_b 'Attitude to Public
Transport Information' .
VARIABLE LABEL R5_11_b 'Attitude to Friend
Finder' .
VARIABLE LABEL R5_12_b 'Attitude to Location-
based Games' .
VARIABLE LABEL R5_13_b 'Attitude to Mobile
Booking/paying' .
VARIABLE LABEL R5_14_b 'Attitude to Location-
based Advertising' .
VARIABLE LABEL R5_15_b 'Attitude to
Safety/Security Information' .

** overall attitudes,  no split according to group.
FREQUENCIES
  VARIABLES=R5_1_b R5_2_b R5_3_b R5_4_b
R5_5_b R5_6_b R5_7_b R5_8_b R5_9_b R5_10_b
R5_11_b R5_12_b R5_13_b R5_14_b R5_15_b
  /BARCHART  PERCENT
  /ORDER=  ANALYSIS .

CROSSTABS
```

```
/TABLES=R5_1_b R5_2_b R5_3_b R5_4_b
R5_5_b R5_6_b R5_7_b R5_8_b R5_9_b R5_10_b
R5_11_b R5_12_b R5_13_b R5_14_b R5_15_b BY
 G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

 GRAPH /BAR(SIMPLE) = PCT BY R5_1_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_2_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_3_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_4_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_5_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_6_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_7_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_8_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_9_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_10_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_11_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_12_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_13_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_14_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.
 GRAPH /BAR(SIMPLE) = PCT BY R5_15_b BY G
 /TEMPLATE='D:\do not delete\LBS small size for
awareness.sgt'.

** are there more positives than negatives from each
group .
** SPLIT THE FILE ACCORDING TO G, WITH
RESULTS SEPARATED BY GROUP.
SPLIT FILE OFF .
SORT CASES BY G .
SPLIT FILE
  SEPARATE BY G .

** binomial is the correct one as have just 2 options .
NPAR TEST
 /BINOMIAL (.50)= R5_1_b R5_2_b R5_3_b
R5_4_b R5_5_b R5_6_b R5_7_b R5_8_b R5_9_b
R5_10_b R5_11_b R5_12_b R5_13_b R5_14_b
 R5_15_b
 /MISSING ANALYSIS.
SPLIT FILE OFF .

** 5_1 TO 5_15 HOW DO THEIR ATTITUDES OF
AWARE OR USED DIFFER .
** take out all those who have never heard of it, as
these would only be influenced by the description
given to them.

** Shorten the label for attitude so it fits into small
graph .
VARIABLE LABEL R5_1_b 'Overall attitude' .
VARIABLE LABEL R5_2_b 'Overall attitude' .
VARIABLE LABEL R5_3_b 'Overall attitude' .
VARIABLE LABEL R5_4_b 'Overall attitude' .
VARIABLE LABEL R5_5_b 'Overall attitude' .
VARIABLE LABEL R5_6_b 'Overall attitude' .
VARIABLE LABEL R5_7_b 'Overall attitude' .
VARIABLE LABEL R5_8_b 'Overall attitude' .
VARIABLE LABEL R5_9_b 'Overall attitude' .
VARIABLE LABEL R5_10_b 'Overall attitude'.
VARIABLE LABEL R5_11_b 'Overall attitude' .
VARIABLE LABEL R5_12_b 'Overall attitude' .
VARIABLE LABEL R5_13_b 'Overall attitude' .
VARIABLE LABEL R5_14_b 'Overall attitude' .
VARIABLE LABEL R5_15_b 'Overall attitude' .

CROSSTABS VARIABLES=R5_1_a (2,3)  R5_1_b
(1,2)
 /TABLES=R5_1_a  BY R5_1_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_2_a (2,3)  R5_2_b
(1,2)
 /TABLES=R5_2_a  BY R5_2_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_3_a (2,3)  R5_3_b
(1,2)
 /TABLES=R5_3_a  BY R5_3_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_4_a (2,3)  R5_4_b
(1,2)
 /TABLES=R5_4_a  BY R5_4_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .
```

```
CROSSTABS VARIABLES=R5_5_a (2,3) R5_5_b
(1,2)
 /TABLES=R5_5_a BY R5_5_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_6_a (2,3) R5_6_b
(1,2)
 /TABLES=R5_6_a BY R5_6_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_7_a (2,3) R5_7_b
(1,2)
 /TABLES=R5_7_a BY R5_7_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_8_a (2,3) R5_8_b
(1,2)
 /TABLES=R5_8_a BY R5_8_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_9_a (2,3) R5_9_b
(1,2)
 /TABLES=R5_9_a BY R5_9_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_10_a (2,3)
R5_10_b (1,2)
 /TABLES=R5_10_a BY R5_10_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_11_a (2,3)
R5_11_b (1,2)
 /TABLES=R5_11_a BY R5_11_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_12_a (2,3)
R5_12_b (1,2)
 /TABLES=R5_12_a BY R5_12_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_13_a (2,3)
R5_13_b (1,2)
 /TABLES=R5_13_a BY R5_13_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_14_a (2,3)
R5_14_b (1,2)
 /TABLES=R5_14_a BY R5_14_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

CROSSTABS VARIABLES=R5_15_a (2,3)
R5_15_b (1,2)
 /TABLES=R5_15_a BY R5_15_b
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT EXPECTED
 /COUNT ROUND CELL
 /BARCHART .

** put labels back as long labels .
VARIABLE LABEL R5_1_b 'Attitude to Nearest
Services' .
VARIABLE LABEL R5_2_b 'Attitude to Local
Weather' .
VARIABLE LABEL R5_3_b 'Attitude to City
Guides' .
VARIABLE LABEL R5_4_b 'Attitude to Local
Phone Numbers' .
VARIABLE LABEL R5_5_b 'Attitude to Walking
Directions' .
VARIABLE LABEL R5_6_b 'Attitude to Driving
Directions' .
VARIABLE LABEL R5_7_b 'Attitude to Traffic
Information' .
VARIABLE LABEL R5_8_b 'Attitude to Roadside
Assistance' .
VARIABLE LABEL R5_9_b 'Attitude to Safety
Camera Information' .
VARIABLE LABEL R5_10_b 'Attitude to Public
Transport Information' .
VARIABLE LABEL R5_11_b 'Attitude to Friend
Finder' .
VARIABLE LABEL R5_12_b 'Attitude to Location-
based Games' .
VARIABLE LABEL R5_13_b 'Attitude to Mobile
Booking/paying' .
VARIABLE LABEL R5_14_b 'Attitude to Location-
based Advertising' .
VARIABLE LABEL R5_15_b 'Attitude to
Safety/Security Information' .

** 6 MORE ABOUT YOU .
** 6_1 CURRENT LIVING ARRANGEMENTS .
```

```
RECODE @6_1 ('parent'=-1) ('child'=-2) ('spouse'=-
3) ('alone'=-4) ('share'=-5) ('official'=-6) ('other'=-7) ('
'=-99) INTO R6_1 .
VARIABLE LABEL R6_1 'Current living
arrangements'.
VALUE LABEL R6_1
-1 'Parent living in a family unit'
-2 'Child living in a family unit'
-3 'Live with spouse or partner'
-4 'Live alone'
-5 'Share with friends/lodgers'
-6 'Official accomodation (eg university hall)'
-7 'Other'
-99 'Did not answer' .
EXECUTE .

CROSSTABS
 /TABLES=R6_1 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R6_1 BY G
 /TEMPLATE='D:\do not delete\LBS horizontal bars
percent living arrangements.sgt'.


** 6_2 NUMBER OF CHILDREN .

** string variable recoded into R6_2_a R6_2_b
R6_2_c R6_2_d at top of syntax .
** these give the numbers of children each person has
.
VARIABLE LABEL
R6_2_a 'Age 0 - 4'
R6_2_b 'Age 5 - 10'
R6_2_c 'Age 11 - 14'
R6_2_d 'Age 15 - 17'
R6_2_e 'Age 18 +' .

** plot counts.
GRAPH
 /BAR(SIMPLE)= NGT(0)(R6_2_a)
NGT(0)(R6_2_b) NGT(0)(R6_2_c) NGT(0)(R6_2_d)
NGT(0)(R6_2_e)
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS 400w by 250h
bars no x label.sgt'.

** plot percentages .
GRAPH
 /BAR(SIMPLE)= PGT(0)(R6_2_a)
PGT(0)(R6_2_b) PGT(0)(R6_2_c) PGT(0)(R6_2_d)
PGT(0)(R6_2_e) BY G
 /MISSING=VARIABLEWISE
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent children.sgt'.

** 6_3 WHERE LIVE TYPE OF PLACE) .

RECODE @6_3 ('city'=1) ('town'=2) ('village'=3)
('rural'=4) (' '=99) INTO R6_3 .
VARIABLE LABEL R6_3 'Location' .
VALUE LABEL R6_3
1 'City'
2 'Town'
3 'Village'
4 'Rural'
99 'Did not answer' .
execute .

CROSSTABS
 /TABLES=R6_3 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R6_3 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 6_5 YEARS IN THAT PLACE .

RECODE @6_5 ('zero years'=1) ('1-5 years'=2) ('6-
10 years'=3) ('11+ years'=4) (' '=99) INTO R6_5 .
VARIABLE LABEL R6_5 'Years as inhabitant' .
VALUE LABEL R6_5
1 'Less than one'
2 '1-5'
3 '6-10'
4 '11 +'
99 'Did not answer' .
execute .

CROSSTABS
 /TABLES=R6_5 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
 /BAR(SIMPLE)=PCT BY R6_5 BY G
 /TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 6_6 QUALIFICATIONS THEY HOLD.

RECODE @6_6 ('no qualifications'=1) ('1 O level'
=2) ('5 O levels' =3) ('2 A levels' =4) ('first degree' =5)
(' ' = -99) INTO R6_6 .
execute .
VARIABLE LABEL R6_6 'Qualification level' .
VALUE LABEL R6_6
1 'No qualifications'
2 '1+ O level passes or equivalent'
3 '5+ O level passes or equivalent'
4 '2+ A level passes or equivalent'
5 'Degree or higher'
-99 'Did not answer' .
EXECUTE .

CROSSTABS
 /TABLES=R6_6 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL .

GRAPH
```

```
/BAR(SIMPLE)=PCT BY R6_6 BY G
/TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.
** check change to horizontal bars .

** 7 YOUR WORK OR STUDY .
** 7_1 STUDYING OR EMPLOYMENT STATUS .
** have to recode so you can define data as missing,
and exclude this from graphs .
** make sure 99 set to define missing in db .

RECODE @7_1_a ('school'=1) (' ' = 99) INTO
R7_1_a .
EXECUTE .
RECODE @7_1_b ('college'=1) (' ' = 99) INTO
R7_1_b .
EXECUTE .
RECODE @7_1_c ('university'=1) (' ' = 99) INTO
R7_1_c .
EXECUTE .
RECODE @7_1_d ('paid work'=1) (' ' = 99) INTO
R7_1_d .
EXECUTE .
RECODE @7_1_e ('voluntary'=1) (' ' = 99) INTO
R7_1_e .
EXECUTE .
RECODE @7_1_f ('looking'=1) (' ' = 99) INTO
R7_1_f .
EXECUTE .
RECODE @7_1_g ('not working'=1) (' ' = 99) INTO
R7_1_g .
EXECUTE .
RECODE @7_1_h ('retired'=1) (' ' = 99) INTO
R7_1_h .
EXECUTE .

** R7_1_i is set to 1 if someone has not answered any
of a to h so can plot this.
** set to 1 initially, then set to 99 if they have
answered any of the prev questions .

COMPUTE R7_1_i = 1 .
EXECUTE .

DO IF (R7_1_a = 1) OR (R7_1_b = 1) OR (R7_1_c
= 1) OR (R7_1_d = 1) OR (R7_1_e = 1) OR (R7_1_f
= 1) OR (R7_1_g = 1) OR (R7_1_h = 1) .
COMPUTE R7_1_i = 99 .
END IF .
EXECUTE .

VARIABLE LABEL R7_1_a 'School' .
VARIABLE LABEL R7_1_b 'College' .
VARIABLE LABEL R7_1_c 'University' .
VARIABLE LABEL R7_1_d 'In paid work or self
employed' .
VARIABLE LABEL R7_1_e 'Doing voluntary work'
.
VARIABLE LABEL R7_1_f 'Looking for work' .
VARIABLE LABEL R7_1_g 'Not working through
choice' .
VARIABLE LABEL R7_1_h 'Retired' .
VARIABLE LABEL R7_1_i 'Did not answer' .

** plot counts .
GRAPH
/BAR(SIMPLE)= N(R7_1_i) N(R7_1_h) N(R7_1_g)
N(R7_1_f) N(R7_1_e) N(R7_1_d) N(R7_1_c)
N(R7_1_b) N(R7_1_a) BY G
/MISSING=VARIABLEWISE
/TEMPLATE='D:\do not delete\LBS 400w by 250h
bars count.sgt'.

** plot percentages by doing percent of data within
each group which is 1, taking into account all data
including that coded as 99.
** 99 not represent missing data.
MISSING VALUES R7_1_a R7_1_b R7_1_c
R7_1_d R7_1_e R7_1_f R7_1_g R7_1_h R7_1_i () .
GRAPH
/BAR(SIMPLE)= PLT(2)(R7_1_i) PLT(2)(R7_1_h)
PLT(2)(R7_1_g) PLT(2)(R7_1_f) PLT(2)(R7_1_e)
PLT(2)(R7_1_d) PLT(2)(R7_1_c) PLT(2)(R7_1_b)
PLT(2)(R7_1_a) BY G
/MISSING=VARIABLEWISE
/TEMPLATE='D:\do not delete\LBS vertical bars
percent half page rhs key.sgt'.

** put missing values back again.
MISSING VALUES R7_1_a R7_1_b R7_1_c
R7_1_d R7_1_e R7_1_f R7_1_g R7_1_h R7_1_i
(99).

** 7_2 HOURS WORKED .

RECODE @7_2 ('none'=1) ('0-20'=2) ('21-40'=3)
('41-50'=4) ('51+'=5) (' '=99) INTO R7_2 .
VARIABLE LABEL R7_2 'Hours worked per week'
.
VALUE LABEL R7_2
1 'None'
2 '0-20'
3 '21-40'
4 '41-50'
5 '51+'
99 'Did not answer' .
EXECUTE .

CROSSTABS
/TABLES=R7_2 BY G
/FORMAT= AVALUE TABLES
/STATISTIC=CHISQ
/CELLS= COUNT
/COUNT ROUND CELL .

GRAPH
/BAR(SIMPLE)=PCT BY R7_2 BY G
/TEMPLATE='D:\do not delete\LBS vertical bars
percent half page.sgt'.

** 7_7 OCCUPATION .
** recode to make new numeric variables from string
variables .

RECODE @7_7 ('managers'=-1) ('professional'=-2)
('associate professional'=-3) ('admin'=-4)
('skilled'=-5) ('personal'=-6) ('sales'=-7) ('process'=-8)
('elementary'=-9) (' '=-99) INTO R7_7 .
VARIABLE LABEL R7_7 'Occupation category' .
VALUE LABEL R7_7
-1 ' Managers and senior officials'
-2 'Professional occupations '
-3 ' Associate professional and technical occupations'
```

```
-4 'Administrative and secretarial occupations'
-5 'Skilled trades occupations'
-6 'Personal service occupations'
-7 'Sales and customer occupations'
-8 'Process, plant and machinery operatives'
-9 'Elementary occupations'
-99 'Did not answer as not working'.
EXECUTE.

** if state in db that 99 is missing, it wont plot a bar
of 99.
** if dont state 99 is missing, then will plot that as a
category.

CROSSTABS
 /TABLES=R7_7 BY G
 /FORMAT= AVALUE TABLES
 /STATISTIC=CHISQ
 /CELLS= COUNT
 /COUNT ROUND CELL.

** plot percent, can put in COUNT in place of PCT.
GRAPH
 /BAR(SIMPLE)=PCT BY R7_7 BY G
 /TEMPLATE='D:\do not delete\LBS horizontal bars
percent living arrangements.sgt'.

** 8 CONTACT DETAILS AND SUBMISSION .
** 8_2 WILLING TO TAKE PART IN FOLLOW
UP STUDIES.

RECODE @8_2 ('yes' = 1) ('no'=2) (' ' = 99) INTO
R8_2.
VARIABLE LABEL R8_2 'Willingness to take part
in follow up research' .
VALUE LABEL R8_2
1 'yes'
2 'no'
99 'Did not answer'.
EXECUTE.

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 /COUNT ROUND CELL.

USE ALL.
SPLIT FILE OFF.
SORT CASES BY G.
SPLIT FILE
 LAYERED BY G.

** resize in word to 150 otherwise cuts text.
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pie.sgt'.

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** END.
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APPENDIX 5A (CHAPTER 5)
INTERVIEW PROTOCOL

The section below describes the interview protocol and contextual probes used in Chapter 5.

[Initial instructions]: 'I would like you to think of a journey which was important to you, and where something went wrong-the journey did not go as smoothly as planned – but you could have altered the outcome for the better if you had been able to find things out. The journey can be recent or a while ago, but you must be able to remember it clearly. The journey can involve any mode of transport, or combinations of transport, for business or pleasure.'

[Probes about the journey, initial prompts, then follow up to understand motivations, reasons, unique contextual characteristics]:

- Can you tell me about the journey-where was the journey to and from?
- What time were you travelling?
- What was the reason for the journey?
- What modes of transport were involved?
- Who were you travelling with?
- Why was the journey important?

[Probes about what happened, follow up to understand impact of context]:

- Can you tell me about what went wrong?
- Can you identify why this happened?
- How did you feel at the time?
- What impact did you think it would have on the success of your journey?

[Probes about solutions, follow up to understand impact of context]

- Can you describe to me what you did to try to sort the problem out?
- How successful was this?
- Were there any reasons why this worked or didn't work?
- Did you try anything else?
- Was there anything in particular you were trying to find out?
- Did you manage to do this?
- What would have been your ideal way of sorting this out – what were the main things you needed to do or find out?
- If someone had said 'pay me enough and I will resolve this problem', how much would you have been willing to pay?
- What is this figure based on – how have you come up with it?

APPENDIX 5B (CHAPTER 5)
SUMMARY OF THE JOURNEYS

The table below summarises, for each participant, the journey purpose and mode of transport, the impact on the individual of the course of events, and the event that initiated that course of events.

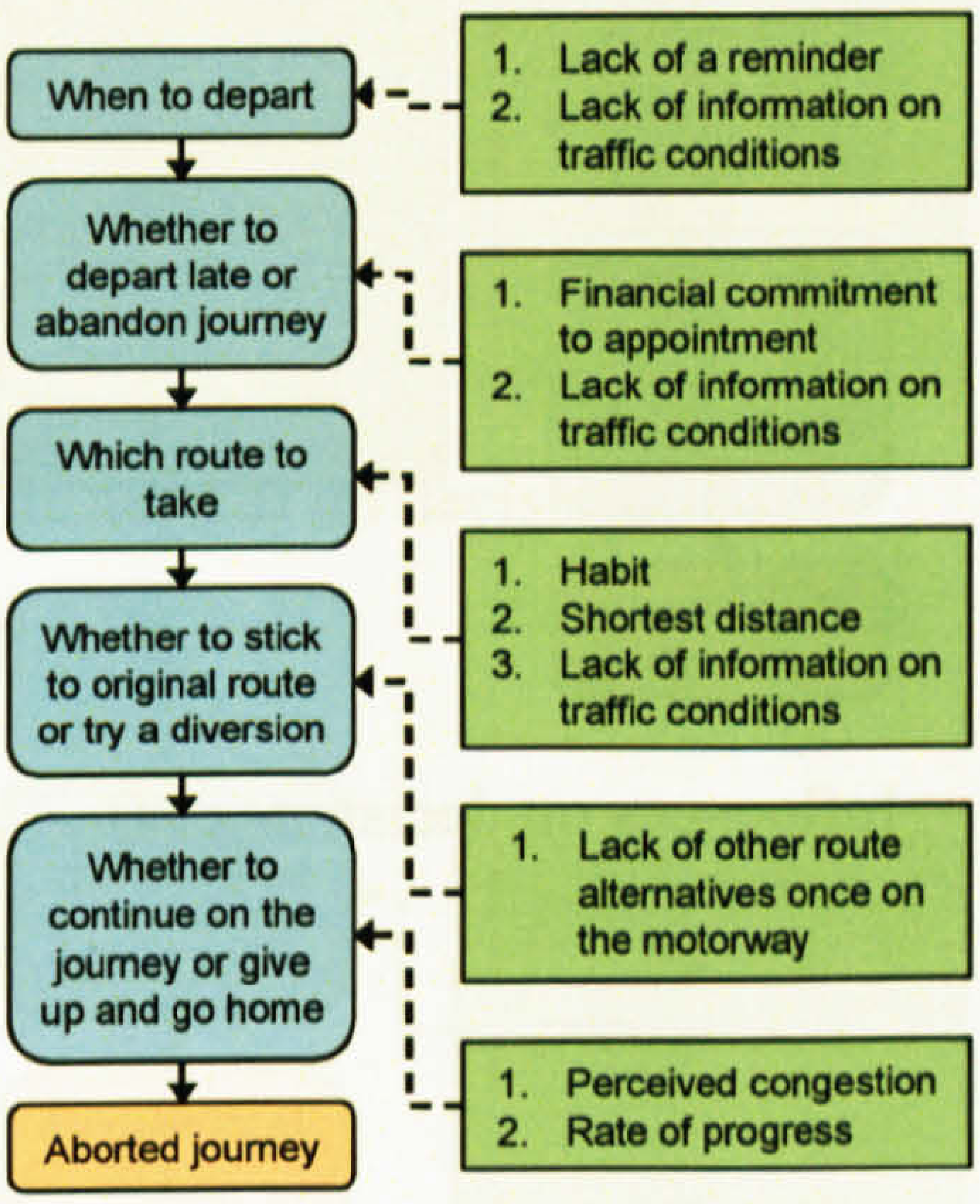
#	Journey	The initiating factor	Impact on the individual
1	Car journey to private medical appointment	Forgetting to leave on time	Missing an appointment > Stressed, frustrated, angry
2	Bus journey from airport to hotel (business)	Lack of pre-trip information on bus journey duration	Arriving late at the hotel > Frustrated, 'pissed off', hungry, tired the next day
3	Car journey to airport (social)	Car broke down	Missing flight > Stress, delay
4	Social flight	Luggage going missing	Loss of personal effects > 'Gutted', upset, cross, stressed, losing time, financial loss
5	Business flight	Luggage going missing	Loss of personal effects > Extremely concerned, financial loss
6	Business flight	Forgot flight ticket	Uncertainty over catching flight as planned > Concerned, unsure, possible financial loss
7	Social flight	Late arrival of flight	Inability to book accommodation > Terrified, personal safety concerns
8	Taxi trip to bus departures (social)	Incomplete pre-trip information on bus departure times	Unnecessary expensive taxi trip > Frustrated, unsure about what to do, financial loss
9	Business flight back home	Technical fault with airplane	Unscheduled overnight stop > 'Pissed off', frustrated, inconvenience of long bus transfer
10	Coach trip home (social)	Got on the wrong bus	Unscheduled overnight stay > Cross, safety concerns, inconvenience, financial loss
11	Flight home (social)	Closure of connecting flight airport	Being required to book onto alternative flight > Shocked, inconvenience, stressed
12	Car travel to	Misreading the ferry	Rush to catch ferry > Stressed,

	catch ferry (social)	departures timetable	angry, concerned about potential financial loss, safety
13	Train journey to festival (social)	Technical fault on preceding train	Late arrival > 'Ridiculous' situation, concern
14	Taxi from station to home (business)	Lack of taxis	Late arrival home > 'Unbelievable' situation, (minor) inconvenience
15	Car travel to a meeting (business)	Heavy traffic (and late departure) (poor journey planning)	Late arrival > Anxious during most of the journey, embarrassment about being late, then acceptance of situation
16	Flight for a meeting (business)	Forgetting passport	Change in flight arrangements > Moment of panic, initial embarrassment about potentially being late, financial cost of new flight
17	Car journey home (business)	Poor weather	Unnecessarily stressful journey > 'Sense of panic', concern for safety, reduction in confidence
18	Car journey to meeting (business)	Flat tyre	Late for meeting > 'Felt really bad', embarrassment at being late
19	Train journey home (social)	Technical fault on preceding train	Late arriving home > Frustrated, irritated
20	Car trip to visit family (social)	Heavy traffic on the motorway	Enforced change of plans (due to late arrival) > Initially stressed, then more relaxed, partner was more frustrated. Then 'not that bothered' after informing people.

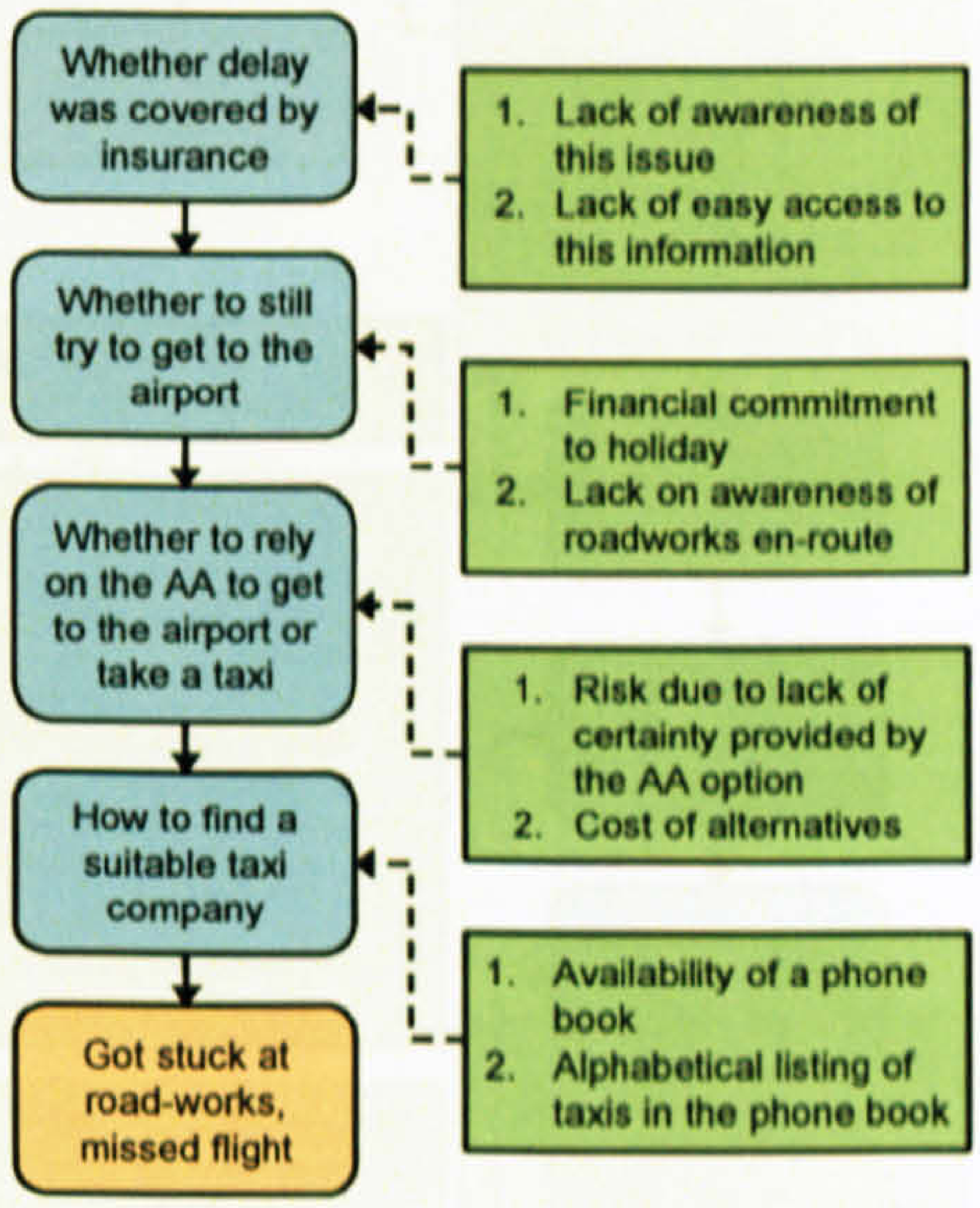
APPENDIX 5C (CHAPTER 5)

SUMMARY OF THE MAIN INFLUENCES ON THE TRAVELLERS' DECISION MAKING

The figures below summarise, for each participant, the main decisions they were trying to make, the influences on these decisions, and the eventual outcome to the course of events.



Influences on decisions (#1)



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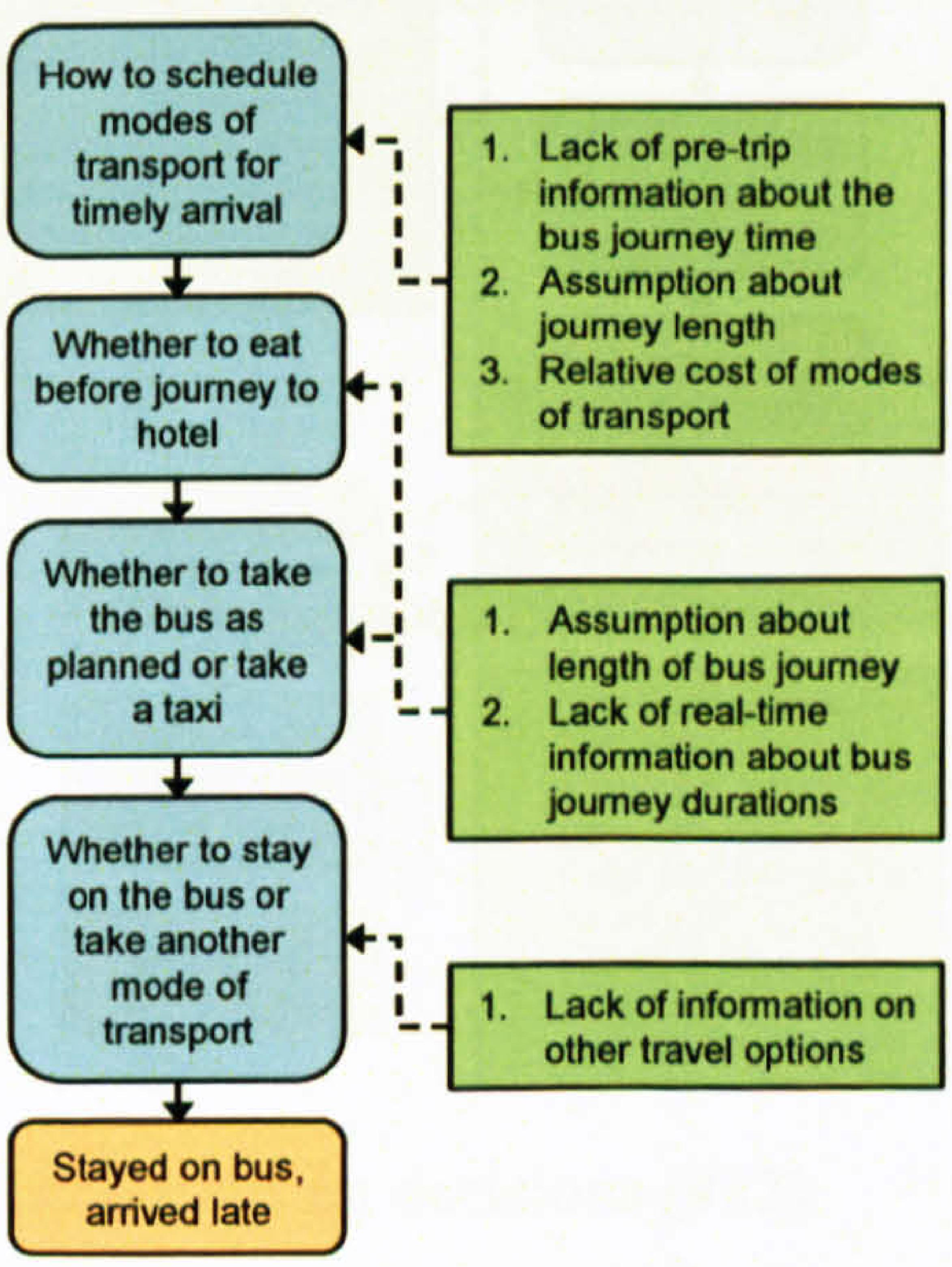
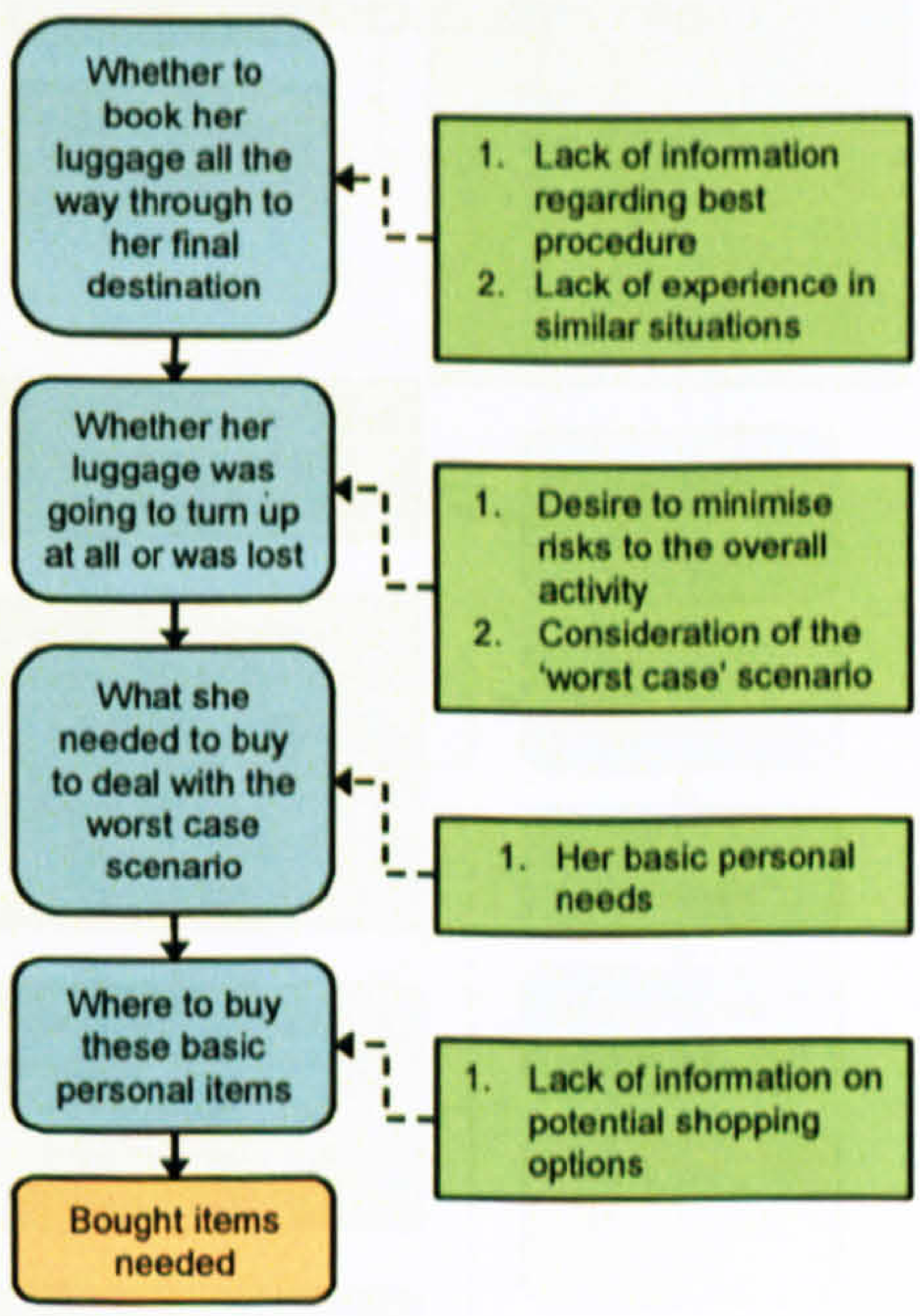


Influences on decisions (#2)



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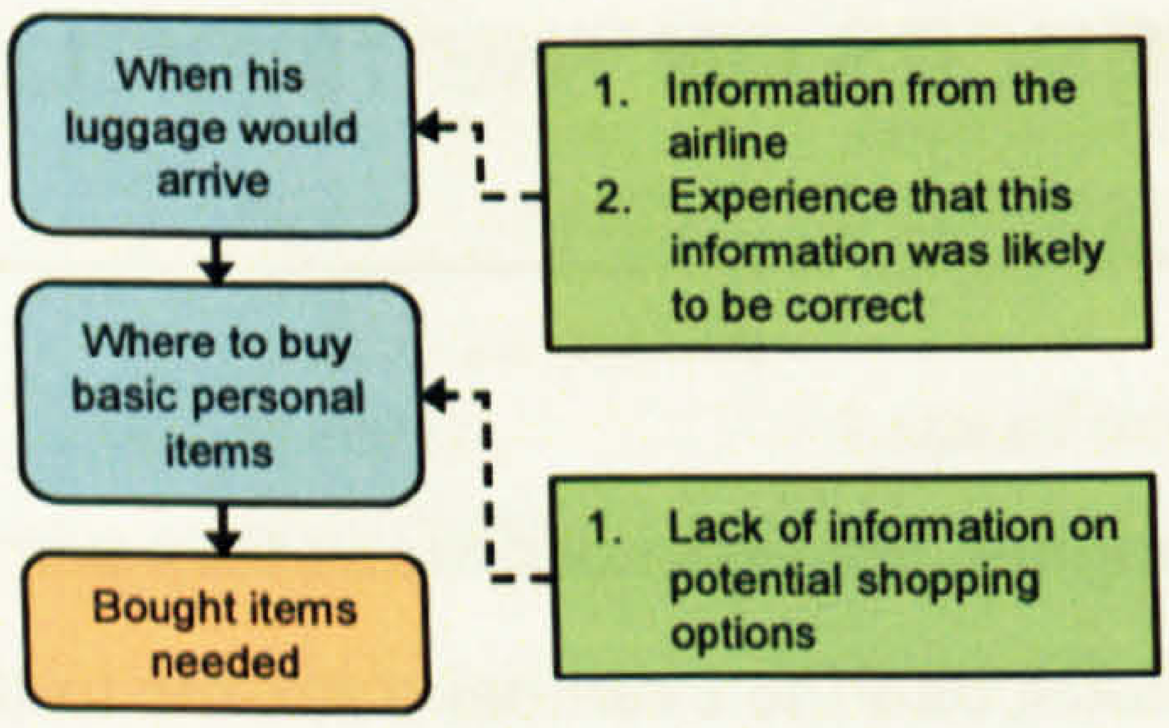
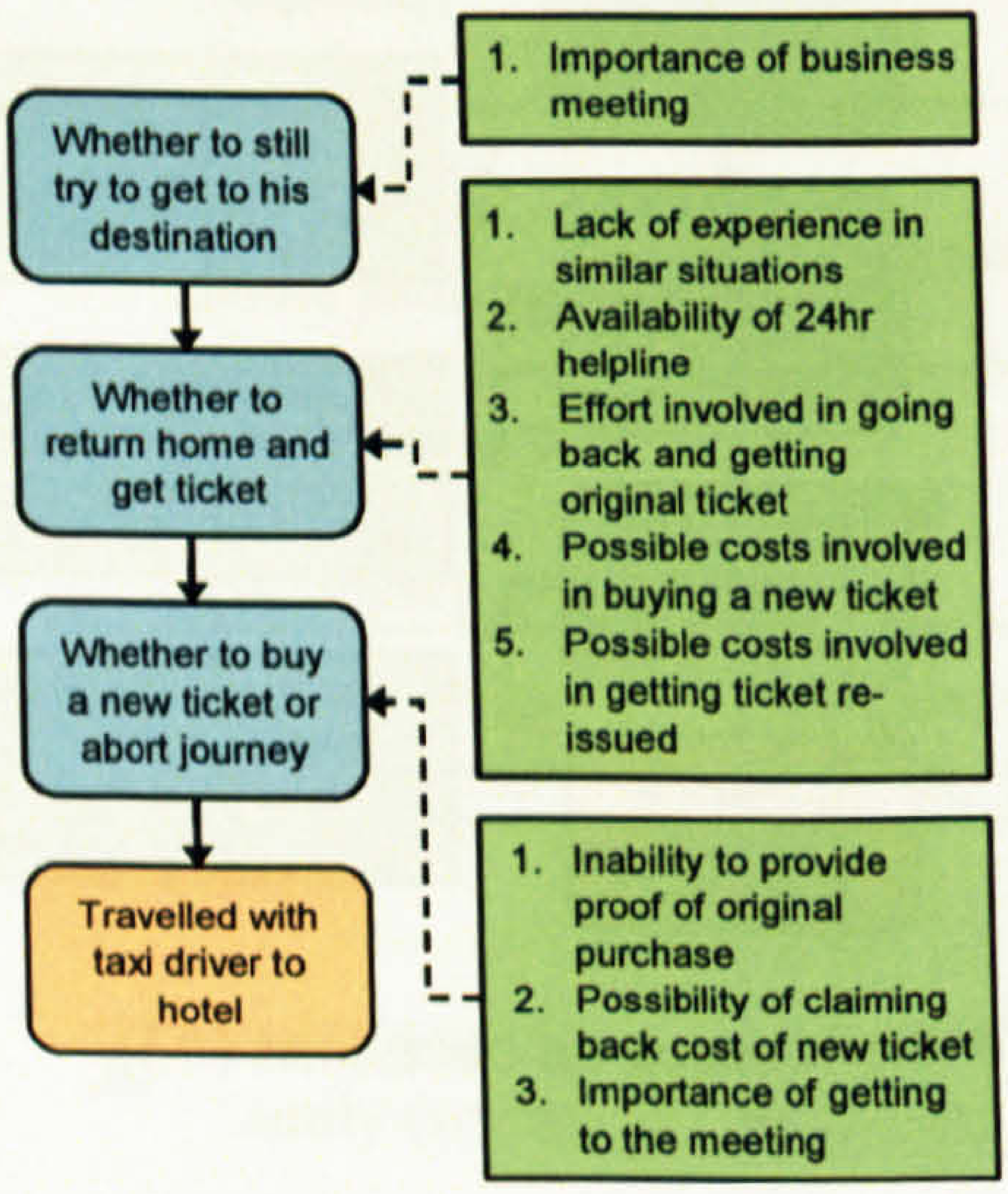


Influences on decisions (#5)



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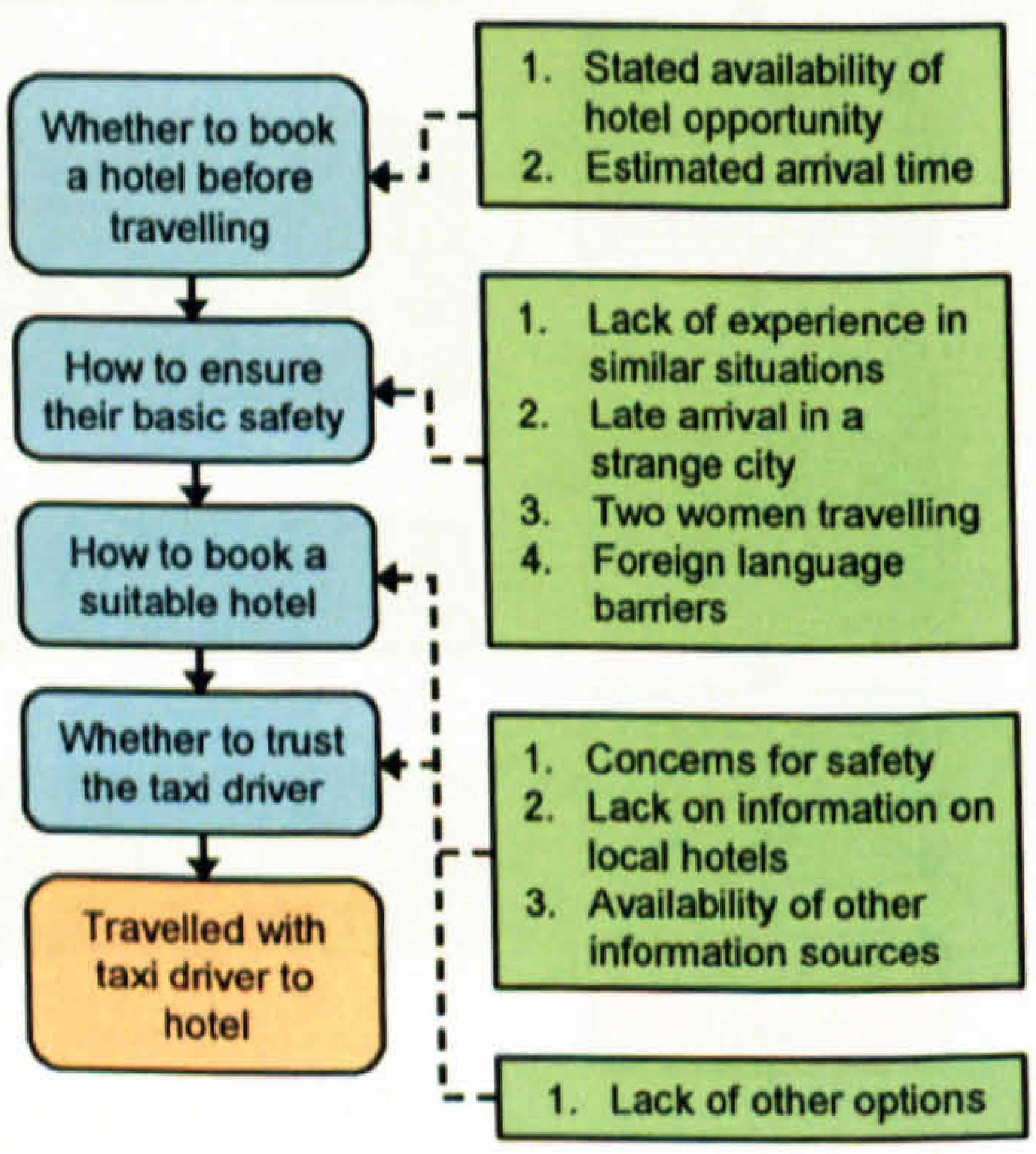
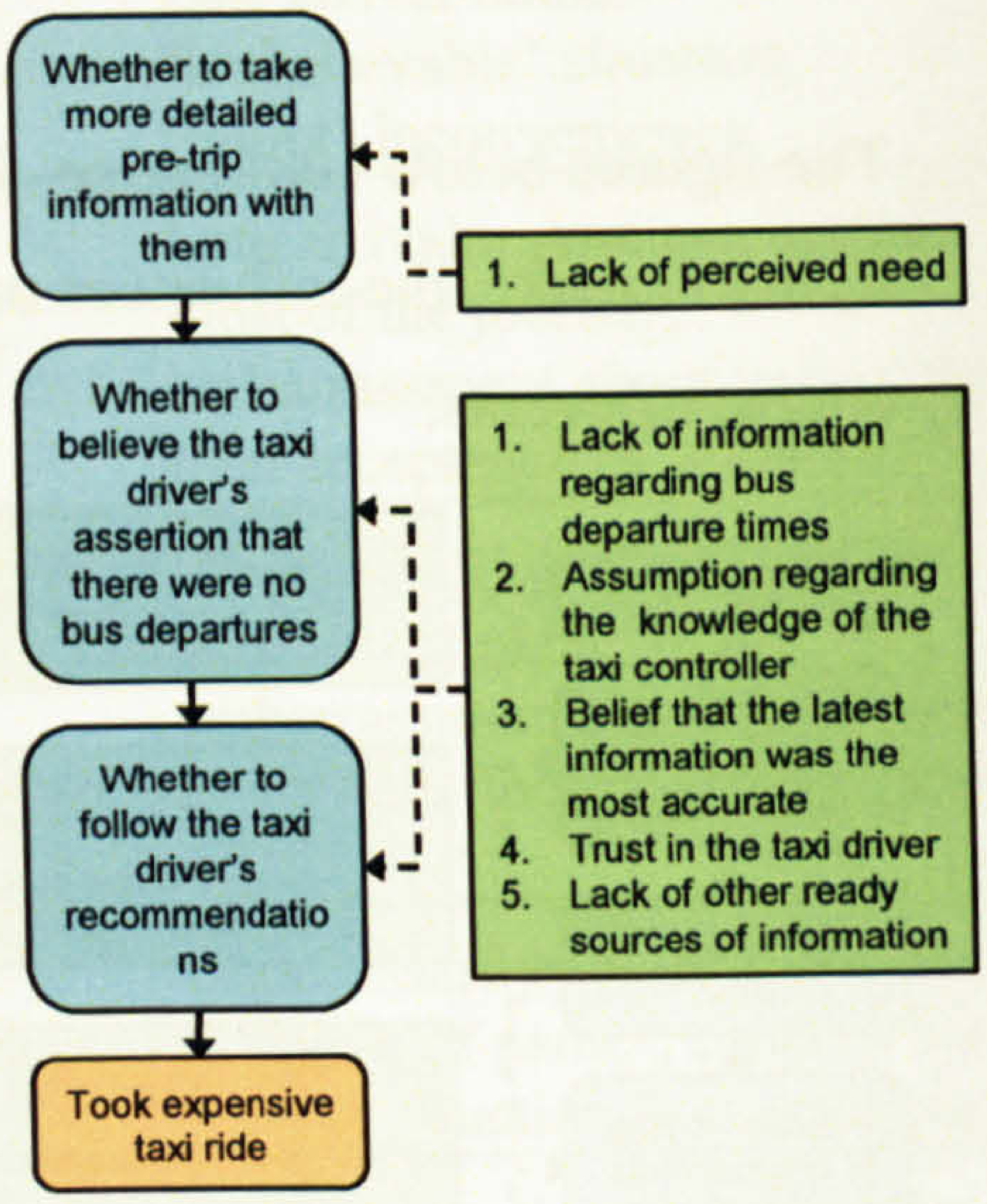


Influences on decisions (#7)



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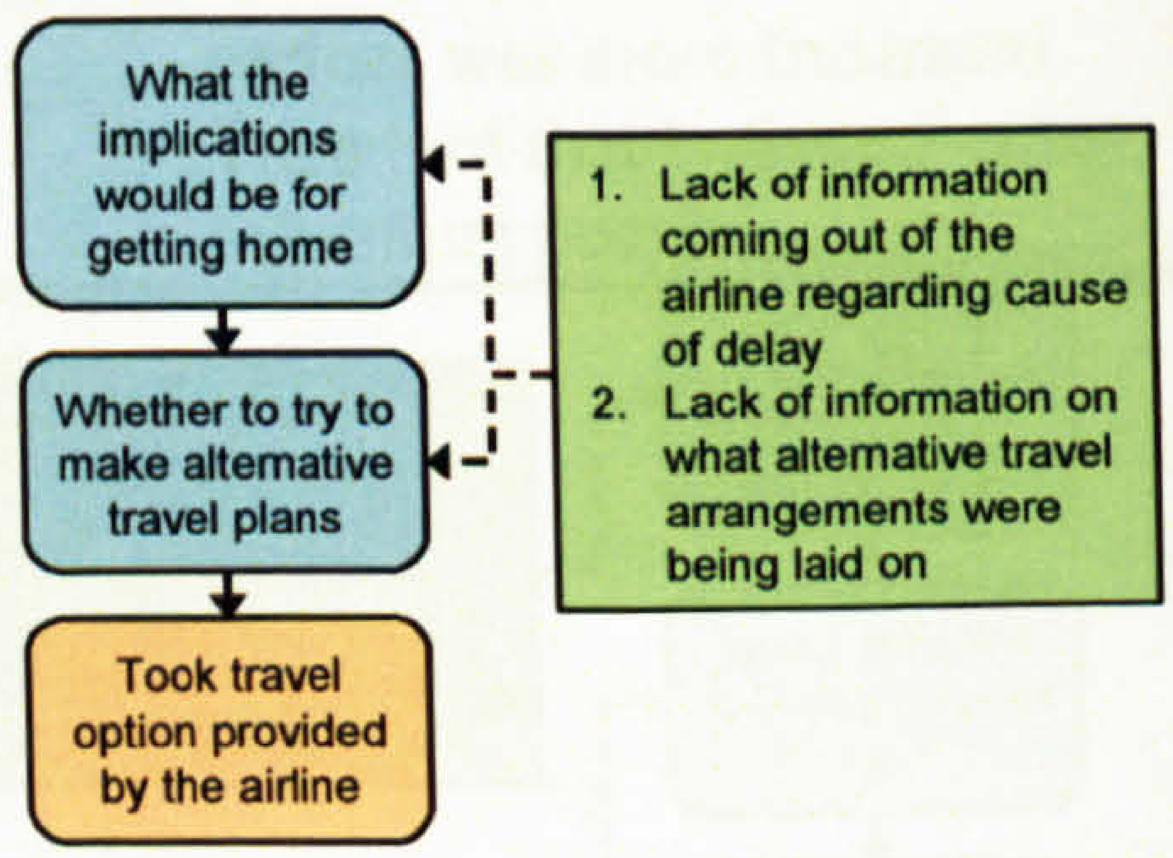
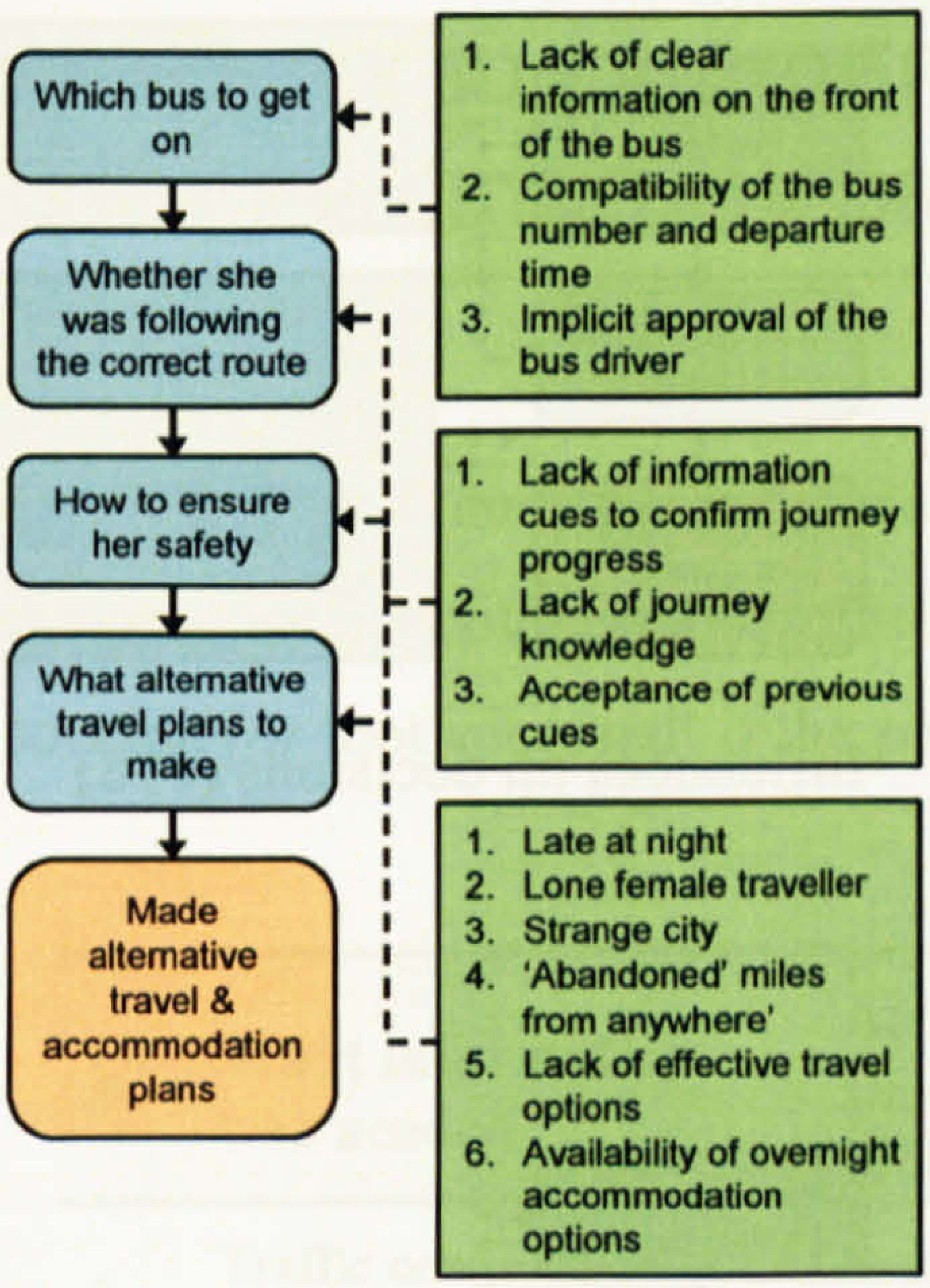
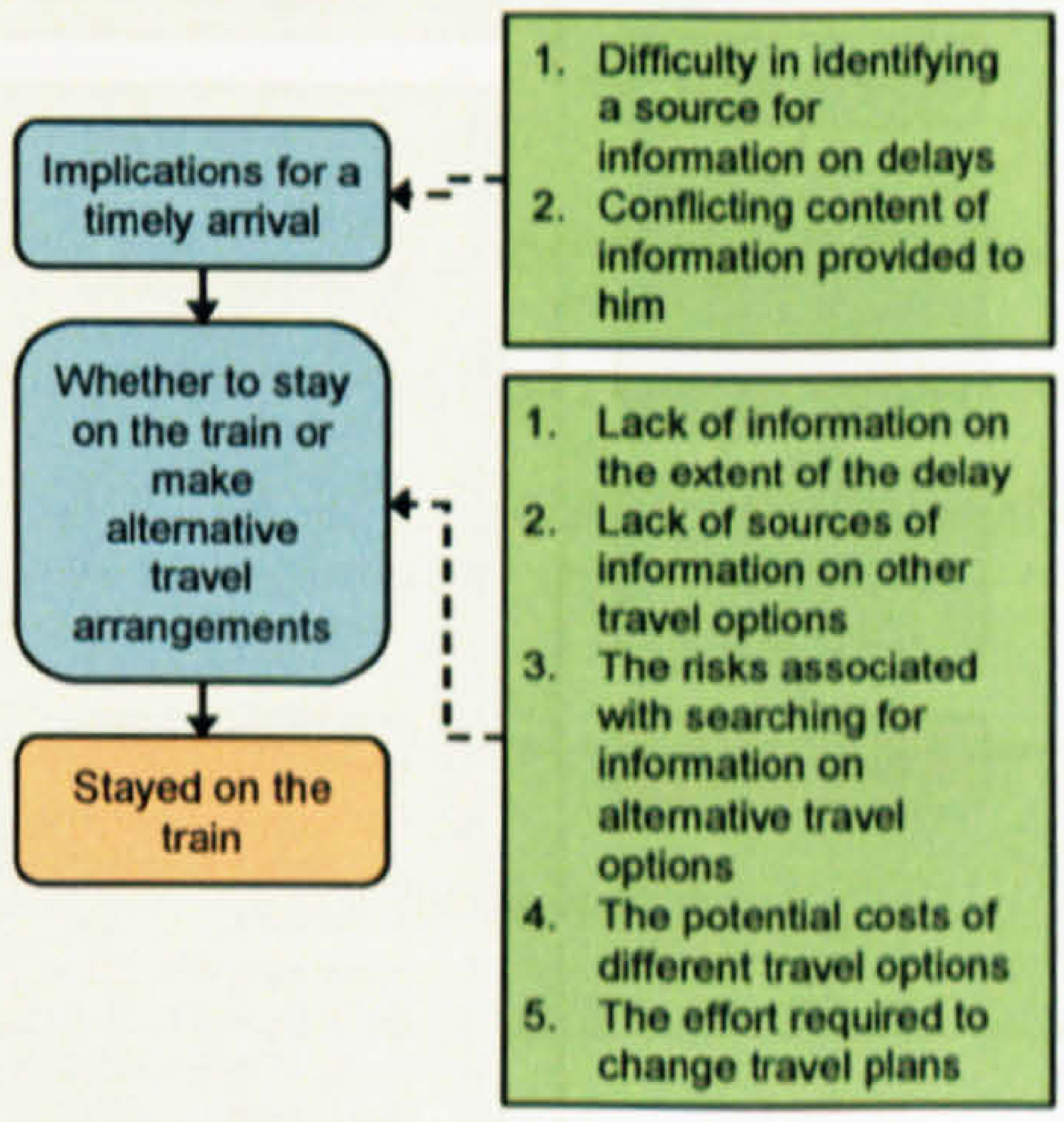


Influences on decisions (#9)



Influences on decisions (#10)



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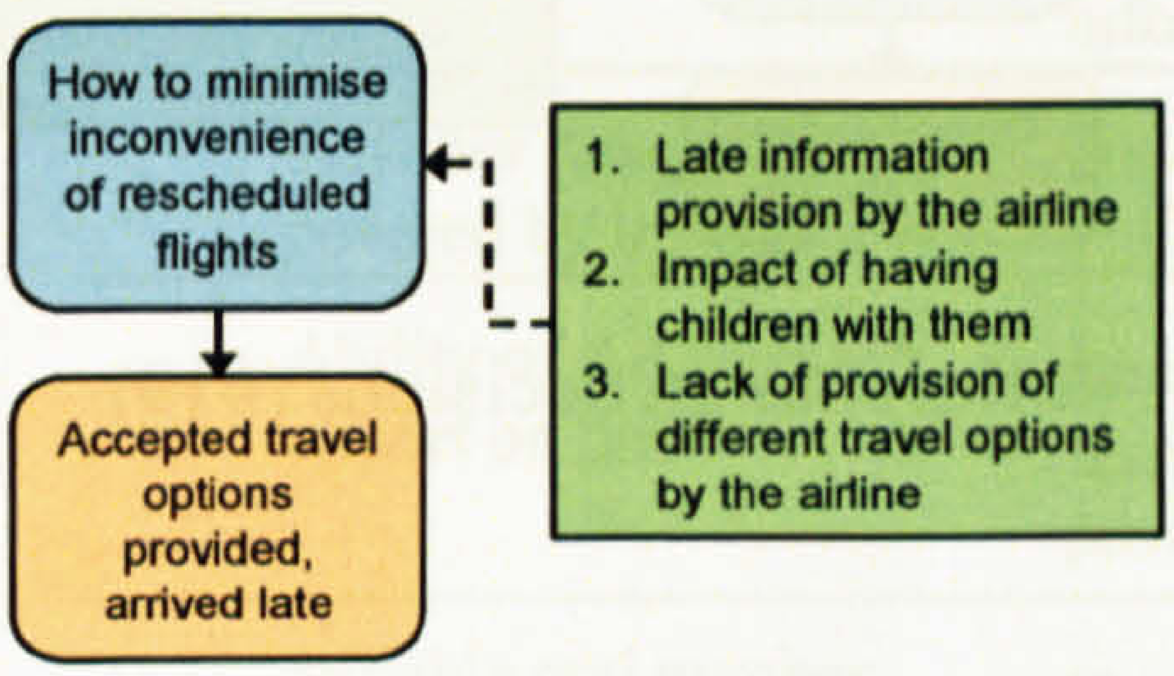

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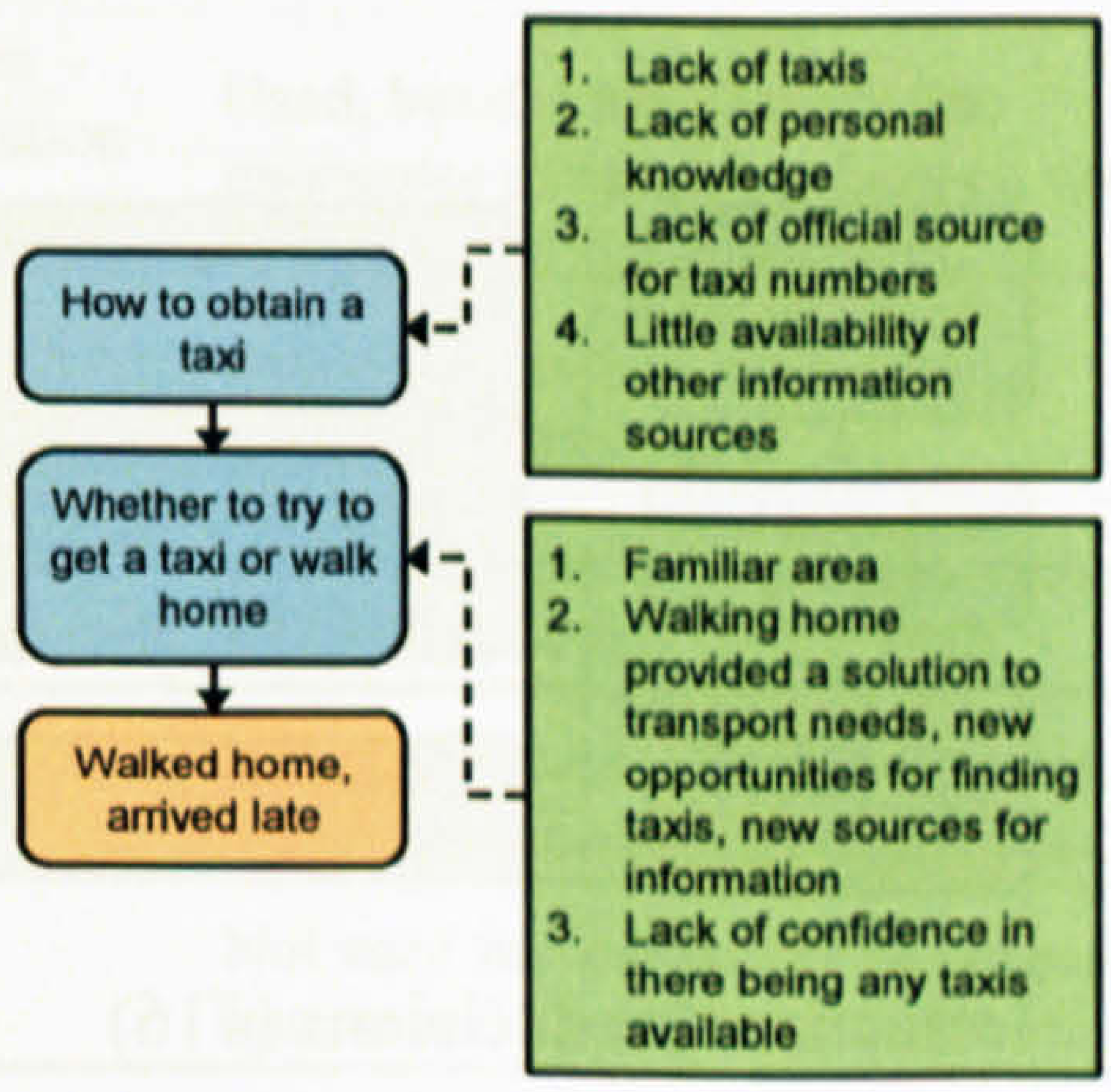

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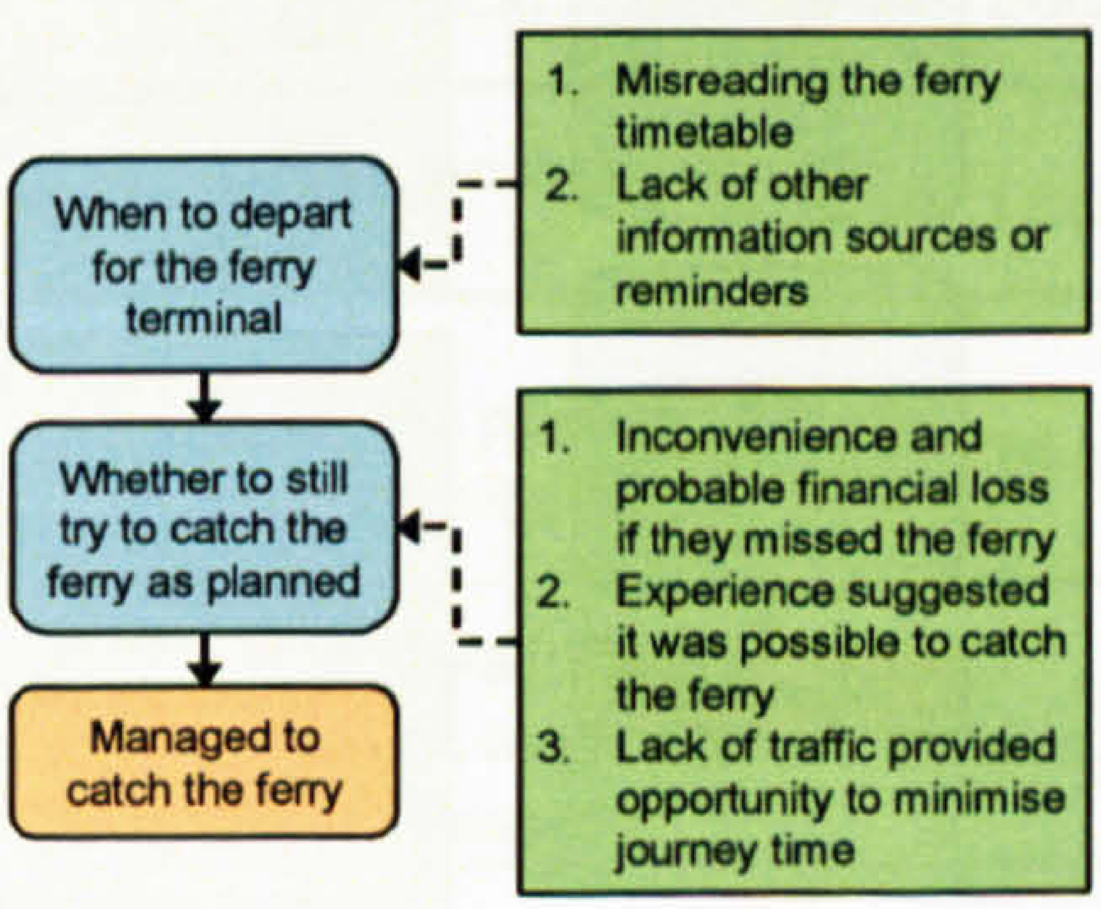
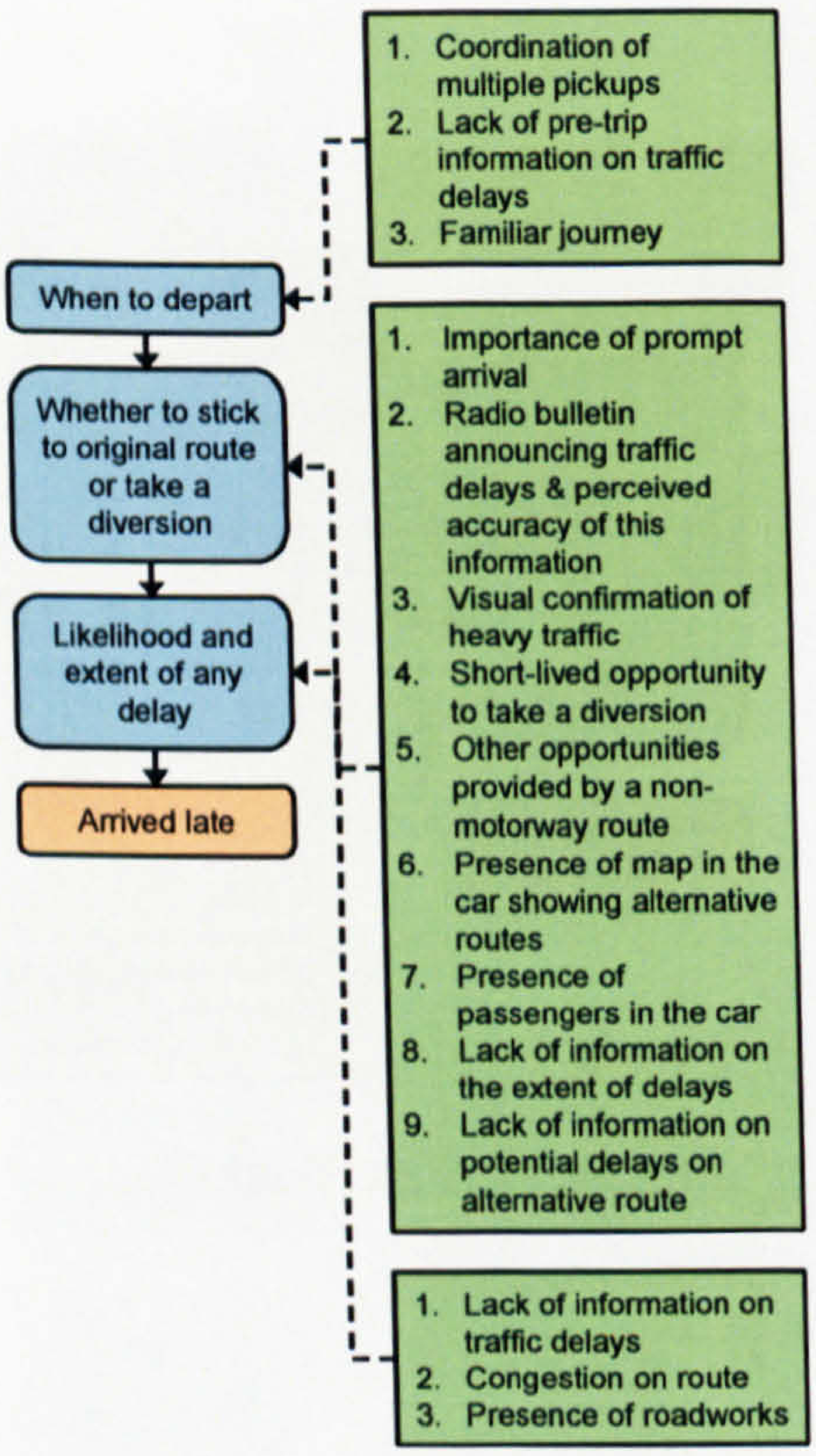
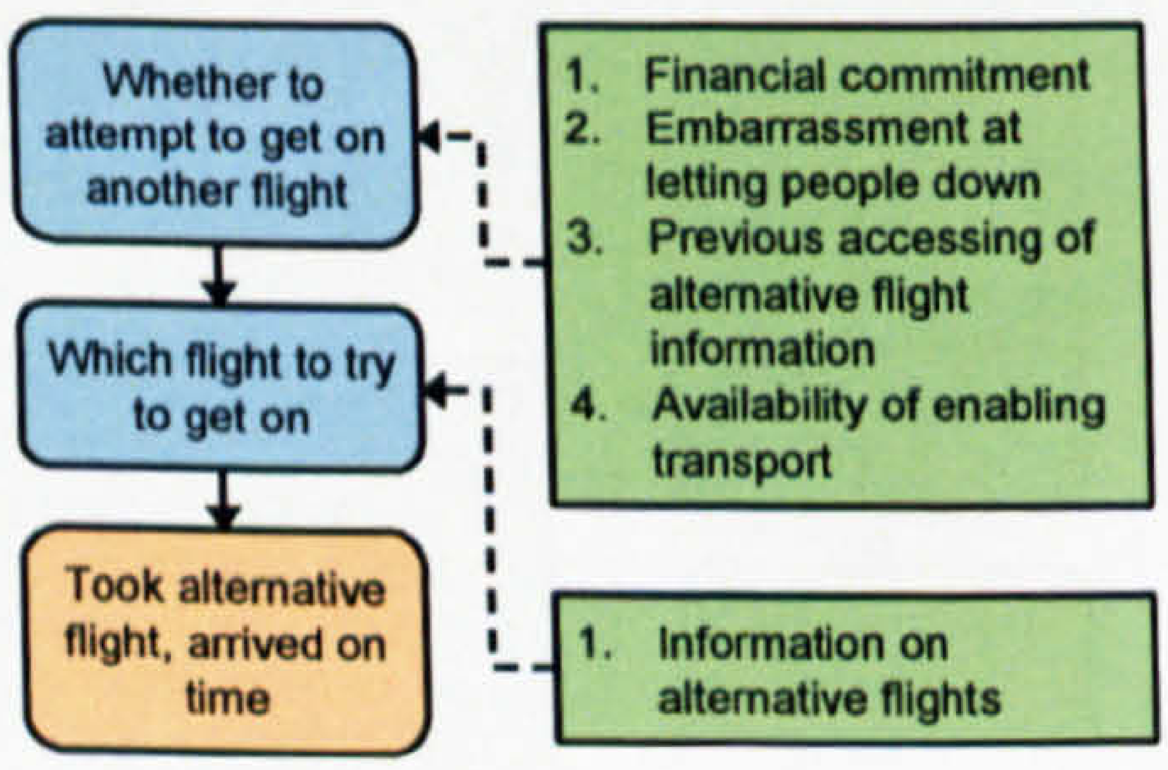


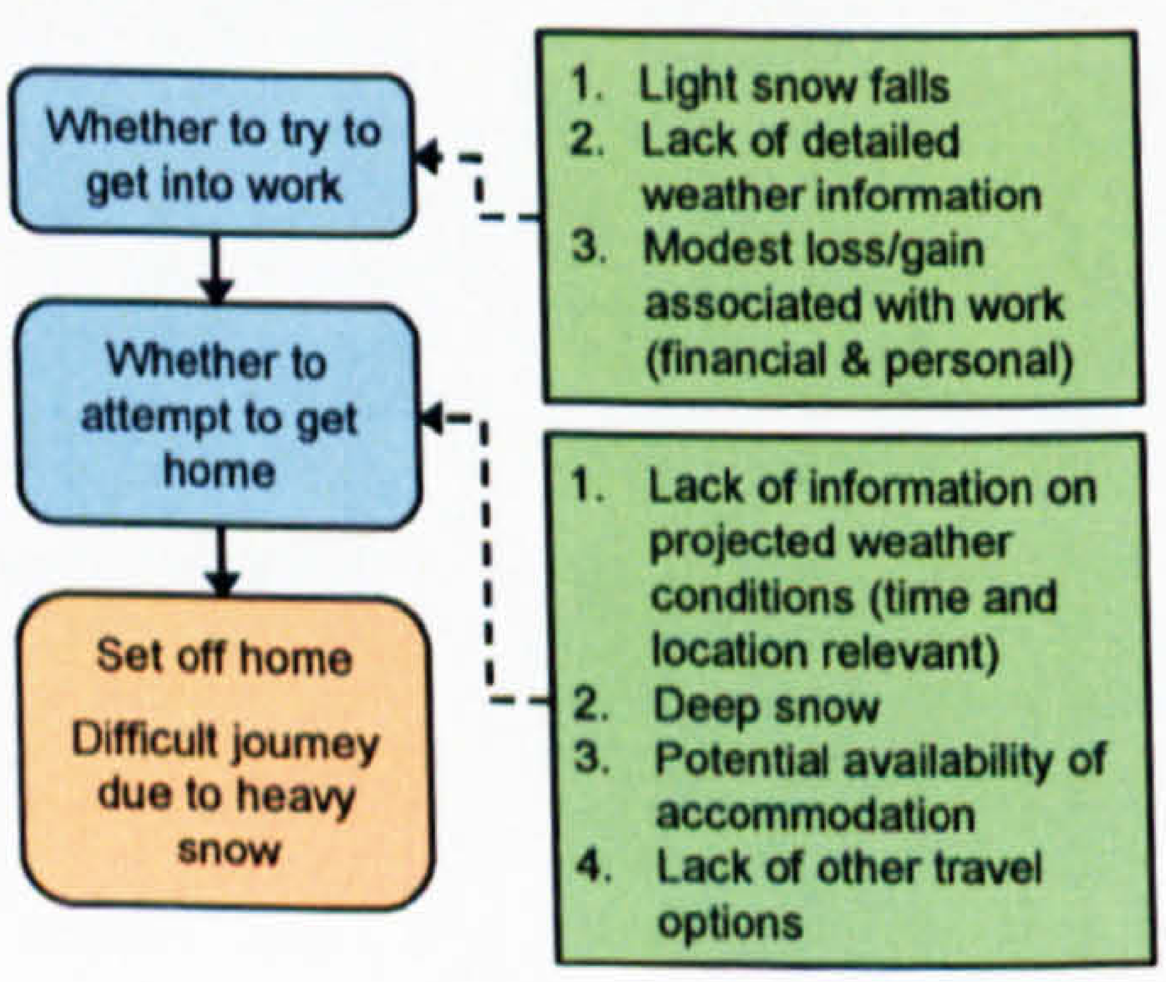
Influences on decisions (#12)



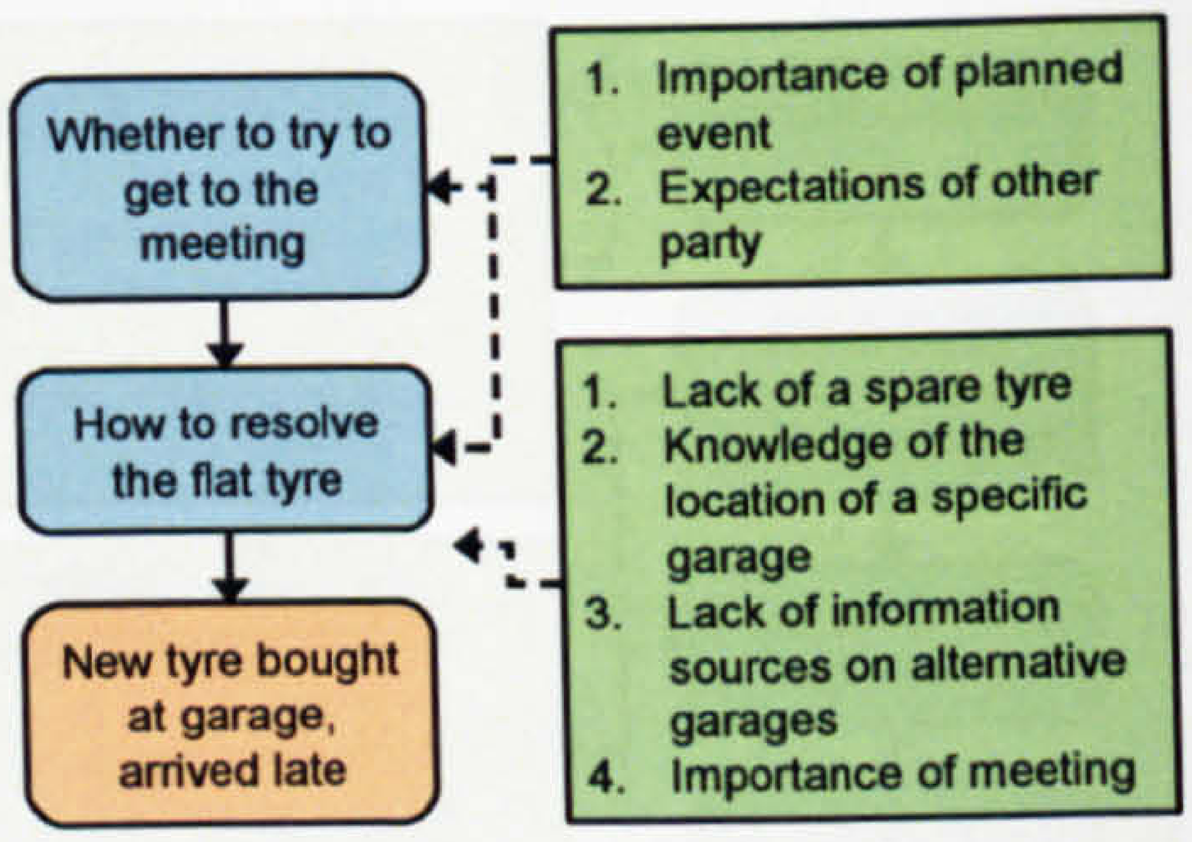
Influences on decisions (#15)



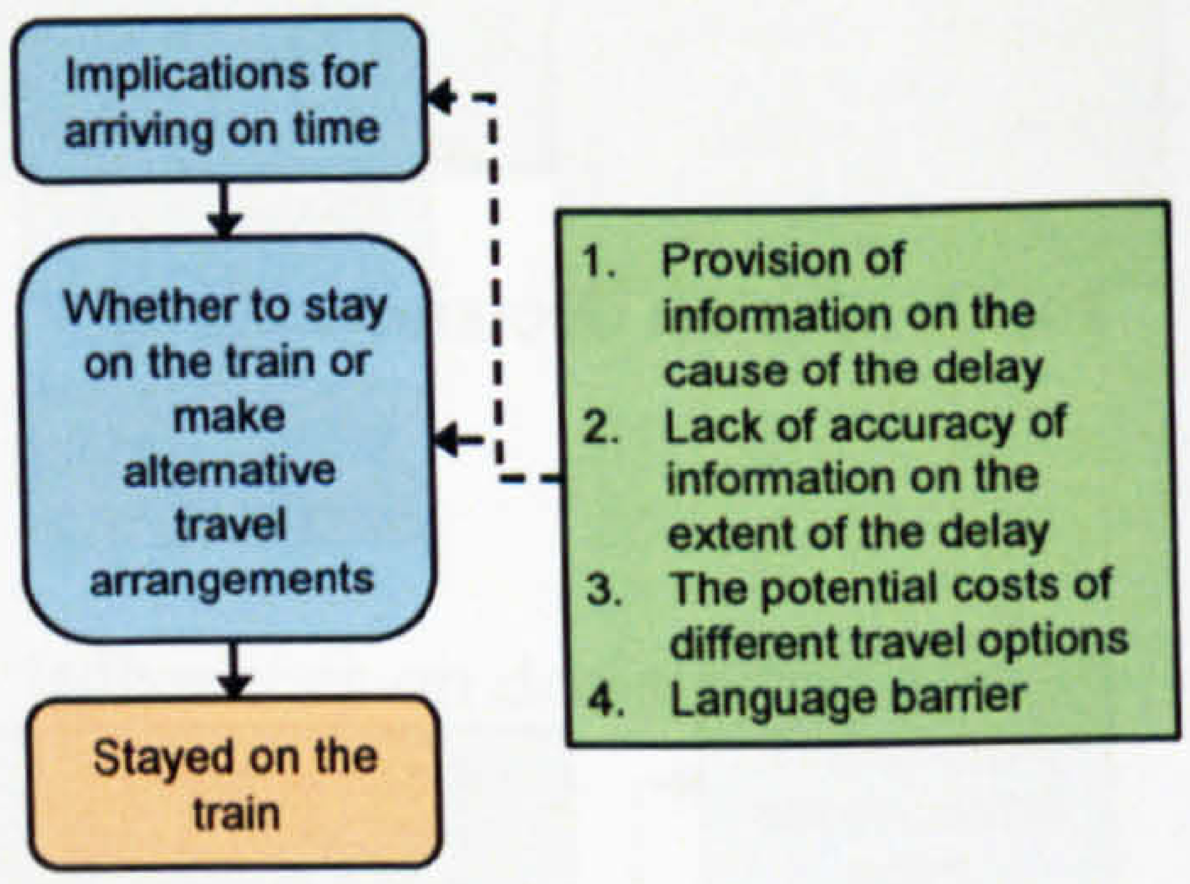
Influences on decisions (#16)



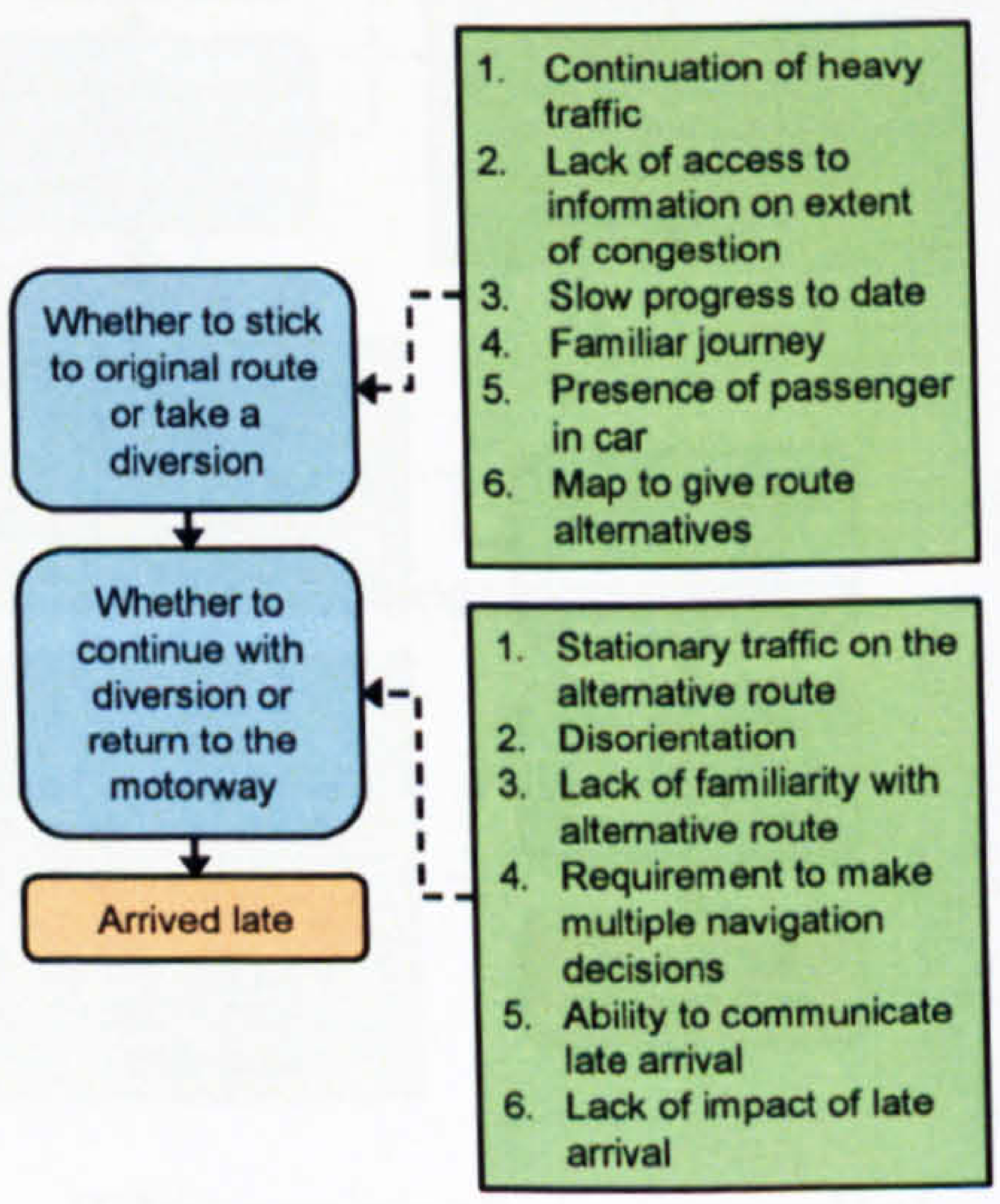
Influences on decisions (#17)



Influences on decisions (#18)



Influences on decisions (#19)



Influences on decisions (#20)

APPENDIX 5D (CHAPTER 5)
USE OF EXISTING INFORMATION SOURCES

The table below summarises, for each participant, the information needed to resolve the problems encountered, the sources used to access information, and the associated success (or 'not accessed' if the participant did not access this source of information).

#	What information was needed	Actual or potential sources of information	The success of this
1	Traffic congestion on possible routes	Source? - not available in time	Not accessed
2	Length of the bus journey to the hotel	Travel agent - could not find this out pre-trip	Not accessed
		At airport – bus information available	Incomplete – did not determine or use bus duration information
3	Whether delay was covered by insurance	Source? – not available in time	Not accessed until after the event
	Ability of AA to reach airport on time	Emergency services – incomplete information provided	Used, but did not provide the *guarantee* of reaching them on time
	Suitable taxi number	Phone book – provided multiple options	Accessed multiple options, eventually successful
	Existence of roadworks on their route	Source? – did not look for this information	Did not access as not aware of the usefulness of this information
4	What had happened to her luggage	Local agent	Asked the local agent who eventually found out where the luggage was
	Where local shops were	Local people	Not very successful due to language barrier and specific requirements
5	Where local shops were for	Local people	Not very successful, due to language barrier and specific requirements
6	What the procedure was for replacing ticket	24 hr helpline	Information incomplete as not informed that he would need to provide proof of original ticket
	What the admin fee would be to get the ticket reissued	Airline bookings desk	Not available as it was closed
	Whether he could get the cost of a second ticket refunded	Credit card company	Did not access until after the event as only made aware later that this was a possibility
7	The location of suitable local hotels	Travel agent (pre-trip)	Not accessed as told this information was available on arrival

#	What information was needed	Actual or potential sources of information	The success of this
		Hotels desk at airport	Not available as was closed due to late arrival at airport
		Local taxi	Successful, but resulted in safety concerns
8	The bus details for trip to destination	The person they were visiting (pre-trip)	Incomplete as did not include the time of the bus departure
		The local taxi operator	Inaccurate and/or misunderstood due to language barrier
9	The cause of the flight delay	The airline	Information not available until after the event
	The travel options that were available to him	The airline	Not forthcoming until later
10	The destination of the bus that she boarded	The board on the front of the coach	Destination board not understood
		Coach driver	Did not volunteer this information
	The direction of travel that the coach was taking	Road signs	Road signs not seen due to her seat position on the coach
	The travel options available	Coach station manager	Accessible (but no coaches available)
		Train station	Accessible (but no trains available)
		Parents	Accessible
11	The details of the alternative flight arrangements	Airline	Informed, but information was late
12	The departure time of the ferry	Printed timetable	Accessed but misinterpreted
13	How long the delay was going to be	Train staff	Train staff did not know how long the delay was going to be
	What the other travel options were	Timetables on train platforms	Too much effort which meant he risked missing the train if it departed
		Unsure of other sources	Unable to access other sources
14	Telephone number for local taxis	Train station posting	Not available officially
		Employee at station	Number was not answered, unsure if it was the correct number
		Employee in a local takeaway	Number (same as before) was not answered
15	Presence of congestion and extent of any delay	Visual confirmation	Provided evidence of presence but no information on extent of delay
		Radio traffic bulletin	Confirmatory, but did not detail potential impact on them
	The alternative routes available	Paper map	Effective, but did not identify the *best* alternative
	Presence of congestion	Radio traffic bulletin	Information not available

#	What information was needed	Actual or potential sources of information	The success of this
	and extent of any delay on alternative routes		
16	Details of alternative flights	Had previously accessed this information	Did not spend time/effort having to obtain this information
17	Impact of weather on the journey to work	Radio traffic bulletin	Did not provide sufficient detail plus forward projection
	Impact of weather on the way home	Source?	Did not access this, did not anticipate a need for this information
18	Location of nearest suitable garage	Passers-by	Could not ask these as not present
		Local drivers	Could not ask these as did not stop
		Visual confirmation-had passed a garage	Used successfully, but did not know if other garages were nearer (doubts over completeness of information)
19	Cause and extent of delay	Train staff	Given information on the cause of delay Updates on extend of delay provided inaccurate
	What the other travel options were	Unsure of sources of information	Lack of easy access to other sources
20	Presence of congestion and extent of any delay	Visual confirmation	Provided evidence of presence but no information on extent of delay
		Radio traffic bulletin	Could not access the traffic feature
	The alternative routes available	Paper map	Ineffective as they became disoriented
	Presence of congestion and extent of any delay on alternative routes	Radio traffic bulletin	Could not access the traffic feature

APPENDIX 5E (CHAPTER 5)
REQUEST FOR 'IDEAL SOLUTIONS'

The table below summarises, for each participant, any direct resolution stated, and/or information that was requested that would have impacted on the course of events.

	Requested a direct solution to the problem	AND/OR Requested information to impact on the course of events
1	Not stated	Reminder to leave on time. The information needed for a decision on whether to try to complete the journey, the routes to take, the associated journey time
2	Not stated	Advance information on bus journey details, specifically what bus to take, where to get it, route details, journey duration etc
3	The Motoring Services to have guaranteed getting them there on time	To have known whether the delay was covered by insurance to alleviate the short term worry of breaking down. To have known what to do at the other end having missed their transfer
4	Someone to find the luggage	Information more quickly on what had happened to the luggage
5	Not stated	Information on local shopping so he could buy some shirts – he wanted someone to say 'lets go to *this* dept store'
6	The 24hr line to have faxed through confirmation	To have had the information to tell him what he needed to do in the circumstances
7	Not stated	To know that there was a suitable hotel nearly, and be able to tell the taxi driver to take them their
8	Not stated	To have had full information on the bus they needed to take – make of bus, bus number, time it left, where it left from
9	The airline to have arranged overnight stay plus flight next morning, to minimise his inconvenience	Information on the cause of the problem. Information on the different travel options available, plus implications of each to have enabled a decision on what he wanted to do.
10	Coach company to have sorted out alternative plans for her	Information to alert her earlier that she was on the wrong bus
11	Not stated	Earlier information on the cancellation of their flight to enable booking onto alternative flights by phone
12	Not stated	Reminder in good time of when the ferry left. A

	Requested a direct solution to the problem	AND/OR Requested information to impact on the course of events
		means of keeping track of where they were to ensure they got to the ferry port on time
13	Not stated	Information on range of travel options, with associated pluses and negatives. In particular the length of the train delay, estimated ETA, and journey times and costs for other modes of transport. 'The information to empower me.'
14	Not stated	List of phone numbers for local taxi companies.
15	Not stated	A route with traffic information that would give a good prediction of estimated time of arrival
16	A flight that let her get on at short notice, or one that left later; someone to fetch her passport.	Not stated
17	Better snow clearing	Information on weather in the morning so she could have decided whether to set out from home. Notification of weather conditions over course of the journey.
18	Someone to have come out and fixed the flat tyre for him	Information on where the nearest garage was (and if possible a solution to the problem, see left)
19	Train officer to plan another way of getting home	Information on the different travel options and the implications in terms of cost and arrival time
20	Not stated	Information on source of delay, plus the time to get past source of blockage based on where they were. Information on alternative routes.

APPENDIX 5F (CHAPTER 5)
WILLINGNESS TO PAY

The table below summarises, for each participant, any stated willingness to pay for (1) a resolution to the problem, and/or (2) information to impact on the course of events. Enclosed in parenthesis [shown thus] is what that willingness to pay was based on; also included are the stated influences on WTP.

#	Summary of willingness to pay
1	£30 to ensure did not miss appointment [cost of appointment]. Little pre-emptive WTP as this was a familiar journey so low perceived risk.
2	£10 to ensure earlier arrival [cost of taxi] – 'Wasn't worth the cost of a taxi'
3	£60 to ensure timely arrival [cost of taxi]. Had invested a lot in the holiday.
4	£500 to find the luggage [financial commitment to holiday]. High WTP as were considering the worst case scenario - 'entire honeymoon appeared to be under threat'.
5	£200 to buy the shirts [importance of meetings next 2 days]. High WTP due to seriousness of situation lack of existing knowledge and lack of accessible information sources.
6	£50 to have guaranteed no problems at the airport [expected admin fee for replacing ticket]. WTP for piece of mind due to lack of experience of similar situations.
7	£20 for the help required [no direct comparison]. WTP limited as despite their concerns about safety, felt they were able to resolve problem one way or another.
8	£30 to have enabled them to get on the appropriate coach or train [less than the taxi fare]. Direct comparison with the equivalent taxi fare which was the other alternative.
9	£ zero if it came out of his pocket £100 if company would reimburse him [no comparison]. No willingness to pay – a point of principle – 'it was an issue of whose fault the problem was, and who was morally obliged to resolve it' (the airline). A willingness to pay if the employer had paid the bill.
10	£30 (15 yrs ago) for provision of additional travel arrangements [equivalent cost of fare, plus extra for hassle]. WTP influenced by feeling she 'didn't want the hassle'. Point of principle – as she felt the fault wasn't hers, she 'shouldn't have had to deal with the situation (although she was willing to pay).
11	£21 for information on changed flight details [no comparison]. Low WTP as at the time they were sure they were going to get onto new flights. But much more if it had meant getting or not getting the flight, eg may have paid for new flights.

#	Summary of willingness to pay
12	£50 to ensure catching the ferry [cost of additional B&B incurred by missing the ferry]. WTP influenced by travelling with children - this increased the importance of things going smoothly, plus the knock on effects of missing the last ferry that night with cost and convenience implications.
13	£2 for information to recommend a particular mode of transport, £30 for solution [potential taxi fare cost]. Low WTP as tended to do nothing in these situations (default option was at no cost).
14	50p for taxi number [cost of phone call?]. Low WTP because he thinks this kind of information should be free, and wasn't sure if there actually were any taxis, so information might not have been useful anyway. Also it was not *that* important that he got a taxi – he knew the area, didn't have too much luggage and it wasn't too far home (but was late at night).
15	£1 for information on routes and delays [cost of a phone call]. Low WTP as although they didn't want to be late, it was accepted with these types of meetings that there might be delays. Contingency plans are usually built in to minimise impact of delays (eg coffee at 9.30 for 10 start). 'Delays are accepted as part of life, you just manage these situations.'
16	£1 to ensure being able to get on another flight [cost of a phone call]. Highly transitory WTP - 'for a split second would have paid £100' due to immediate embarrassment, then solution became almost worthless', as she was sure she could sort it out. Although important, it wasn't a *vital* meeting - 'in the end it doesn't really matter'
17	£20 for weather information before leaving for work [financial loss of not going to work], £5 for weather information on the way home. Relatively high WTP due to lack of experience of similar events, lack of confidence, inability to judge the impact of the sequence of events on her (what effect the weather would have). Higher WTP for enabling major decisions.
18	£40 for someone to come out and fix the tyre [cost of tyre plus £10-15 for convenience]. Willing to pay for convenience of having someone come out and sort the problem out. Repair to the tyre was possible, but he 'wasn't bothered, just wanted it fixed'.
19	£10 for solution to the problem (eg train manager to lay a coach on) [potential taxi fare], £5 for accurate information on the extent of the delay. WTP based on motivation to get to the party.
20	£10 to take away the delay, £5 for information on delays and alternative routes [no comparison]. WTP influenced by having a mobile phone, and being to tell people (family) that they were going to be late – it didn't really matter if they were late. Higher WTP from her friend – he would be more stressed in the situation and hated being late.

APPENDIX 5F (CHAPTER 5)

WILLINGNESS TO PAY

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11	£21 for information on changed flight details [no comparison]. Low WTP as at the time they were sure they were going to get onto new flights. But much more if it had meant getting or not getting the flight, eg may have paid for new flights.

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15	£1 for information on routes and delays [cost of a phone call]. Low WTP as although they didn't want to be late, it was accepted with these types of meetings that there might be delays. Contingency plans are usually built in to minimise impact of delays (eg coffee at 9.30 for 10 start). 'Delays are accepted as part of life, you just manage these situations.'
16	£1 to ensure being able to get on another flight [cost of a phone call]. Highly transitory WTP - 'for a split second would have paid £100' due to immediate embarrassment, then solution became almost worthless', as she was sure she could sort it out. Although important, it wasn't a *vital* meeting - 'in the end it doesn't really matter'
17	£20 for weather information before leaving for work [financial loss of not going to work], £5 for weather information on the way home. Relatively high WTP due to lack of experience of similar events, lack of confidence, inability to judge the impact of the sequence of events on her (what effect the weather would have). Higher WTP for enabling major decisions.
18	£40 for someone to come out and fix the tyre [cost of tyre plus £10-15 for convenience]. Willing to pay for convenience of having someone come out and sort the problem out. Repair to the tyre was possible, but he 'wasn't bothered, just wanted it fixed'.
19	£10 for solution to the problem (eg train manager to lay a coach on) [potential taxi fare], £5 for accurate information on the extent of the delay. WTP based on motivation to get to the party.
20	£10 to take away the delay, £5 for information on delays and alternative routes [no comparison]. WTP influenced by having a mobile phone, and being to tell people (family) that they were going to be late – it didn't really matter if they were late. Higher WTP from her friend – he would be more stressed in the situation and hated being late.

APPENDIX 5G (CHAPTER 5)
POTENTIAL IMPACTS

The table below summarises, for each participant, how the causal factor, and/or the course of events that ensued could have been influenced. Where there was no potential to impact on these two factors, this is shown thus.

	Potential to influence the causal factor	Potential to influence the series of events
1	Reminder to leave earlier to reduce impact of heavy traffic	Too late once on the motorway, as it did not enable alternative routes to be taken
2	Catching an earlier flight to enable earlier arrival at hotel	Catching a taxi instead of a bus on arrival at the airport
3	Car broke down, could not have anticipated this	Information on insurance cover regarding delay would have resulted in change of plans Easier access to taxi information could have resulted in getting a taxi more quickly Information on roadworks - would have realised they were not going to get the flight
4	Lost luggage out of her hands	If had known that luggage *would* arrive, wouldn't have gone shopping Better information for quicker and more successful shopping for essential personal items.
5	Rerouted luggage out of his hands	Information on shopping for the shirts he needed to replace
6	Simple reminder to take his ticket	Information on his best options, to give him more certainty about the best course of action to take
7	Could not influence the delayed flight	Information on whereabouts and availability of local hotels to enable booking into a suitable hotel
8	More complete pre-trip information on buses	The rest of the information regarding bus times to give confidence to catch the bus as originally planned
9	Couldn't influence the cancellation of the flight	Information on the different alternative travel and accommodation options open to him
10	Getting on the right bus (by enabling understanding of the destination at the front of the bus)	Tracking of journey once underway to indicate earlier that she on the wrong bus. Information on alternative travel options at the point of realising she was on the wrong bus

	Potential to influence the causal factor	Potential to influence the series of events
11	Airport was closed due to poor weather	Earlier notification of this, and provision of other travel options and implications, to enable choice to travel as planned, travel another day instead
12	Information to ensure they left on time - understanding of timetable or reminder	Once they had left late, the possibility of getting to the ferry terminal on time, plus implications of missing the ferry (eg having to stay overnight, pay for another B&B)
13	Couldn't do anything about the train delay	Information on expected delay, other travel options and their implications, to make an optimum travel decision
14	There were no taxis available at the station (but potential to pre-book)	Information on taxi numbers to *possibly* obtain a taxi, however was possible that there were non available
15	Information on journey time to prompt an earlier departure	Information on extent of delay, alternative route choices and ETA
16	Reminder to take her passport	She had previously accessed information on alternative flights and used this to book alternative flight
17	No influence on poor weather. Information on future weather conditions to enable a decision to go into work or not	Information on likely weather conditions, and changes in these, on the way home to increase confidence during drive home
18	Couldn't prevent a flat tyre	Information on the location of the nearest garage to enable repair by the nearest outlet
19	Couldn't influence the delay of the preceding train	Information on expected delay, other travel options and their implications, to make an optimum travel decision
20	Couldn't influence the traffic delays Prompt for earlier departure	Information on extent of delay and alternative route choices, for increased confidence in the actions they took.

APPENDIX 7A (CHAPTER 7)

ROUTE DESCRIPTION AND ASSESSMENT OF ADDED VALUE AT EACH MANOEUVRE

Below is a table that describes the route used for the study in Chapter 7. This also shows a subjective assessment of driver confidence, navigation performance and information value at each manoeuvre. Colour coding shows whether the route the driver is likely to take *without additional information* is correct or incorrect, or if there was no obvious route that a driver would take.

Man. No.	Description of manoeuvre	Assessed driver confidence	Assessed driver action and whether correct	Main influences on confidence and route choice	Potential value of information
M0	*Depart Jaguar Car Plant*	--	--	--	--
M1	Merge onto A444, keeping to left hand lane to bypass roundabout, onto A4114 London Rd	Low	Move onto the roundabout Incorrect	Multiple lanes Two major routes Major signage to the right	High
M2	Straight on at traffic lights at Daventry Road	Medium	Go straight on Correct	Major route continues straight on	Medium
M3	Straight on at traffic lights at Quarryfield Lane	High	Go straight on Correct	Major route continues straight on	Low
M4	First exit at roundabout (J4 on ringroad), just after traffic lights	Low	No obvious route	Multiple lanes 2 major routes signposted	High
M5	Merge to the right to join the ring road, (not leaving at J5)	Medium	Merge onto ring road Correct	Multiple lanes Complex junction Joining more major road	Medium
M6	Continuing on the ring road past J6	Medium	Continue on the ring road Correct	Multiple lanes Complex junction Continuing on more major	Medium

Man. No.	Description of manoeuvre	Assessed driver confidence	Assessed driver action and whether correct	Main influences on confidence and route choice	Potential value of information
				road	
M7	Continuing on the ring road past J7	Medium	Continue on the ring road Correct	Multiple lanes Complex junction Continuing on more major road	Medium
M8	Merging to left to leave the ring road at J8	Medium	Continue on the ring road Incorrect	Multiple lanes Complex junction Leaving more major road	High
M9	First exit left at the Holyhead roundabout, onto the A4114 Holyhead Rd	Medium	Turn left (with uncertainty) Correct	Major route left	Medium
M10	Straight on at traffic lights cross road with Baras Lane	Medium	Continue straight on Correct	Major route ahead	Medium
M11	Straight over at the roundabout with retail park entry (un-named road) on left	High	Continue straight on correct	Major route ahead	Low
M12	Straight over at the traffic lights with retail park entry (un-named road) on left	High	Continue straight on Correct	Major route ahead	Low
M13	Right turn at the traffic lights at the cross roads	High	Continue straight on Incorrect	Turning off the major route	High
M14	*Turn left into the Holyhead Pub car park*	--	--	--	--
M15	*Leave train station travelling along Park Rd*	--	--	--	--
M16	Right turn at crossroads into Manor Road	Low	No obvious route	Give way No major route	High
M17	Turn left at T junction into Stoney Road	Low	No obvious route	Give way No major route	High

Man. No.	Description of manoeuvre	Assessed driver confidence	Assessed driver action and whether correct	Main influences on confidence and route choice	Potential value of information
M18	Turn left at T junction into Quinton Rd	Low	No obvious route	Give way No major route	High
M19	Second exit (straight on) at roundabout at J5 on ringroad	Low	No obvious route	Complex junction Multiple major routes Taking a minor route	High
M20	Turn right at traffic lights to go down Little Park Street	Medium	Continue straight on Incorrect	Major route ahead Turning off the major route	High
M21	Follow road to right at T junction traffic lights to go down Earl St	High	Go round to the right Correct	Following major route to the right Other route no entry	Low
M22	Straight over traffic lights cross road into Gosford Street	High	Continue straight on Correct	Following major route	Low
M23	3rd exit (right) at roundabout into Sky Blue Way	Low	No obvious route	Complex junction Multiple major routes	High
M24	Straight over at traffic lights at junction with Oxford Street	Medium	Go straight on Correct	Following route ahead	Medium
M25	Bear left at traffic lights onto Walsgrave Road	Medium	Bear right Incorrect	Multiple lanes Two major routes	High
M26	Turn left at traffic lights into Swan Lane	High	Go straight on Incorrect	Turning off more major route	High
M27	*Arrive at cov city football ground*	--	--	--	--
M28	Leaving Marconi, left turn at cross roads onto Allard Way	Low	No obvious route	Two major routes	High
M29	Right turn at traffic lights at	High	Turn right? Correct	Multiple lanes Complex	High

Man. No.	Description of manoeuvre	Assessed driver confidence	Assessed driver action and whether correct	Main influences on confidence and route choice	Potential value of information
	crossroads onto Binley Road A427			junction	
M30	Straight on at traffic lights at Princethorpe Way	High	Continue straight on Correct	Following major route ahead	Low
M31	Bear left at traffic lights onto Brinklow Road	Low	No obvious route	Two routes available	High
M32	Bear left at traffic lights onto Clifford Bridge Rd	Low	No obvious route	Two routes available	High
M33	Straight on (1st exit) at roundabout	Medium	Continue ahead? Correct	Following major route ahead	Medium
M34	Straight on (1st exit) at roundabout at Dorchester Way	High	Continue ahead Correct	Following major route ahead	Low
M35	Right (2nd exit) at roundabout onto Ansty Road	Low	No obvious route	Two major routes	High
M36	Straight on at traffic lights with A4082 Woodway Lane	High	Go straight on Correct	Following major route ahead	Low
M37	Straight over at roundabout at Brade Drive	High	Go straight on Correct	Following major route ahead	Low
M38	Turning right at roundabout into Parkway (Cross Point Business Park)	High	Go straight on Incorrect	Turning off the major route	High
M39	Left turn at roundabout into Olivier Way	Low	No obvious route	Multiple route choices	High
M40	Turn left at mini-roundabout	Low	No obvious route	Multiple route choices	High
M41	Right turn at min-roundabout into Cinema car park	-	-	-	-

APPENDIX 7B (CHAPTER 7)
THE CODING SCHEMA USED TO CATEGORISE THE CUES

Below is a description of the coding schema used to analyse the navigation cues generated in Chapter 7.

Coding (1): Information in relation to the navigation task

In relation to each manoeuvre or progress point, information was categorised as follows: *Preview* information was that used to give the driver advance warning that a manoeuvre (or progress point) was coming up: it was information that was preparatory to that manoeuvre or progress point. Examples were 'you will be turning left in 100m' and 'move into the left hand lane as you approach the roundabout'. Information coded as *identify* was used to pinpoint an exact point on route, for example 'turn left at the traffic lights' and 'go round a sharp bend'. *Confirm* information, usually described in relation to manoeuvres, was used to confirm that the driver has accomplished that aspect of the task successfully (e.g. has taken the correct turning). An example is 'turn right into *Blake Drive*'.

Coding (2): Information usage at or between manoeuvres

Based on a path-node distinction, all information cues were coded as being relevant *at* or *between* manoeuvres. Examples of instructions at manoeuvres were 'turn left at the traffic lights', or 'go straight over the roundabout'. Information at manoeuvres adds value by enabling a navigation decision to be made at that driver decision point, while maintaining driver confidence and safety. In addition to instructions *at* a manoeuvre, cues were also coded in relation to a manoeuvre if they related to driver lateral positioning or longitudinal speed control *on approach* to a manoeuvre, or if they were 'confirmation' cues. Examples of these types of instructions were '*keep to the left* as you come up to the roundabout', and '*bear left* into Binley Road'.

Examples of cues generated at progress points were 'continue up the hill' or 'go past the pub on your right'. Progress points were not discrete geographical locations, since they represented where instructions were given along sections of the route between manoeuvres. In contrast to manoeuvres, information at progress points does not result in a navigation decision, but adds value by locating the driver along the path and maintaining driver confidence.

The basis of this manoeuvre/progress distinction was that information coded in relation to a manoeuvre was that which aided the driver's task at that manoeuvre. However, it is recognised that in a very limited number of cases, information along paths (and hence coded as *progress* information) was key to completing manoeuvres successfully, eg 'Go past the large white building'. 'Take the next left'.

Coding (3): Extent of information provision at each manoeuvre

A 5-way categorisation of the instructions that participants gave at all manoeuvres en-route was used to indicate the level of detail contained in navigation instructions at each manoeuvre. This coding made no distinction between the direction of travel, ie a turn instruction or an instruction to continue in a given direction were considered as equivalent levels of information. The coding categories are shown below.

Basis for coding this category	Driver implications	Example instruction
No information given at that manoeuvre, and no previous instruction that could be followed	Manoeuvre is not a driver decision point.	N/A
No instruction given **at that manoeuvre**, but a prior instruction was valid	Driver did not need additional information since instructions at a previous manoeuvre could be used	An instruction 'follow signs for Birmingham' was given at the previous manoeuvre and these signs were still being followed A prior instruction to 'keep going'
A basic direction indication only was given **at that manoeuvre**, no additional information was used	Driver only needed the direction of turn to complete the manoeuvre	'Turn left' 'Carry straight on'
No additional information was given at the manoeuvre, but a prior landmark was used to identify the manoeuvre	Driver needed the direction of turn, plus a landmark along the pathway to complete the manoeuvre	'Go past the tower block' 'Take the next left'
Direction information, plus additional information was given	Driver needed additional information (eg landmark, junction description) at the manoeuvre	'Turn left at the large roundabout' 'Turn right following signs for Birmingham'

Coding (4): Direction of travel

The most basic information that a driver needs in order to follow a route is direction information, which can take the form of ego-centric, local or global directions. Information was coded to identify where basic ego-centric or local instructions were provided in the absence of other supporting information. These were of the form: 'turn left', 'straight over', '3rd exit', '2nd left'.

A more detailed analysis of the direction information used within this study was not undertaken for the following reasons:

- Ego-centric (eg 'turn left') and local (eg '1st exit at the roundabout') directions were purely a function of the route described by the participants. Since this route was a specified to participants there should be no variation in the use of ego-centric directions (ie all participants should use the same sequence of 'left', 'right', 'straight on' etc). The exceptions to this are where participants made an error in their route description, or directions were interpreted differently by participants (eg a 'straight on' was described as 'bear right').
- Global directions (such as 'head east') were not used at all by participants.
- It was assumed that a basic direction cue such as 'keep going' or 'turn left' would be needed at each manoeuvre, whether this was used on its own or combined with other information
- The main focus of the study was to determine the value attached to particular types of information, therefore any differences in the descriptions applied to direction cues (eg some participants describing the a particular manoeuvre in terms of 'straight on' and others applying the descriptor of 'turn left', was relatively unimportant.

Coding (5): Information category

A three-tier coding categorisation was used to identify the *type of* navigation information used by participants, where this was used in addition to basic direction information. This categorisation was bases on the schema developed by Burnett (1998) and refined through the use of a pilot study, described in May et al. (2002). A general code was used to identify the type of information; the table below shows the top-level categorisation of navigation information.

Following the approach taken in much of the literature, the definition of a landmark included buildings (e.g. post offices), street furniture (e.g. traffic lights) and built aspects of the environment (e.g. bridges), but excluded geographical features such as hills and bends in the road. The main information categories are shown below.

Specific Code	General information type	Example(s)
DSN	Direction sign used for its navigation information	Follow the signs for city centre

Specific Code	General information type	Example(s)
DIST	Distance, referred to in qualitative or quantitative terms	300 metres; quite a long way
EN	Environment, describing a geographical region or area	Residential; commercial; industrial
JN	Junction type, a driver main decision point	T – junction; crossroads
JNN	Junction name or number	J. 27; Redhill Roundabout
LM	Landmark, an object or building referred to, coded according to category	Pubs; post offices; traffic lights; bridges
LC	Lane positioning or lane changing instruction	Stay in/get in left lane
GN	Geometry of node, a descriptor applied to a junction or manoeuvre	Sharp; veer
GP	Geometry of path, a descriptor applied to a road	Bendy; straight
RM	Road marking, any information on the road surface	Dotted line; give way
RT	Type of road, according to visual appearance	Ring road; dual carriageway
SNN	Street name/number	Holyhead Road; A423
TM	Time, referred to in qualitative or quantitative terms	5 minutes; for a while

Since the landmark category included a wide range of different item types, this category was sub-coded as shown below:

Asda (supermarket)	Office World (store)
Bridge/Flyover	Park
Building - barn	Building - blue
Bus stop	Phone box
Big W (general store)	Pedestrian Lights
Cemetery	Police station
Church	Petrol station
Council house	Pub
Cinema	Building - red brick
Direction sign (object)	Restaurants

Fire station	Safeway (store)
Flats	Sky Dome
Garage	Shops (row of)
Homebase (DIY store)	Tesco (supermarket)
Hospital	Traffic Lights
Hotel	Trees
MacDonalds (restaurant)	Toys-R-Us (toy store)
Megabowl (bowling)	Traffic sign
Museum	University

Landmark categories were sorted in descending frequency, and those that fell outside a 95% cumulative frequency were coded under a miscellaneous category (approx. 30 landmarks, each with 4 or less references). The landmark coding categorisation also included directions signs where these were referred to as objects as opposed to being used for the navigation information portrayed by them. For example, if a direction sign was used in the context of 'follow signs for the city centre' it was coded under the main DSN category; if it was used in the context of 'turn left at the sign for the city centre', it was coded under the landmark (LM) category, and then sub-coded as DSO.

It was decided to individually code specific objects that were (a) relatively unique (ie did not form a homogenous category), and/or (b) frequently referred to in relation to other similar items. Therefore buildings such as the fire station, council house and Asda™ supermarket were each assigned individual codes.

Coding (6): Information primacy and redundancy

All information items identified as navigation cues were coded according to whether they were being used as primary or secondary information at that driver decision point. *Primary* information was defined as that which is needed by a driver for them to complete the manoeuvre or identify a particular point on the route. It is that which provides most value to a driver - if primary information was removed from the navigation instructions, it would make it impossible to complete, or create substantial driver uncertainty about, the navigation task. Examples would be 'turn left after *300m*', or 'turn right at the *roundabout*'. *Secondary* information was defined as information that the driver does not necessarily need in order for them to complete the manoeuvre or identify a progress point on the route, but that aids the navigation task. This is information that is partially redundant and whilst it may aid navigation, or increase navigational confidence, it could be removed whilst still enabling the manoeuvre or progress point to be identified. Examples would be 'turn left at the first set of traffic lights *in 300m'*, or 'turn right at the roundabout, *sign posted to Birmingham*'. Redundant information provides less value than primary information for a given navigation task.

It is important to note that particularly within this coding category, there was a need for experimenter judgment, and hence subjectivity when coding the importance of each navigation cue. In general, this coding was based on an assessment of whether the participant could successfully complete a particular manoeuvre, or locate themselves en-route, if that information cue was taken away. Where more than one information cue was used to describe a navigation decision, they were considered in the order in which they appeared, and a secondary code applied when it was felt that prior cues provided enough information for successful task completion. Consider the following examples:

'Turn left at the traffic lights with the church on your left.'

The 'traffic lights' were coded as primary; the 'church' secondary as this information was not *necessary* to enable the turning to be completed.

'Turn left opposite the pub and park.'

There is more ambiguity with this statement, since either the pub or the park could be treated as secondary information. In this case, because the pub was mentioned first, 'pub' was coded as primary, and 'park' as secondary.

Information description

The *terminology* used to describe navigation cues was not analysed since it fell outside the scope of this study. However a distinction was made between the same object being referred to by using *different* information categories, and different wording being used *within* a particular category. For example, a particular road could be referred to using the GP, RT or SNN categories, and was coded accordingly.

APPENDIX 7C (CHAPTER 7)

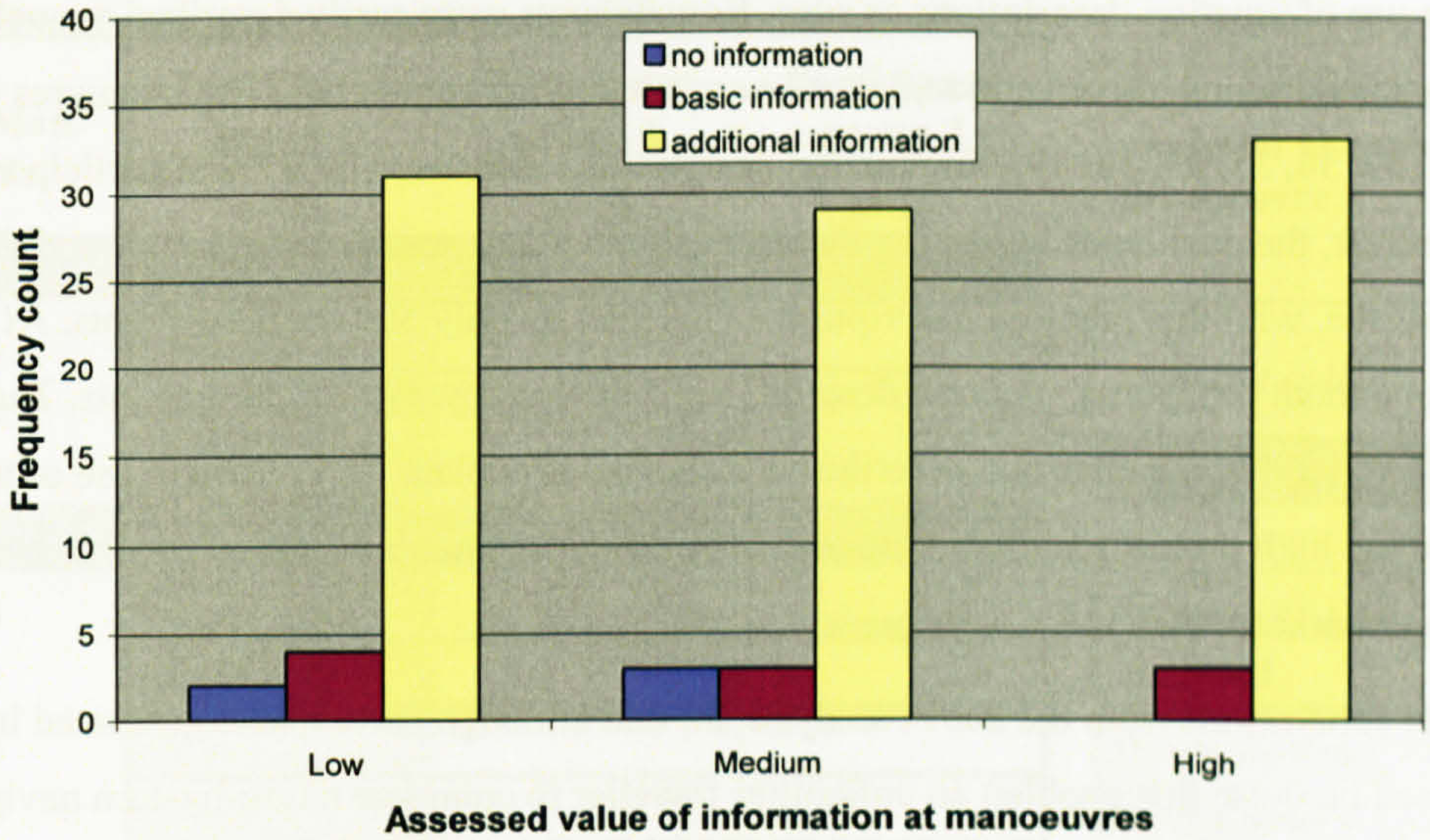
THE RELATIONSHIP BETWEEN THE GENERATION OF CUES BY PARTICIPANTS AND THE ASSESSED VALUE OF INFORMATION AT MANOEUVRES

The aim of this section was to discuss the extent to which cues were identified by participants based on them adding value, or merely because they 'were present', either within the video representation of the route (for the video group), or the participants' cognitive map (for the cognitive map group).

It is possible to compare the assessed value of navigation information at particular manoeuvres with the generation of cues at particular manoeuvres. However, this comparison must also take into account that one influence on the cues generated by participants within the study is the extent to which previous navigation instructions they generated were still valid - ie where a participant did not generate an explicit cue at a manoeuvre because a previous navigation instruction could still be used by a participant.

There were two manoeuvres where this occurred: at M6 when continuing past the first exit on the ring road (n=4) and at M7 when continuing past the second exit on the ring road (n=6). In addition, there were four manoeuvres where it was judged that a single participant did not provide an explicit navigation instruction at that manoeuvre because a previous instruction was still valid. Therefore, with the exception of the driver passing ring road exits (M6, M7), cues were generated independently of previous navigation instructions, ie it is valid to compare the cues generated by participants with the added value of navigation information at each manoeuvre. A limitation of all of this analysis is its subjectivity based on experimenter judgement.

The data shown in the figure below shows the extent to which either (1) no instructions, (2) direction-only based instructions (such as 'turn left' or 'continue straight on', or (3) more detailed instructions including additional cues such as junction descriptions or landmarks were generated at each manoeuvre. (Manoeuvres M6 and M7 must be excluded from this analysis as discussed above). This figure gives the mean number of participants who generated either no information, basic information (direction indication only) or additional information (including categories additional to turn information) at those manoeuvres assessed as having low, medium or high information needs as shown in Appendix 7A.



The generation of no, basic or complex instructions by participants according to value of information at particular manoeuvres (value categorised as low, medium or high according to Appendix 7A)

The figure above provides limited evidence that participants were generating cues according to the value of information at particular manoeuvres, since there were no instances where participants did not generate cues at manoeuvres assessed in Appendix 7A as those with high added information value. However participants did not differentiate between basic instructions (those encompassing only a direction) and instructions containing additional information, according to the value of information at that manoeuvre – they did not generate additional cues where the information value at a manoeuvre was higher. A limitation of this analysis is that by definition, those locations where information value was very low (eg proceeding past turnings off the major route) were not included in this analysis, as they were not defined as driver decision points. The data shown in the figure above is therefore range limited in respect to the value variable, and does not include those potential driver decision points where the value of information is very low.

Once the range limitation of the value variable has been taken into account, the variability of the cues generated in this study can therefore be explained by (1) their value adding capacity, and (2) their availability - cues were identified by participants because they were useful, but also because they were there. It was apparent that where highly visible landmarks such as traffic lights, superstores and large bridges were present, they tended to be identified as cues irrespective of the potential value of information at that manoeuvre. The bridge shown in Chapter 7 text was used by 25 participants even though it only served to increase confidence between manoeuvres. There was also evidence that the ease with which cues could be described played a role in their generation by participants. There was considerable variation in the use of junction descriptions as cues. Roundabouts were easily described as such by participants, and at conventional manoeuvres involving roundabouts (manoeuvres 4, 9, 11, 19, 23, 33, 34, 35, 37, 38, 39, 40) junction descriptions were used by 95% of participants. In contrast, the dual lanes bypassing the roundabout at manoeuvre M1 were more difficult to describe, with this junction description being used by only 50% of participants. At other (non-roundabout junctions), junction descriptions were used by 39% of participants. The need to be able to easily recognise and describe cues also helps explain the consistent use of traffic lights and the high proportion of participants who referred to unique, familiar objects such as supermarkets when these were present.

The conclusions from the above analysis are that although participants generated instructions based on those that enabled an unfamiliar traveller to complete a turn-by-turn navigation strategy, the generation of cues was also highly influenced by the nature of the cue itself, and particularly the visual prominence of potential cues and the ease with which they could be described.

APPENDIX 8A (CHAPTERS 8 & 9)
DATA COLLECTION SUMMARY

Man. No.	Participant group 1 n=16	Participant group 2 n=16	Participant group 3 n=16
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37			

Key: data collected & analysed at each manoeuvre

Data *not collected*:

Chapter 8: data analysed
- Driver confidence
- Driving errors
- Navigation errors

Chapter 9: data analysed
- Driver confidence
- Driving errors
- Navigation errors
- Visual glance data
- Driver workload

Data collected but not analysed:
- Driver confidence
- Driving errors
- Navigation errors

APPENDIX 8B (CHAPTERS 8 & 9)
DESCRIPTION OF THE ROUTE

#	Location	Nature of turning	Distinguishing features
1	Exit Meadowcroft Rd, turning left onto A6	Turning onto more major road at oblique T junction	No data collected at this manoeuvre
2	Turn right onto 'The Parade'	Turning off the major road	Traffic light controlled crossroads
3	Proceed onto Leicester Rd	Continuing on the same road as it bears left	No visual indication of a change in road
4	Turn right before the church into Wigston Rd	Turning off the major road	Turning into narrow, partially obscured turning
5	Turn right onto Wigston Rd (becomes Oadby Rd)	Right at T junction onto more major road	No data collected at this manoeuvre
6	1st exit at roundabout onto Bull Head street	Turning onto more major road	Give way
7	Turn right onto Moat street	Turning off the more major road	Traffic light controlled crossroads
8	Turn left onto Launceston Rd	Turning off the more major road	
9	Turn left onto Bodmin Avenue	Turning off the more major road	
10	Turn left onto Horsewell Lane	Left at T junction	No data collected at this manoeuvre
11	Turn left onto Moat street	Left at T junction onto more major road	Give way
12	Turn right onto Long Street	Right at mini roundabout onto more minor road	Give way
13	Right onto Wakes Rd	Turning right off current road	
14	1st exit at roundabout onto Bull Head St	Turning onto more major road	No data collected at this manoeuvre
15	Turn left onto Carlton Drive	Turning off the more major road	Accelerating on approach to turn
16	Turn right onto Chellaston Rd	Turning off the more major road	
17	Turn left onto Exeter Rd	Turning off the current road	
18	Turn right onto Aylestone Rd	Turning right at T junction onto more major road	
19	Turn right onto Goldhill	Turning off the more major road	
20	Turn left onto Windley Rd	Turning left at cross roads	Give way
21	Turn left onto Stonesby	Turning left at T junction onto	Give way

#	Location	Nature of turning	Distinguishing features
	Avenue	more major road	
22	Turn right onto West Avenue	Turning off the more major road	
23	Turn right onto Pullman Rd	Turning off the current road	
24	Turn right onto Station Rd	Turning off the major road at mini roundabout	Give way
25	Turn right onto Fairfield Rd	Turning off the more major road	
26	Turn left onto Kirkdale road	Turning left at T junction	Give way
27	Turn left onto Leopold Rd	Turning off the current road	Close to preceding turn
28	Turn right onto Blaby Rd	Turning right at T junction onto more major road	Give way
29	Proceed onto Little Glen Rd	Straight over mini roundabout	Give way
30	Turn left onto Leicester Rd	Turning left at T junction onto more major road	Traffic light controlled T junction, highly visible from a distance
31	1st exit off Blaby roundabout onto	Turning onto more minor road	Continuing in ahead direction, close to preceding turn
32	Turn left at mini roundabout onto Sycamore St	Veering left at mini roundabout	Give way, close to preceding turn
33	Turn left onto Home Close	Turning off the more major road	Turning into narrow, partially obscured turning, close to preceding turn
34	Turn left onto Northfield Rd	Sharp bend in the road	No data collected at this manoeuvre
35	Turn right onto Leicester Rd	Turning right at T junction onto more major road	Give way
36	2nd exit off roundabout onto Leicester Rd	Turning onto more major road	Give way, close to preceding turn
37	Turn right onto Grange drive	Turning off the more major road	

APPENDIX 8C (CHAPTERS 8 & 9)

DATA SHEET FOR RECORDING DRIVING ERRORS

This shows the data sheet used by the Advanced Driving Instructor to record the category and severity of driving errors committed by the participant.

Safety checklist (driving instructor)

Sub name......................... No......... Date........... Time............

To assess the level of driver safety at each manoeuvre

All manoeuvres to be assessed, including non-target ones

Completed at each manoeuvre by the driving instructor

Weather description ....

Category	Code
Minor	M
Serious	S
Dangerous	D

Manoeuvre No	Description	9- Use of mirrors and rear observation when signalling, changing direction and speed			10- Give appropriate signals			11 - Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users			15 - Junctions, aspects include speed of approach, observation, turning right or left and cutting corners			17 - Positioning in normal driving and lane discipline			21 - Awareness and planning		
		M	S	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S	D
0	to start off																		
1	exit meadowcourt rd (turning left onto A6)																		
2	turning right onto 'The																		

Manoeuvre No	Description	9- Use of mirrors and rear observation when signalling, changing direction and speed			10- Give appropriate signals			11 - Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users			15 - Junctions, aspects include speed of approach, observation, turning right or left and cutting corners			17 - Positioning in normal driving and lane discipline			21 - Awareness and planning		
		M	S	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S	D
	Parade' (Oadby)																		
3	proceed on Leicester rd road (road bears left)																		
4	right by the church, Wigston rd																		
5	right from the church (onto Wigston rd)																		
6	1st exit off Wigston roundabout (onto Bull Head street)																		
7	right onto Moat street																		
8	left onto Launceston rd																		
9	left onto Bodmin ave																		
10	left onto Horsewell lane																		
11	left onto Moat street																		
12	right onto Long street																		
13	right onto Wakes Rd																		
14	1st exit off Wigston roundabout																		
15	left onto Carlton drive																		
16	right onto Chellaston rd																		
17	left on Exeter rd																		
18	right onto Aylestone rd																		

Manoeuvre No	Description	9- Use of mirrors and rear observation when signalling, changing direction and speed			10- Give appropriate signals			11 - Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users			15 - Junctions, aspects include speed of approach, observation, turning right or left and cutting corners			17 - Positioning in normal driving and lane discipline			21 - Awareness and planning		
		M	S	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S	D
19	right onto Goldhill																		
20	left onto Windley rd																		
21	left onto Stonesby Ave																		
22	right onto West Ave																		
23	right onto Pullman rd																		
24	right onto Station rd																		
25	right onto Fairfield rd																		
26	left onto Kirkdale road																		
27	left onto Leopold rd																		
28	right onto Blaby rd																		
29	proceed onto Little Glen rd																		
30	left onto Leicester rd																		
31	1st exit off Blaby roundabout																		
32	left at mini roundabout																		
33	left onto Home close																		
34	left onto Northfield rd																		
35	right onto Leicester rd																		
36	2nd exit off Blaby roundabout																		
37	right onto Grange drive																		
	End																		

APPENDIX 8D (CHAPTERS 8 & 9)

WAYPOINT ENTRY AND SHEET FOR RECORDING DRIVER CONFIDENCE AND NAVIGATION ERRORS

This shows the experimenter sheet used to (1) enter and trigger the waypoints for the three routes on the navigation system, (2) record the driver confidence levels (high, medium or low) at each of the Preview 1, Preview 2, Final and Post manoeuvre points, and (3) record and categorise actual or intended navigation errors. The grey shading indicates where no confidence rating was collected due to the proximity of the previous manoeuvre.

Confidence Ratings & Navigation Errors - Subject Ratings Sheet

Subject Name: **Date:** **Subject No.:** **Start Time:**

STOP – ROUTE 1 - Enter R1-W1, R1-W2, R1-W3D

1- exit Meadowcourt Rd (turning left onto A6)

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

2 - turning right onto 'The Parade' (Oadby)

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

3 - proceed on Leicester Rd road (road bears left)

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

4 - right by the church, Wigston Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

STOP – Next Waypoint, Avoid Cross Street, Re-calculate route

5 - right from the church (onto Wigston Rd)

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

6 - 1st exit off Wigston roundabout (onto Bull Head Street)

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

7 - right onto Moat Street

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

8 - left onto Launceston Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

9 - left onto Bodmin Ave

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

STOP – ROUTE 2 – Enter R2-W1, R2-W2, R2-W3, R2-W4D

TELL THEM TO FOLLOW ROAD ROUND TO RIGHT

10 - left onto Horsewell Lane

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

11 - left onto Moat Street

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

12 - right onto Long Street

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

13 - right onto Wakes Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

14 - 1st exit off Wigston Roundabout

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

15 - left onto Carlton Drive

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

16 - right onto Chellaston Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

17 - left on Exeter Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

18 - right onto Aylestone Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

19 - right onto Goldhill

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

STOP – ROUTE 3 – Enter R3-W1, R3-W2, R3-W3, R3-W4D

20 - left onto Windley Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

21 - left onto Aylestone Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

22 - right onto West Ave

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

23 - right onto Pullman Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

24 - right onto Station Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

25 - right onto Fairfield Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

26 - left onto Kirkdale Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

27 - left onto Leopold Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

28 - right onto Blaby Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

29 - proceed onto Little Glen Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – Next Waypoint

30 - left onto Leicester Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

31 - 1st exit off Blaby Roundabout

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

32 - left at mini roundabout

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

33 - left onto Home Close

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

ON MOVE – ROUTE 4 – Enter R4-D and Proceed

34 - left onto Northfield rd – NO MESSAGES GIVEN HERE

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

35 - right onto Leicester Rd

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

36 - 2nd exit off Blaby Roundabout

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

37 - right onto Grange Drive

	Low	Med	High	Comments/Reasons for rating
Preview 1				
Preview 2				
Final				
After man.				

Navigation Error			
Too soon	Too late	No turn	Other (state)

END – Drive back to Sainsbury's

APPENDIX 9A (CHAPTER 9)

NASA RTLX INTRODUCTION, FACTOR DEFINITIONS AND RATING SCALES

This shows the instructions, scale definations and rating scales used to measure driver mental workload at the end of the trial

Please read the following instructions carefully

Driving is actually a very complex skill which most of us take for granted. Imagine all the different components and pieces of behaviour which are involved in successfully controlling the vehicle through the traffic environment. For instance, you have to look out for pedestrians, judge distance and speed in relationship to other vehicles, control position on the road via the steering wheel whilst simultaneously attending to gear changes and pedal controls. In other words, driving demands the human to perform a number of tasks at once.

Fortunately an experienced driver learns how to bring together these skills and perform them in a manner which demands little conscious control. This comes with practise and experience on the road. Most of us can remember those days as learner drivers when we were forced to remember each skill in turn and there are always seemed to be too much to be done in too little time.

The attached sheet has attempted to break down the driving task into six distinctive components. Please read each through the descriptions of each factor and inform the experimenter when you have finished.

SIX FACTORS WHICH CONTRIBUTE TO THE DIFFICULTY OF THE DRIVING TASK

NB – Navigating is part of the overall task of driving

1. MENTAL DEMAND

This factor refers to any mental demands **placed on you** by the driving task (e.g. in planning, thinking, deciding, remembering, looking, searching). Was the driving task mentally easy or demanding?

2. EFFORT

This factor refers to the mental effort **required by you** to maintain a safe level of driving. Was little concentration required, or did you have to concentrate a lot during the course of the journey?

3. PHYSICAL DEMAND

This factor refers to any **physical activity** you have just experienced whilst driving (e.g. operating the car's controls, using the route guidance device, etc).

4. TIME PRESSURE

This factor refers to how **hurried or harassed** you felt whilst driving (e.g. due to the presence of other vehicles, traffic flow, following the route guidance information, etc).

5. DISTRACTION

This factor refers to the extent to which you felt **distracted** from the driving task. Safe driving requires you to demonstrate a reasonable amount of vigilance to events outside the vehicle. Information both inside and outside the car (visual and/or aural) has the potential to distract you from the driving task.

6. STRESS LEVEL

Ideally you should fell relaxed and unworried whilst driving. However, circumstances may cause you to fell stressed (i.e. annoyed, frustrated, worried, irritated). This factors refers to how **relaxed versus stressed** you felt whilst driving.

RATING SCALES

Place a line through each scale that represents the magnitude of each factor on the task written in **bold** below:

Driving whilst using the Route Guidance System to Navigate

Mental Demand	Low	|---|	High
Mental Effort	Low	|---|	High
Physical Demand	Low	|---|	High
Time Pressure	Low	|---|	High
Distraction	Low	|---|	High
Stress Level	Low	|---|	High