Route guidance systems: optimal navigation via the use of landmarks

Driver reaction to navigation instructions incorporating good and poor landmarks

Deliverable no: 4
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ABSTRACT

The study consisted of a road-based trial involving 48 participants using a navigation system to complete a complex urban route. The participants were divided into three matched groups experiencing one of the following landmark conditions: good, poor or no landmarks, incorporated in verbal instructions. A range of objective and subjective measures were taken to assess driver performance with and attitudes to each of the landmark categories. The aims were to:

- assess the impact on driver performance and attitudes of presenting navigation instructions which included good, poor or no landmarks
- validate the REGIONAL model, which was developed to predict the navigational value of individual landmarks
- identify any other factors (e.g. driver or manoeuvre characteristics) that may affect the value of landmarks

The main conclusions were:

Clear behavioural differences were found between the three landmark categories of good, poor and no landmarks:

- The good landmarks condition was the one that most consistently resulted in safer and more effective driver behaviour
- Poor landmarks resulted in an equivalent (to good landmarks) amount of time looking at the display
- No landmarks resulted in driver confidence equivalent to that for good landmarks
- Older drivers had longer average glance durations.
- Glance duration decreased over time for all conditions.

Participants' attitudes varied little across landmark condition:

- Participants were positive about system use (particularly older drivers) and found the voice instructions/landmarks, the distance countdown bar and the road layout particularly useful
- Suggested improvements were: the addition of mini-roundabouts on the display, lane specification, counting of roads and identification of distance between landmark and manoeuvre

The regression model and certain sub-factors were able to predict changes in behaviour, plus an effect of manoeuvre was found:

- The REGIONAL regression model for landmark value could predict driver confidence but could not predict other measures of driver behaviour.
- Driver confidence also showed a relationship with the component factors of Visual Characteristics, Visual Effort for Scanning, Pre-Warning, Influence of Surroundings, Level of Task Demand, Degree of Interaction and Visibility Distance
- The predictive value of the model and individual factors was lessened for manoeuvres that were: early in the trial, had other, equally/more likely manoeuvres nearby, were concealed in some way, were in a busy traffic situation

1 INTRODUCTION

Previous research suggests that considerable usability benefits may arise from using landmarks (e.g. traffic lights, churches, bridges) within the turn-by-turn visual and voice directions provided by in-vehicle route guidance and navigation systems. The overall aim of the REGIONAL project is to ensure that landmarks can become an integral part of future route guidance and navigation systems for vehicles.

The road-based evaluation reported in this deliverable aimed to assess the effects on driver behaviour of particular landmark information (for more detailed aims see section 2). It is therefore of interest to consider previous, related studies to identify:

- The driver behaviour measures that other researchers have used
- The measures that have shown a change according to landmark information
- Age effects
- Gender effects

1.1 Evaluation studies

Alm et al (1992) conducted a road trial in which 20 drivers used a simulated route guidance system that provided simultaneous visual and aural directions. The design was factorial, such that in the control group 10 drivers (matched by gender only) were presented with only very simple left/right/straight on information, whereas in the experimental group, the remaining subjects received the same information plus information regarding landmarks along the route.

Subjects in the landmark condition felt significantly more confident as to where to turn ($p<0.05$). No further statistical differences were found between the two conditions. However, several non-significant trends were revealed by the data. For instance, subjects presented with landmarks generally felt more satisfied with the content of visual information and rated their mental workload (using the NASA-TLX) to be lower. Furthermore, there were fewer navigational errors made by those who were presented with landmarks.

However, this study was primarily subjective in the measures taken, and, as pointed out by Alm et al., the route was not very complex (15 decision points over a 3.5 mile journey which took on average 7 minutes to drive) and few landmarks were presented to the driver (only traffic lights on six occasions). Consequently, the relative effect of landmark use on the usability of the route guidance system may have been limited.

Green et al (1993) conducted a study whose principal aim was to examine the feasibility of using a simulator for conducting route guidance evaluations. However, the study also investigated the potential for presenting landmarks to drivers. A sample of 48 subjects, split equally by gender and age, sat in a mock-up of a car and watched a videotape of an unfamiliar 25 minute trip through the state of Michigan, North America. They received route guidance and traffic information during the journey. The design was factorial with four conditions: visual route guidance information only, visual with landmarks, auditory route guidance information only, auditory with landmarks. The landmarks used were traffic lights, stop signs and bridges. Subjects were instructed to press one of three buttons when they could see the junction referred to by the system (left/ right/straight on), and to press the brake pedal if the car in front braked.

Subjective data, as opposed to performance-related variables, revealed the most differences with respect to the effect of landmark presentation. For instance, it was found that drivers strongly preferred HMIs that contained landmarks over those without. In commenting on this study, it must be noted that, in addition to landmarks, a number of other types of information were presented by the simulated route guidance system, including street names (which may be considered as landmarks in their own right), accurate road layout and compass directions. Use of such a wide range of supporting information types may have negated any potential effect that landmarks could have on objective performance.

Of those studies found in the literature, only one empirical study has explicitly revealed performance-related benefits for a route guidance system that utilises landmarks. Bengler et al (1994) conducted a simulator-based experiment in which 24 experienced drivers aged 21-49 viewed a series of videotaped routes whilst carrying out a simple tracking task (i.e. using the steering wheel to keep a computer-generated cross in the centre of the road view). A factorial design was employed, such that half of the subjects were provided with visual only route guidance

information - a simplified representation of the junction with no other information. The remaining subjects were also provided with landmark information at junctions. It is not apparent from the paper as to the range of landmark types presented, or the complexity of the routes followed. However, the authors do provide traffic lights and stop signs as examples of landmarks in the introductory section. Subjects were instructed to use the route guidance information to make navigational decisions, and to register their judgements by turning the steering wheel and employing the indicators. Three types of indicator/steering error were registered: those in which the driver reacted too early and had to correct his/her action; those in which the driver reacted too late or not at all; and those in which reactions were in the wrong direction. Therefore, these parameters were being used to indicate navigational, rather than driving, performance. Route guidance information that included landmarks was found significantly to reduce the number of incorrect uses of the indicators for all three error types. There was also a trend for reduced steering errors with landmark information (approximately 30% fewer errors), but this difference was not significant.

Philips (1999) describes a study that tested the influence of landmark information in route guidance displays on navigation performance in a simulated driving environment. Forty-eight participants drove in a high-fidelity simulator and navigated using route guidance displays with and without landmark icons. The results indicated that landmarks were beneficial as a navigation aid; they helped drivers make turning decisions more quickly, especially in reduced visibility conditions (i.e. foggy conditions).

Allerton (2000) conducted a study to investigate the relative benefits of landmarks for good and poor navigators. Conclusions were that they showed a greater advantage for the poor navigators, but other results are of more relevance to the current study. Navigation instructions were provided verbally by the experimenter and included distance, junction-type (where possible) and direction. In the landmark condition, landmarks were included after the distance information. The main findings (when comparing the 2 conditions for all 12 participants) were that including landmarks resulted in higher mental demand and mental effort (as measured by NASA RTLX scores) but resulted in participants feeling better prepared for a manoeuvre. No differences in performance were found for any other measures, which included ease of understanding, driver confidence (both measures post-trial), navigation errors and driving errors.

1.2 Ageing effects

It is frequently stated that the western world population is an ageing one. For example, in the UK in 1993 those over 50 constituted 40% of British adults (+16). Projected growth rates suggest that the proportion of over 50s will grow to approximately 48% of the adult population by 2021 (Coleman, 1993).

Several age-related factors are discussed in the literature that have implications for the HMI for route guidance systems (Burns, 1997; Marin-Lamellet et al 1991; Yanik, 1989):

- Perceptual changes (e.g. reductions in visual field, static and dynamic acuity, depth perception; increases in glare sensitivity, accommodation time and time required for dark adaptation; poor hearing)
- Cognitive changes (e.g. reduced spatial ability; greater problems in tasks involving dividing attention, attention switching and selective attention)

Jackson (1998) suggests that, contrary to expectations, detailed guidance instructions can have a detrimental effect upon way finding performance, particularly for elderly individuals.

Other than the work reported by Jackson (1998), above, there appear to be few empirical studies in the literature that have directly addressed the implications of ageing for the content of information for route guidance systems. There are several other results of indirect relevance, for instance, a number of authors have found that older drivers experience greater visual demand with in-vehicle displays than do younger drivers (Graham and Mitchell, 1997;Green et al, 1993; Noy, 1989; Pauzie and Marin-Lamellet 1989). Furthermore, Walker et al (1991) found in a simulator experiment that older drivers were prone to make more navigational errors as task difficulty and display complexity increased. Such results would suggest that careful consideration should be given to the choice of information for use by this group of drivers, and the distribution of information across the visual/auditory modalities and verbal/spatial formats.

In Burns' (1997) postal survey (which asked respondents to identify how they would want a passenger to describe the location of a turn), there were no large differences between elderly and

non-elderly drivers with regard to way finding information needs relating to both motorways/major roads. For driving though towns/cities, there were differences between elderly and non-elderly drivers, with the largest age effect for landmarks, where 15% more non-elderly drivers wanted landmark information than did elderly drivers.

In response to a question asking respondents how they would want a passenger to describe the location of a turn, there were differences based on the elderly/non elderly categorisation of respondents. Overall, landmarks were the second most popular information source (44%) – see figure 5 and there was an age effect, with 16% more elderly drivers listing road numbers among their top three responses, and correspondingly 15% more non-elderly drivers listing landmarks.

Burnett, (1998) undertook a questionnaire survey of 200 experienced drivers (149 male and 51 female, mean age 38, range 19 to 75 years) as a broad investigation of drivers' preferences for information. The results showed a general trend for older subjects to rate the different information types as more useful for navigation than did younger subjects. ANOVA tests revealed significant age effects regarding preferences for several of the landmarks: river, dip in road, hump-back bridge, church, cinema, bus/coach station, multi-story car park, bridge over road, railway station, monument, advertising hoarding and park. In general, there was a trend for older subjects to rate each landmark (as a subset of total navigation information) as better for navigation than did younger subjects.

In a study by Dabbs et al (1998) of gender differences in navigation strategy and geographic knowledge, 90 men and 104 women completed cognitive spatial tests, gave directions from local maps, and identified places on a world map. Gender differences are reported in section 6.2 below. Age differences were found, independent of gender, with older subjects of both sexes giving more abstract Euclidean directions than younger subjects. The authors state that the age effect, which was independent of sex, supports a developmental view of spatial cognition.

The simulator study described by Philips, (1999) (see section 1.1) specifically tested the influence of landmark information in navigation system displays on navigation performance in a simulated driving environment. It was found that landmarks were particularly beneficial to older drivers by improving their turning accuracy and turn signal accuracy, especially in the fog.

In the study reported by Janes (2000), 12 older (aged 55+) and 12 younger (25-35) drivers followed two predetermined urban routes of approximately five miles each. In one condition, the participants were allowed to view a map prior to driving; in the other condition, no map was provided. In both conditions, the 'question asking' protocol was used i.e. the driver asked the experimenter (who sat alongside the driver) for any information needed in order to reach the given destination. Although this study specifically addressed the needs of older drivers, no significant differences were found between younger and older drivers for the type of landmark information requested, or the timing of this information.

1.3 Gender differences

It is certain that there are differences between males and females in current navigational behaviour. As an illustration, a survey conducted by Streff and Wallace (1993) in the US found that paper maps were used more and preferred by males. However, females preferred a combination of methods for navigation (e.g. written notes, a map, a passenger). In addition, females reported more problems with navigating in unfamiliar areas. The extent to which results of this kind have implications for the design of a route guidance system is not clear. They would suggest that females may be less able, or less confident, in using a map-based navigation display, and would prefer verbal instructions. Indeed, Mashimo et al (1993) found some evidence that males were better able to navigate with a North-up map display than females.

Ward et al (1986) revealed gender differences with respect to the preference for landmark information. In their study 176 undergraduate students were instructed to study a map that included a scale, a variety of landmarks and compass directions, and then to provide directions for different origins and destinations on the map. They found that males used more distances and cardinal directions in their directions than did females, who placed a greater reliance on landmarks and relational terms (e.g. left/right). Although the authors did not explore directly why landmarks were chosen, they do postulate that females use cardinality less in dealing with the environment due to stylistic preferences, rather than a lack of competence in using a co-ordinate reference scheme. On the basis of these results one might expect that the presentation of landmarks by route

guidance systems would lead to greater benefits, in terms of system acceptance, for females than for males, although no study has addressed this possibility.

In Burns', (1997) postal survey (see also section1.2), there were gender differences with regard to the information that drivers would request from passengers to locate a turning. Eleven percent more female drivers wanted landmark information from a passenger than did male drivers. The largest gender difference was regarding road numbers, where 15% more male drivers wanted road numbers than did female drivers.

In the survey conducted by Burnett, (1998) (described in section 1.2), females considered landmarks to be more useful for navigation than did males. This result was found for all three categories of road types investigated (dual carriageways and motorways, single carriageway out-of-town roads, and roads within cities). This gender preference for particular landmarks was significant (at $p<0.05$ or better) for the following landmarks (out of a total of 29 types): shop/restaurant, park, wood/forest, bus/coach station, railway station, superstore, monument, cinema, advertising hoarding and traffic lights.

In the study by Dabbs et al., (1998) (see section1.2) it was found that on the spatial tests, men were better than women in mental rotation skill, but men and women were similar in object location memory. In giving directions, men were more abstract and Euclidian, using miles and north-south-east-west terms, whereas women were more concrete and personal, using landmarks and left-right terms.

1.4 Summary of literature

1.4.1 Landmarks

In empirical studies investigating landmarks for navigation, the following driver behaviour effects have been found for landmark use (compared with no landmarks):

- Increased confidence
- More satisfaction with the content of visual information
- Lower mental workload
- Fewer navigational errors
- Strong preference for instructions incorporating landmarks
- Less indicator errors
- Less steering errors
- Faster turning decisions

It is important to note that several studies found no effect, on objective measures, of including landmarks. This was less often the case where subjective measures (usually relating to confidence and preferences) were used. No other studies in the literature have compared good landmarks with poor landmarks.

1.4.2 Age

There is very little research that looks specifically at older drivers' reactions to landmark information. However, several studies have reported effects relating to other in-vehicle information. Older drivers (usually defined as 50+ or 55+) show the following characteristics when compared to younger drivers (different studies often present conflicting findings):

- Greater visual demand from in-vehicle displays
- More navigational errors (as task difficulty and display complexity increased)
- Less likely to state a need for landmark information and more likely to want road numbers
- More likely to rate navigation information components, including landmarks, as useful
- Improved turn accuracy and indicator accuracy (especially in fog) when using landmarks
- In direction-giving, provide more abstract Euclidian directions

1.4.3 Gender

Gender issues have mostly been investigated in relation to natural navigation methods and preferences. Few studies have empirically investigated gender influences on system design, including landmarks. The few, relevant, results available are:

- Males use/prefer paper maps, females use/prefer a combination of methods (written notes, map, passenger)
- In direction-giving, males use more distances and compass directions, females more landmarks and relational (left-right) terms
- When identifying navigation information of most use, more females stated landmarks, more males stated road numbers
- Males are better able to navigate with a north-up map display
- Males have better mental rotation skills

2 OBJECTIVES OF THE STUDY

The study aimed to:

- assess the impact on driver performance and attitudes of presenting navigation instructions which included good, poor or no landmarks
- validate the REGIONAL model (see Figure 1 below) which was developed to predict the navigational value of individual landmarks
- identify any other factors (e.g. driver or manoeuvre characteristics) that may affect the value of landmarks

The REGIONAL predictive model

One of the outputs of the REGIONAL project is a predictive model (developed though regression analysis) that can be used to determine the value of a landmark based on 3 factors. 'Value' is the extent to which the landmark is an effective cue for navigation, i.e. one that will make the identification of the next manoeuvre as easy as possible. The model is shown in Figure 1.

V = (.340) DEGOFINT + (.255) USEOFLOC + (.134) VISCAR

Where:

DEGOFINT = Degree of Interaction

USEOFLOC = Usefulness of Location

VISCAR = Visual Characteristics

Figure 1. REGIONAL regression model for calculation of landmark value

3 METHOD

3.1 Overview

The study consisted of a road-based trial involving 48 participants using a navigation system to complete a complex urban route. The participants were divided into three matched groups experiencing one of the following landmark conditions: good, poor or no landmarks incorporated in verbal instructions. A range of objective and subjective measures were taken to assess driver performance with and attitudes to each of the landmark categories.

3.2 Experimental design

The study employed a between subjects design with three matched groups of subjects each experiencing one landmark condition from those shown in Table 1.

Landmark condition	Condition description	Visual Display (same for all, see Figure 2)	Voice Instruction (e.g.)
GOOD	Good* landmarks	Junction layout Distance countdown bar Current road name Next road name	Left turn at the traffic lights
POOR	Poor* landmarks		Left turn after the bus stop
NONE	No landmarks		Left turn ahead
* as calculated by the REGIONAL predictive model			

Table 1. Experimental conditions

For the GOOD and POOR categories, the manoeuvres that had both types of landmark were designated 'target manoeuvres'. Some manoeuvres did not have landmarks that could be used. In these cases, the voice instruction was the same as that for the NONE condition and they were designated 'non-target manoeuvres'. This is representative of what would happen in future systems that implemented landmarks (i.e. not all manoeuvres can be associated with a landmark).

3.3 Navigation system

The navigation system used was an Alpine DVD Route Guidance Navigation System. The two possible screens on the **visual** display are shown in Figure 2 and Figure 3. This was identical to the version on the market. The **auditory** information provided by the system was turned off and replaced by three sets of verbal instructions (one for each landmark condition) recorded onto a PC. Each message was triggered at a pre-set distance (using the navigation system countdown bar as a guide). The rules for message sets are shown in Table 2 below and a full set of the displays, messages and trigger distances is provided in Appendix 1 The version of the system used in the trials used yards and miles to represent distance. This is not unusual for UK drivers and was therefore valid for the trials.

Figure 2. Navigation display: screen shown when close to manoeuvre

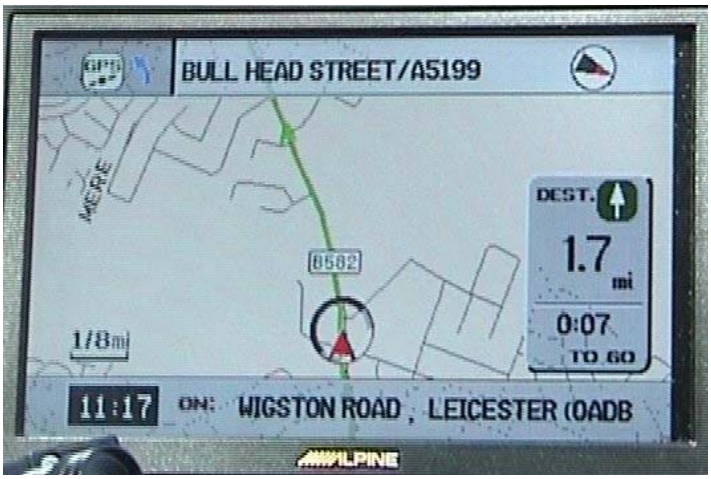


Figure 3. Navigation display: screen shown when between manoeuvres

The system was used in 'Hybrid' mode; this meant that if there was more than 500yds until the next manoeuvre a map with a highlighted route was shown (Figure 3). When close to a manoeuvre this changed to the detailed junction layout shown in Figure 2. This mode was chosen over 'Map' (where only the map is shown) and 'Arrows' (where, between the detailed junction layout, the system presents only the direction of the next turn and the next road name) as it was felt to be the mode that provided the most comprehensive navigation information. Also, it is likely to be the mode chosen by most drivers.

The recorded auditory messages were based on the actual messages that the system provides when in 'Maximum Voice Prompt' mode. The 'real' messages are designed to adapt to each manoeuvre depending on internal system algorithms. They were therefore not standard with regard to the distance at which they were given prior to a manoeuvre. For empirical rigour it was necessary for the recorded messages to be given at set distances for all target manoeuvres. The set distances followed the rules shown in Table 2 and were close to that experienced when using the 'real' system.

Auditory message	Rules for determining distance at which message was given	Rules for omitting this message
Preview 1	Given at 500yds or as soon as display changed after previous manoeuvre (i.e. if less than 500yds)	If distance between previous and next manoeuvre was less than 300yds (i.e. there was only time for Preview 2)
Preview 2	Given at 200yds or as soon as display changed after previous manoeuvre (i.e. if less than 200yds)	Never omitted
Final	Given at 50yds (beep)	Never omitted

Table 2. Rules for the presentation of auditory navigation messages

3.4 Participants

Participants were recruited from the general public via web notice boards, local newspaper advertisements and posters. They were made aware that they would be using and commenting on a navigation system over an extended route. However, they were not provided with details on the nature of the study and no mention of landmarks was made.

The basic criteria for the subjects were:

- Over 21 years of age
- Clean driving licence
- No knowledge of the route used within the trial

Participants were then selected to ensure a match across landmark categories for each of the following four variables. This was based on a factorial design (giving 16 possible combinations of the four variables):

- Gender (male, female)
- Age (21-40, 55 plus)
- Self-reported navigation ability (below average, above average)
- Self-reported distance judgement ability (below average, above average)

3.5 Experimental route & target manoeuvres

The route was chosen on the basis of ten target manoeuvres, other manoeuvres were incidental (i.e. only existed to link together the target manoeuvres into a continuous circuit). The 10 target manoeuvres were chosen to meet the criteria identified in Table 3 and it was these that would enable comparison across landmark categories. The location of the experimental route was an area in the south of Leicester, England, a city with a population of 320,000. The area did not include the city centre and was chosen because it was likely to be unfamiliar to the planned participant pool.

Criteria
Left or right turn off main route
Other potential turns nearby
Possessed both a good and poor landmark that could be used to identify the turn
Ideally, at least a 500yd approach to allow for 3 auditory messages (see Table 2)

Table 3. Criteria for choice of target manoeuvres

Details of the 10 target manoeuvres are provided in Appendix 2.

To force the navigation system to link all ten target manoeuvres together as required, it was necessary to programme the route by using the Waypoints function on the navigation system. This meant that, when close to a Waypoint, the visual display showed that the 'destination' was approaching (indicated by a red and white 'target' symbol. It was then necessary to select the next waypoint using the remote control and calculate the next part of the route. This meant leaving the map view for approximately 5 seconds and using two menu screens. There was no alternative to this, except to have many stops on the route. Therefore the Waypoint method was used and this was explained to the participants as part of the experimental protocol. The location of each waypoint along the route is indicated in the checklist in Appendix 6.

An overview of the route is shown in Appendix 3.

3.6 Independent variables

3.6.1 Landmark condition

For the ten target manoeuvres, each subject consistently experienced one of three landmark conditions: good landmarks, poor landmarks or no landmarks. Full details are provided in Table 1.

3.6.2 Landmark value

This was calculated for each of the 20 landmarks (10 Good, 10 Poor). The possible range of values is 0 – 100. The landmarks available within the area used limited the range of values that could be achieved for the study. Nevertheless, the range achieved was acceptable (and sufficient for later statistical analysis): 21 – 86 (mean 53.75). Values for each landmark are provided in.

3.6.3 Participant variables

Variable	Categories
Age	Young (21-40) Old (55+)
Gender	Male Female

Table 4. Independent variables - participant

3.7 Dependent variables

The subjective and objective data recorded was chosen on the basis of:

- Industry interviews carried out early in the research that identified which measures would convince industry of the benefits of landmarks
- Measures that would enable comparison with other similar studies

The variables covered four key constructs, described below along with the metrics measured

3.7.1 Driving safety

Code	Variable	Period of measurement	Measurement method & metrics
3.7.1.1 Visual Behaviour			
NOG	Number of glances to the navigation display	From Preview 1 to the point at which car crosses manoeuvre point	Video camera for frame counts (25 frames per second)
AVEGD	Average glance duration		
PCMT	Percentage of moving time looking at navigation display		

Code	Variable	Period of measurement	Measurement method & metrics
3.7.1.2 Driving Errors (see Appendix 4 for driving instructor's score sheet)			
DROBS	Driving error: Observation (Type 9 - Use of mirrors and rear observation when signalling, changing direction/speed)	From Preview 1 to the point at which car crosses manoeuvre point	Assessment by driving instructor at each manoeuvre. Errors coded according to: Minor error = 1 Serious error = 5 Dangerous error = 10
DRIND	Driving error: indicators (Type 10 - Give appropriate signals)		
DRINT	Driving error: interaction (Type 11 - Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users)		
DRJUN	Driving error: junctions (Type 15 - Junctions, aspects include speed of approach, observation, turning right or left and cutting corners)		
DRPOS	Driving error: positioning (Type 17 - Positioning in normal driving and lane discipline)		
DRPLN	Driving error: planning (Type 21 - Awareness and planning)		
DRTOT	Total driving errors, of all types (calculated sum post-hoc)		
3.7.1.3 Driver Workload (see Appendix 5 for participant rating sheet)			
DWMD	Driver workload: mental demand	Immediately post-trial (i.e. after Manoeuvre 37)	Subjective ratings on NASA-RTLX 6 item workload rating scale
DWME	Driver workload: mental effort		
DWPD	Driver workload: physical demand		
DWTP	Driver workload: time pressure		
DWDI	Driver workload: distraction		
DWSL	Driver workload: stress level		
DWTOT	Driver workload: overall		

Table 5. Dependent variables – driving safety

3.7.2 *Driver confidence*

See Appendix 6 for experimenter score sheet

Code	Variable	Period of measurement	Measurement method & metrics
CF1	Confidence rating for Preview 1	Immediately after Preview 1 voice message	Driver statement of high, medium or low confidence immediately after each auditory navigation message: 1 = Low confidence 2 = Medium confidence 3 = High confidence
CF2	Confidence rating for Preview 2	Immediately after Preview 2 voice message	
CF3	Confidence rating for Final	Immediately after Final 'beep'	
CF4	Confidence rating After Manoeuvre	Immediately after manoeuvre is completed	
CFAV3	Average confidence rating for all voice messages on approach to manoeuvre	Calculated from CF1, CF2, CF3 or (where no Preview 1 message) from CF2, CF3	
CFAV4	Average confidence rating for complete manoeuvre	Calculated from CF1, CF2, CF3, CF4 or (where no Preview 1 message) From CF2, CF3, CF4	

Table 6. Dependent variables – driver confidence

3.7.3 *Navigation Errors*

See Appendix 6 for experimenter score sheet

Code	Variable	Period of measurement	Measurement method & metrics
NAVER	Number of navigation errors of all types	Once for each manoeuvre	Tick box 0 = no error 1 = error
NAVTY	Number of navigation errors of each type		Tick box 0 = no error 1 = turned too soon 2 = turned too late 3 = no turn

Table 7. Dependent variables - navigation errors

3.7.4 *Driver attitudes and self-assessment of performance*

See Appendix 7 for driver attitude questionnaires

Variable	Period of measurement	Measurement method & metrics
Initial perceptions of navigation system (having been given a verbal description of it's functionality)	Pre-trial	Questionnaire with 7-point Likert scale
Limited exposure attitudes to navigation system (after limited use)	After Manoeuvre 4	
Final attitudes to navigation system (after prolonged use)	Immediately post-trial (i.e. after Manoeuvre 37)	

Table 8. Dependent variables – driver attitudes

3.8 Experimental protocol

The whole trial took approximately two and a half hours and followed the stages outlined in Table 9 below. Related Appendices are stated in parentheses.

Trial stage	Description	Time (min.)
Participant introduction	Explain trial stages Safety considerations Consent form (**Error! Not a valid result for table.**) Demographics questionnaire (Appendix 9) Initial perceptions questionnaire (Appendix 7)	20
Vehicle familiarisation	Explain relevant vehicle controls (vehicle used was Landrover Freelander) Participant drives 15 miles to start point	25
System familiarisation and distance judgment	Carry out distance judgement task Explain system visual and voice information Explain confidence ratings and waypoints Practice confidence ratings and waypoints	25
Full trial	Participant drives route, follows navigation system and gives confidence ratings After Manoeuvre 4, stop and complete Limited Exposure questionnaire (Appendix 7) Stop after Manoeuvre 37	50
Post-trial	Complete NASA RTLX (Appendix 5) and Final Attitudes questionnaire (Appendix 7) Participant or experimenter drives back to start	30

Table 9. Experimental protocol

4 PREDICTED FINDINGS

Based on previous studies in the literature, 4 findings were predicted:

1. Good landmarks will result in better* driver performance than Poor landmarks, which will, in turn be better than No landmarks
2. An increase in landmark value will lead to better* driver performance
3. There will be no effects of age on driver performance
4. There will be no effects of gender on driver performance

* 'Better driver performance' is defined as:

- Looking at the navigation display less often
- Looking at the navigation display for less time
- Increased driver confidence
- Less driving errors
- Less navigation errors
- Lower driver workload
- Positive driver attitudes to the system

5 RESULTS – DEMOGRAPHIC SUMMARY

	Landmark category			Gender		Age		Self-rated navigational ability		Self-rated distance judgement ability	
	Good	Poor	None	Male	Female	Young	Old	Below average	Above average	Below average	Above average
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age	46.8 (16.4)	42.3 (17.0)	44.3 (17.0)	45.7 (15.9)	43.2 (17.4)	29.0 (6.5)	59.9 (4.5)	44.5 (16.2)	44.3 (17.2)	44.6 (16.3)	44.3 (17.2)
Miles driven in last year (000's)	8.2 (3.7)	14.6 (16.1)	12.8 (9.0)	15.4 (14.0)	8.4 (4.9)	12.4 (13.0)	11.4 (8.7)	10.3 (6.7)	13.4 (14.0)	12.9 (13.5)	10.9 (7.9)
No. of unfamiliar journeys per month	3.8 (4.6)	2.9 (2.7)	2.6 (1.9)	2.3 (1.7)	3.9 (4.2)	3.6 (3.9)	2.6 (2.4)	3.0 (2.7)	3.2 (3.8)	3.9 (4.1)	2.3 (1.8)
Self-rated navigational ability (1-5)	3.3 (1.0)	3.4 (.9)	3.4 (1.0)	3.4 (1.0)	3.4 (.9)	3.3 (1.1)	3.5 (.8)	2.9 (.7)	3.9 (.9)	3.5 (.8)	3.3 (1.1)
Preferred navigation method (1-5)	2.9 (1.0)	2.3 (1.0)	2.9 (.9)	2.6 (.9)	2.8 (1.0)	2.8 (1.1)	2.6 (.9)	3.0 (.9)	2.4 (1.0)	2.8 (1.0)	2.6 (1.0)
Self-rated distance judgment (1-5)	3.1 (.6)	3.2 (.8)	3.1 (.9)	3.3 (.7)	3.0 (.8)	3.2 (.9)	3.1 (.6)	3.2 (.7)	3.1 (.8)	2.7 (.6)	3.6 (.5)
Self-rated confidence with IT (1-5)	3.3 (.7)	3.3 (.9)	3.1 (1.0)	3.4 (1.0)	3.1 (.7)	3.5 (.8)	3.0 (.8)	3.3 (1.0)	3.2 (.7)	3.1 (.8)	3.4 (.9)

Table 10. Summary of participant demographics (see Appendix 9 for rating scales)

6 RESULTS – VISUAL BEHAVIOUR

6.1 Data coding

The period of analysis for each manoeuvre was from the start time to stop time, defined as follows:

Start time the point at which the navigation system display changed to the detailed junction layout (see Figure 2) and the verbal message began

Stop time the point at which the test vehicle crossed the manoeuvre (usually identified by the dotted line across a junction entry point)

The analysis split the glances into those carried out whilst moving and those whilst stationary, defined as follows:

Moving free flowing traffic

Stationary zero speed or very slow in traffic queue

Only the glances made whilst moving were analysed as the visual behaviour measures aimed to identify safety effects (these are negligible whilst stationary).

The dependent variable **number of glances** was defined for each manoeuvre as the number of times that the participant looked towards the navigation system for that manoeuvre, between the start and stop times as defined above.

The dependent variable **average glance duration** was defined for each manoeuvre as the average duration of all moving glances towards the navigation system for that manoeuvre.

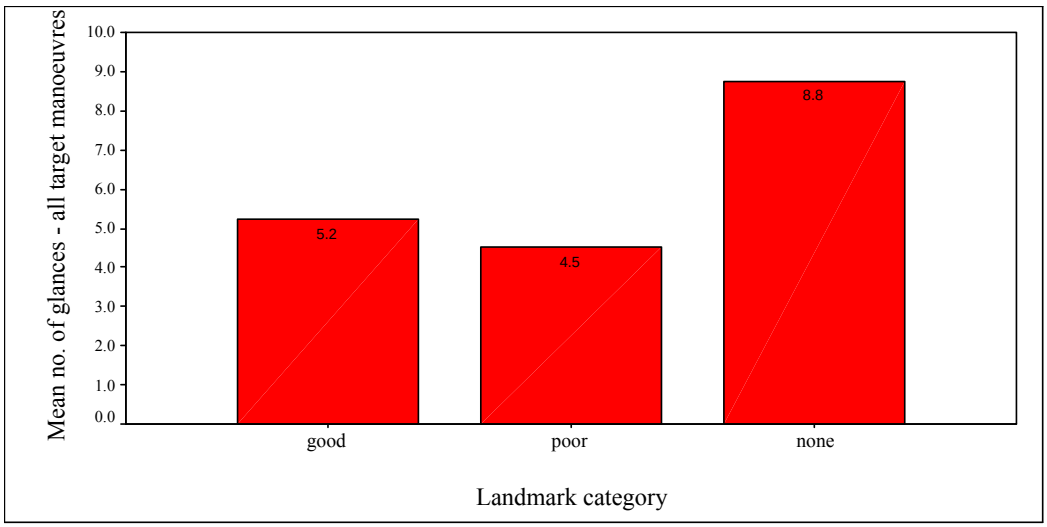
The dependent variable **percentage moving time** was calculated for each manoeuvre as the total time spent glancing towards the display as a percentage of the total moving time for that manoeuvre between the start and stop times, as defined above.

Data was coded as missing data for 2 manoeuvres for a particular subject, as the navigation system had operated unreliably at these.

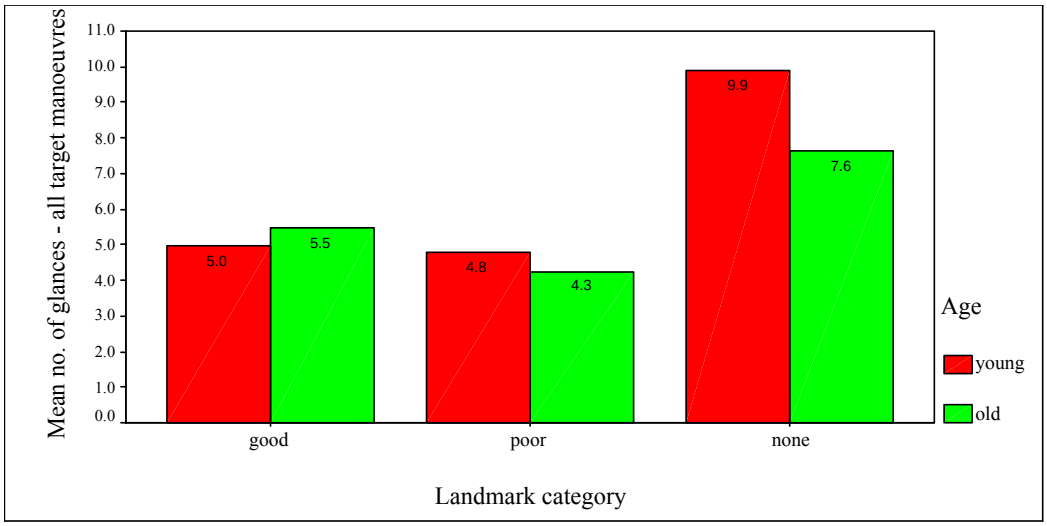
No other data was removed, although missing data also appeared in the 'average glance duration' category, where a participant had made no glances.

6.2 Number of glances to the navigation display and average glance duration

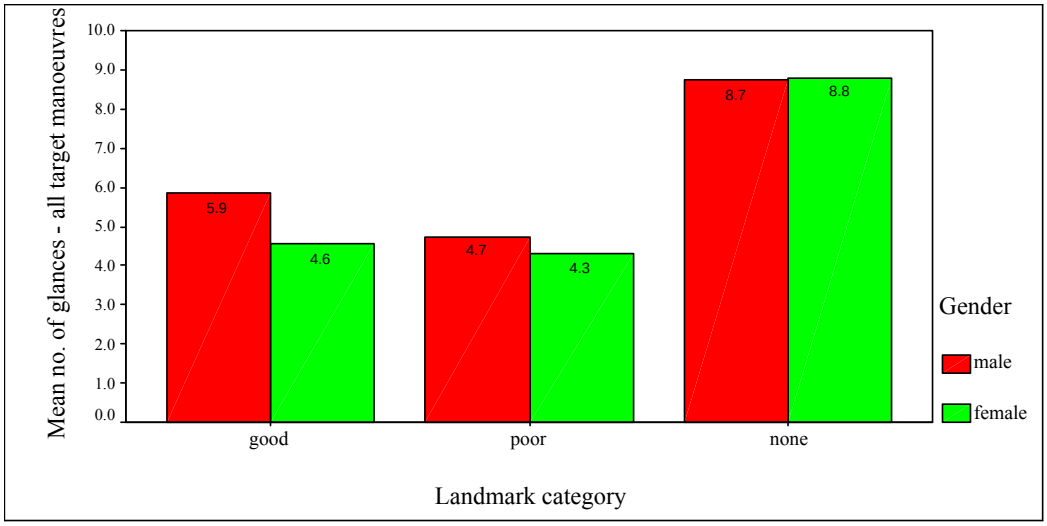
6.2.1 Overall effects – number of glances



Graph 1. Mean number of glances by landmark condition

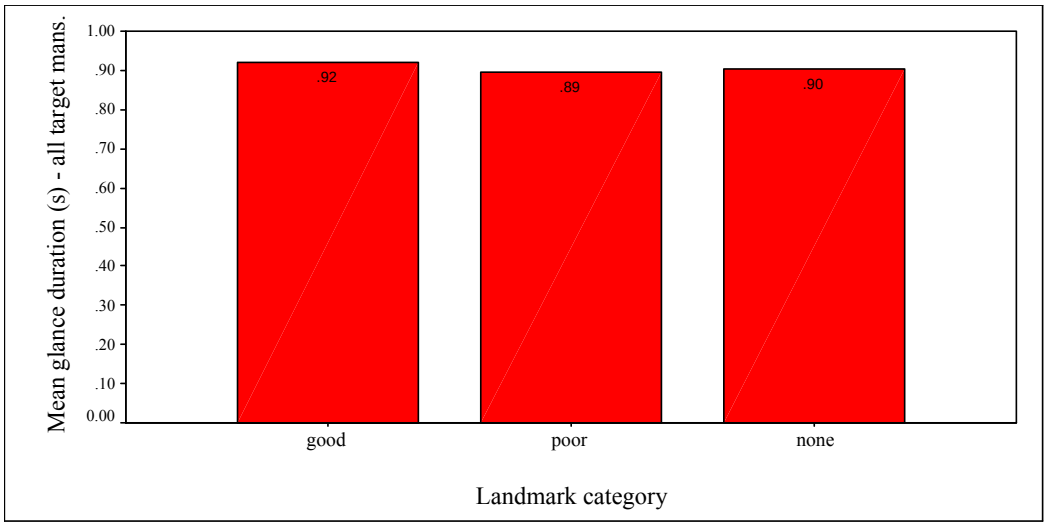


Graph 2. Mean number of glances by landmark condition, split by age

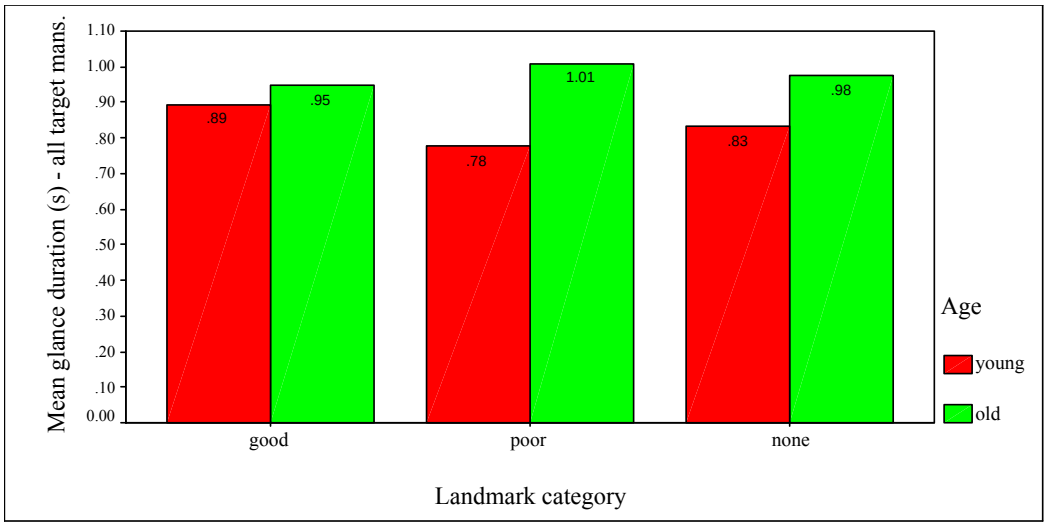


Graph 3. Mean number of glances by landmark condition, split by gender

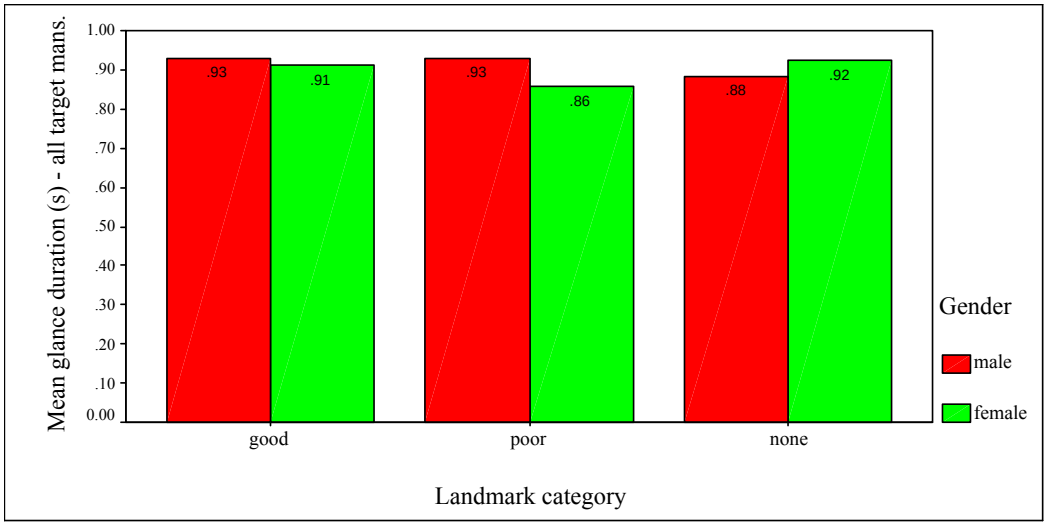
6.2.2 *Overall effects – average glance duration*



Graph 4. Mean glance durations by landmark condition



Graph 5. Mean glance durations by landmark condition, split by age

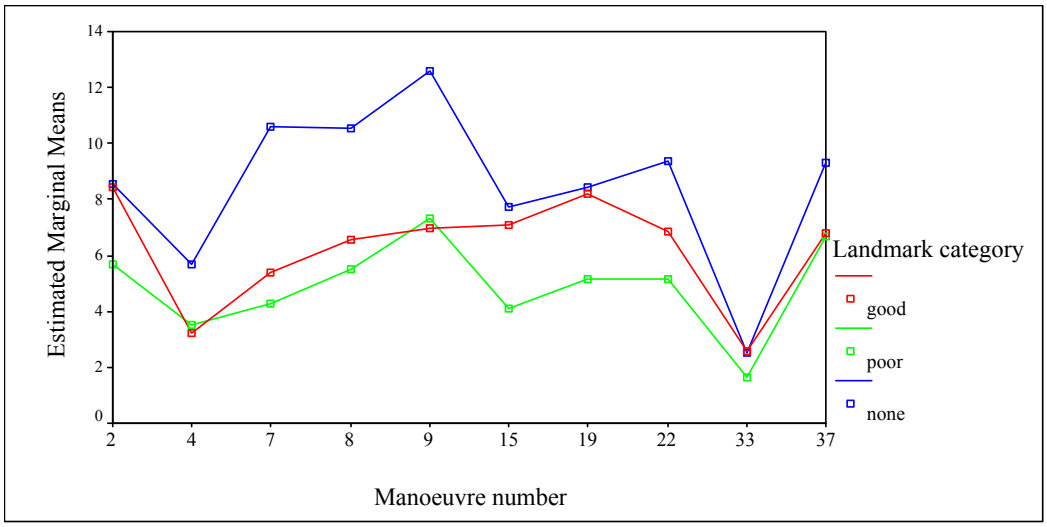


Graph 6. Mean glance durations by landmark condition, split by gender

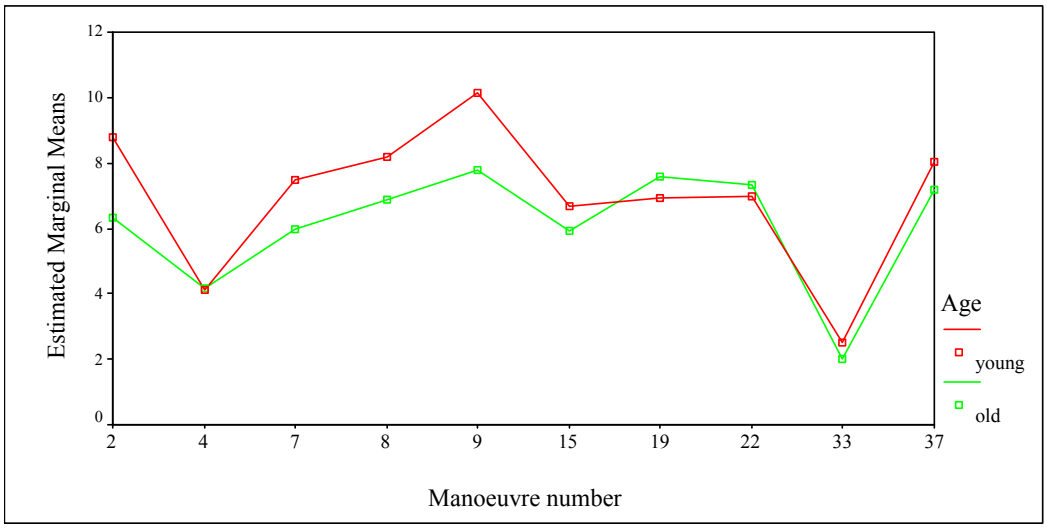
6.2.3 Analysis

A 3*2*2*10 (LANDMARKS*GENDER*AGE*MANOEUVRE) mixed MANOVA was conducted on the dependent variables of (1) **number of glances** towards the display, and (2) **average glance duration** towards the display; there was one value of each of these dependent variables for each subject, at each manoeuvre. LANDMARKS, GENDER and AGE were between subject variables, and MANOEUVRE was a within subjects factor. Multivariate and univariate results are reported below.

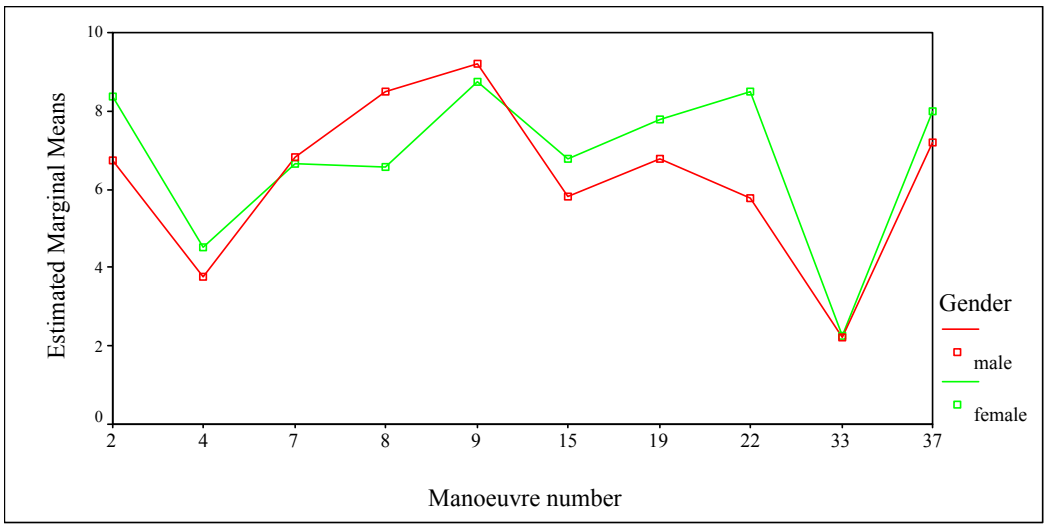
6.2.4 *Graphs showing first order effects for number of glances*



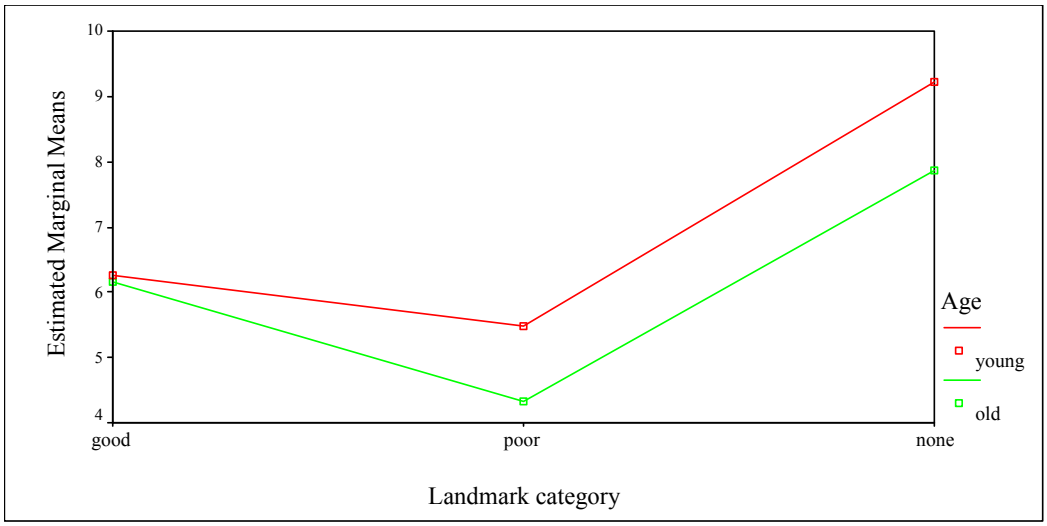
Graph 7. Number of glances by manoeuvre (split by landmark condition) - estimated marginal means



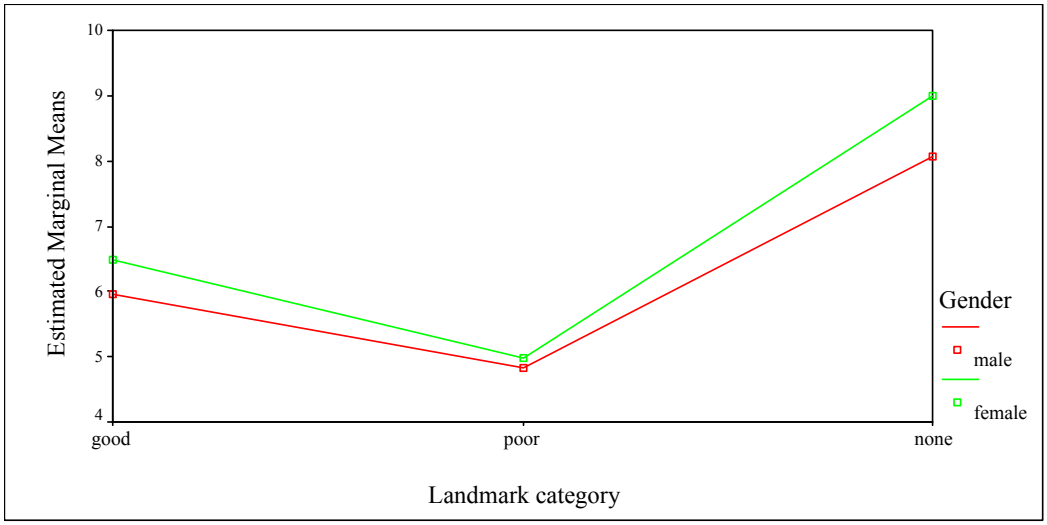
Graph 8. Number of glances by manoeuvre (split by age) - estimated marginal means



Graph 9. Number of glances by manoeuvre (split by gender) - estimated marginal means

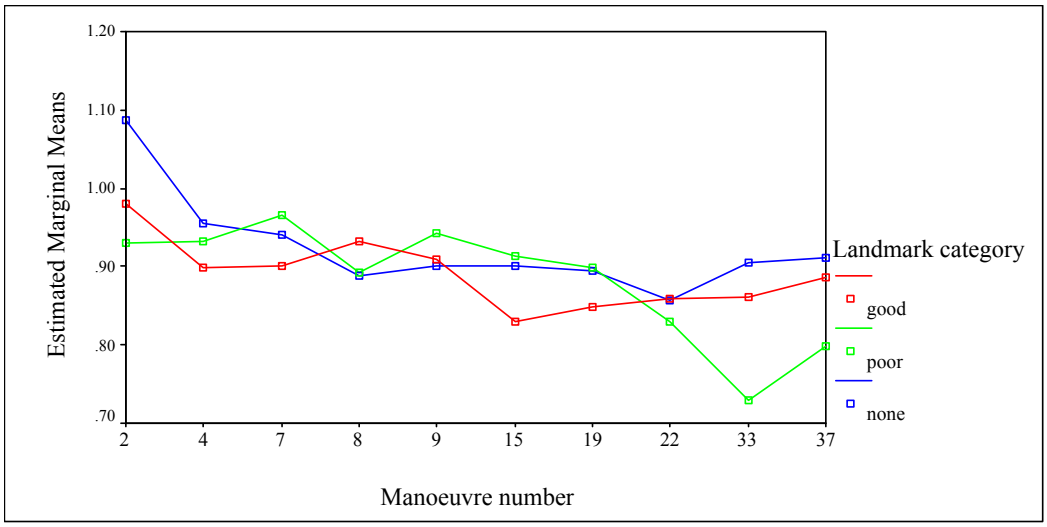


Graph 10. Number of glances by landmark condition (split by age) - estimated marginal means

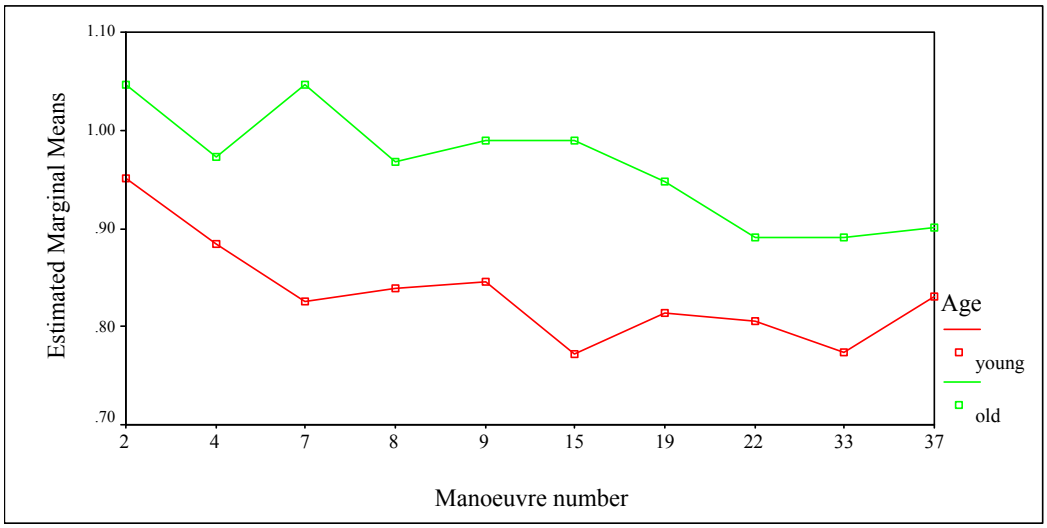


Graph 11. Number of glances by landmark condition (split by gender) - estimated marginal means

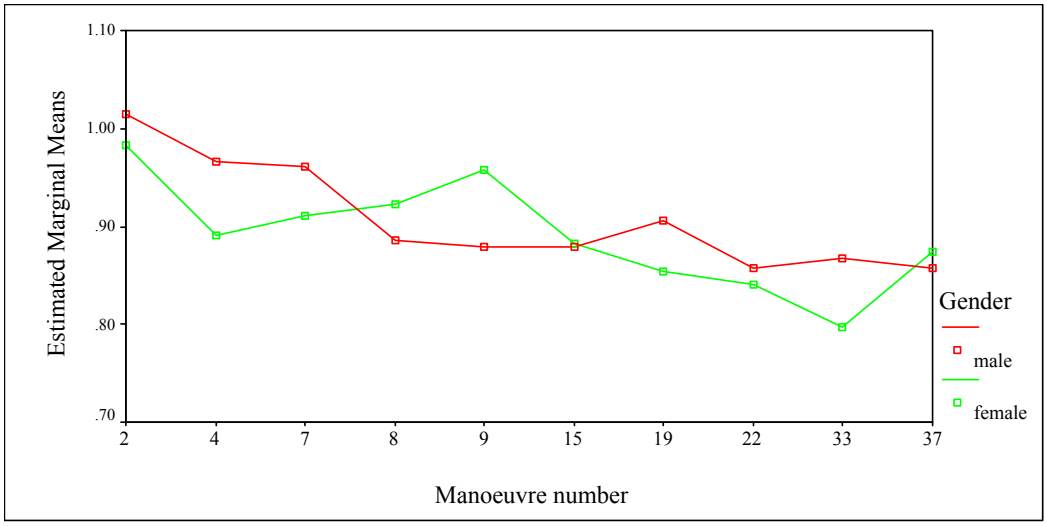
6.2.5 *Graphs showing first order effects for average glance duration*



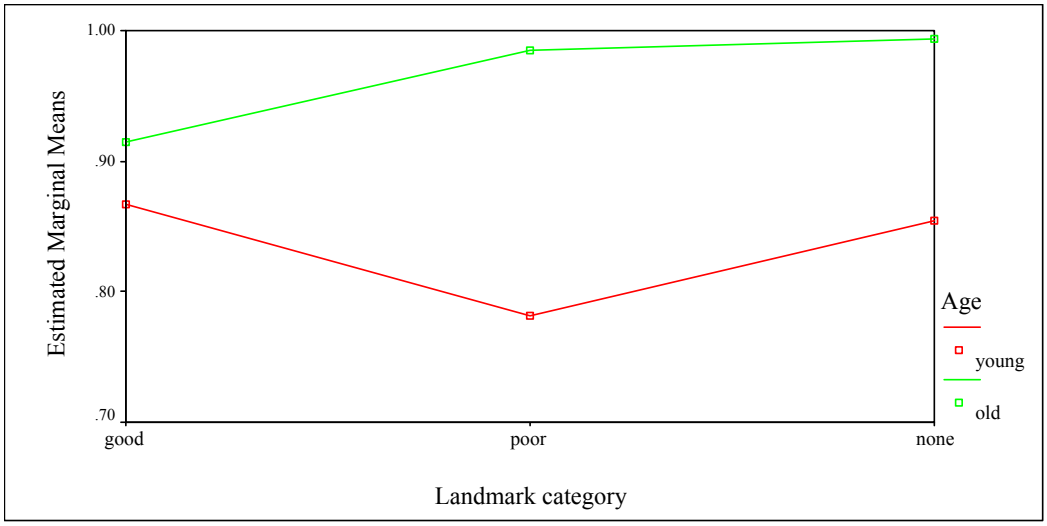
Graph 12. Average glance duration by manoeuvre (split by landmark condition) - estimated marginal means



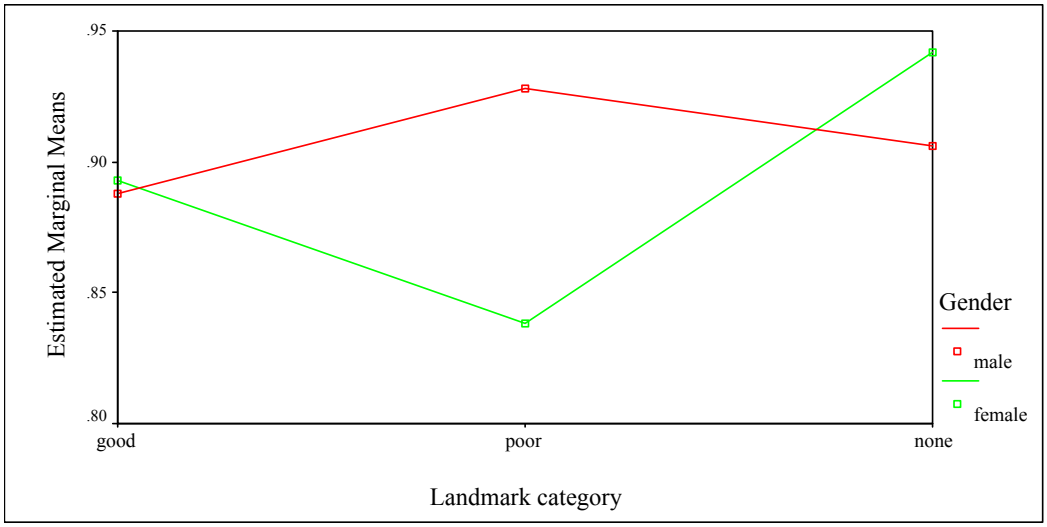
Graph 13. Average glance duration by manoeuvre (split by age) - estimated marginal means



Graph 14. Average glance duration by manoeuvre (split by gender) - estimated marginal means



Graph 15. Average glance duration by landmark condition (split by age) - estimated marginal means



Graph 16. Average glance duration by landmark condition (split by gender) - estimated marginal means

6.2.6 Multivariate statistics (dependent variables)

Multivariate results are based on Wilks' Lambda, with significance reported at $p < 0.05$.

The main between subjects effect of LANDMARKS was significant $F(4,42) = 3.401$, $p = 0.017$

The main between subjects effect of AGE was significant $F(2,21) = 5.516$, $p = 0.012$

The main between subjects effect of GENDER was not significant.

The main within subjects effect of MANOEUVRE was significant $F(18,5) = 22.579$, $p = 0.001$

6.2.7 Univariate statistics (number of glances, average glance duration)

Mauchly's test of sphericity reported a significant chi value for both dependent variables of **number of glances** and **average glance duration**, therefore corrected values using Huynh-Feldt Epsilon are reported.

The main between subjects effect of LANDMARKS was significant for **number of glances** $F(2,22) = 7.232$, $p = 0.004$, but not significant for **average glance duration**.

The main between subjects effect of GENDER was not significant for either **number of glances** or **average glance duration**.

The main between subjects effect of AGE was not significant for **number of glances**, but significant for **average glance duration** $F(1,22) = 11.114$, $p = 0.003$.

There were no significant interactions between the within subjects variables for either **number of glances** or **average glance duration**.

The main within subjects effect of MANOEUVRE was significant for both **number of glances** $F(9,198) = 19.340$, $p < 0.001$, and for **average glance duration** $F(9,198) = 4.134$, $p < 0.001$.

The interaction effect between MANOEUVRE and LANDMARK was significant for **number of glances**, $F(18,198) = 2.703$, $p < 0.001$, but not significant for **average glance duration**.

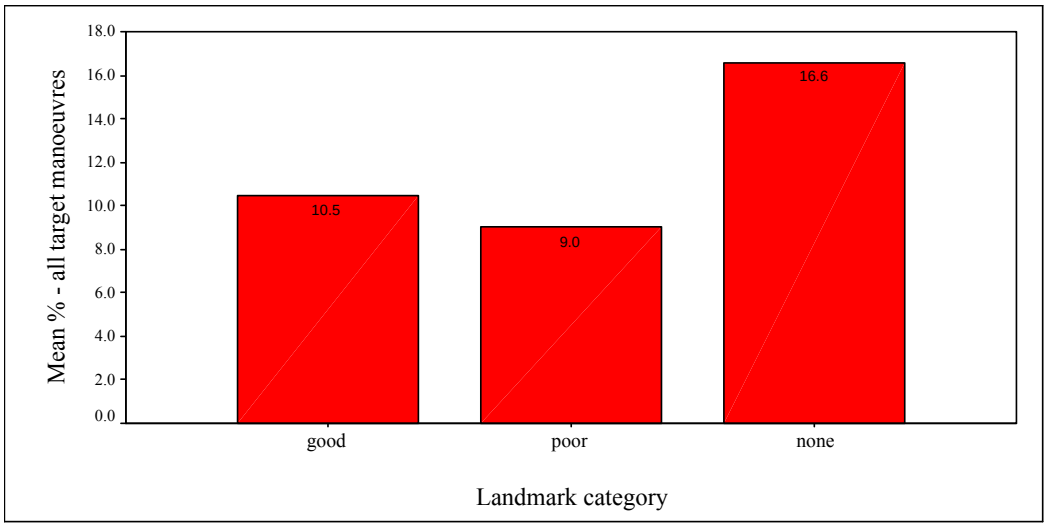
The interaction effect between MANOEUVRE and GENDER was significant for **number of glances**, $F(9,198) = 2.029$, $p = 0.038$, but not significant for **average glance duration**.

The interaction effect between MANOEUVRE and AGE was not significant for **number of glances**, or **average glance duration**.

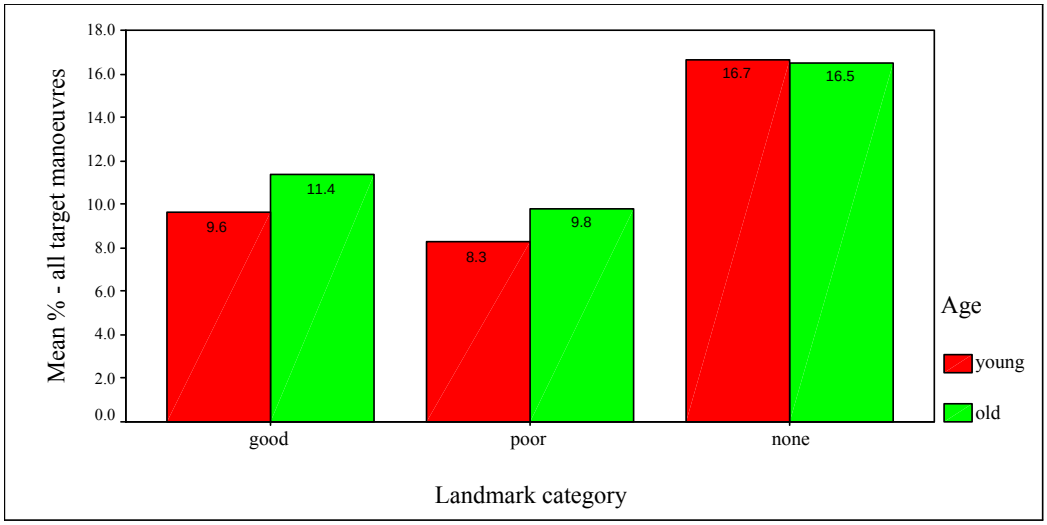
Employing the Bonferroni post-hoc test to the between subjects factor of LANDMARK, significant differences were found for **number of glances** between the no landmark condition and the good landmark condition ($p = 0.04$), and for **number of glances** between the no landmark condition and the poor landmark condition ($p = 0.005$). There was no significant difference for **number of glances** between the good landmark condition and the poor landmark condition. There were no significant differences for **average glance duration** for any of the post-hoc comparisons between the good, poor and no landmark conditions.

6.3 Percentage moving time

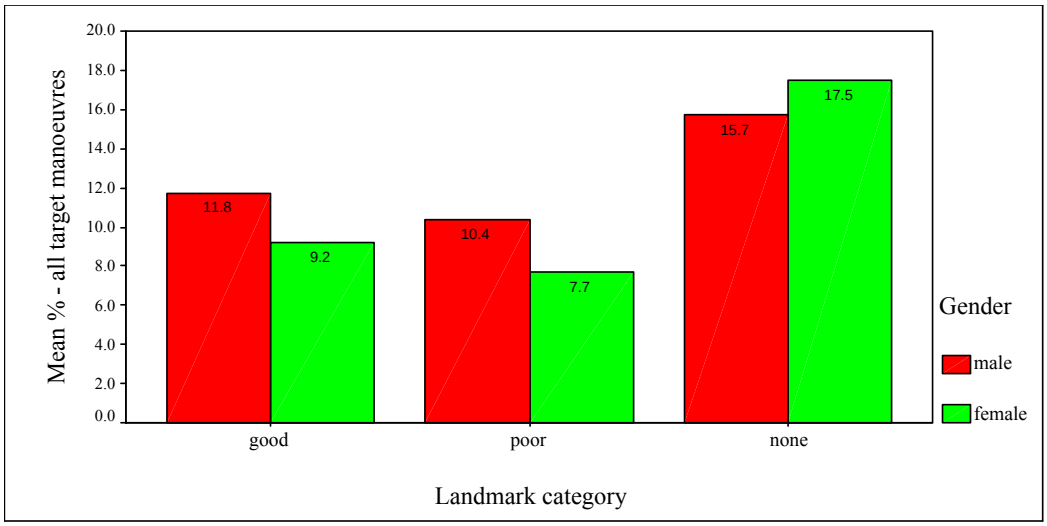
6.3.1 Overall effects



Graph 17. Mean percentage moving time looking at display by landmark condition



Graph 18. Mean percentage moving time looking at display by landmark condition, split by age

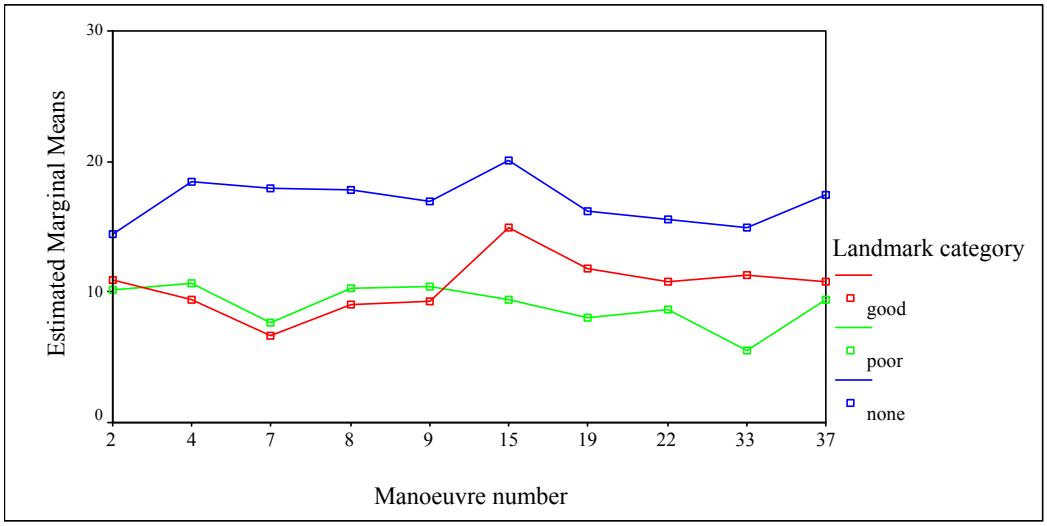


Graph 19. Mean percentage moving time looking at display by landmark condition, split by gender

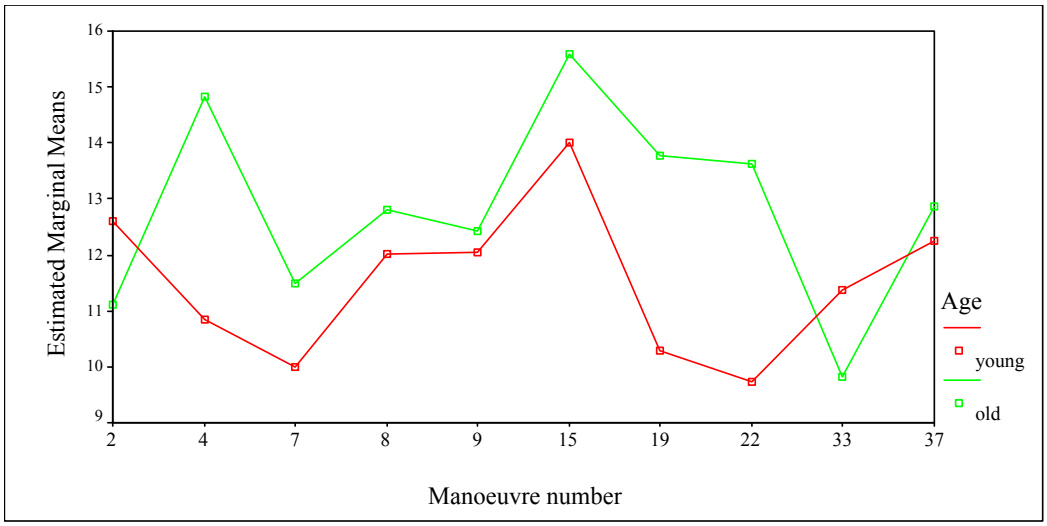
6.3.2 *Analysis*

A 3*2*2*10 (LANDMARKS*GENDER*AGE*MANOUVRE) mixed ANOVA was conducted on **percentage moving time**. This value was calculated at each manoeuvre for each subject by dividing the total time spent glancing to the display by the total time spent approaching the manoeuvre, and then converting this to a percentage. Stationary periods were excluded as described above. There was one value for this measure for each subject, at each manoeuvre. LANDMARKS, GENDER and AGE were between subject variables, and MANOEUVRE was a within subjects factor.

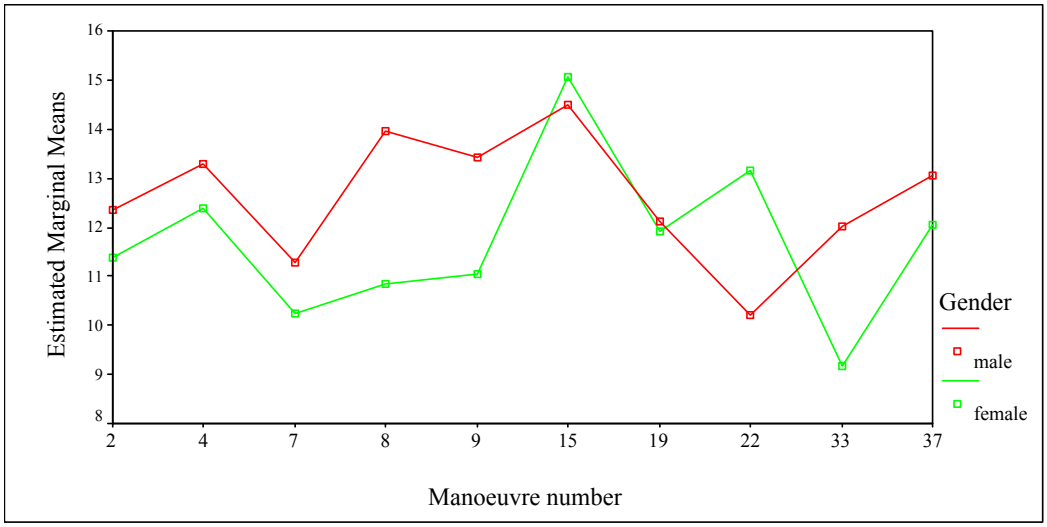
6.3.3 *Graphs showing first order effects for percentage moving time*



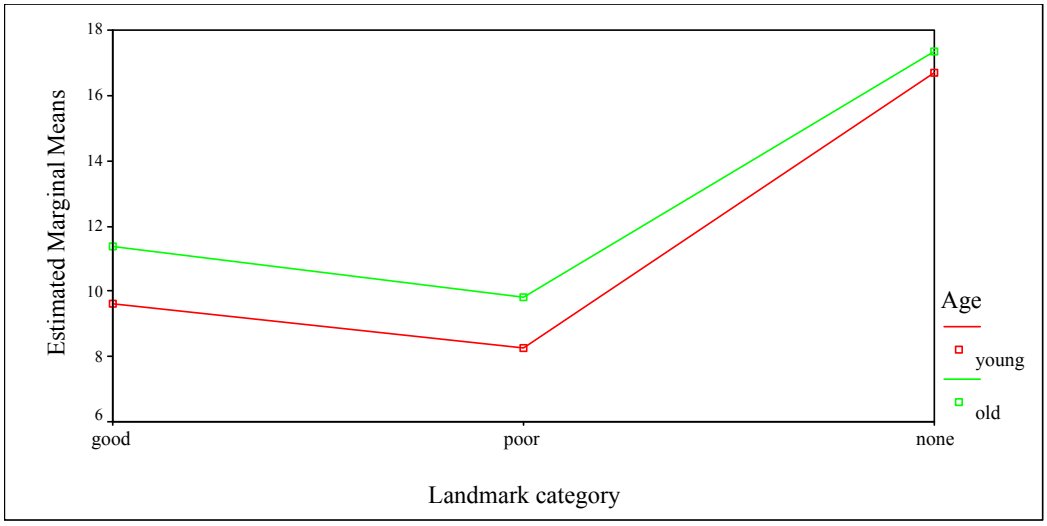
Graph 20. Percentage moving time by manoeuvre (split by landmark condition) - estimated marginal means



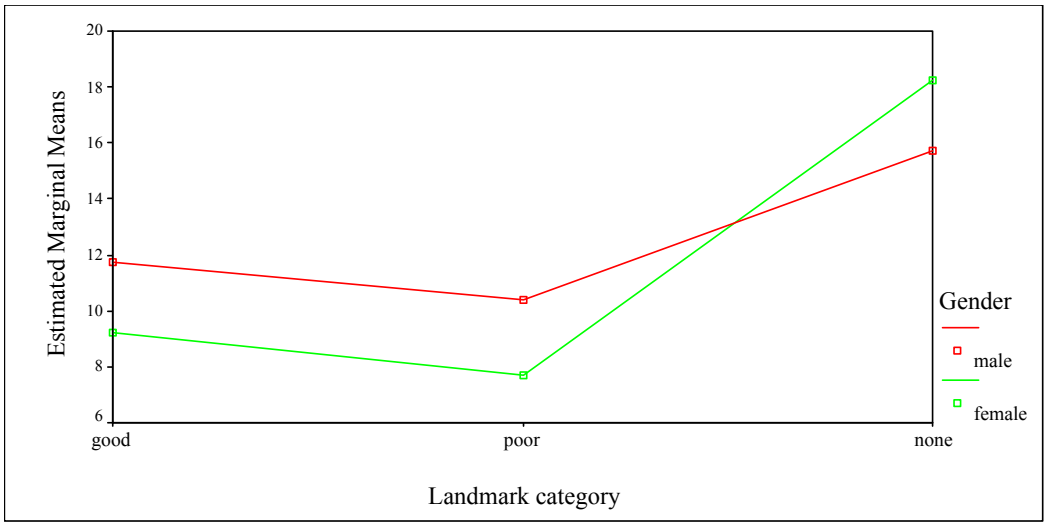
Graph 21. Percentage moving time by manoeuvre (split by age) - estimated marginal means



Graph 22. Percentage moving time by manoeuvre (split by gender) - estimated marginal means



Graph 23. Percentage moving time by landmark condition (split by age) - estimated marginal means



Graph 24. Percentage moving time by landmark condition (split by gender) - estimated marginal means

6.3.4 *Univariate statistics (percentage moving time)*

Mauchly's test of sphericity reported a significant chi value for the dependent variable; therefore corrected values using Huynh-Feldt Epsilon are reported.

The main between subjects effect of LANDMARKS was significant $F(2,189) = 14.468$), $p < 0.001$.

The main between subjects effect of GENDER was not significant.

The main between subjects effect of AGE was not significant.

There were no significant interactions between the within subjects variables.

The main within subjects effect of MANOEUVRE was significant $F(9,315) = 2.582$, $p = 0.007$.

The interaction effect between MANOEUVRE and LANDMARK was significant, $F(18,315) = 1.936$, $p = 0.013$.

The interaction effect between MANOEUVRE and GENDER was not significant.

The interaction effect between MANOEUVRE and AGE was not significant.

Employing the Bonferroni post-hoc test to the between subjects factor of LANDMARK, significant differences were found for percentage moving time between the no landmark condition and the good landmark condition ($p = 0.001$), and between the no landmark condition and the poor landmark condition ($p < 0.000$). There was no significant difference for percentage moving time between the good landmark condition and the poor landmark condition.

7 RESULTS – DRIVER CONFIDENCE

7.1 Definition of variables

The raw questionnaire data consisted of up to four confidence ratings by each participant for each manoeuvre. The first three confidence ratings were either a 'high', 'medium' or 'low' given in response to each verbal message during the approach to a manoeuvre. These dependent variables are termed 'Preview 1', 'Preview 2' and 'Final'. The fourth confidence rating was given by each participant having completed each manoeuvre; this dependent variable is termed 'Post'.

Each confidence rating of 'high', 'medium' or 'low' was coded as 3, 2 or 1 respectively.

Various analyse were undertaken; these are described separately below.

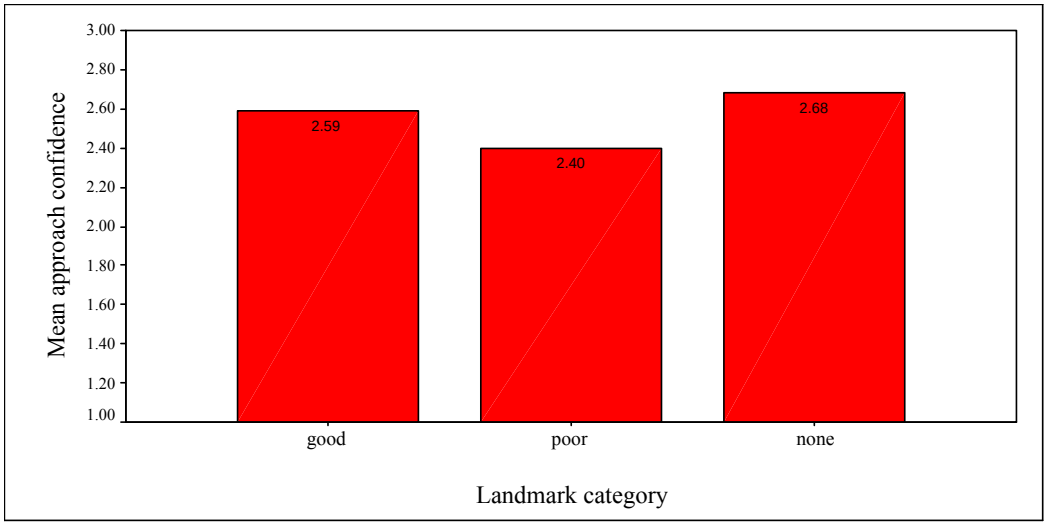
- Overall confidence during approach to manoeuvre
- Overall confidence over complete manoeuvre, including the driver confidence post-manoeuvre
- Average confidence after Preview 1 message
- Average confidence after Preview 2 message
- Average confidence after Final message
- Average confidence after completion of manoeuvre
- Changes in confidence over the approach to the manoeuvre

7.2 Overall confidence during approach to manoeuvre

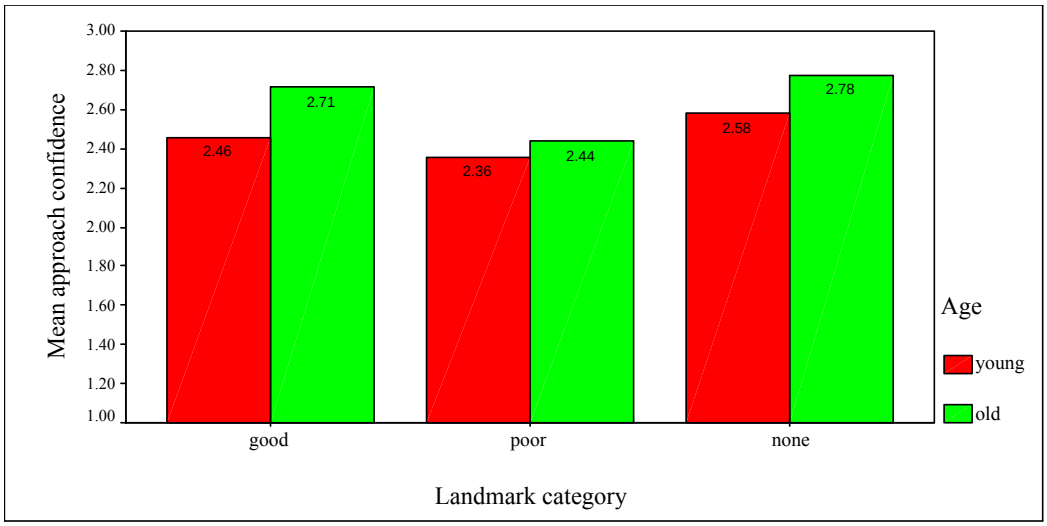
7.2.1 Data coding

For each participant, for each manoeuvre, the mean value of the variable **overall approach confidence** was calculated from the subjective ratings given after the Preview 1, Preview 2 and Final messages. This calculated variable is used to represent the overall level of confidence for each participant for each manoeuvre, over the period where the navigation system is providing guidance for that manoeuvre.

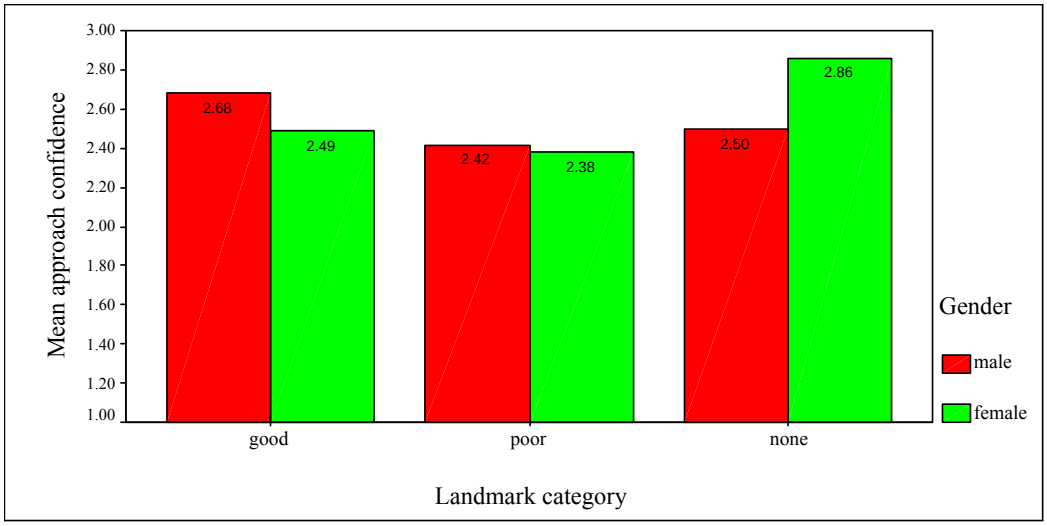
7.2.2 Overall effects



Graph 25. Mean approach confidence by landmark condition

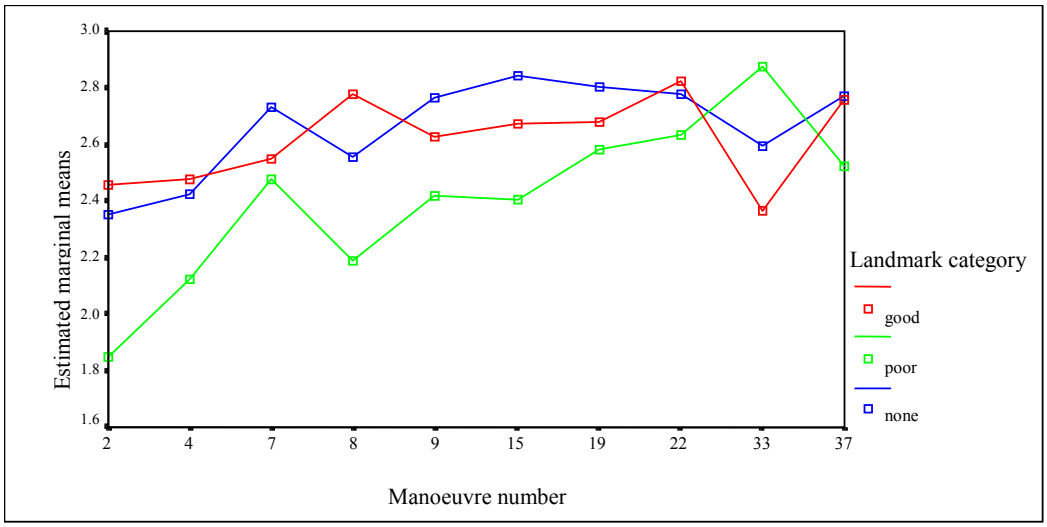


Graph 26. Mean approach confidence by landmark condition, split by age

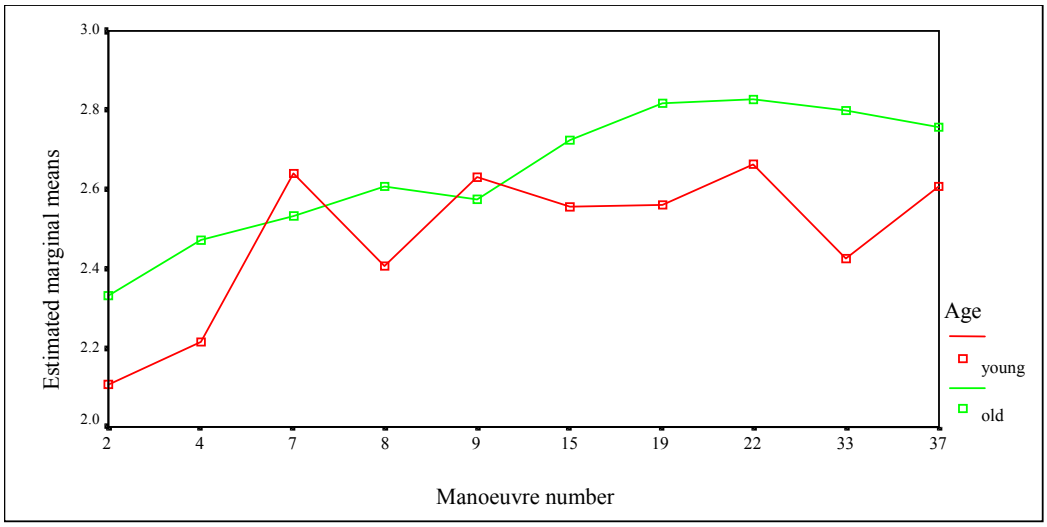


Graph 27. Mean approach confidence by landmark condition, split by gender

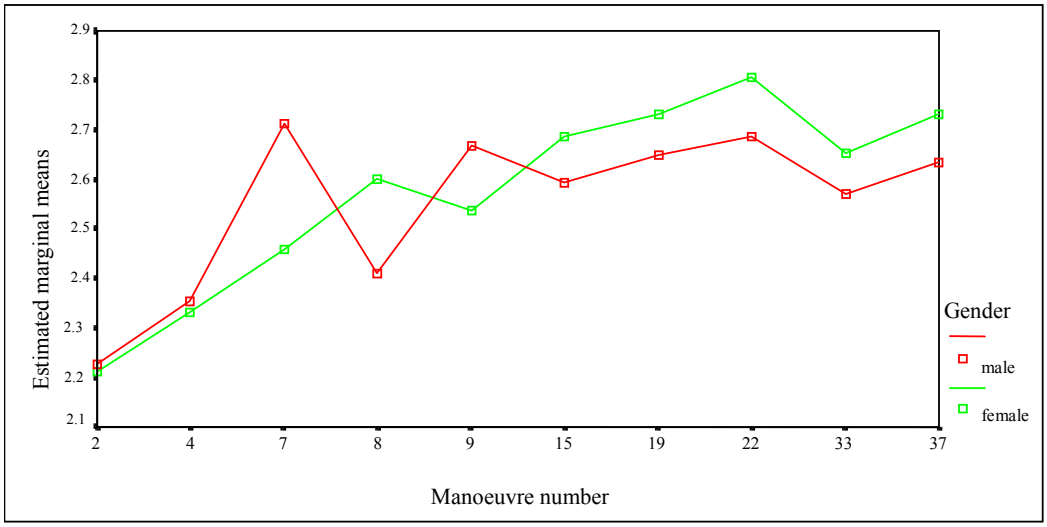
7.2.3 Graphs showing interaction effects for overall approach confidence



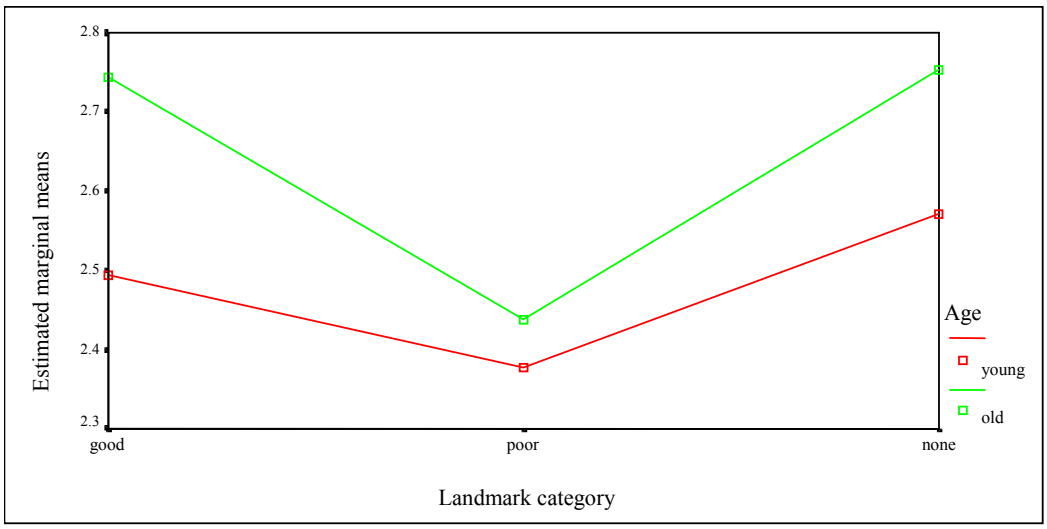
Graph 28. Approach confidence by manoeuvre (split by landmark condition) - estimated marginal means



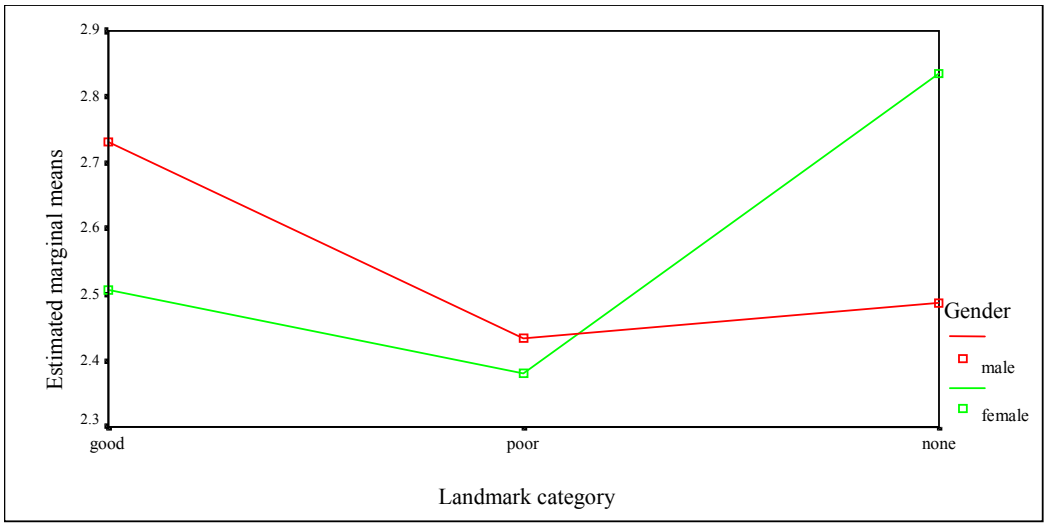
Graph 29. Approach confidence by manoeuvre (split by age) - estimated marginal means



Graph 30. Approach confidence by manoeuvre (split by gender) - estimated marginal means



Graph 31. Approach confidence by landmark condition (split by age) - estimated marginal means



Graph 32. Approach confidence by landmark condition (split by gender) - estimated marginal means

7.2.4 *Univariate results*

Mauchly's test of sphericity reported a significant chi value for the dependent variable **overall approach confidence**, therefore corrected values using Huynh-Feldt Epsilon are reported.

The main between subjects effect of LANDMARK was significant $F(2,29) = 3.624$, $p = 0.039$

The main between subjects effect of AGE was near significance $F(1,29) = 3.654$, $p = .066$).

The main between subjects effect of GENDER was not significant.

The main within subjects effect of MANOEUVRE was significant $F(8.8,255.4) = 7.226$, $p < 0.001$.

The interaction effect between MANOEUVRE and LANDMARK was significant $F(17.6,255.4) = 2.490$, $p = 0.001$

The interaction effect between GENDER and LANDMARK was significant $F(2,29) = 3.847$, $p = 0.033$.

The interaction effect between GENDER and AGE was significant $F(1,29) = 4.617$, $p = 0.04$

All other interaction effects were not significant.

7.2.5 *Multivariate results*

A multivariate analysis was carried out on the variable **overall approach confidence**, in order to identify *particular manoeuvres* where there was a significant effect due to the within subjects variable of LANDMARK.

The main effect of LANDMARK was significant for manoeuvres:

2 significant $F(2,29) = 4.695$, $p = 0.017$, post hoc differences between good and poor, and poor and none

8 significant $F(2,29) = 5.679$, $p = 0.008$, post hoc differences between good and poor only

33 significant $F(2,29) = 4.137$, $p = 0.026$, post hoc differences between good and poor only

7.3 Overall confidence over complete manoeuvre

This measure adds the post-manoeuvre confidence rating to the analysis completed for overall confidence during approach to manoeuvre. The analysis showed very similar results to those in section 7.2 so, for economy of space, the results are not replicated here.

7.4 Average confidence after each message, and post manoeuvre

7.4.1 Definition of variables

Four variables were calculated as follows

Preview 1 confidence

The mean confidence rating for a participant across all manoeuvres after the Preview 1 message

Preview 2 confidence

The mean confidence rating for a participant across all manoeuvres after the Preview 1 message

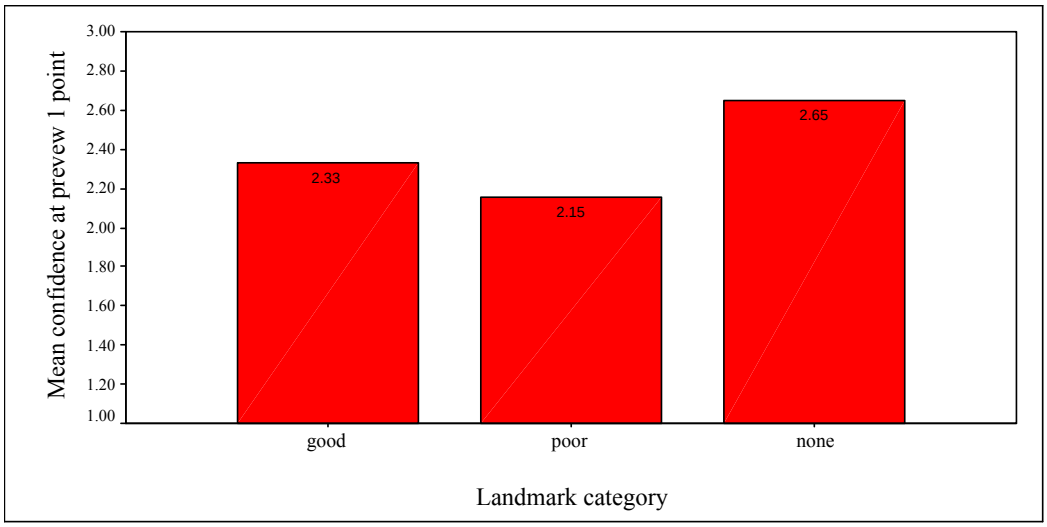
Final confidence

The mean confidence rating for a participant across all manoeuvres after the Preview 1 message

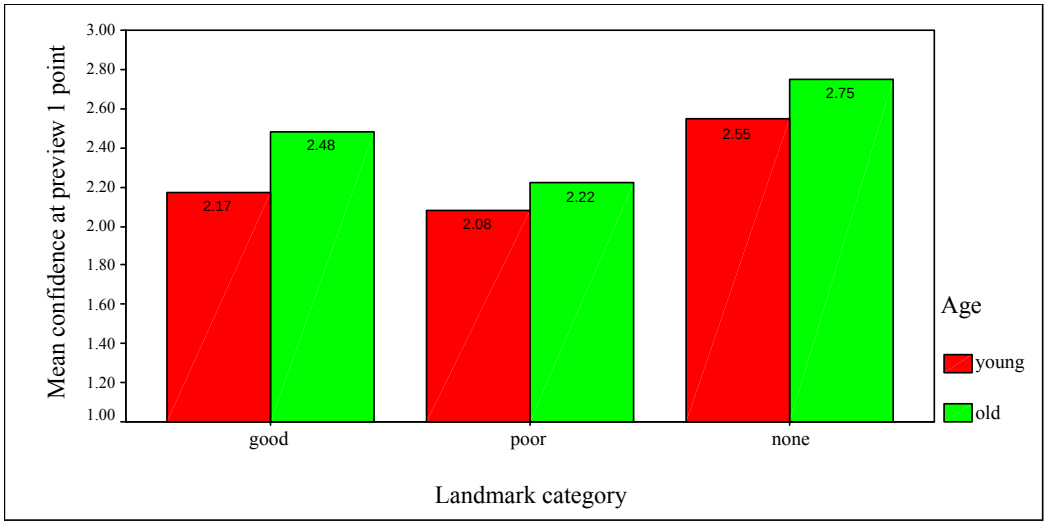
Post confidence

The mean confidence rating for a participant across all manoeuvres after the Preview 1 message

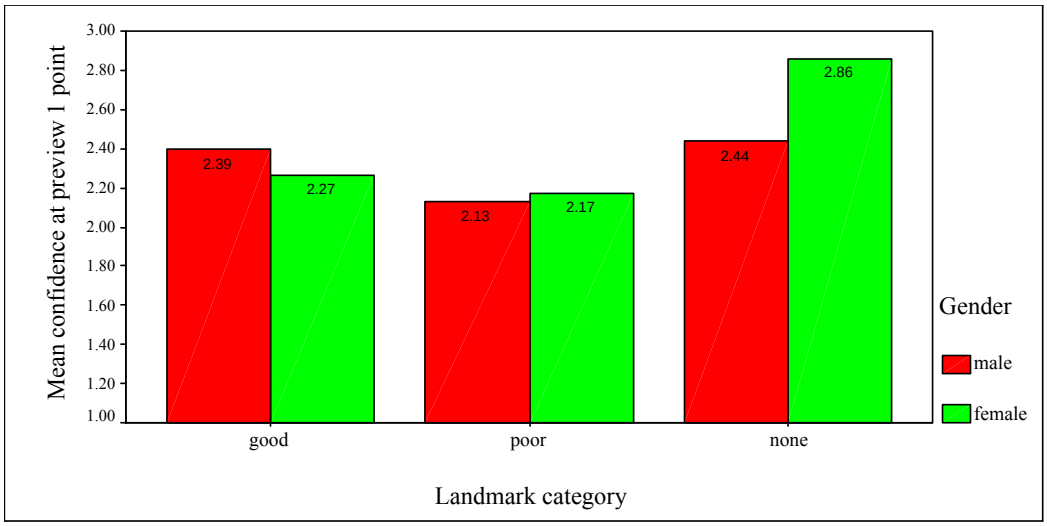
7.4.2 Overall effects – preview 1 confidence



Graph 33. Mean preview 1 point confidence by landmark condition

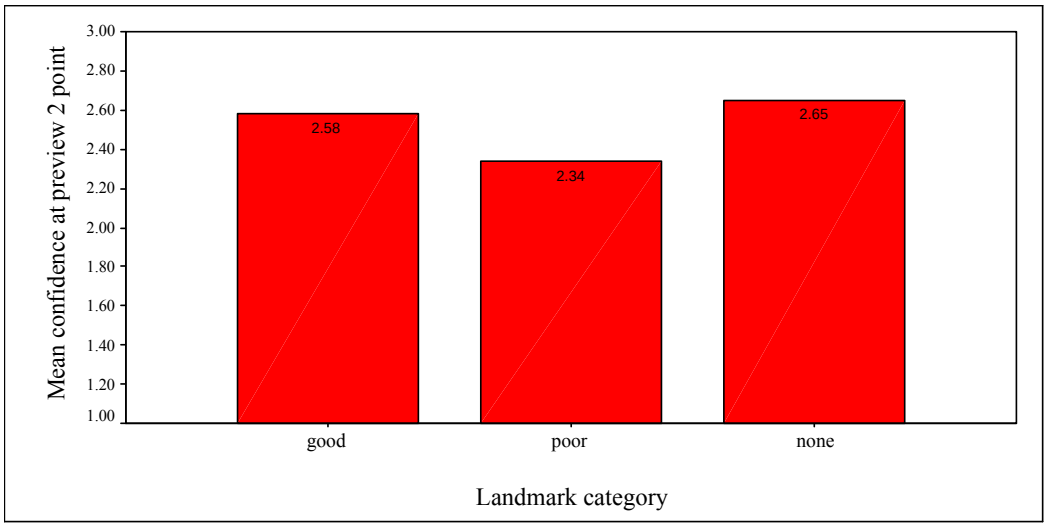


Graph 34. Mean preview 1 point confidence by landmark condition, split by age

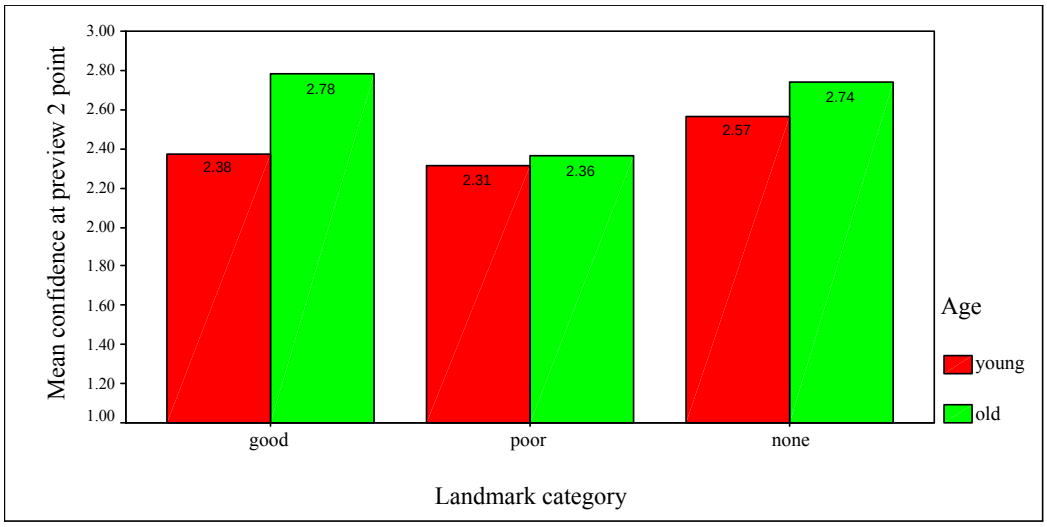


Graph 35. Mean preview 1 point confidence by landmark condition, split by gender

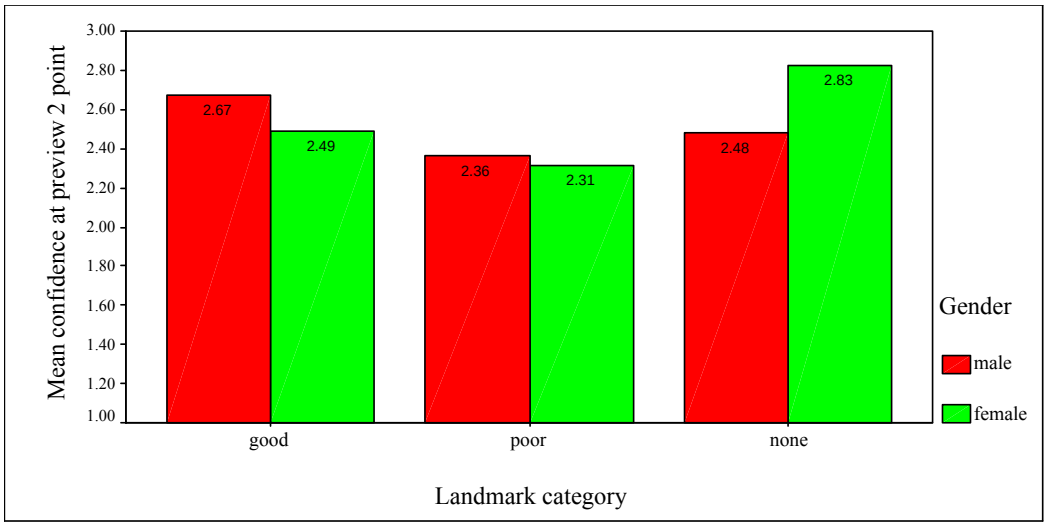
7.4.3 Overall effects – preview 2 confidence



Graph 36. Mean preview 2 point confidence by landmark condition

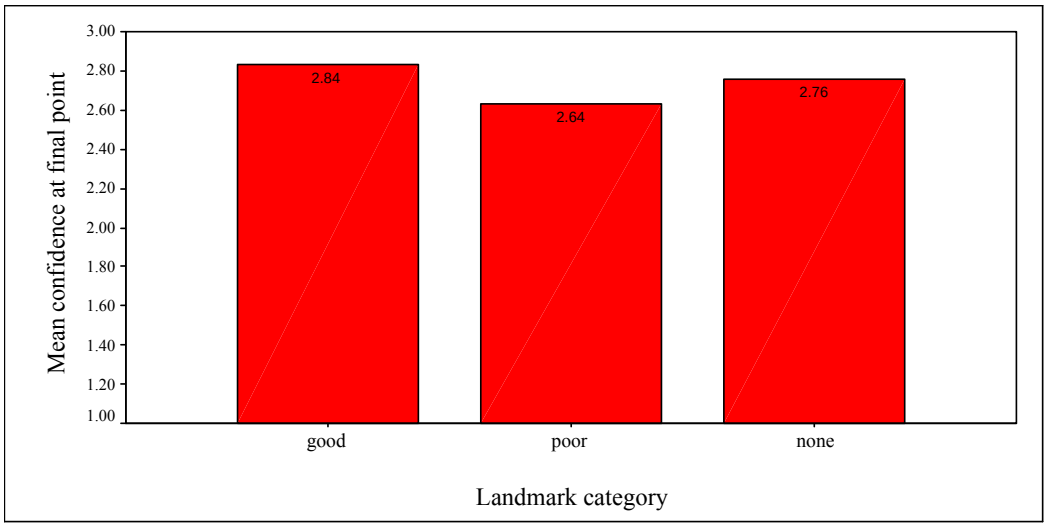


Graph 37. Mean preview 2 point confidence by landmark condition, split by age

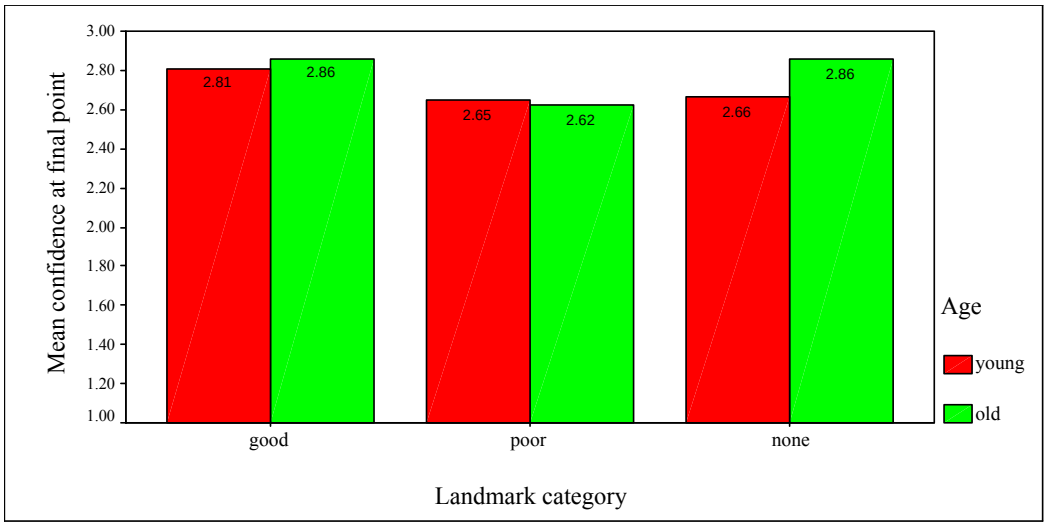


Graph 38. Mean preview 2 point confidence by landmark condition, split by gender

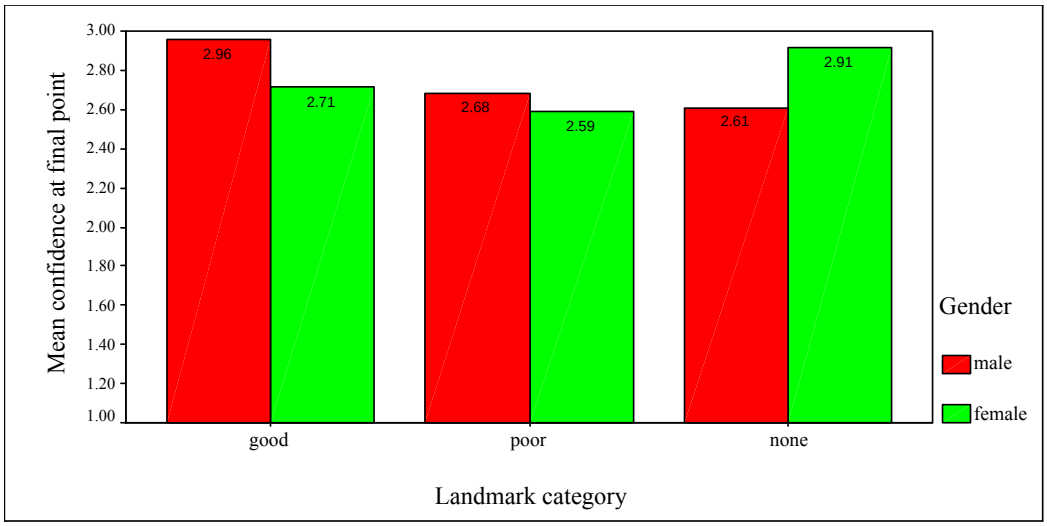
7.4.4 Overall effects – final confidence



Graph 39. Mean final point confidence by landmark condition

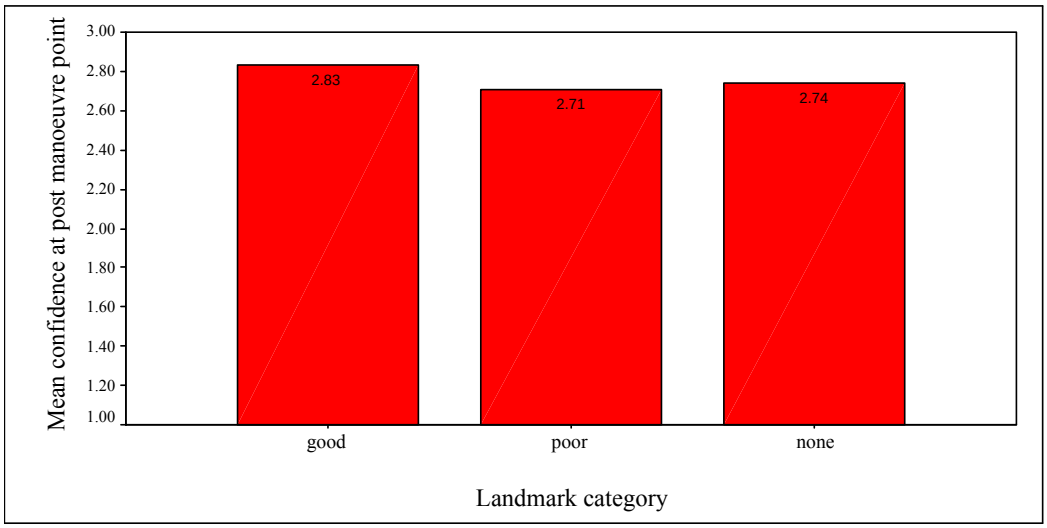


Graph 40. Mean final point confidence by landmark condition, split by age

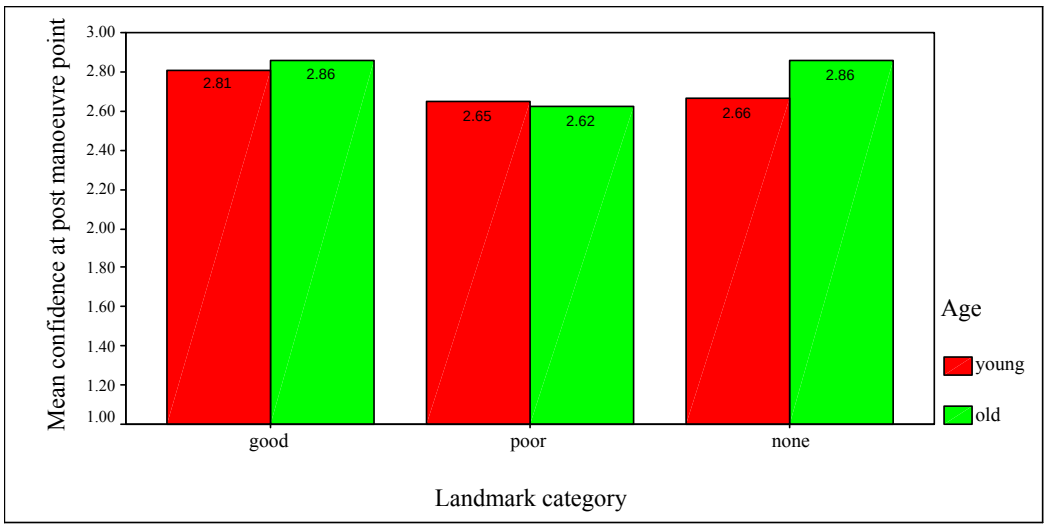


Graph 41. Mean final point confidence by landmark condition, split by gender

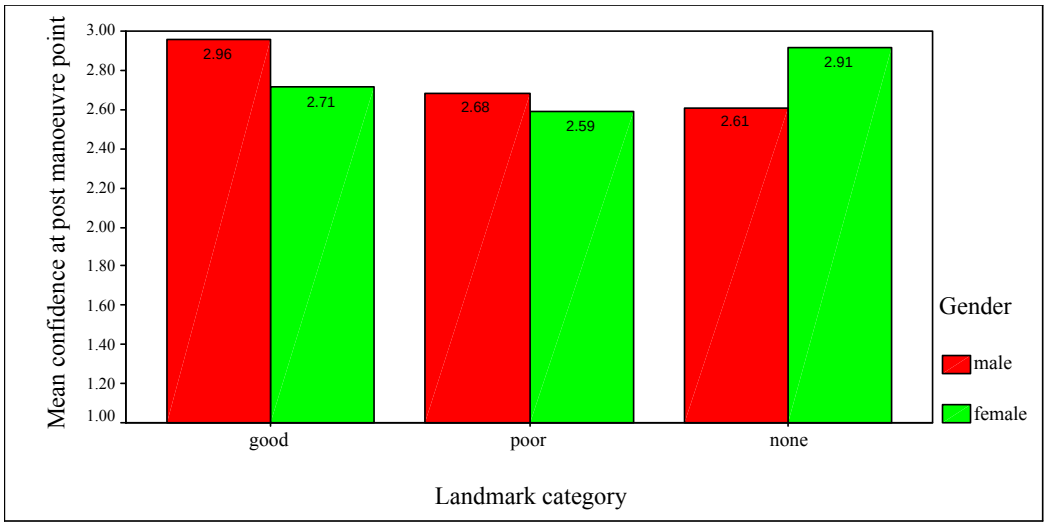
7.4.5 Overall effects – post manoeuvre confidence



Graph 42. Mean post manoeuvre point confidence by landmark condition



Graph 43. Mean post manoeuvre point confidence by landmark condition, split by age

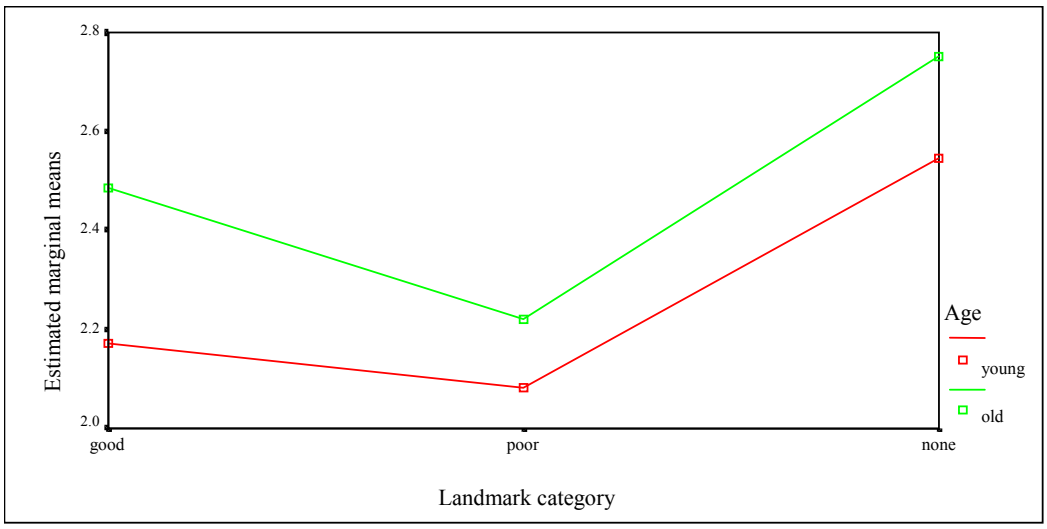


Graph 44. Mean post manoeuvre point confidence by landmark condition, split by gender

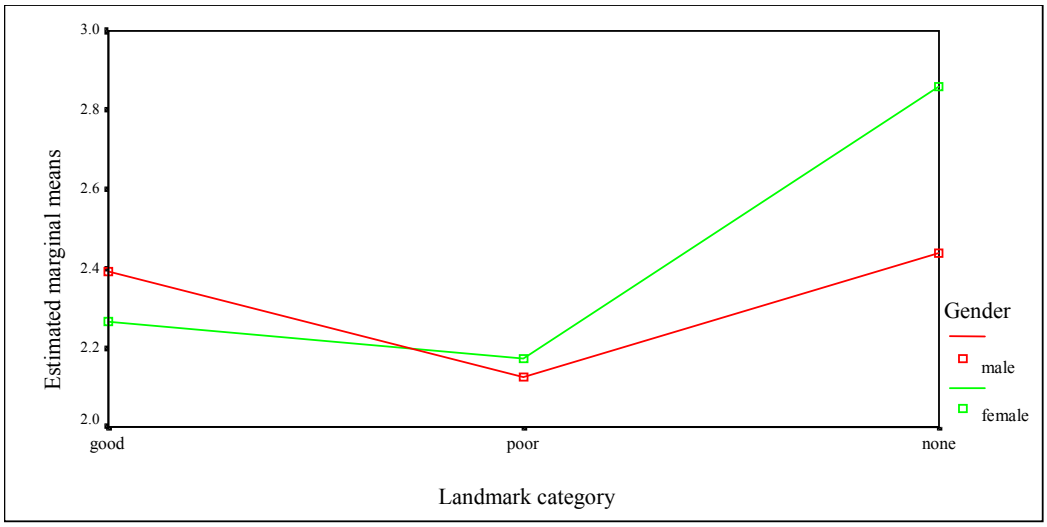
7.4.6 *Analysis*

A 3*2*2 (LANDMARKS*GENDER*AGE) MANOVA was conducted on the 4 variables of **Preview 1 confidence**, **Preview 2 confidence**, **Final confidence** and **Post confidence**, where LANDMARKS, GENDER and AGE were all between subjects variables.

7.4.7 *Graphs showing interaction effects for Preview 1 confidence*

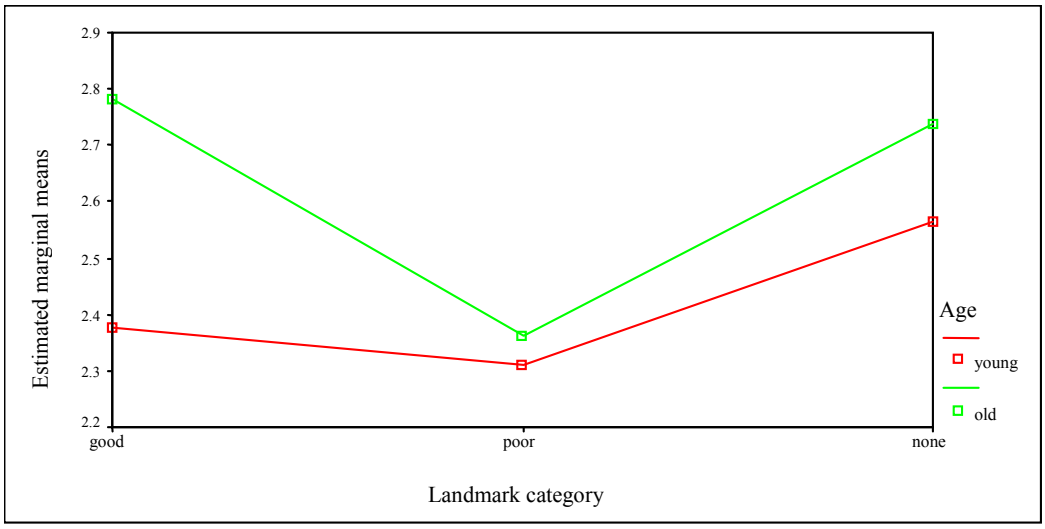


Graph 45. Preview 1 confidence by landmark condition (split by age) - estimated marginal means

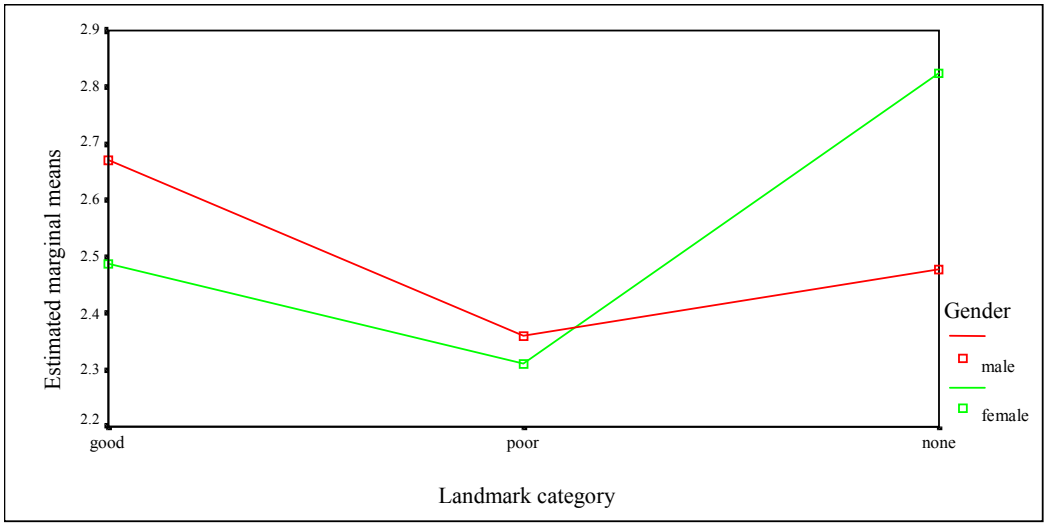


Graph 46. Preview 1 confidence by landmark condition (split by gender) - estimated marginal means

7.4.8 Graphs showing first/second order effects for Preview 2 confidence

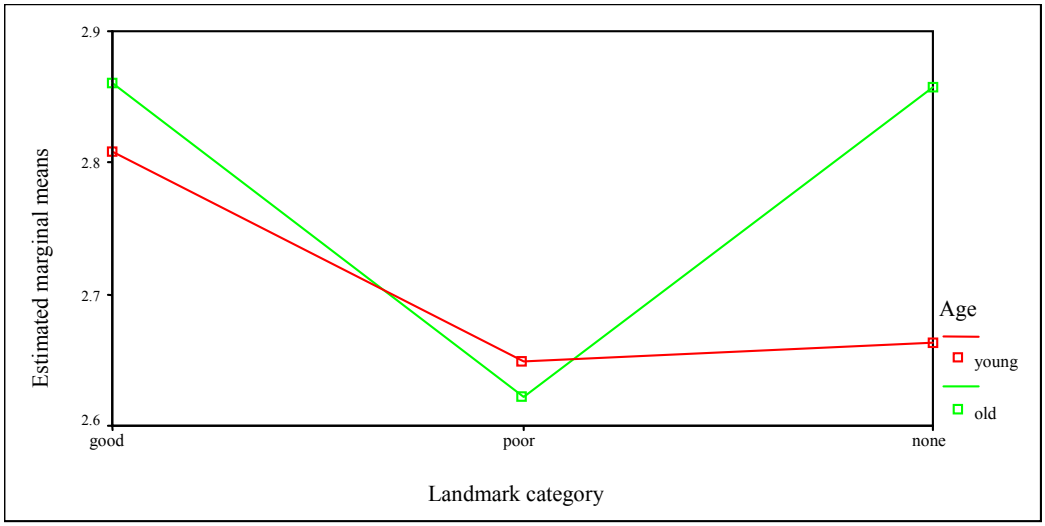


Graph 47. Preview 2 confidence by landmark condition (split by age) - estimated marginal means

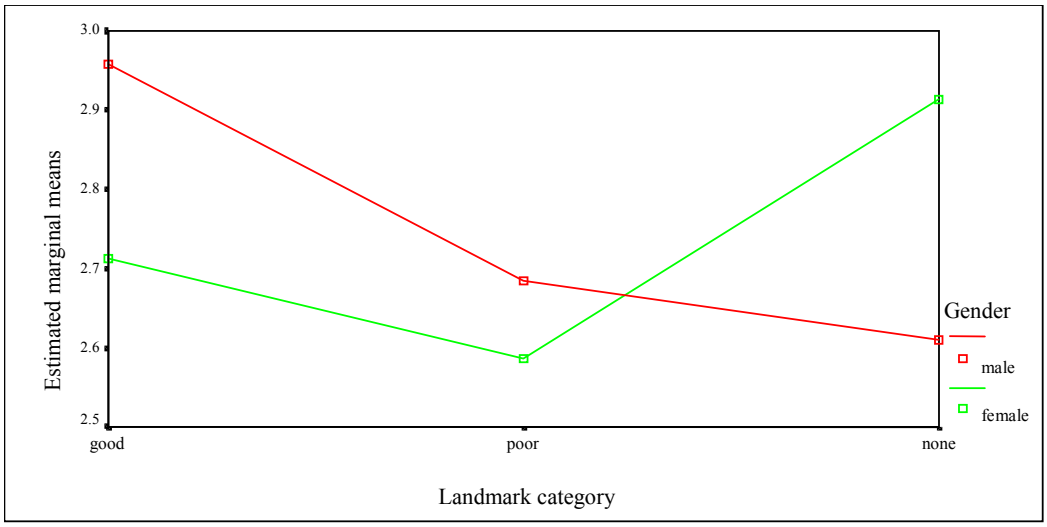


Graph 48. Preview 2 confidence by landmark condition (split by gender) - estimated marginal means

7.4.9 Graphs showing first/second order effects for Final confidence

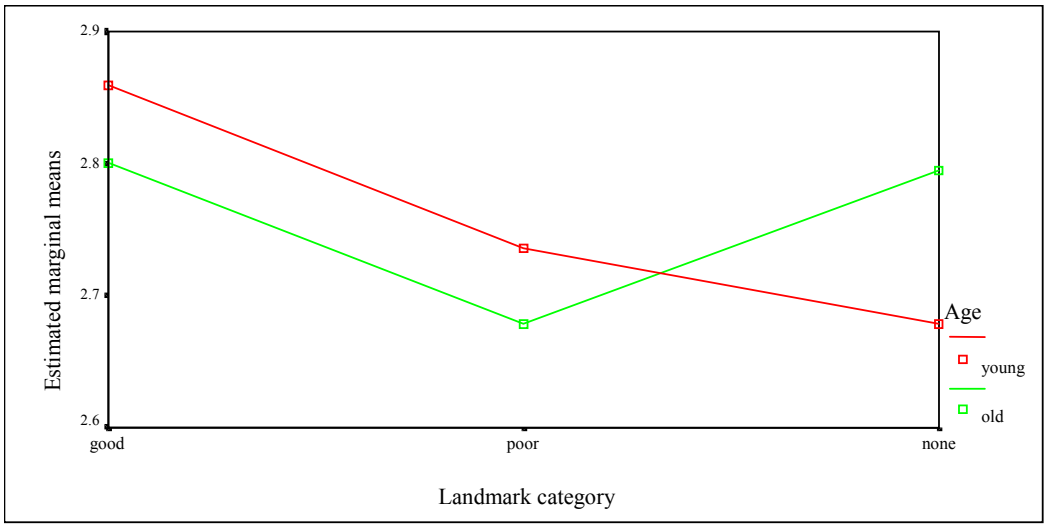


Graph 49. Final confidence by landmark condition (split by age) - estimated marginal means

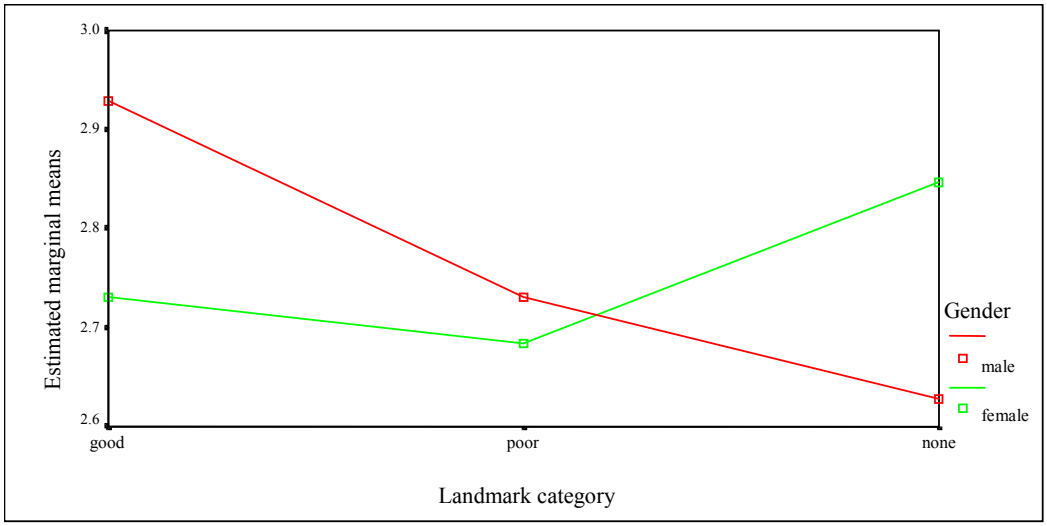


Graph 50. Final confidence by landmark condition (split by gender) - estimated marginal means

7.4.10 Graphs showing first/second order effects for Post confidence



Graph 51. Post confidence by landmark condition (split by age) - estimated marginal means



Graph 52. Post confidence by landmark condition (split by gender) - estimated marginal means

7.4.11 *Multivariate results (all dependent variables)*

Multivariate results are based on Wilks' Lambda, with significance reported at $p < 0.05$. This analysis considers all 4 dependent variables concurrently.

The main effect of LANDMARK was significant $F(8,66) = 2.689$, $p = 0.012$

7.4.12 *Univariate results*

Average confidence after Preview 1 message

The main effect of LANDMARK was significant $F(2,36) = 4.884$, $p = 0.013$. A Bonferroni post hoc test on the LANDMARK variable only showed significant differences between the poor and the no landmarks condition ($p = .012$).

The main effect of AGE was not significant.

The main effect of GENDER was not significant.

The interaction of LANDMARK*GENDER was not significant.

The interaction of LANDMARK*AGE was not significant.

Average confidence after Preview 2 message

The main effect of LANDMARK was significant $F(2,36) = 4.943$, $p = 0.013$. A Bonferroni post hoc test on the LANDMARK variable showed significant differences between the poor and the no landmark conditions ($p = .015$), and a near-significant difference between the poor and the good landmark conditions ($p = .080$).

The main effect of AGE was significant $F(1,36) = 5.934$, $p = 0.02$

The main effect of GENDER was not significant.

The interaction of LANDMARK*GENDER was significant $F(1,36) = 3.410$, $p = 0.044$

The interaction of LANDMARK*AGE was not significant.

Average confidence after Final message

The main effect of LANDMARK was significant $F(2,36) = 4.224$, $p = 0.022$. A Bonferroni post hoc test on the LANDMARK variable showed significant differences between the good and poor landmark conditions ($p = .020$).

The main effect of AGE was not significant.

The main effect of GENDER was not significant.

The interaction of LANDMARK*GENDER was significant $F(1,36) = 8.380$, $p = 0.001$

The interaction of LANDMARK*AGE was not significant.

Average confidence post manoeuvre

The main effect of LANDMARK was not significant.

The main effect of AGE was not significant.

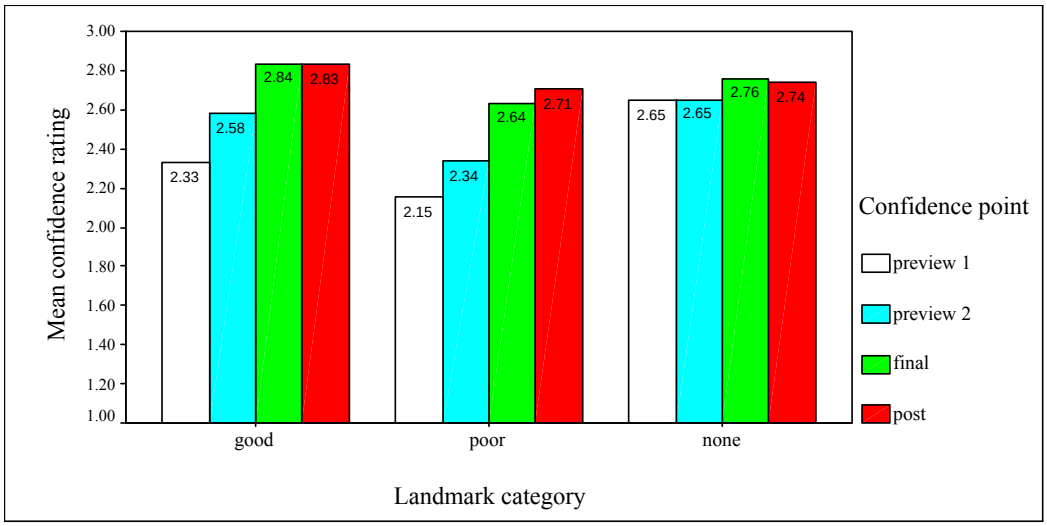
The main effect of GENDER was not significant.

The interaction of LANDMARK*GENDER was significant F(1,36) = 3.663, p = 0.036

The interaction of LANDMARK*AGE was not significant.

7.5 Changes in confidence

7.5.1 Overall effects



Graph 53. Changes in mean confidence levels over a manoeuvre by landmark category

7.5.2 Analysis

Two separate analyses were undertaken: (1) analysis of mean confidence levels across all manoeuvres, and (2) analysis of the individual confidence ratings for each manoeuvres.

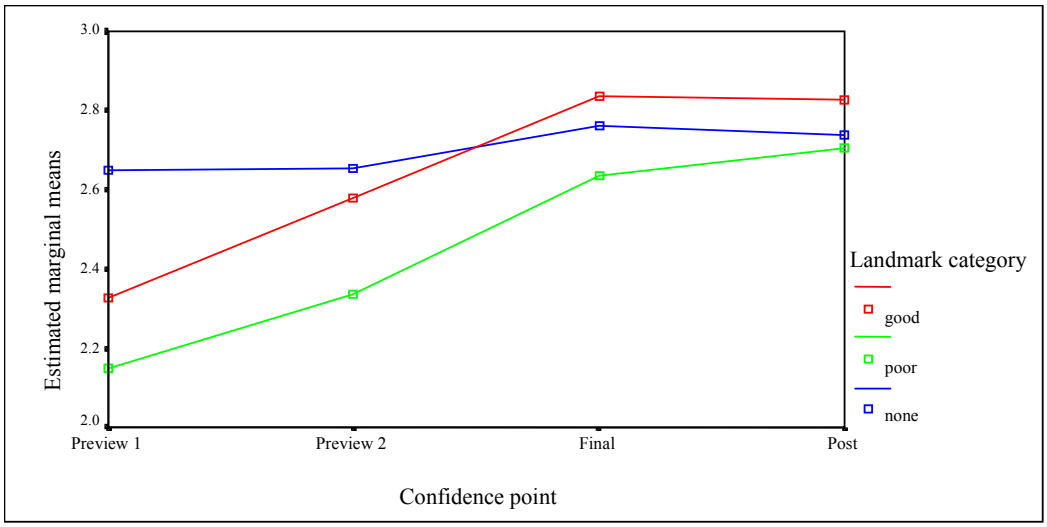
The mean confidence ratings for Preview 1, Preview 2, Final and Post were calculated for each participant, across all manoeuvres. A variable CONFIDENCE POINT defined as a within subjects variable. For statistical analysis, CONFIDENCE POINT took three levels, corresponding to the mean confidence ratings at Preview 1, Preview 2 and Final. The Post confidence rating was not included in the statistical analysis, since there was no auditory information presented to the participants after each manoeuvre, and hence no differences in this information for the three LANDMARK conditions of good, poor and none. For the plots of means, shown in section 7.5.3, this variable took four levels, to enable a visual comparison with the Post manoeuvre confidence levels.

A 3*3*2*2 (LANDMARKS*CONFIDENCE POINT*GENDER*AGE) MANOVA was conducted, where LANDMARKS, GENDER and AGE were all between subjects variables and CONFIDENCE POINT was a within subjects variable.

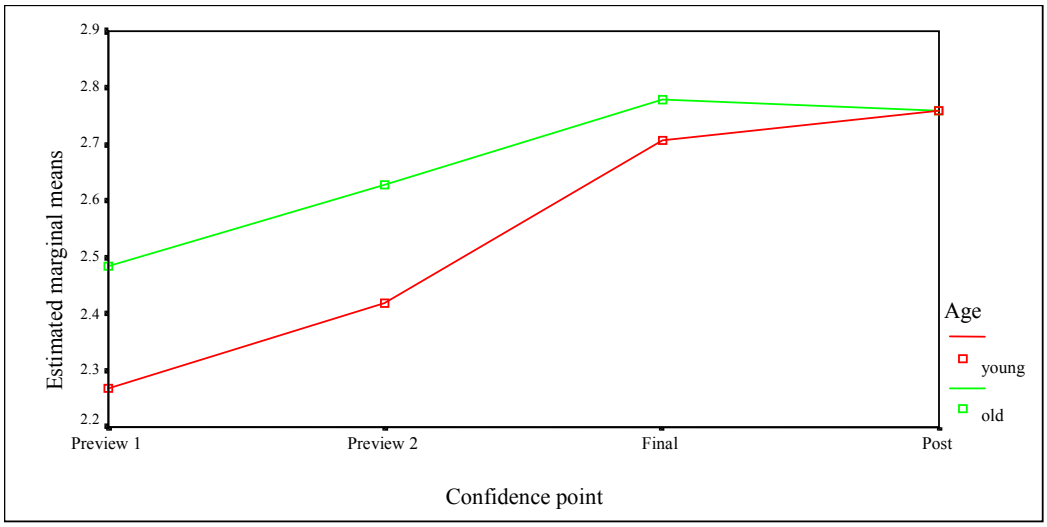
A Friedman test for related samples was undertaken on the raw data (the confidence rating at Preview 1, Preview 2, Final and Post, for each subject, for each manoeuvre) for the three participant groups, split according to the LANDMARKS condition (good, poor or none).

The statistical analysis was a 3 level ANOVA on mean confidence ratings for Preview 1, Preview 2 and Final. Post-manoeuvre confidence was not included in the analysis, but is shown on the graphs for comparison purposes.

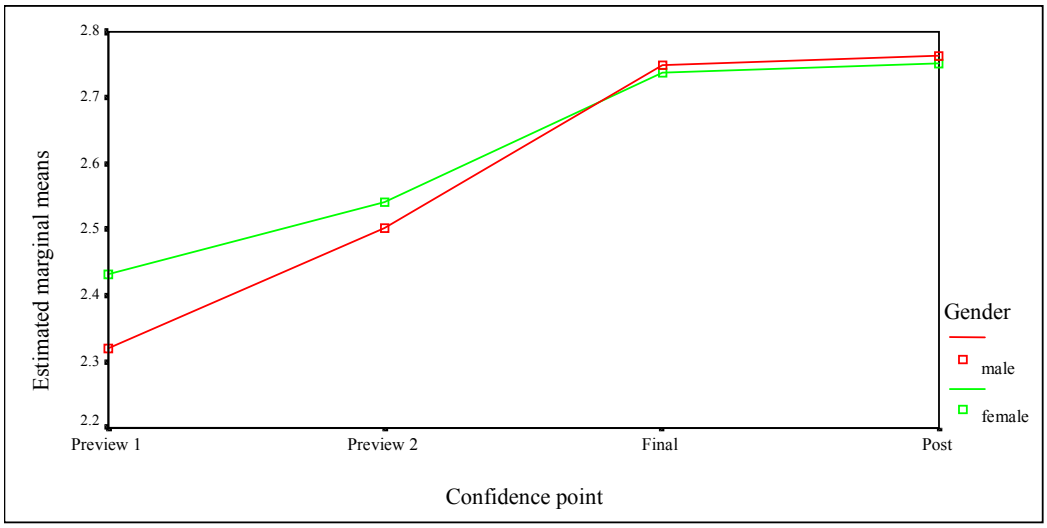
7.5.3 *Graphs showing first/second order effects for mean confidence levels at message points*



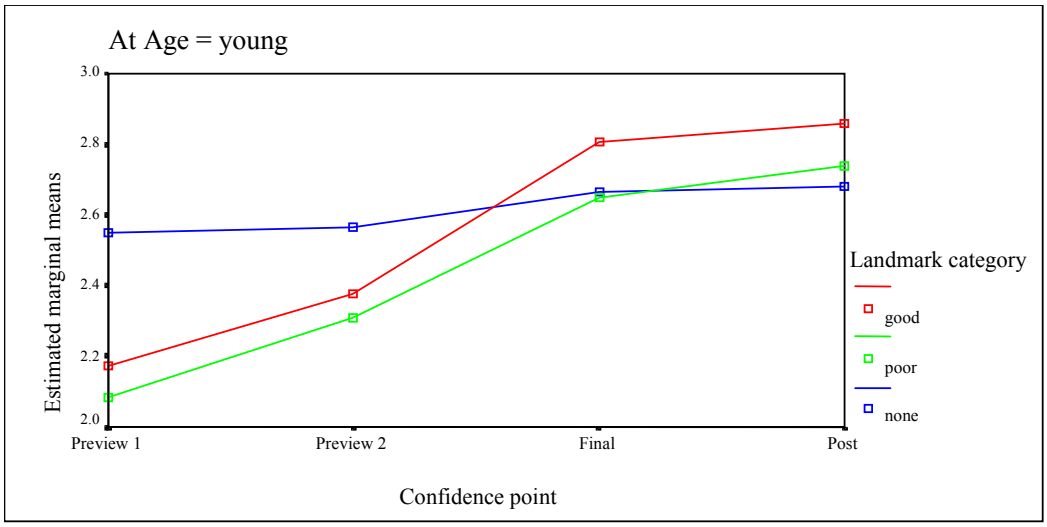
Graph 54. Confidence over time (split by landmark condition) - estimated marginal means



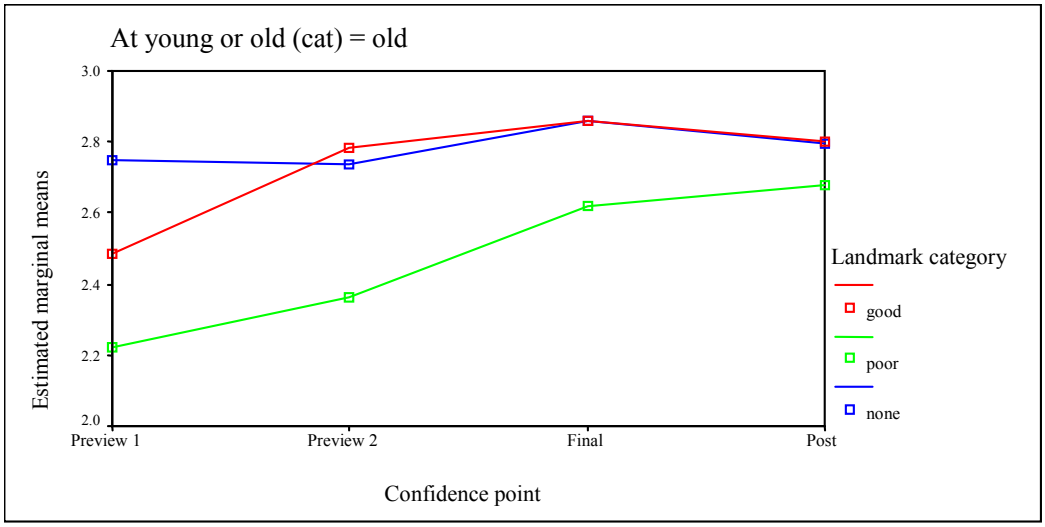
Graph 55. Confidence over time (split by age) - estimated marginal means



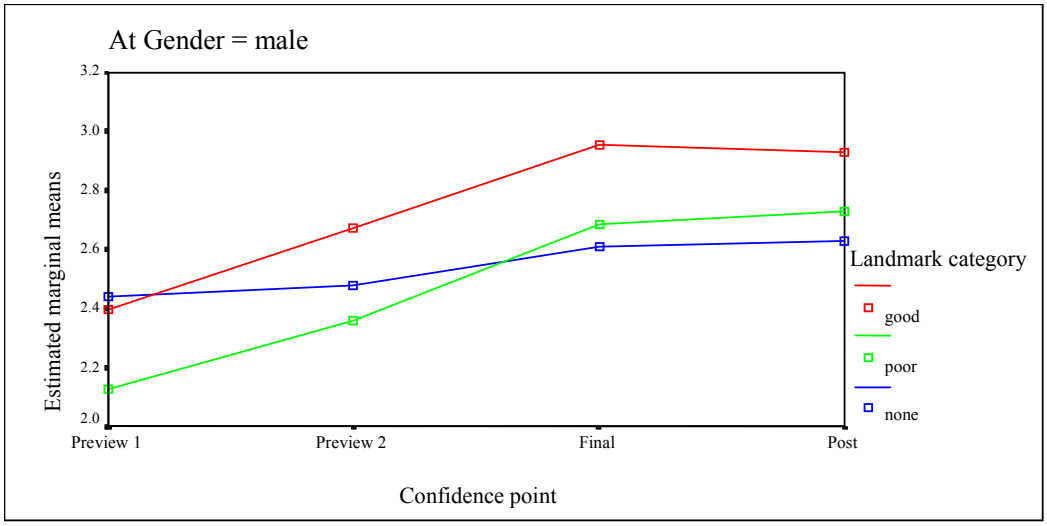
Graph 56. Confidence over time (split by gender) - estimated marginal means



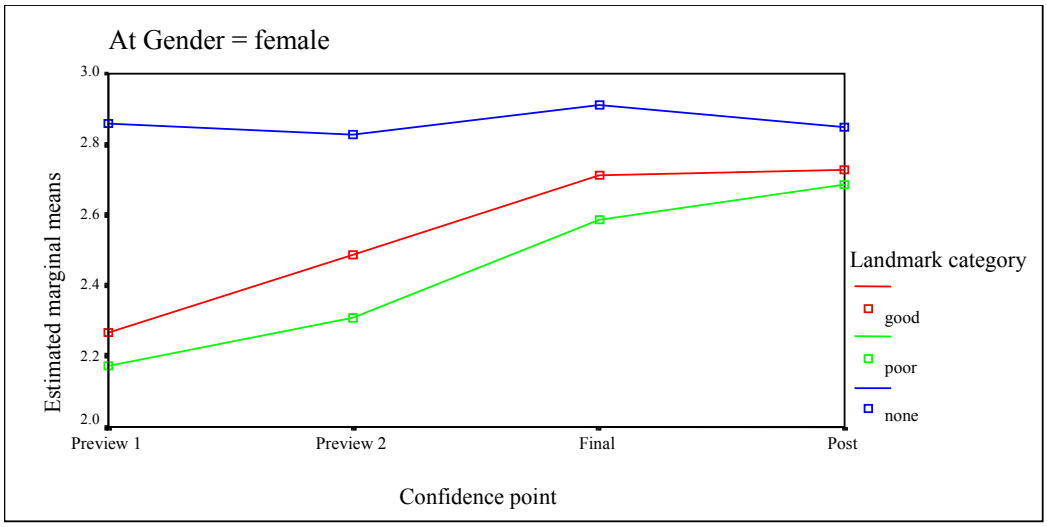
Graph 57. Confidence for young participants over time (split by landmark condition) - estimated marginal means



Graph 58. Confidence for old participants over time (split by landmark condition) - estimated marginal means

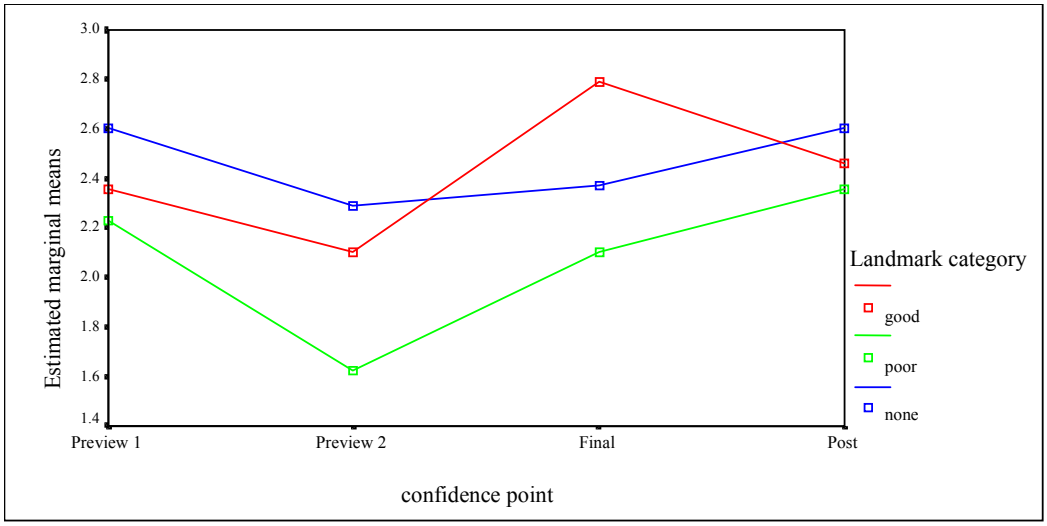


Graph 59. Confidence for male participants over time (split by landmark condition) - estimated marginal means

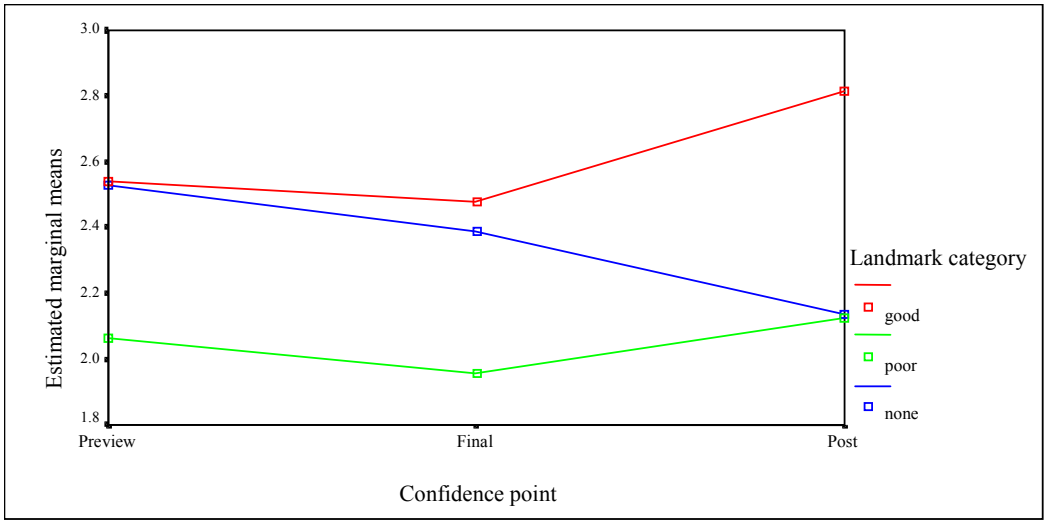


Graph 60. Confidence for female participants over time (split by landmark condition) - estimated marginal means

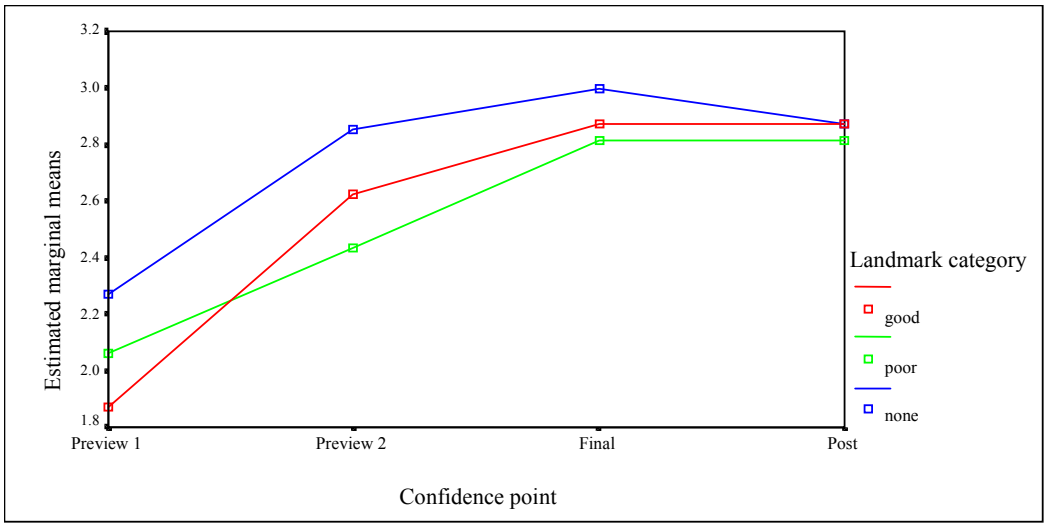
7.5.4 Graphs showing changes in confidence for each manoeuvre



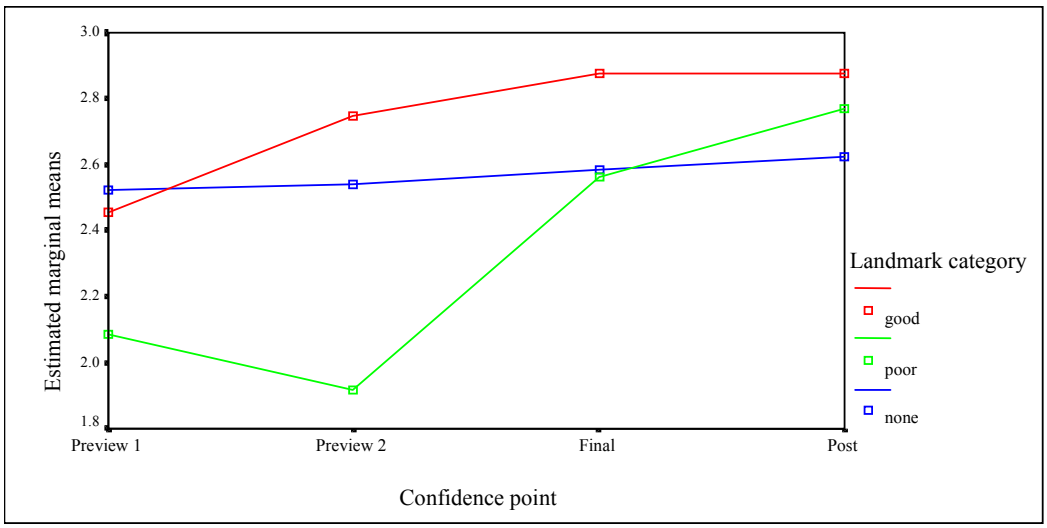
Graph 61. Manoeuvre 2 – confidence over time (split by landmark condition) - estimated marginal means



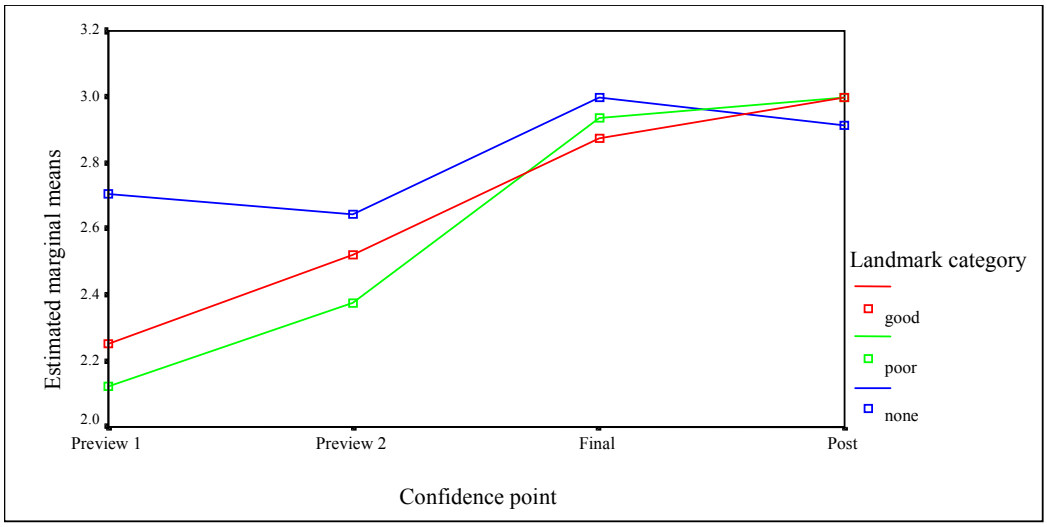
Graph 62. Manoeuvre 4 – confidence over time (split by landmark condition) - estimated marginal means



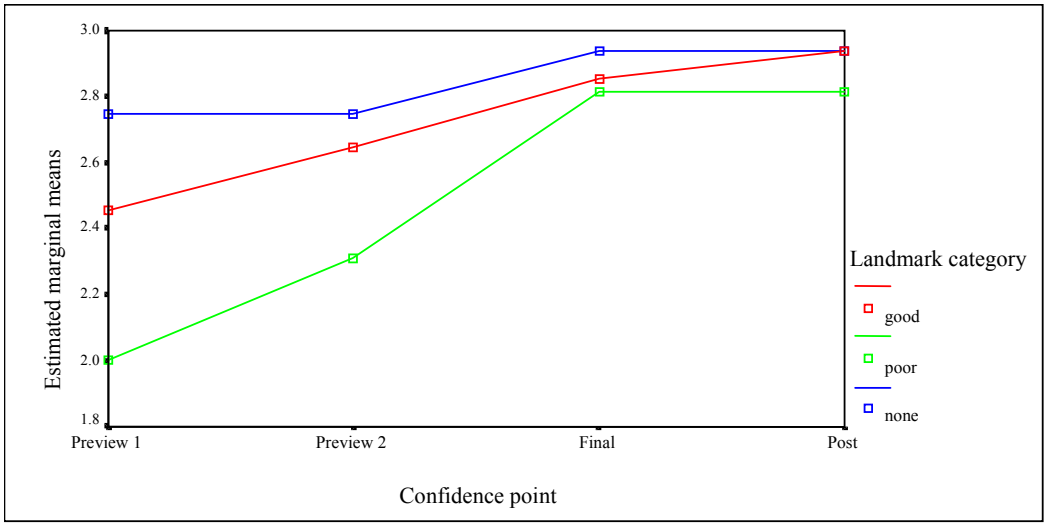
Graph 63. Manoeuvre 7 – confidence over time (split by landmark condition) - estimated marginal means



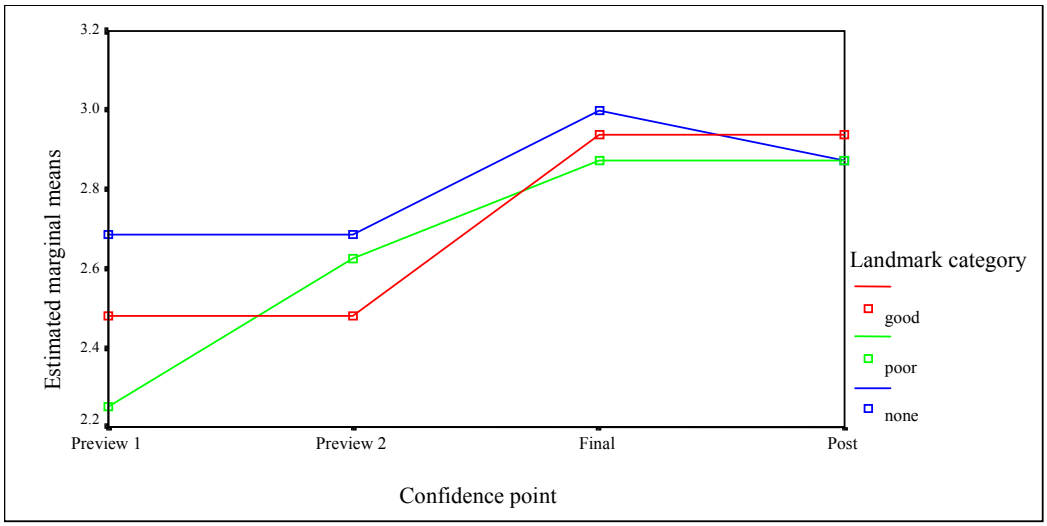
Graph 64. Manoeuvre 8 – confidence over time (split by landmark condition) - estimated marginal means



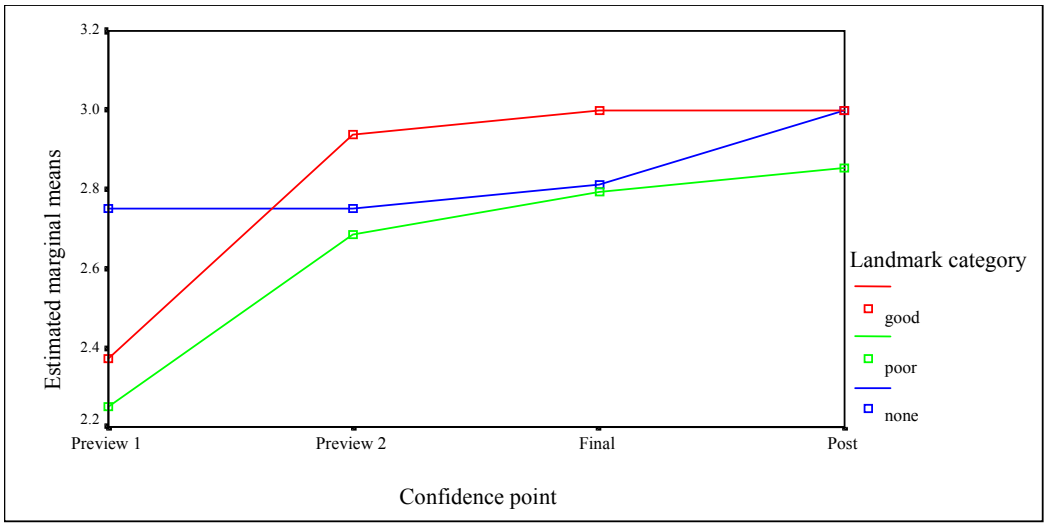
Graph 65. Manoeuvre 9 – confidence over time (split by landmark condition) - estimated marginal means



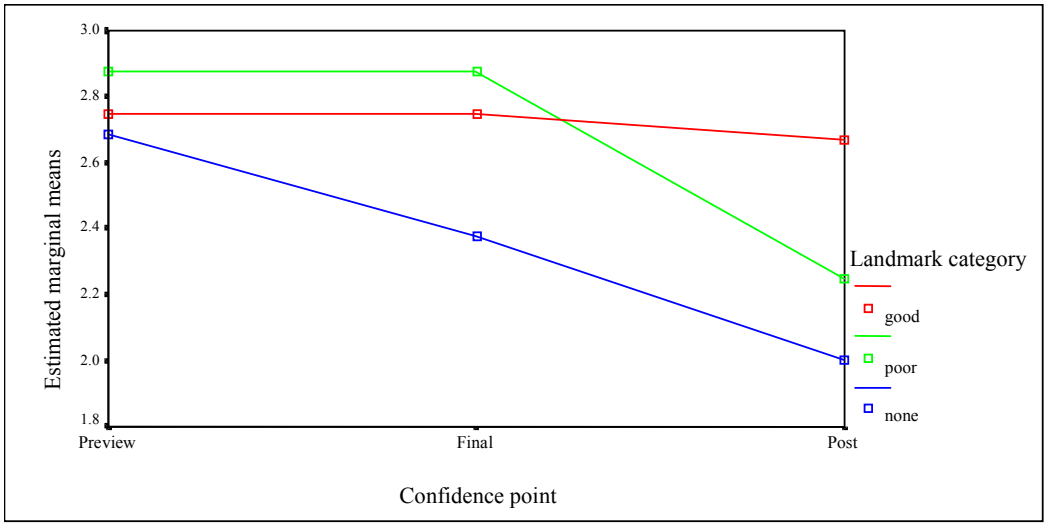
Graph 66. Manoeuvre 15 – confidence over time (split by landmark condition) - estimated marginal means



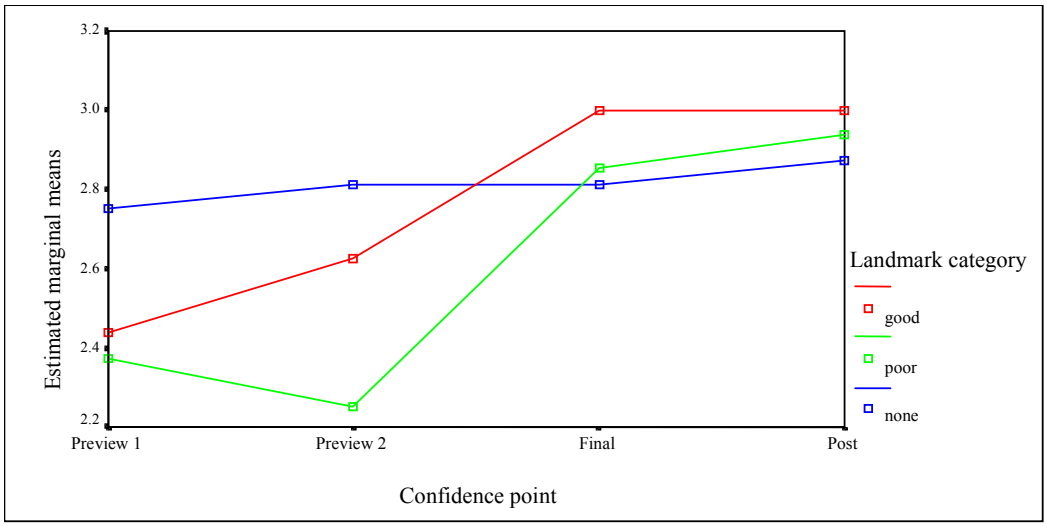
Graph 67. Manoeuvre 19 – confidence over time (split by landmark condition) - estimated marginal means



Graph 68. Manoeuvre 22 – confidence over time (split by landmark condition) - estimated marginal means



Graph 69. Manoeuvre 33 – confidence over time (split by landmark condition) - estimated marginal means



Graph 70. Manoeuvre 37 – confidence over time (split by landmark condition) - estimated marginal means

7.5.5 *Multivariate results (all dependent variables)*

Multivariate results are based on Wilks' Lambda, with significance reported at $p < 0.05$. The main effect of CONFIDENCE POINT was significant $F(2,35) = 18.026$, $p < .001$.

No interactions were significant.

7.5.6 *Univariate results (repeated measures)*

Mauchly's test of sphericity reported a significant chi value for the dependent variables; therefore corrected values using Huynh-Feldt Epsilon are reported.

The main within subjects effect of CONFIDENCE POINT was significant $F(1.918,69.032) = 28.144$, $p < .001$.

The interaction effect of CONFIDENCE POINT*LANDMARK was significant $F(1.918,69.032) = 3.835$, $p = .013$.

The interaction effect of CONFIDENCE POINT*GENDER was not significant.

The interaction effect of CONFIDENCE POINT*AGE was not significant.

The main between subjects effect of LANDMARK was significant $F(2,36) = 5.548$, $p < .008$.

The main between subjects effect of GENDER was not significant.

The main between subjects effect of AGE was significant $F(1,36) = 4.579$, $p = .039$.

7.5.7 *Non-parametric results (raw data for each manoeuvre)*

The results for the Friedman test for 3 related samples on each participant group (LANDMARK condition: good, poor, none) calculated across the Preview1, Preview2 and Final confidence ratings for each manoeuvre, are shown in Table 11 below. There was insufficient data to calculate this test result for manoeuvre numbers 4 and 33 (as there was no Preview 1 message at these manoeuvres).

Manoeuvre no.		Good	Poor	None
2.	N	14	15	15
	χ^2	12.600	8.706	4.903
	df	2	2	2
	p	.002	.013	.086
4	-	-	-	-
7	N	16	16	15
	χ^2	20.421	14.176	12.091
	df	2	2	2
	p	.000	.001	.002
8	N	15	15	15
	χ^2	9.333	6.200	1.077
	df	2	2	2
	p	.009	.045	.584
9	N	15	15	16
	χ^2	10.667	14.606	10.333
	df	2	2	2
	p	.005	.001	.006
15	N	15	16	16
	χ^2	5.840	15.200	4.500
	df	2	2	2
	p	.054	.001	.105
19	N	13	16	16
	χ^2	12.000	9.172	10.000
	df	2	2	2
	p	.002	.010	.007
22	N	16	16	16
	χ^2	16.222	8.818	.400
	df	2	2	2
	p	.000	.012	.819
33	-	-	-	-
37	N	16	16	16
	χ^2	11.091	10.333	.400
	df	2	2	2
	p	.004	.006	.819

Table 11. Non-parametric results for Preview 1, Preview 2 and Final confidence for each manoeuvre

8 RESULTS – DRIVING SAFETY

8.1 Analysis

The driver error scores were based on a real-time subjective assessment of the participant's driving performance by a UK Driving Standards Agency Approved Driving Instructor (ADI). An error coding scheme was developed in conjunction with the driving instructor, based on the error categorisation used in the UK driving test (indicated by 'Type' below), and the permissible error rate for a test pass. Each participant was assessed at each manoeuvre according to whether the error was a minor, serious or dangerous error, within the following error categories:

DROBS	Observation	Type 9 - Use of mirrors and rear observation when signalling, changing direction and speed
DRIND	Indicators	Type 10 - Give appropriate signals
DRINT	Interaction	Type 11 - Response to signs and signals including traffic signs, road markings, traffic lights, traffic controllers and other road users
DRJUN	Junctions	Type 15 - Junctions, aspects include speed of approach, observation, turning right or left and cutting corners
DRPOS	Positioning	Type 17 - Positioning in normal driving and lane discipline
DRPLN	Planning	Type 21 - Awareness and planning

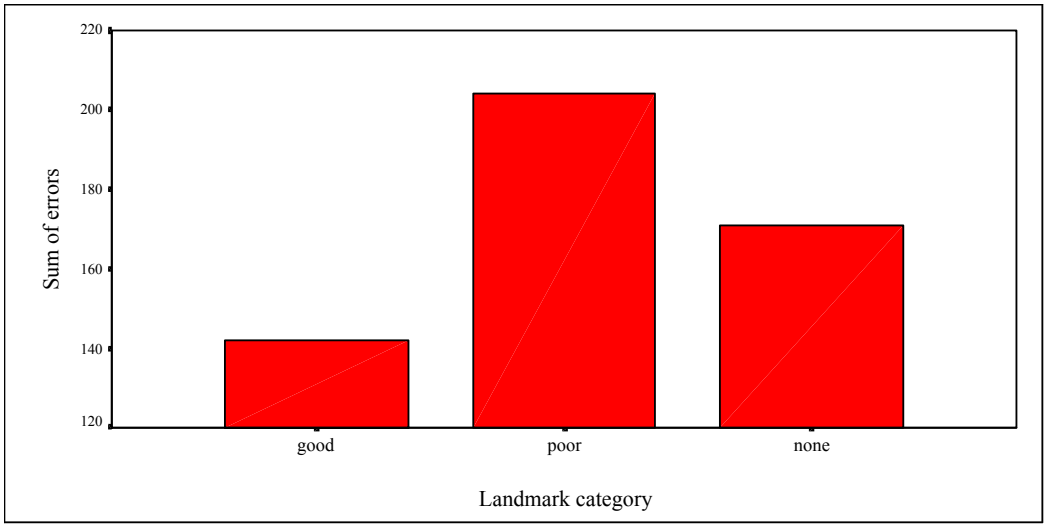
In a UK standard driving test if the driver commits more than fifteen minor driver errors or either one serious or dangerous error they will fail the test. Since the participants who took part in the road trials were all relatively experienced (drove regularly and aged over 21), the driving instructor therefore suggested assigning a value of 1 to a minor error and a value of 5 to a serious error. In addition, the driving instructor was of the opinion that a participant committing 10 minor errors over the period of the trial (all 37 manoeuvres) was exhibiting habitually poor driving performance and therefore dangerous driving behaviour. This was the rationale for assigning a value of 10 to a dangerous driving error. These scaling factors were employed to enable a single 'error' figure to be calculated for each participant for each manoeuvre under each of the error categories shown above. Overall 'error' figures (DRTOT) were additionally calculated by performing a straight sum across manoeuvres and across participants.

It is recognised that the final values obtained are to some extent arbitrary; however they *are* based on recognised error categories and scoring methods.

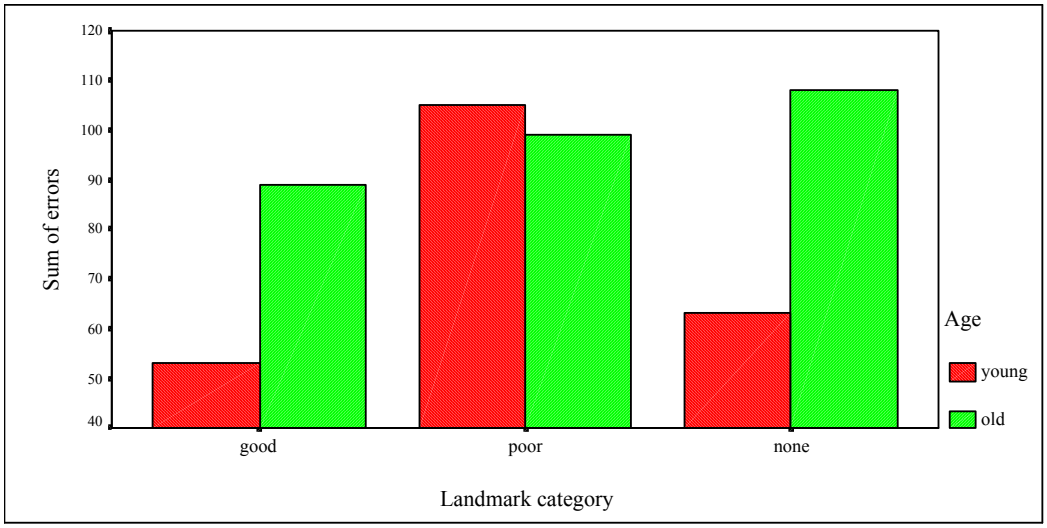
There were therefore six dependent variables of interest: **Observation**, **Indicators**, **Interaction**, **Junctions**, **Positioning** and **Planning**, plus an overall error value which was a sum across the six dependent variables.

A Kruskal-Wallis test for three independent samples was conducted on the total error sum for each of these variables, with samples split according to LANDMARK (good, poor or none).

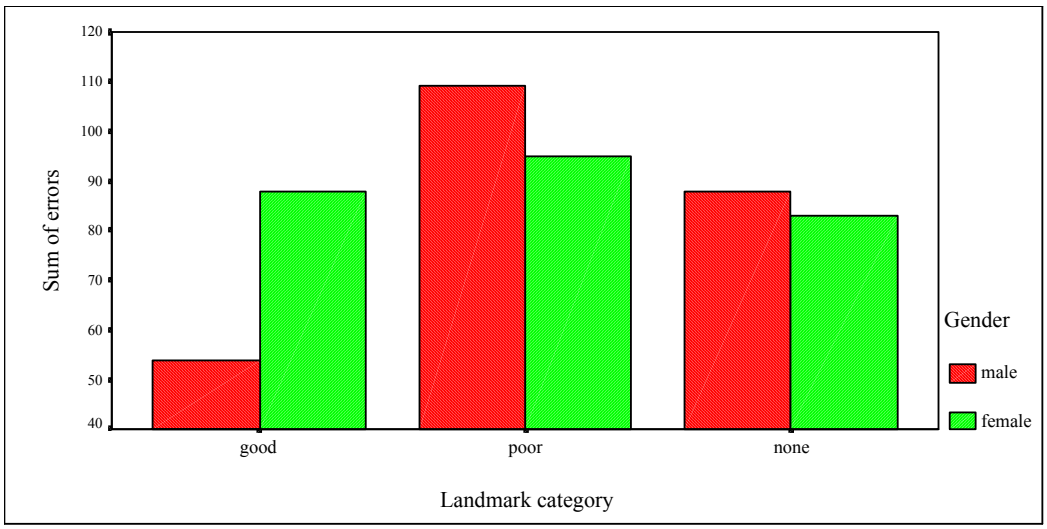
8.2 Graphs showing driving error totals across all manoeuvres



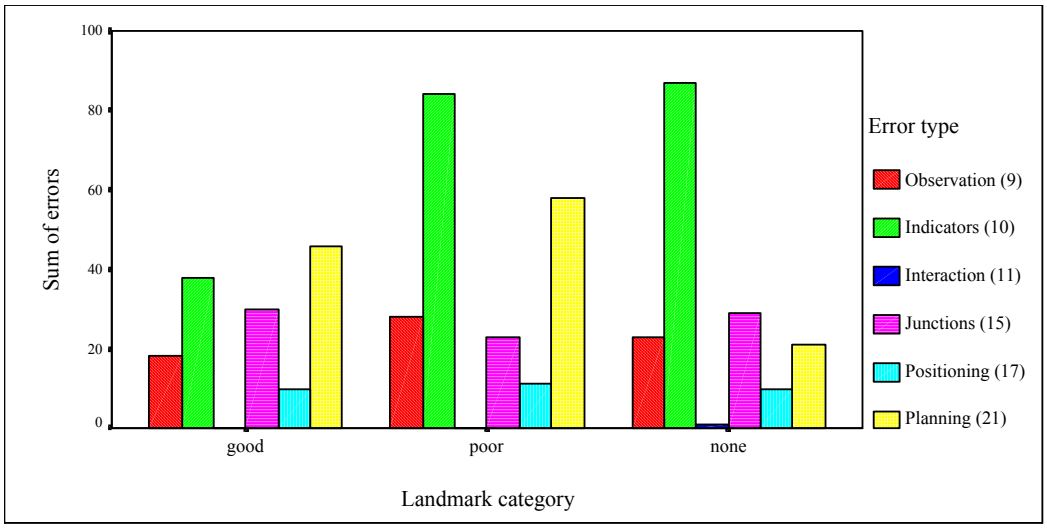
Graph 71. Sum of driving errors by landmark condition



Graph 72. Sum of driving errors by landmark condition (split by age)



Graph 73. Sum of driving errors by landmark condition (split by age)



(figures in brackets refer to the related section of the driving test form)

Graph 74. Sum of driving errors by landmark condition (split by error type)

8.3 Non parametric statistics

Based on the results of a Kruskal-Wallis test for three independent samples, conducted separately for on the total error sum for each of the variables Observation, Indicators, Interaction, Junctions, Positioning, Planning plus the total errors score (a sum across all variables):

The effect of the between subjects factor of LANDMARK on the dependent variable **Indicators** was significant ($\chi^2 = 10.537$, df = 2, $p = .005$). The effect of the between subjects factor of LANDMARK on the other five dependent variables (**Observation**, **Interaction**, **Junctions**, **Positioning** and **Planning**) was not significant, nor was the effect on the total error score.

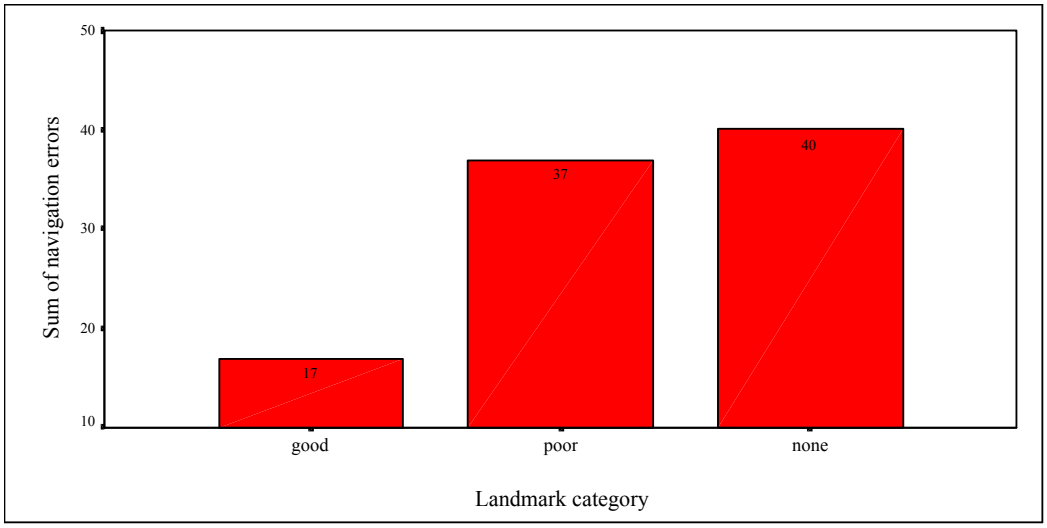
9 RESULTS – NAVIGATION PERFORMANCE

9.1 Analysis

The single dependent variable investigated was **Navigation Error**: this was a straight sum, for each participant, of the number of navigation errors committed by each participant over the trial period. A navigation error was defined as taking an incorrect turn (earlier or later than the target manoeuvre) or not turning at all.

A Kruskal-Wallis test for three independent samples was conducted on the variable **Navigation Error**, with samples split according to LANDMARK (good, poor or none).

9.2 Graphs



Graph 75. Number of navigation errors by condition

9.3 Results

Based on a Kruskal-Wallis test for three independent samples, the effect of the between subjects factor of LANDMARK on the dependent variable **Navigation Error** was significant ($\chi^2 = 17.541$, df = 2, $p < .001$).

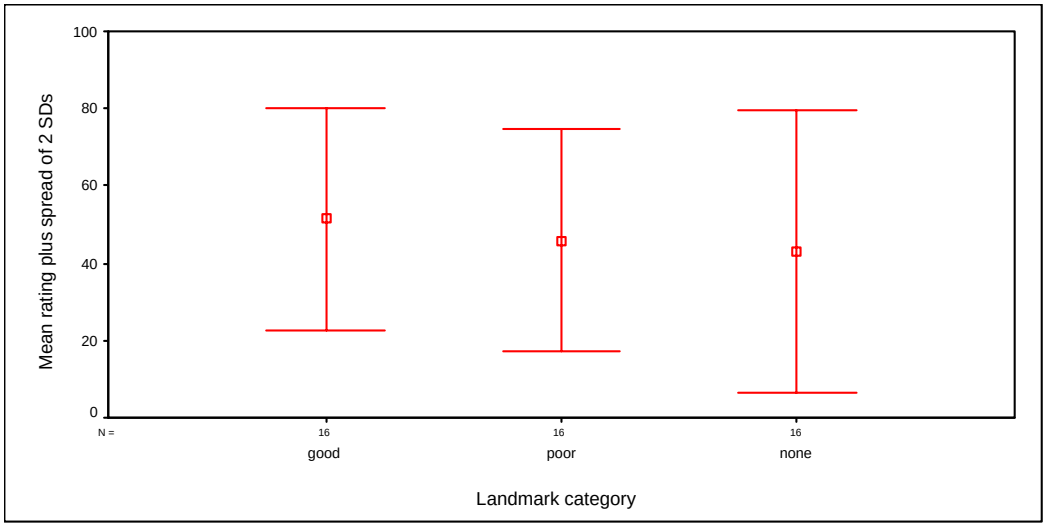
10 RESULTS – DRIVER WORKLOAD

10.1 Analysis

The NASA-RTLX subjective workload assessment tool was used to give a subjective task loading on each of the NASA component factors of **Mental Demand**, **Mental Effort**, **Physical Demand**, **Time Pressure**, **Distraction**, and **Stress Level**. Each participant rated each of these factors on a 100mm long bar, the raw data therefore comprising a value between 0 and 100 on each of the above component factors, for each participant. A 3*2*2 (LANDMARKS*GENDER*AGE) MANOVA was conducted on the six dependent variables, where LANDMARKS, GENDER and AGE were all between subjects variables.

A total NASA-RTLX score was generated for each participant by calculating a mean value of the six component factors. A 3*2*2 (LANDMARKS*GENDER*AGE) ANOVA was conducted on this variable, where LANDMARKS, GENDER and AGE were all between subjects variables.

10.2 Graph



Graph 76. Error bar plot of NASA-RTLX scores (mean of individual NASA components) by landmark condition, with bars representing 1SD above, and 1SD below the mean values

10.3 Results

Aggregate (overall) NASA-RTLX score

An ANOVA was conducted to examine the effects of landmarks, age and gender on the aggregate NASA-RTLX score. This aggregate score was calculated as the mean value of the six independent NASA components comprising **Mental Demand**, **Mental Effort**, **Physical Demand**, **Time Pressure**, **Distraction**, and **Stress Level**.

The main effects of LANDMARK (good, poor or none), GENDER (male, female) and AGE (young, old) were not significant.

None of the first order (LANDMARK* GENDER, LANDMARK*AGE, GENDER *AGE) interactions were significant.

NASA component scales

A MANOVA was conducted to examine the effects of LANDMARKS, AGE and GENDER on all of the individual NASA components (comprising Mental Demand, Mental Effort, Physical Demand, Time Pressure, Distraction and Stress Level). Results are reported using Wilks' Lambda, with significance at $p < 0.05$.

The main effects of LANDMARK, GENDER and AGE were not significant.

None of the first order interactions (LANDMARKS*GENDER, LANDMARKS*AGE, GENDER*AGE) were significant.

11 RESULTS – QUESTIONNAIRE DATA

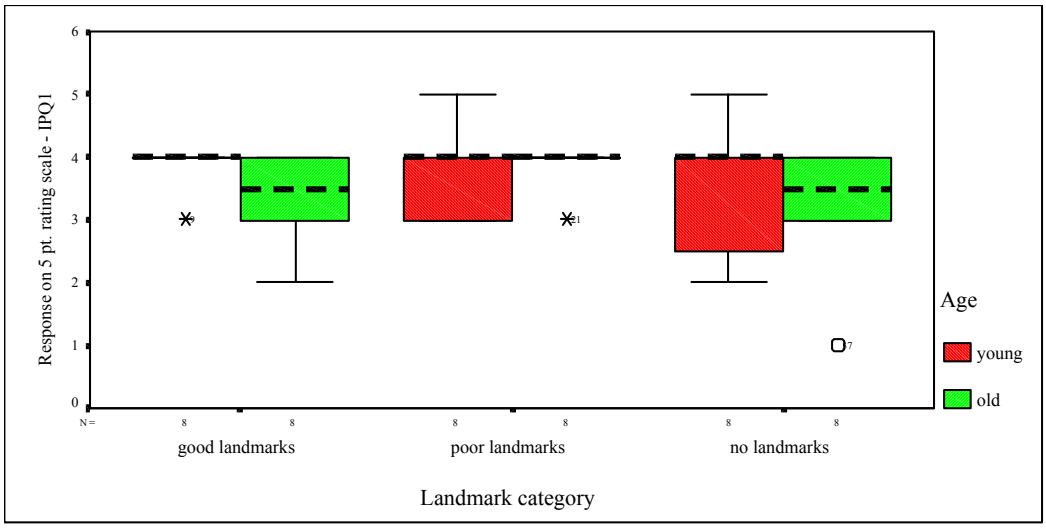
11.1 Initial Perceptions Questionnaire

The following graphs present box plots of the results from the 7 questions within the Initial Perceptions Questionnaire split by LANDMARK condition, and participant AGE.

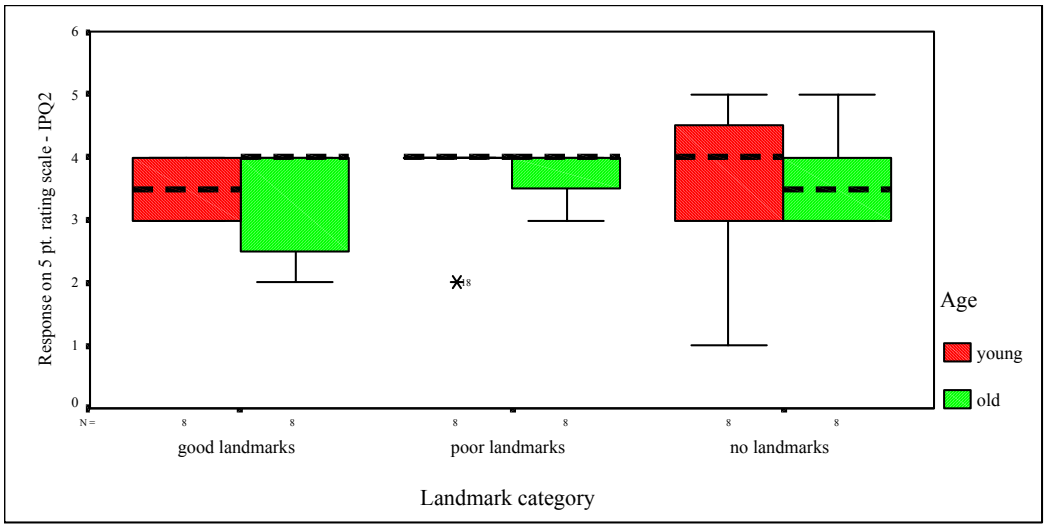
Note that a box plot is a summary plot based on the median, quartiles, and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A dashed line across the box indicates the median.

All responses are on 5-point scale, indicating agreement with the specified statement as follows:

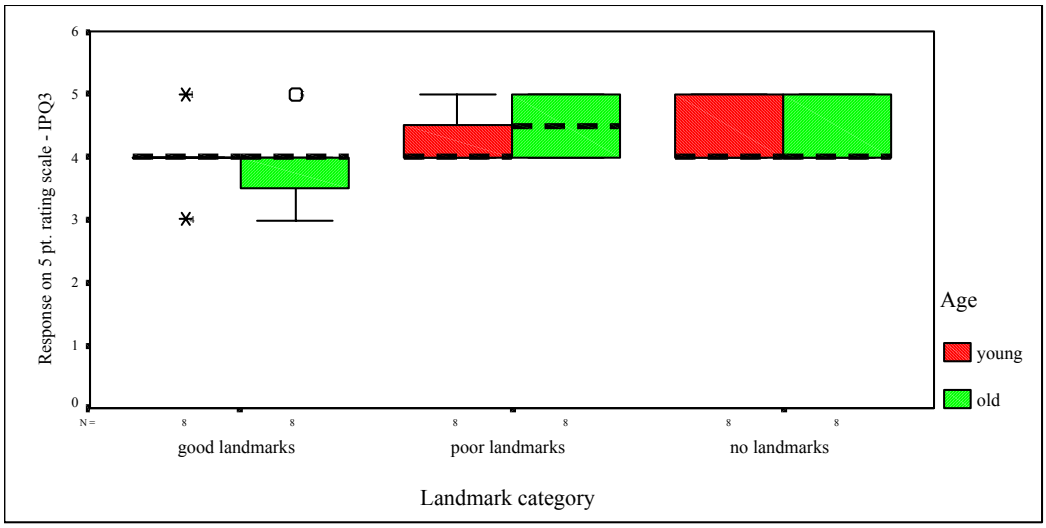
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5



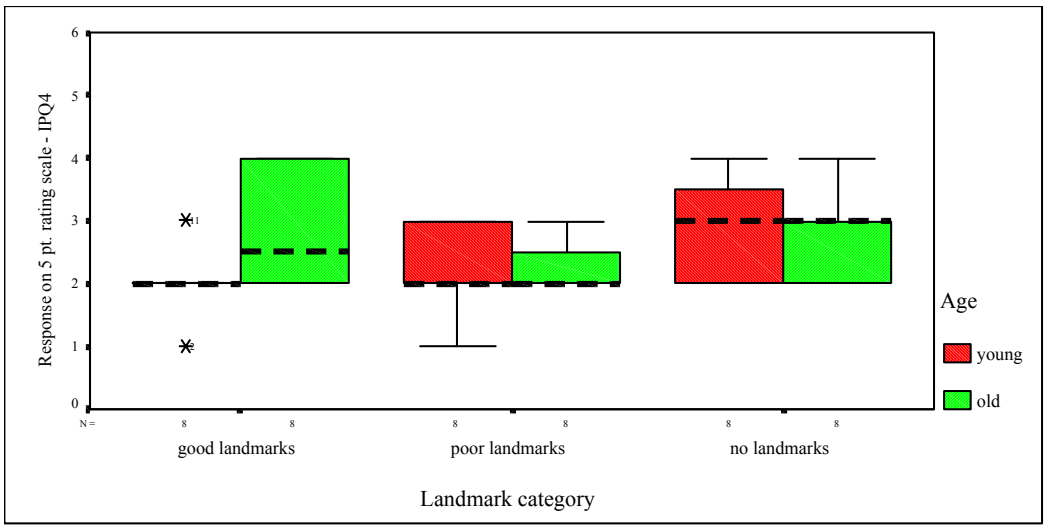
Graph 77. IPQ1 - A navigation system reduces the amount of stress during driving



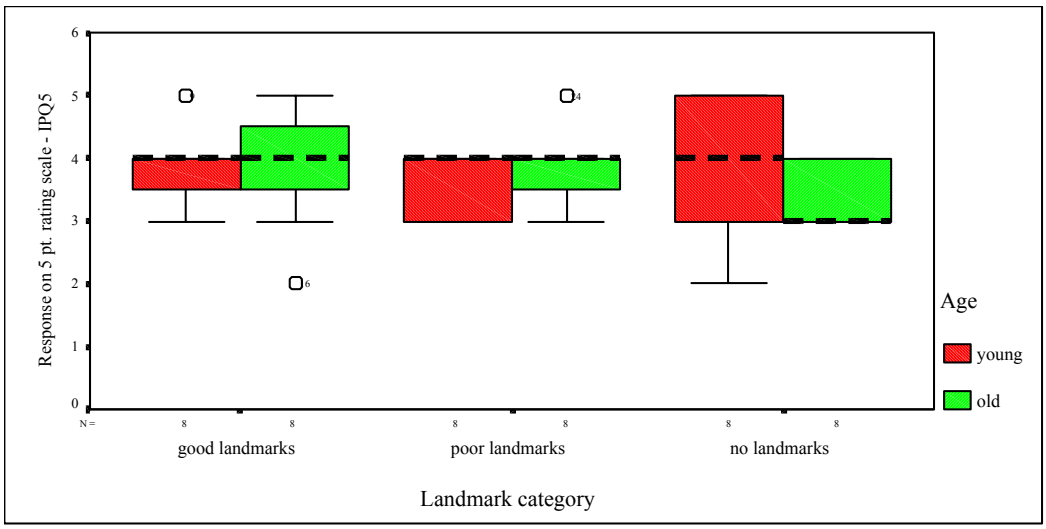
Graph 78. IPQ2 - Using a navigation system is a fun way of navigating



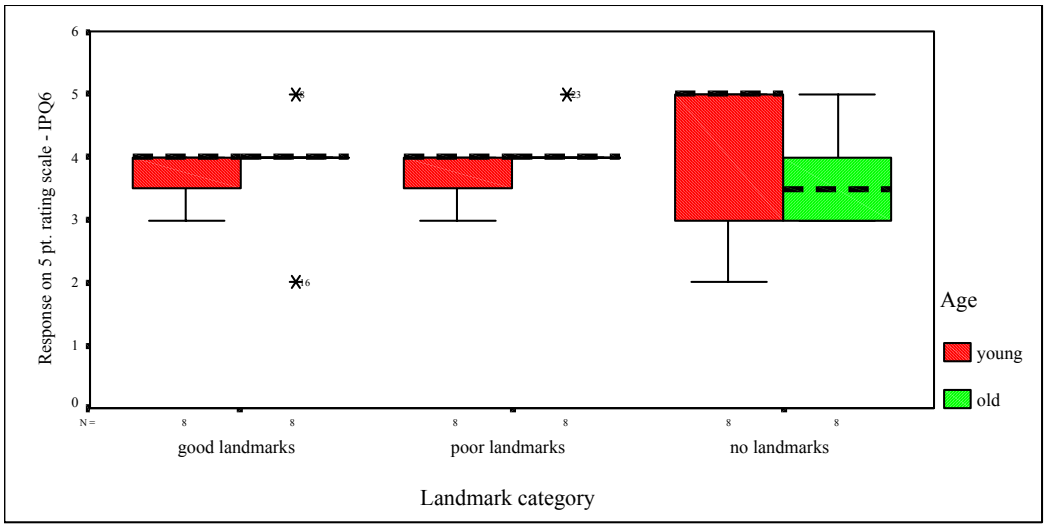
Graph 79. IPQ3 - I am looking forward to using a navigation system



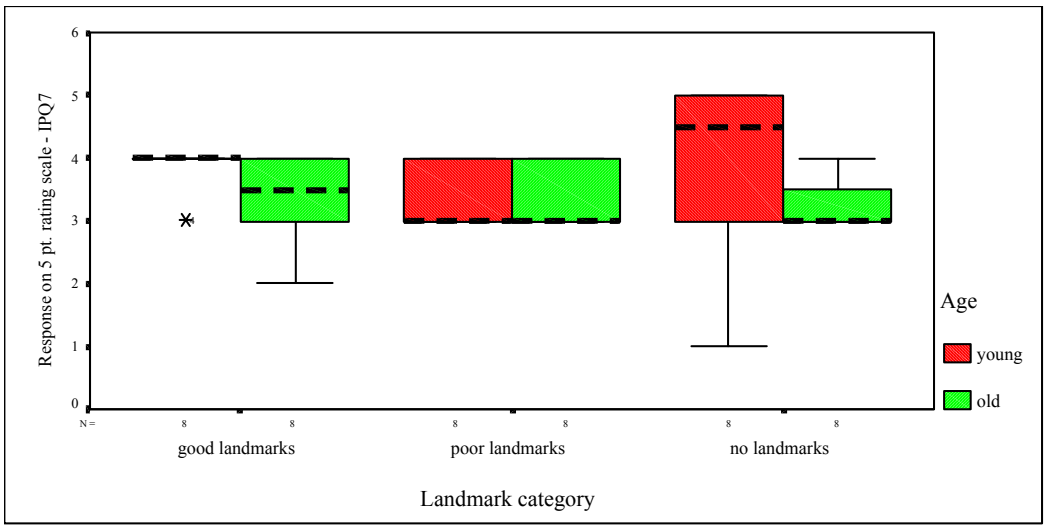
Graph 80. IPQ4 - Using the navigation system makes driving more difficult



Graph 81. IPQ5 - A navigation system is an easy method of finding my way in an unfamiliar area



Graph 82. IPQ6 - With a navigation system, I think I would be less likely to get lost



Graph 83. IPQ7 - I would prefer using a navigation system to my usual way of navigating in a car

A Kruskal-Wallis test for 3 independent samples (LANDMARK condition: good, poor or none) was applied to the results from each question. This test was significant for Question 3: there was a significant effect of LANDMARK condition ($\chi^2 = 5.987$, df = 2, $p = .05$). The mean rankings for Question 3 were: good landmarks 18.63; poor landmarks 27.44; no landmarks 27.44.

The results for all other questions were insignificant for LANDMARK condition.

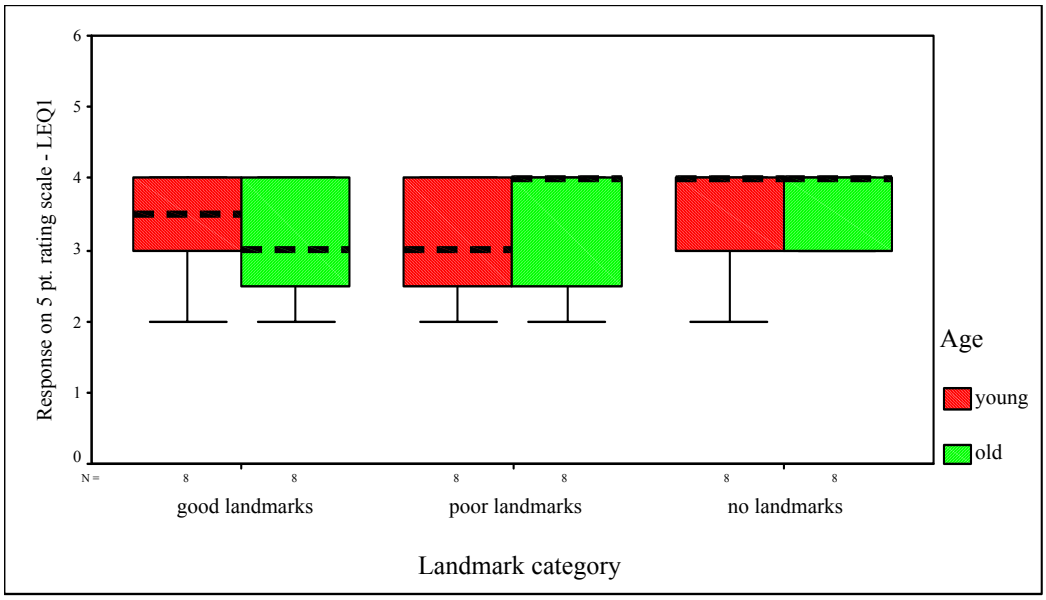
11.2 Limited Exposure Questionnaire

The following graphs present box plots of the results from the 14 questions within the Limited Exposure Questionnaire (note there was no Question 6), split by LANDMARK condition, and participant AGE.

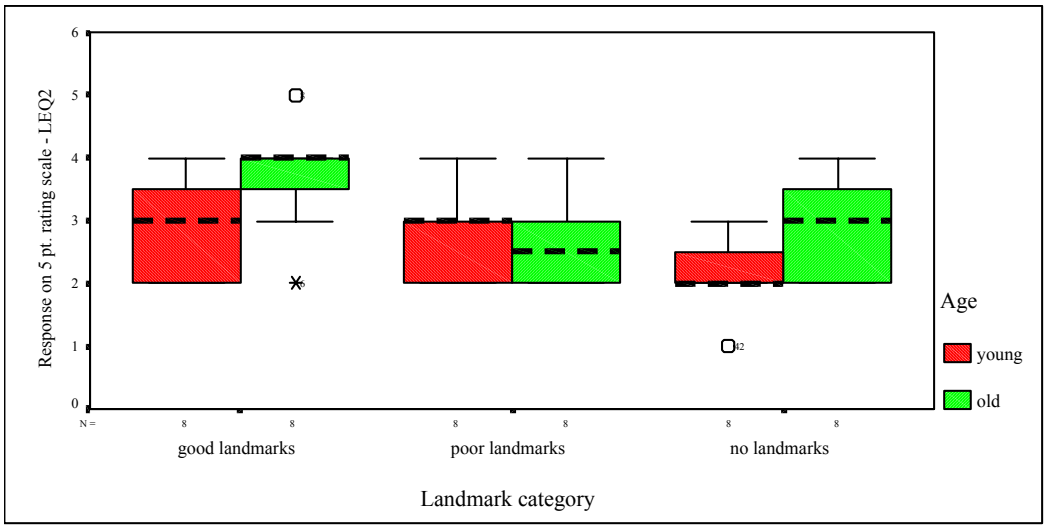
Note that a box plot is a summary plot based on the median, quartiles, and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A dashed line across the box indicates the median.

All responses are on 5-point scale, indicating agreement with the specified statement as follows:

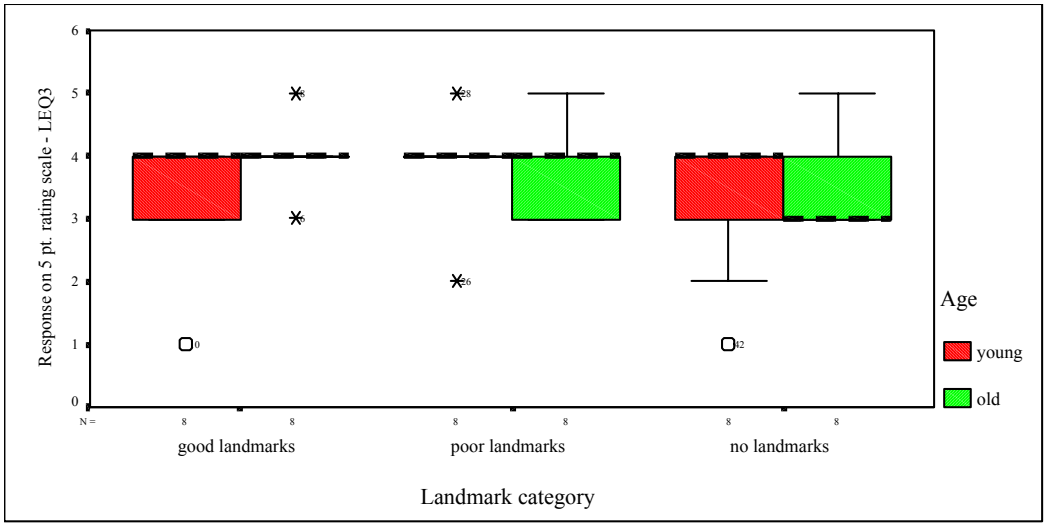
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5



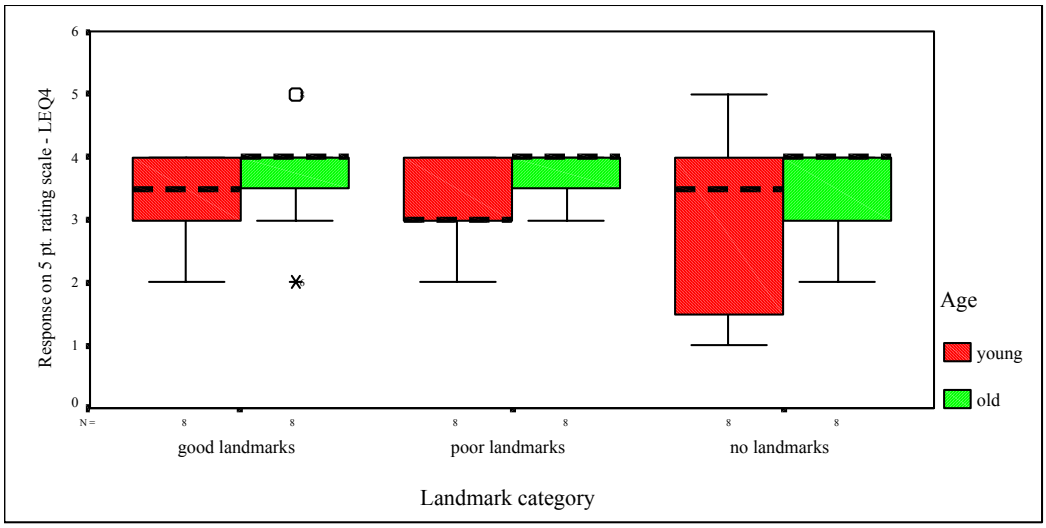
Graph 84. LEQ1 - Using a navigation system is a fun way of navigating



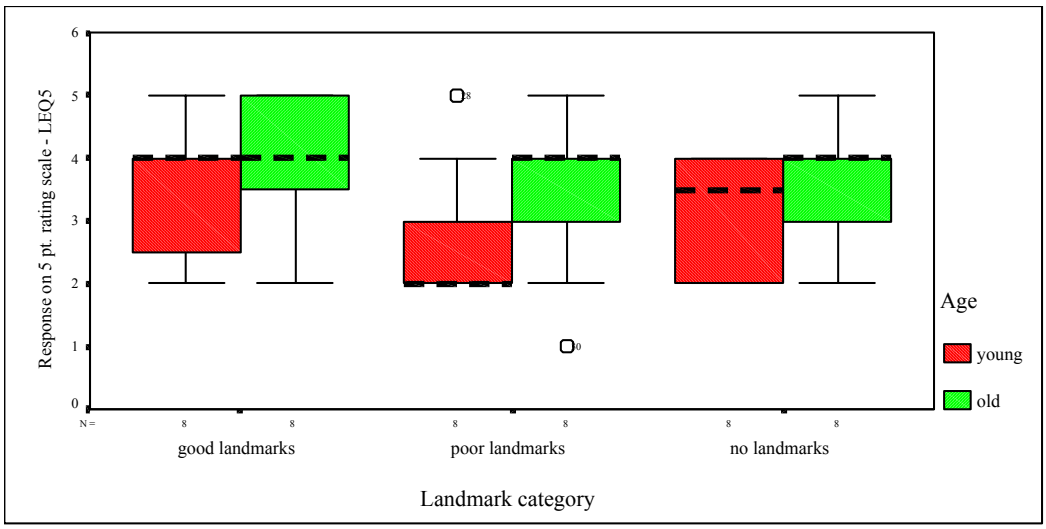
Graph 85. LEQ2 - The navigation system always did what I expected



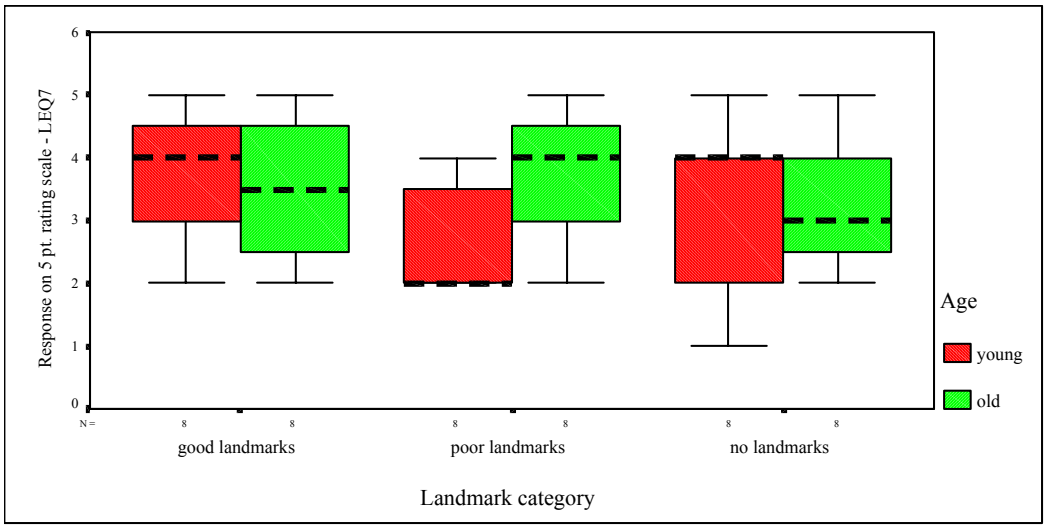
Graph 86. LEQ3 - I liked the visual display for the navigation system



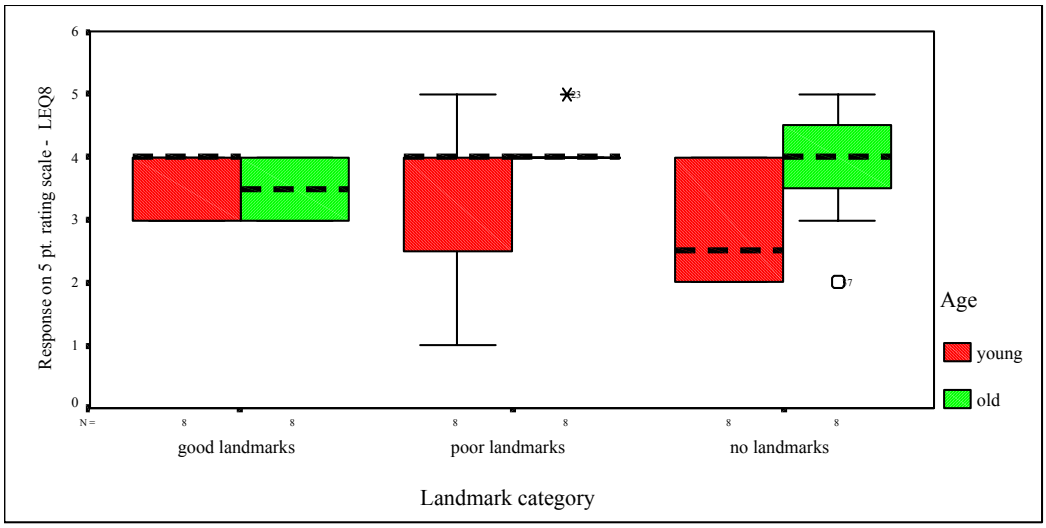
Graph 87. LEQ4 - The navigation system had an overall feeling of 'quality'



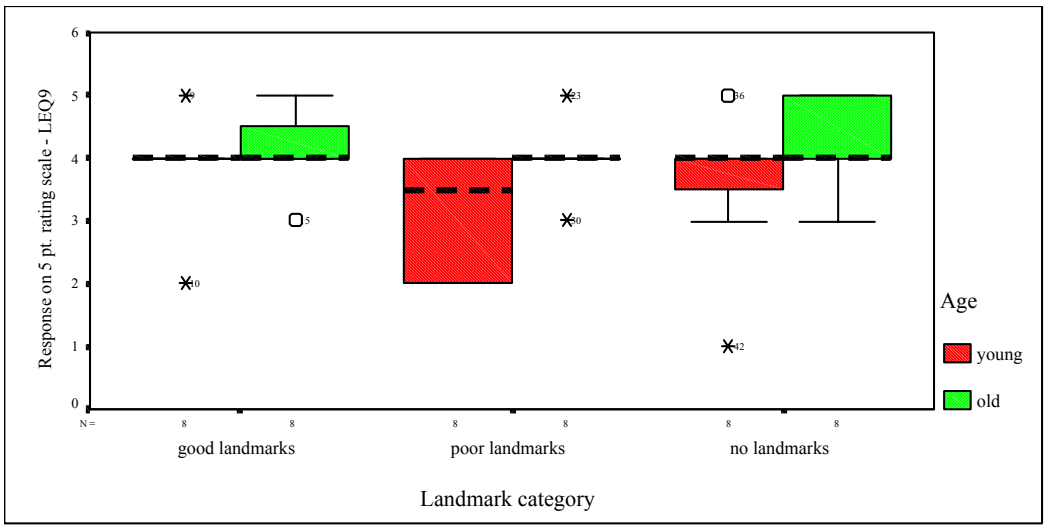
Graph 88. LEQ5 - A navigation system is an easy method of finding my way in an unfamiliar area



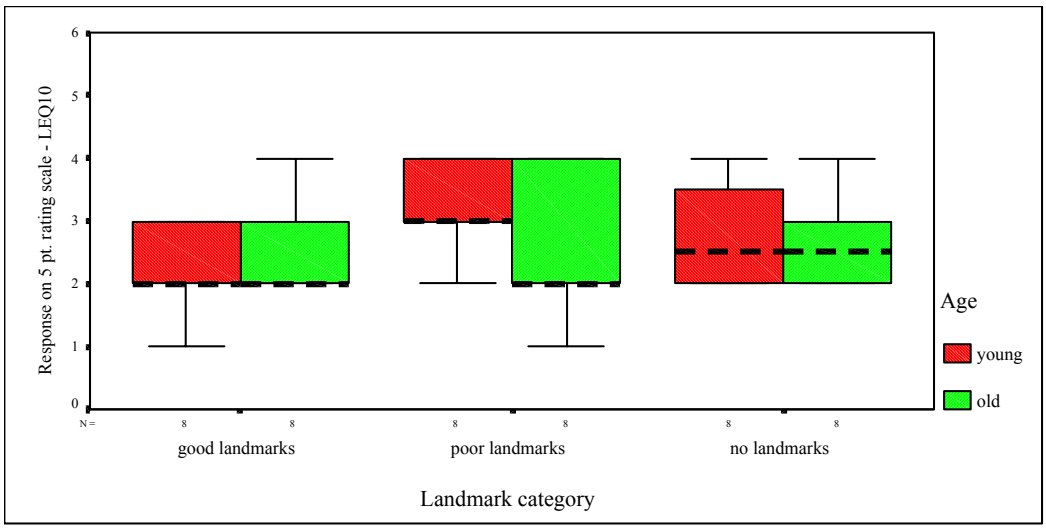
Graph 89. LEQ7 - I would prefer using a navigation system to my usual way of navigating in a car



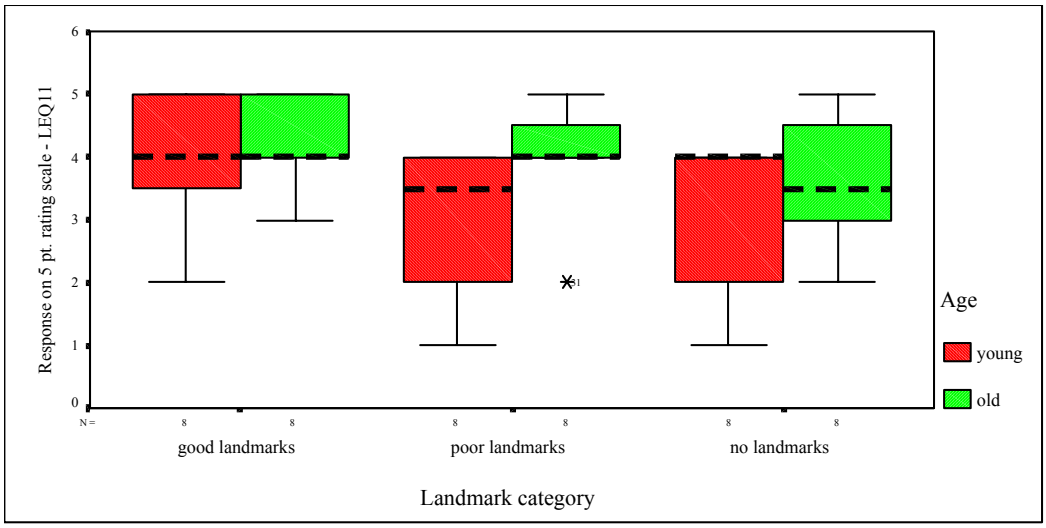
Graph 90. LEQ8 - The navigation system seemed to operate consistently



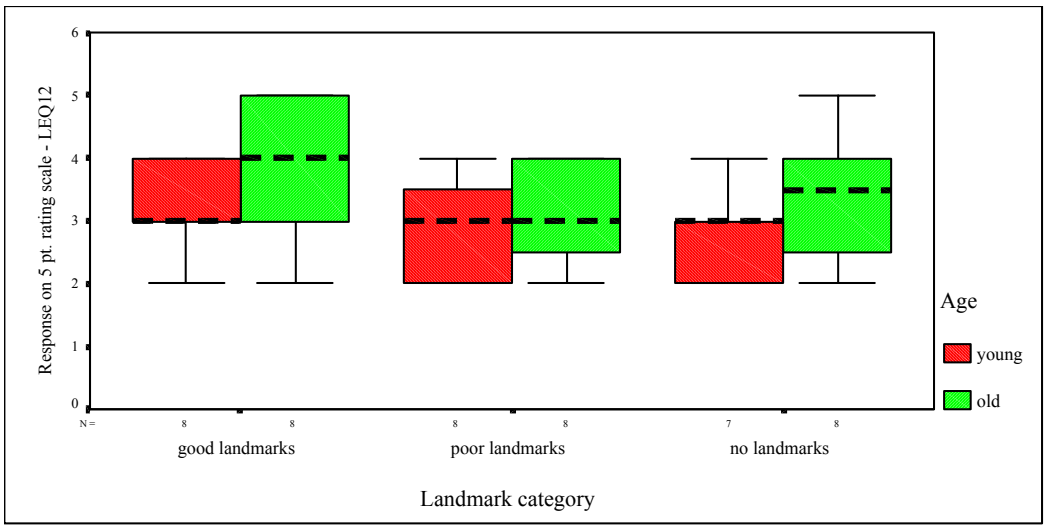
Graph 91. LEQ9 - I am looking forward to using a navigation system (again)



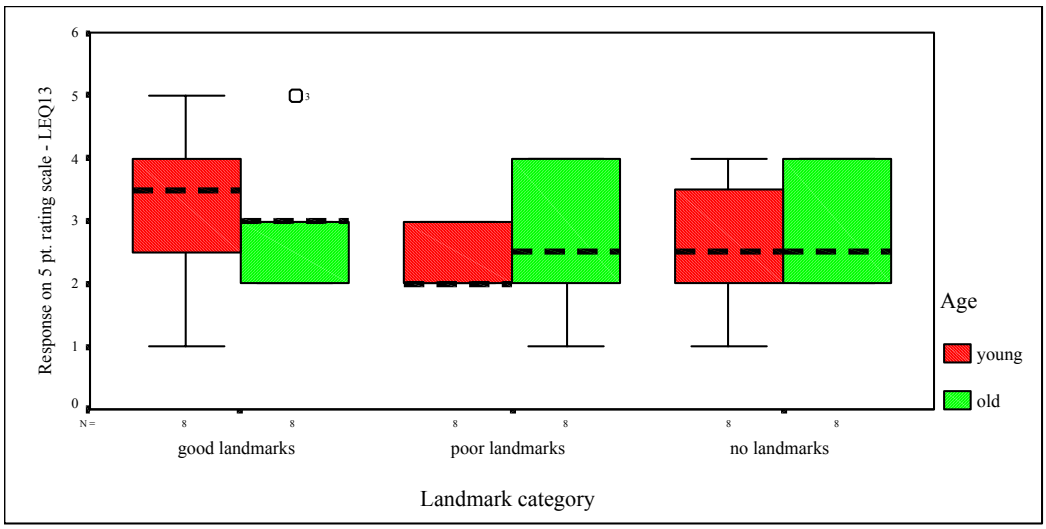
Graph 92. LEQ10 - Using the navigation system makes driving more difficult



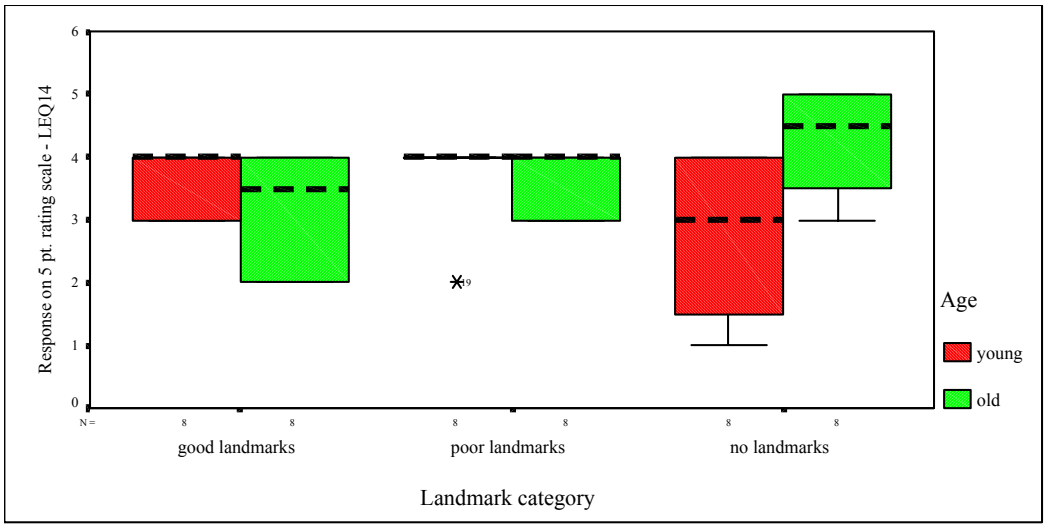
Graph 93. LEQ11 - With a navigation system, I think I would be less likely to get lost



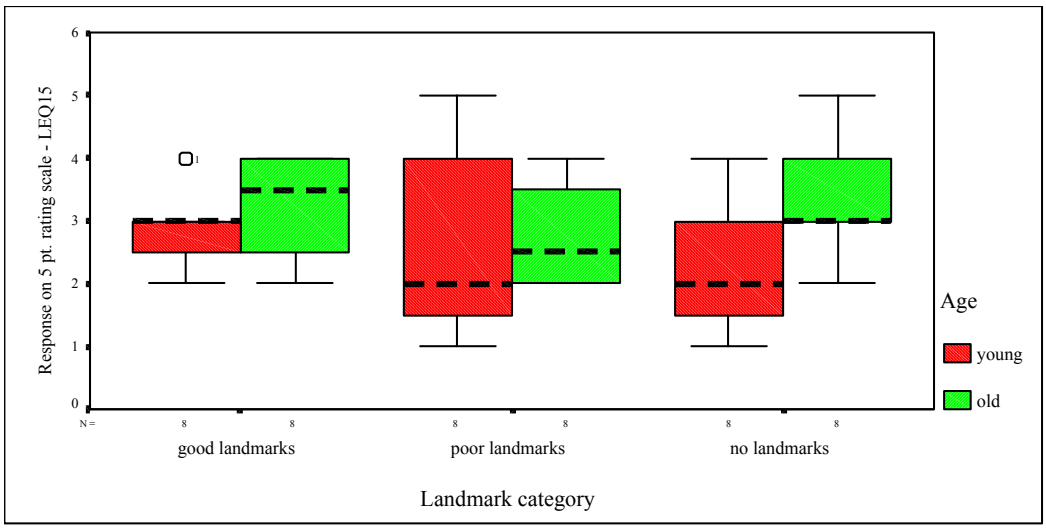
Graph 94. LEQ12 - The navigation system exceeded my expectations



Graph 95. LEQ13 - A navigation system reduces the amount of stress during driving



Graph 96. LEQ14 - I liked the voice instructions from the navigation system



Graph 97. LEQ15 - The information from the navigation system was always easy to understand

A Kruskal-Wallis test for 3 independent samples (LANDMARK condition: good, poor or none) was applied to the results for each of questions LE Q1 to LE Q15. This test was significant for Question 2 "The navigation system always did what I expected": there was a significant effect of LANDMARK condition ($\chi^2 = 6.637$, df = 2, $p = .036$). The mean rankings for Question 2 were: good landmarks 31.25; poor landmarks 22.53; no landmarks 19.72.

The results for all other questions within the Limited Exposure Questionnaire were insignificant for LANDMARK condition

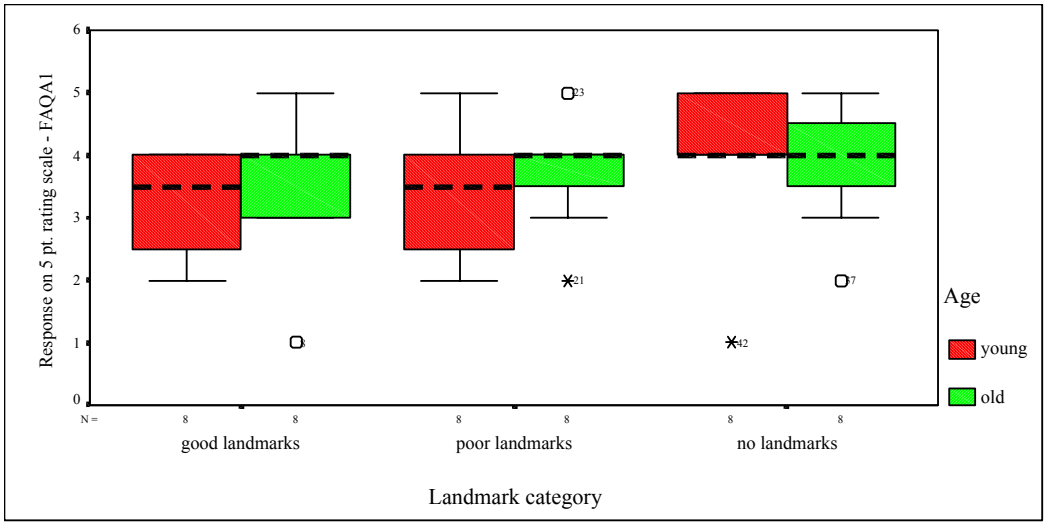
11.3 Final Acceptance Questionnaire Part A (attitudes to system use)

The following graphs present box plots of the results from the 26 questions within the Final Acceptance Questionnaire Part A, split by LANDMARK condition, and participant AGE.

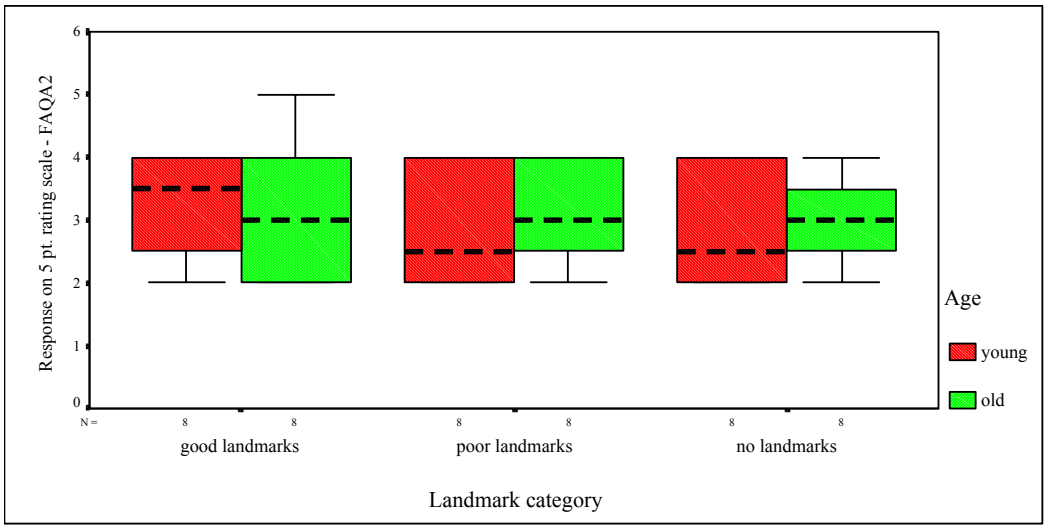
Note that a box plot is a summary plot based on the median, quartiles, and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A dashed line across the box indicates the median.

All responses are on 5-point scale, indicating agreement with the specified statement as follows:

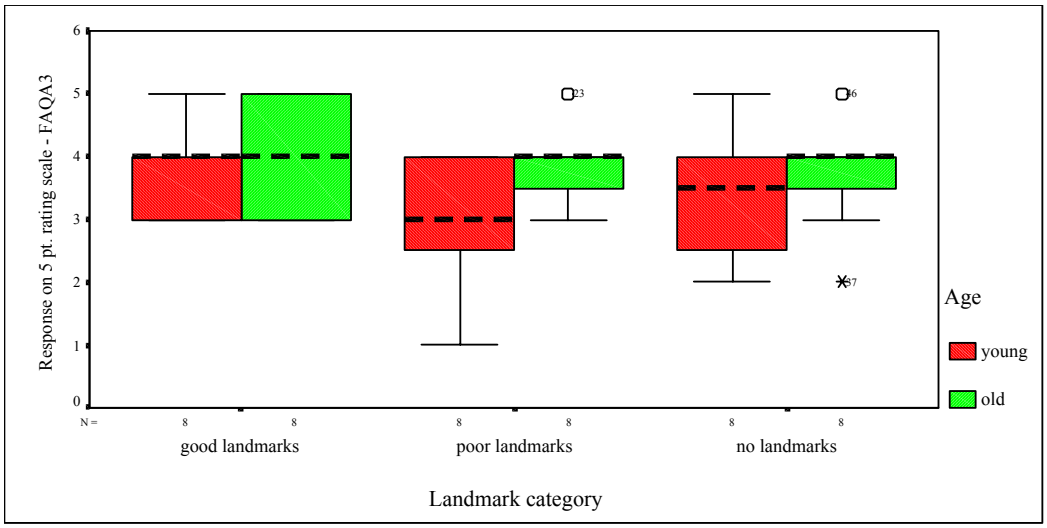
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5



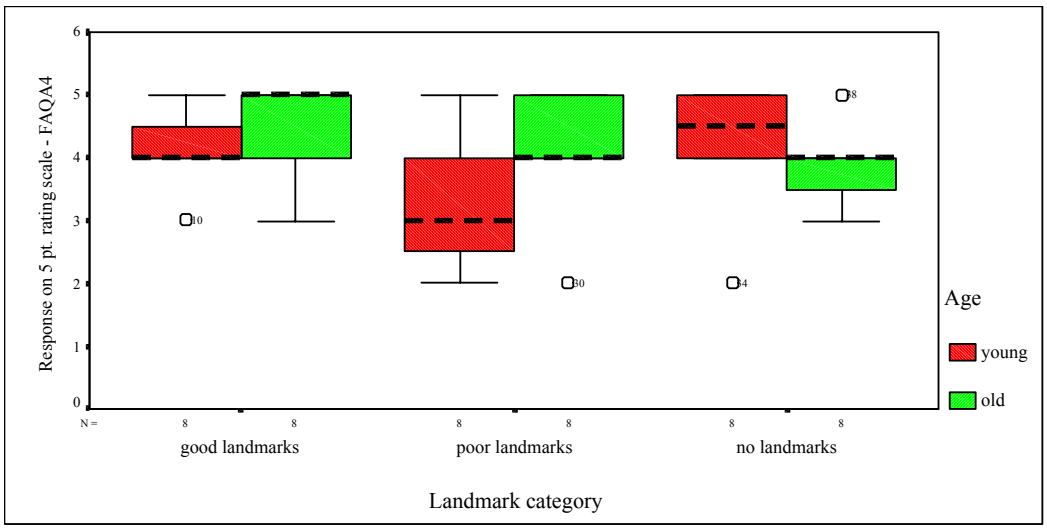
Graph 98. FAQA1 - Using a navigation system is a fun way of navigating



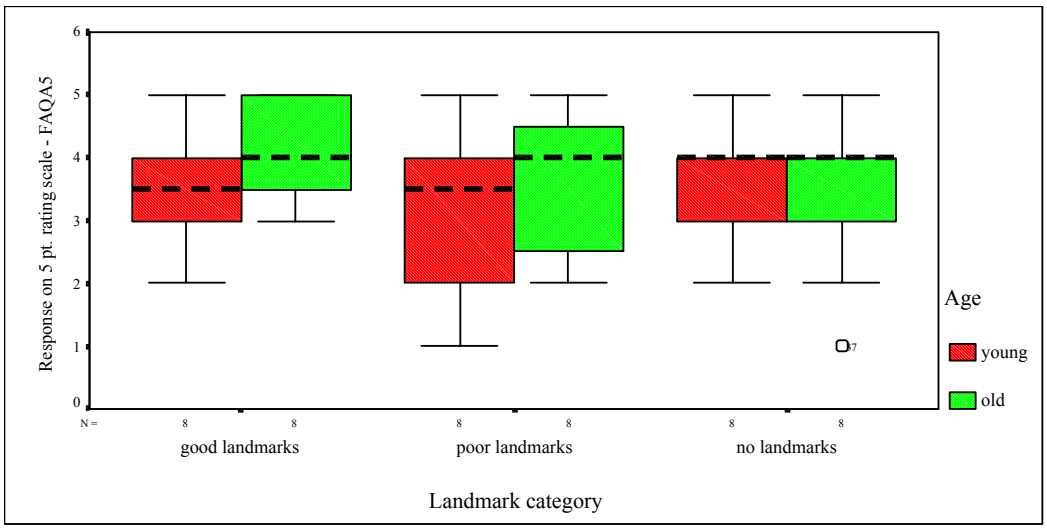
Graph 99. FAQA2 - The way the navigation system worked fitted in with how I would normally navigate



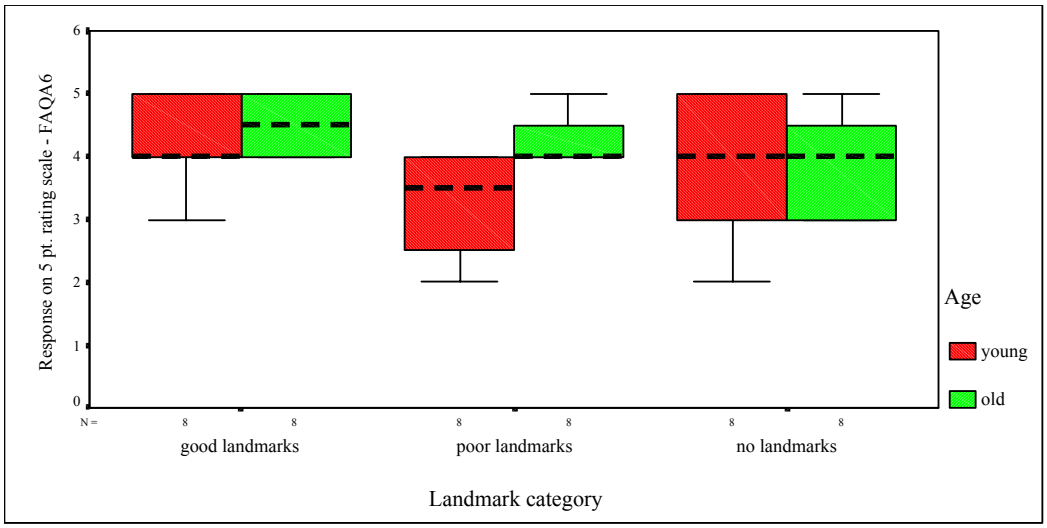
Graph 100. FAQA3 - The navigation system had an overall feeling of 'quality'



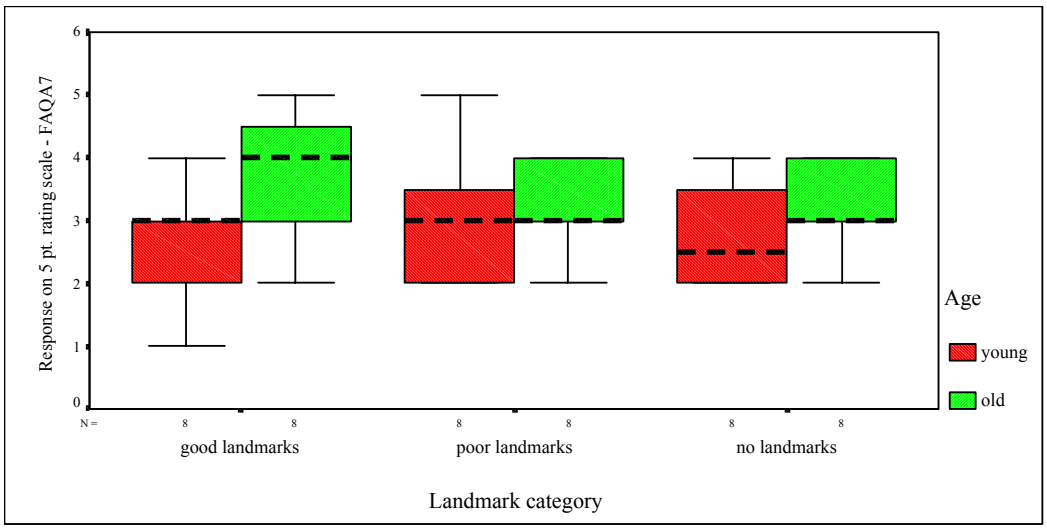
Graph 101. FAQA4 - A navigation system is an easy method of finding my way in an unfamiliar area



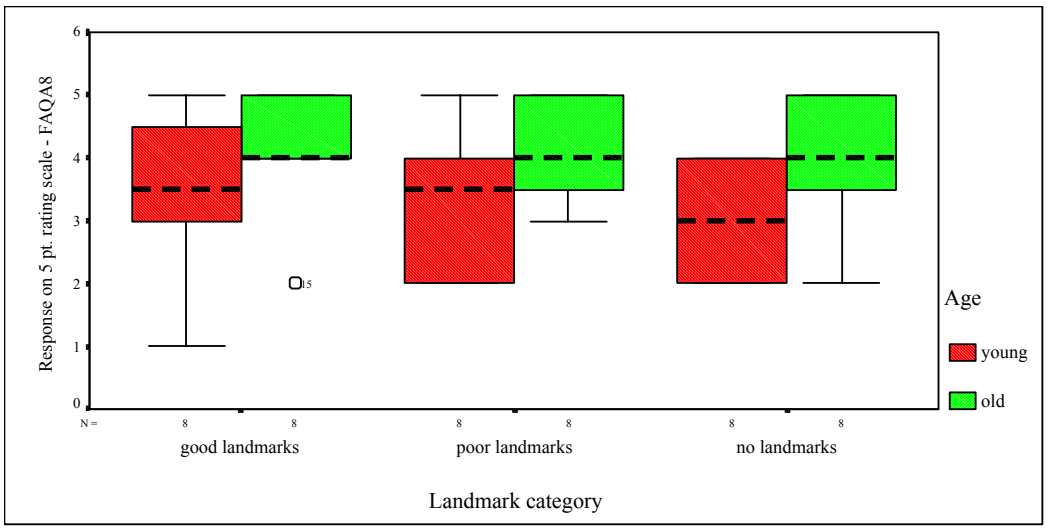
Graph 102. FAQA5 - I always trusted the navigation system to give me the right instructions



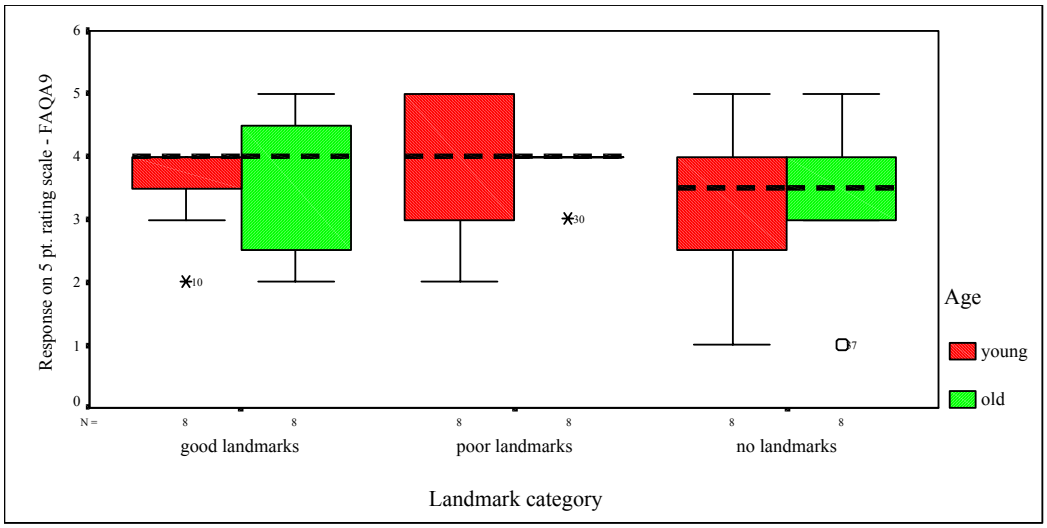
Graph 103. FAQA6 - With a navigation system, I think I would be less likely to get lost



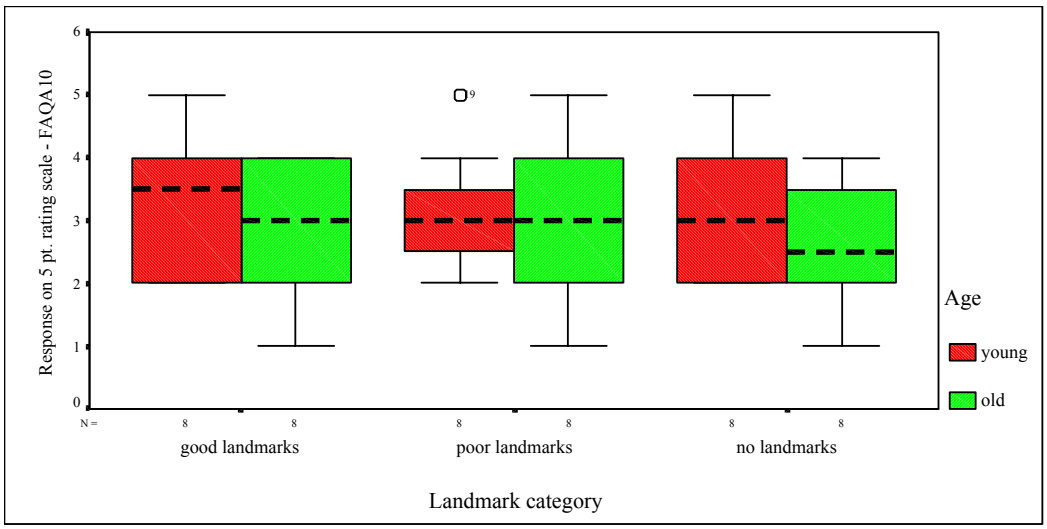
Graph 104. FAQA7 - The navigation system always did what I expected



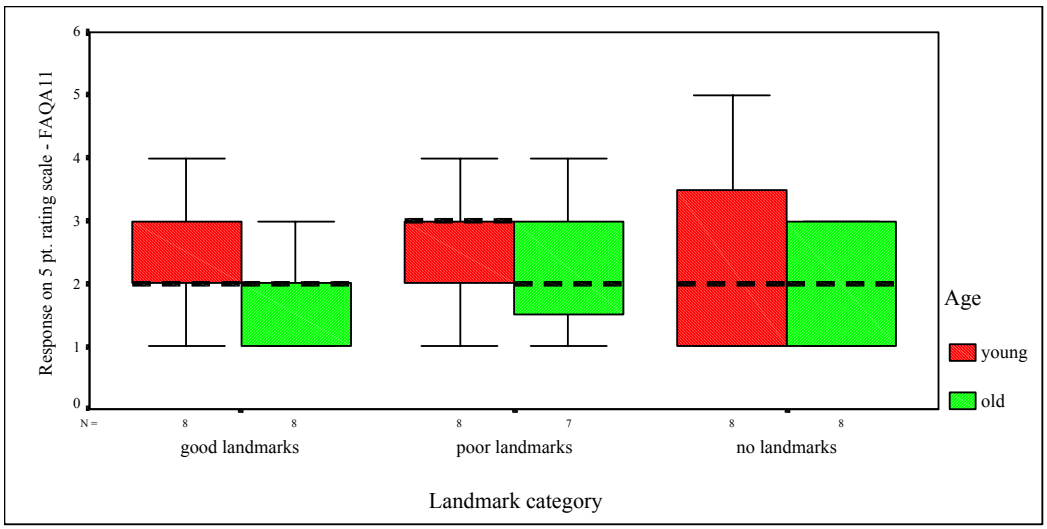
Graph 105. FAQA8 - I always paid attention to the road when driving round the route



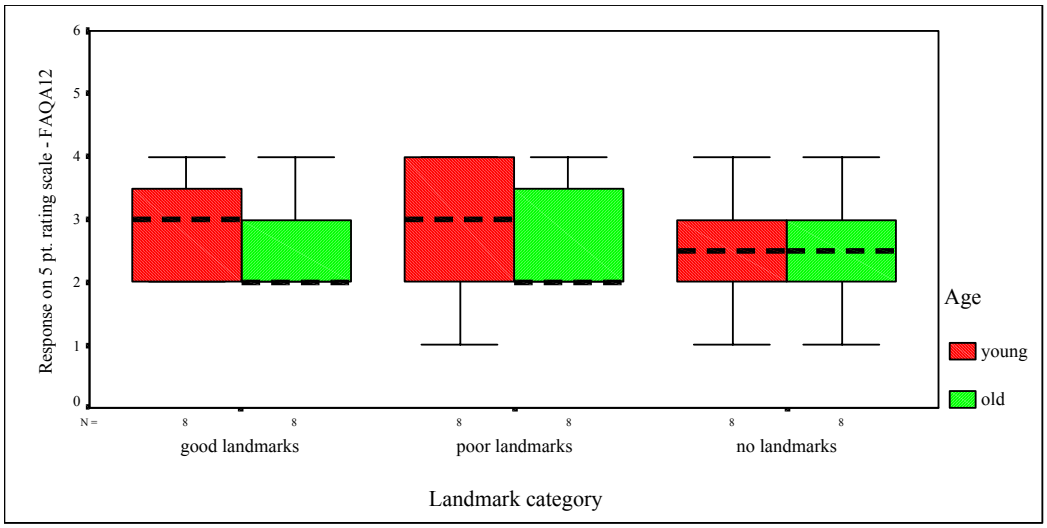
Graph 106. FAQA9 - I liked the visual display for the navigation system



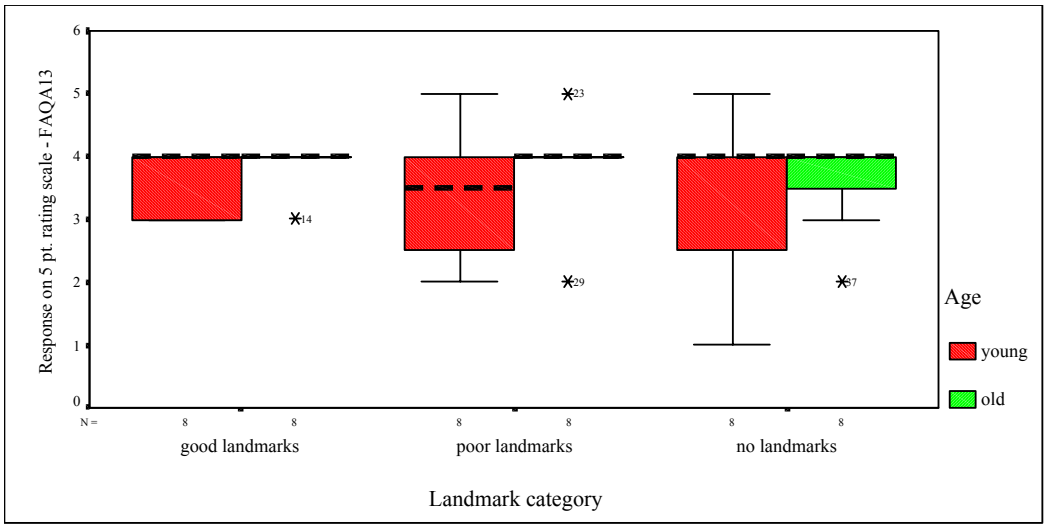
Graph 107. FAQA10 - I found using the navigation system distracted me whilst driving



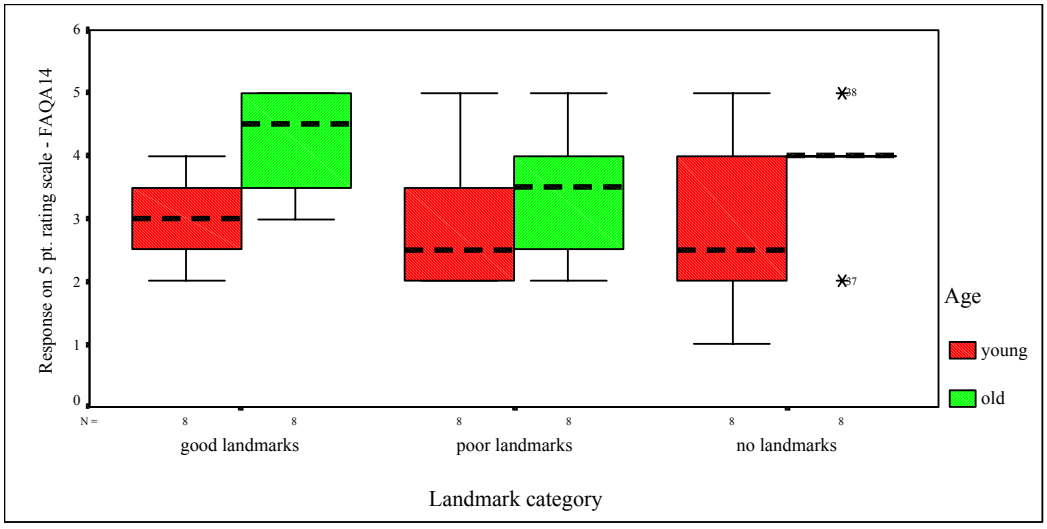
Graph 108. FAQA11 - I found it frustrating using the navigation system



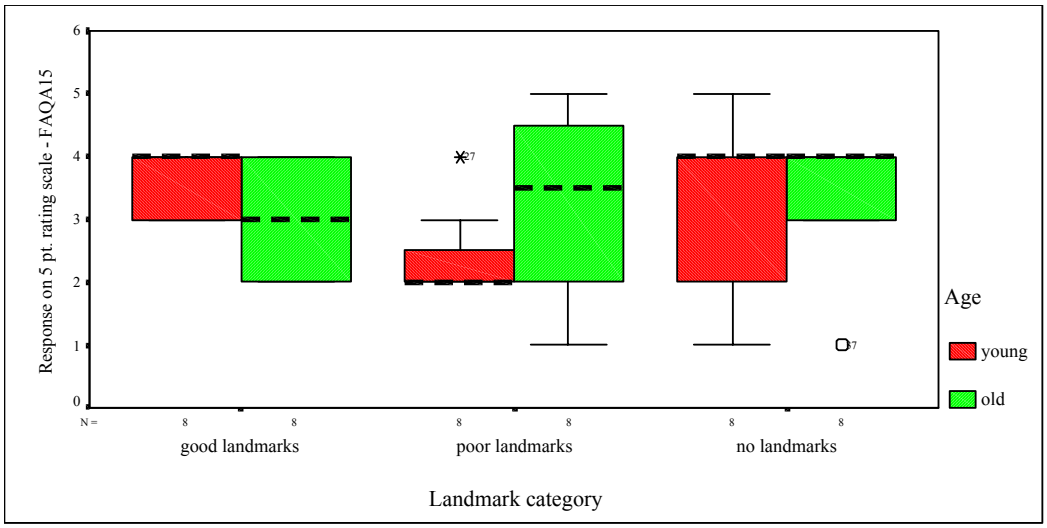
Graph 109. FAQA12 - I sometimes got messages from the navigation system that I was not expecting



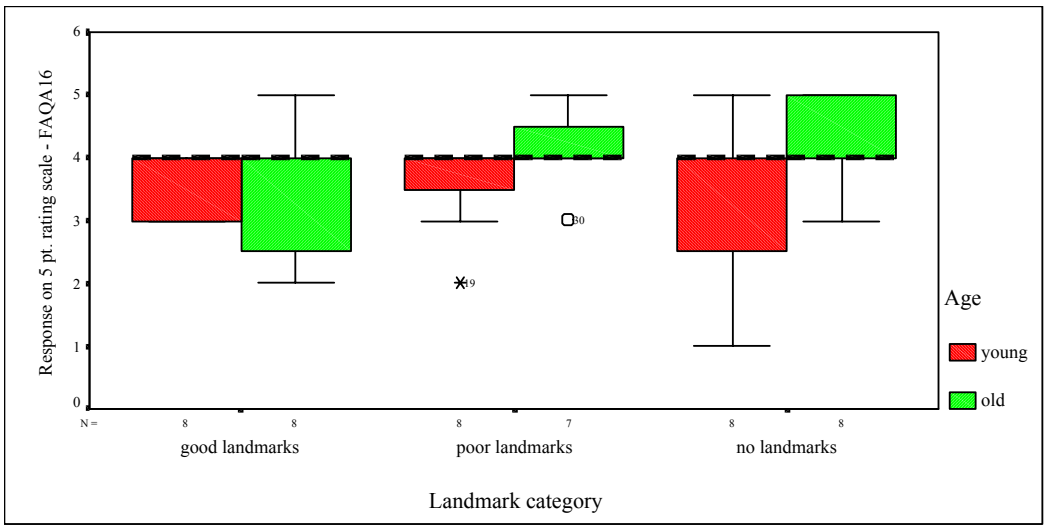
Graph 110. FAQA13 - The navigation system seemed to operate consistently



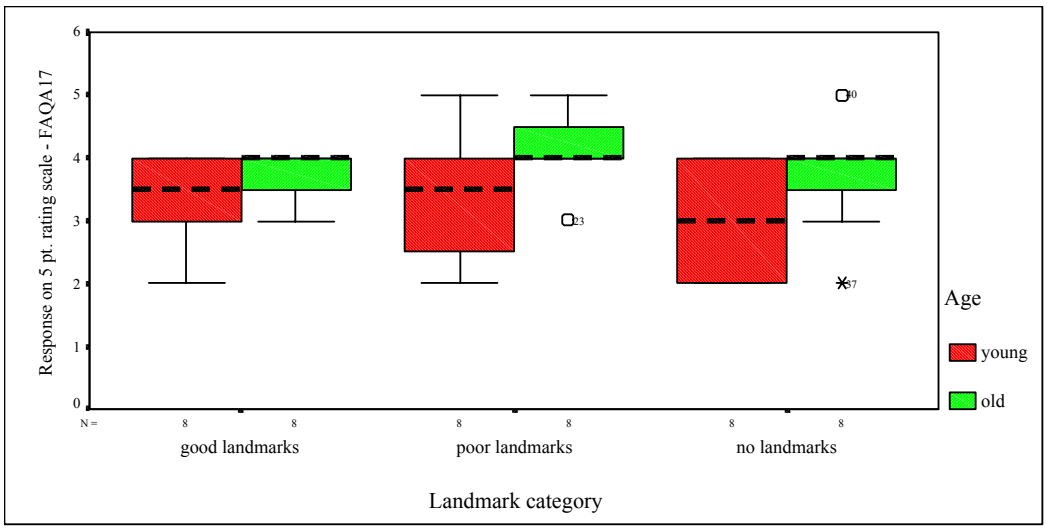
Graph 111. FAQA14 - The navigation system exceeded my expectations



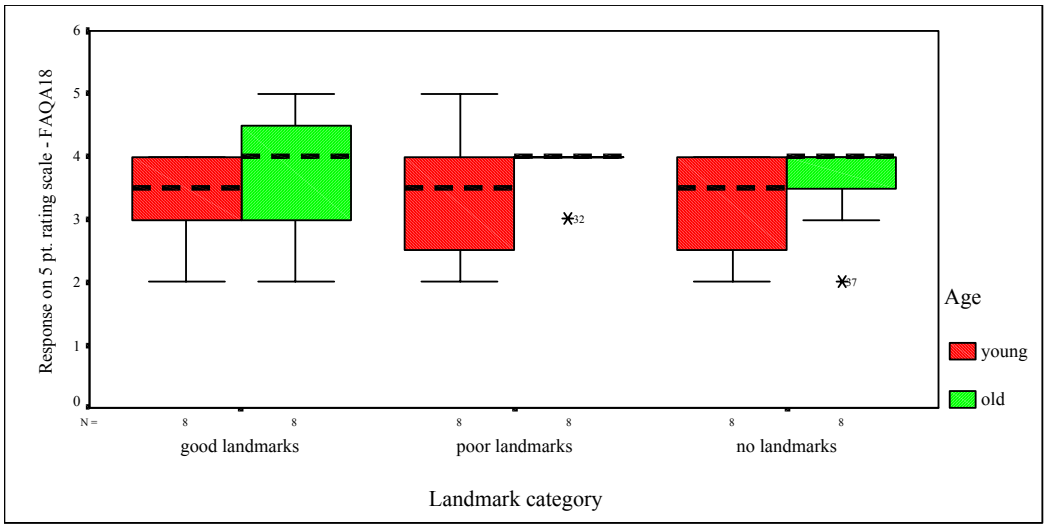
Graph 112. FAQA15 - A navigation system reduces the amount of stress during driving



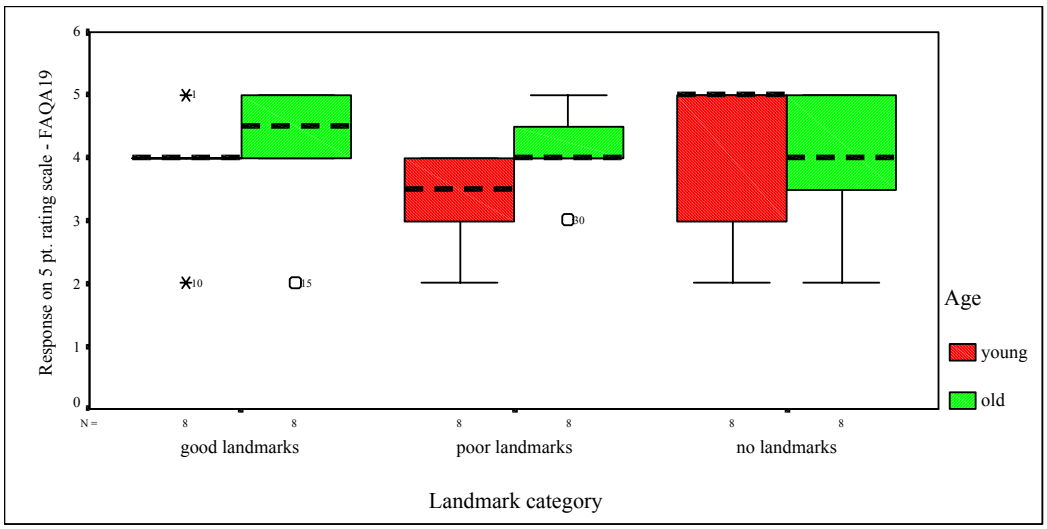
Graph 113. FAQA16 - I liked the voice instructions from the navigation system



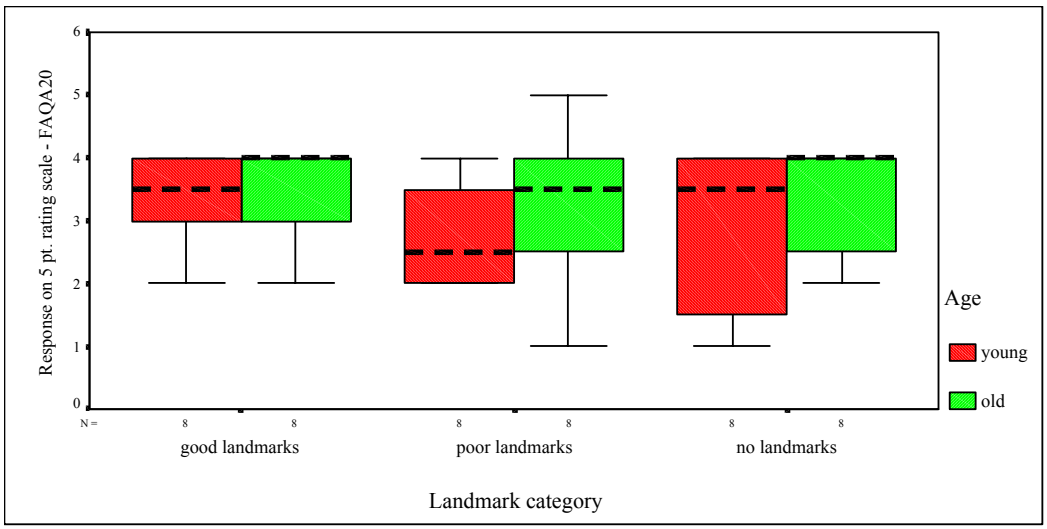
Graph 114. FAQA17 - I always thought the navigation system was working properly



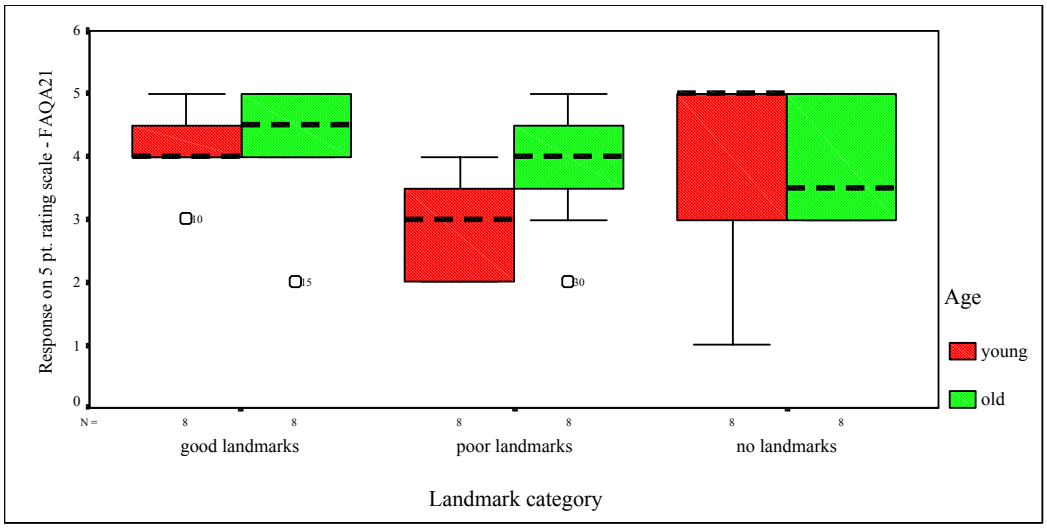
Graph 115. FAQA18 - I drove safely at all times when driving round the route



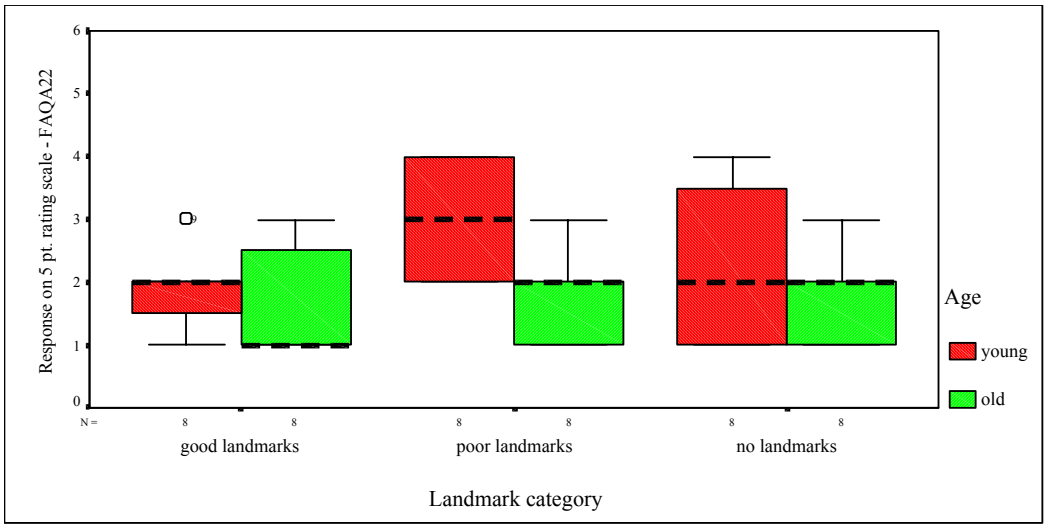
Graph 116. FAQA19 - I am looking forward to using a navigation system (again)



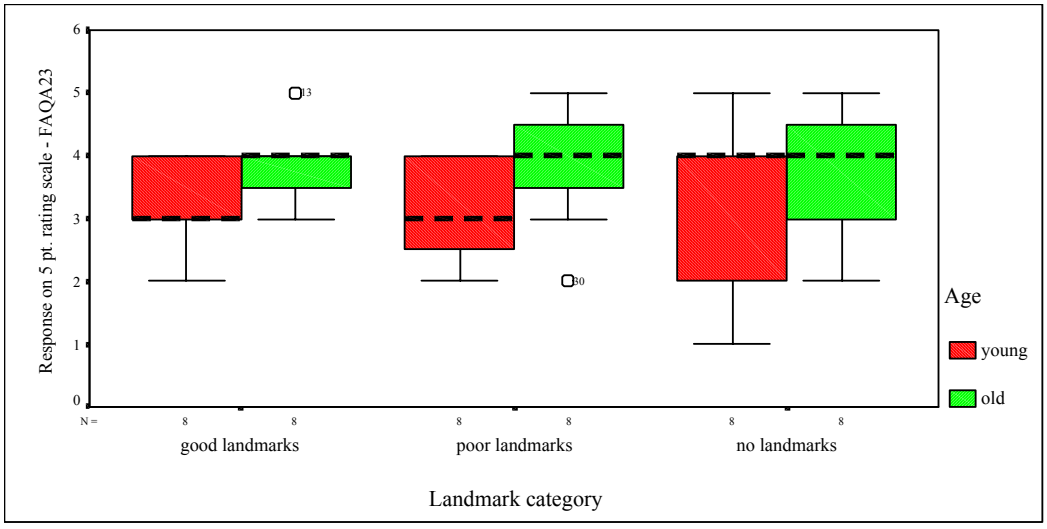
Graph 117. FAQA20 - Using the navigation system felt like a 'natural' thing to do



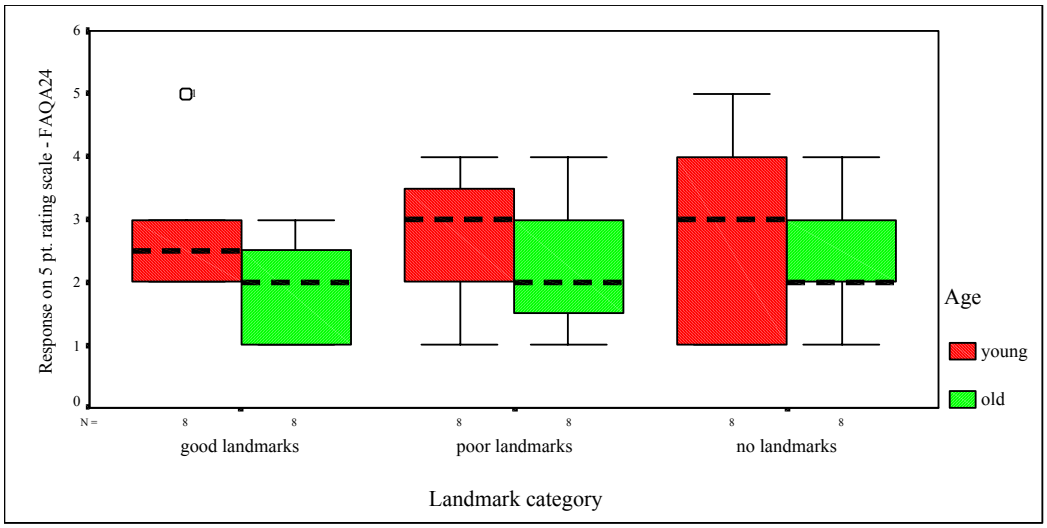
Graph 118. FAQA21 - I would prefer using a navigation system to my usual way of navigating in a car



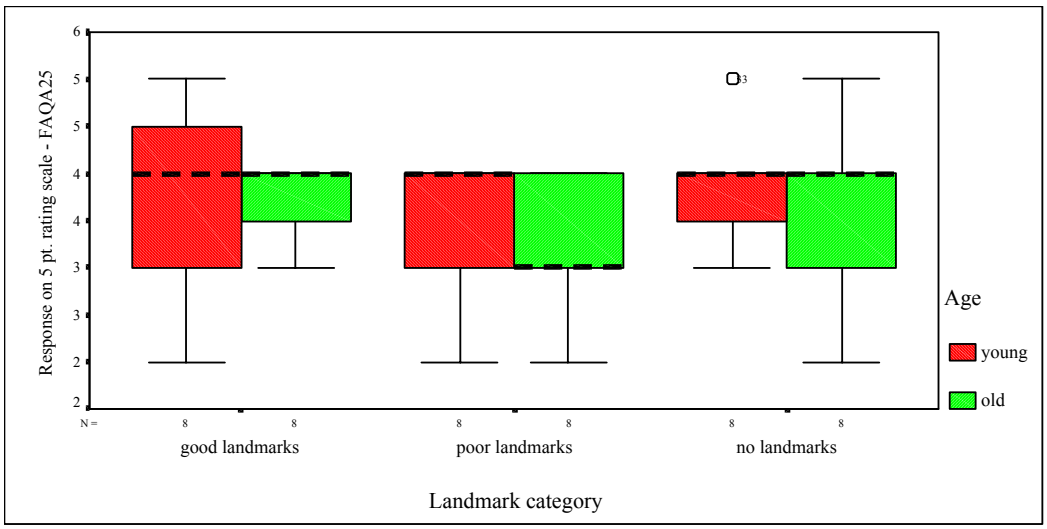
Graph 119. FAQA22 - I am disappointed with the performance of the navigation system



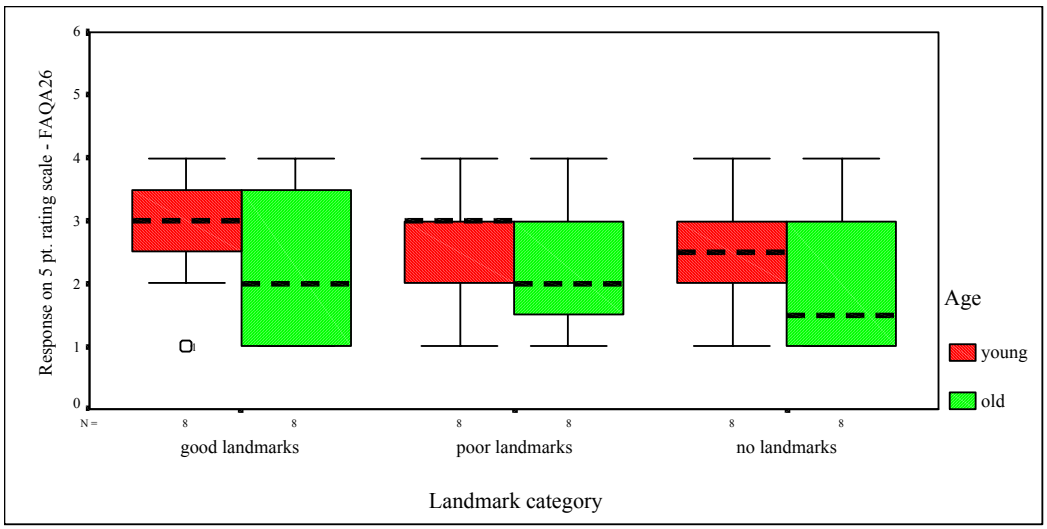
Graph 120. FAQA23 - I felt happy when I was using the navigation system



Graph 121. FAQA24 - Using the navigation system makes driving more difficult



Graph 122. FAQA25 - I looked at the display a lot when I was driving round the route



Graph 123. FAQA26 - At the end of the drive, I felt relieved that the ordeal was over

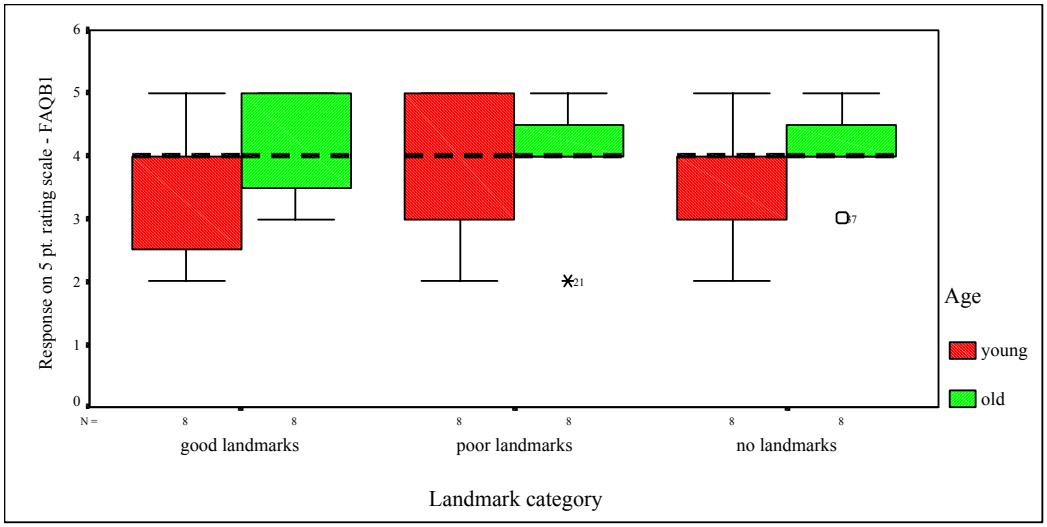
11.4 Final Acceptance Questionnaire Part B (attitudes to system design)

The following graphs present box plots of the results from the 11 questions within the Final Acceptance Questionnaire Part B, split by LANDMARK condition, and participant AGE.

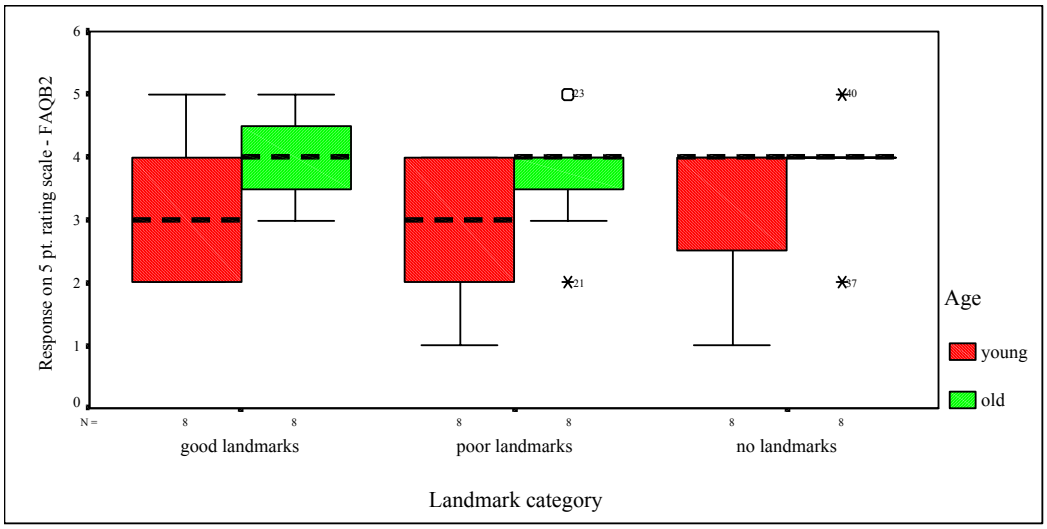
Note that a box plot is a summary plot based on the median, quartiles, and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A dashed line across the box indicates the median.

All responses are on 5-point scale, indicating agreement with the specified statement as follows:

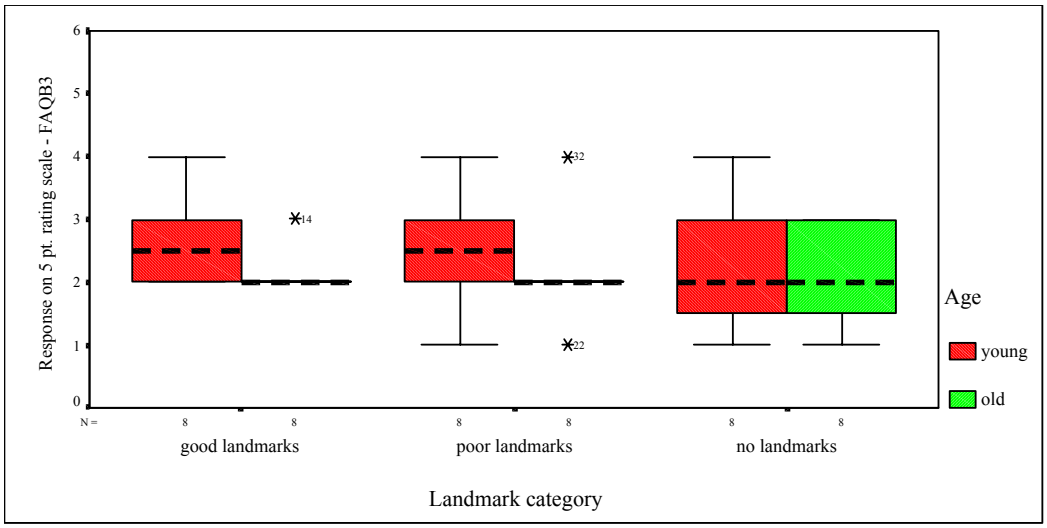
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5



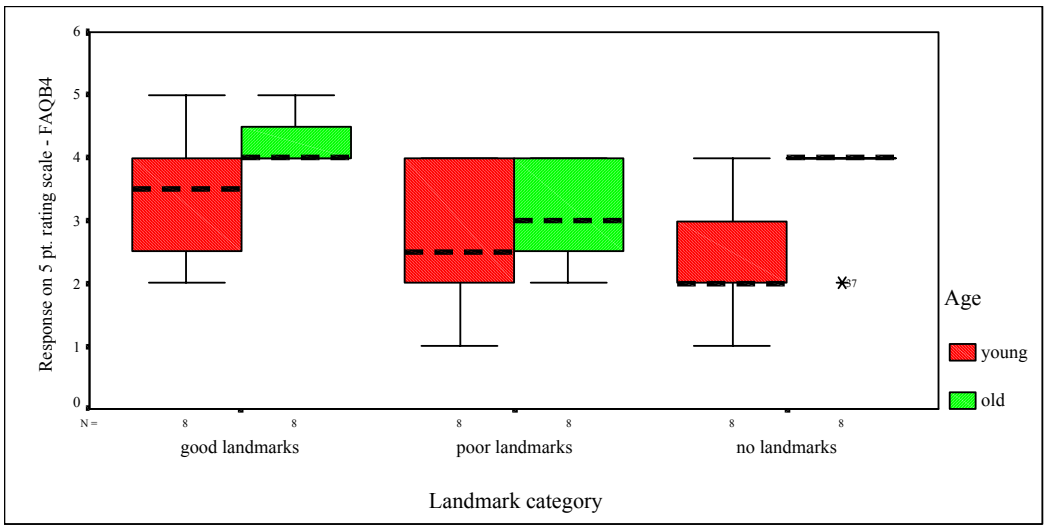
Graph 124. FAQB1 - The distance countdown bar told me exactly where I needed to turn



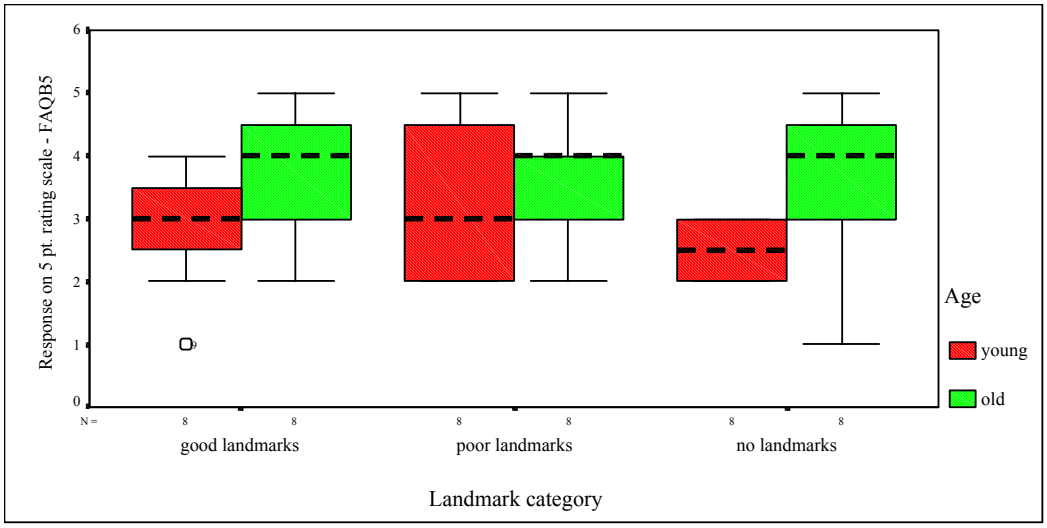
Graph 125. FAQB2 - The information from the navigation system was always accurate



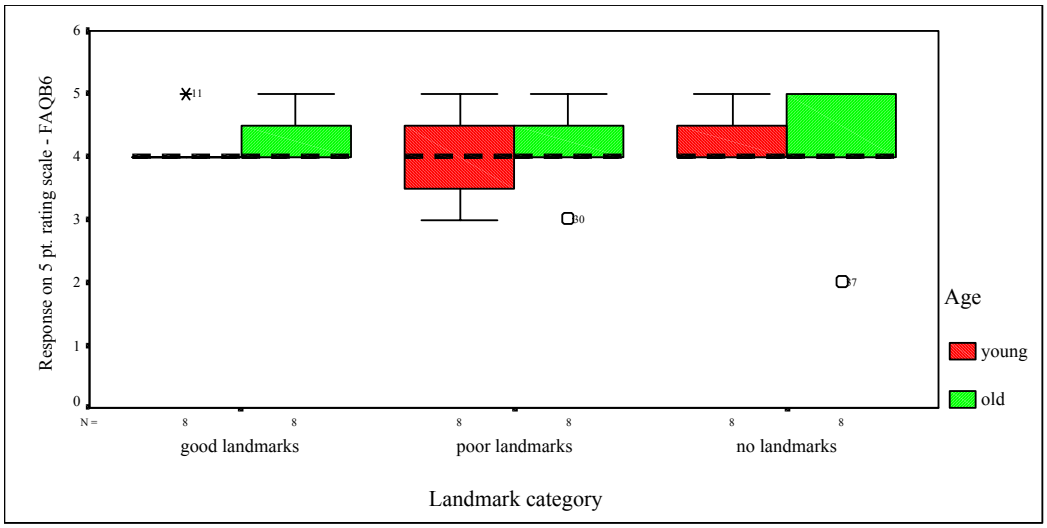
Graph 126. FAQB3 - The navigation system gave me too much information



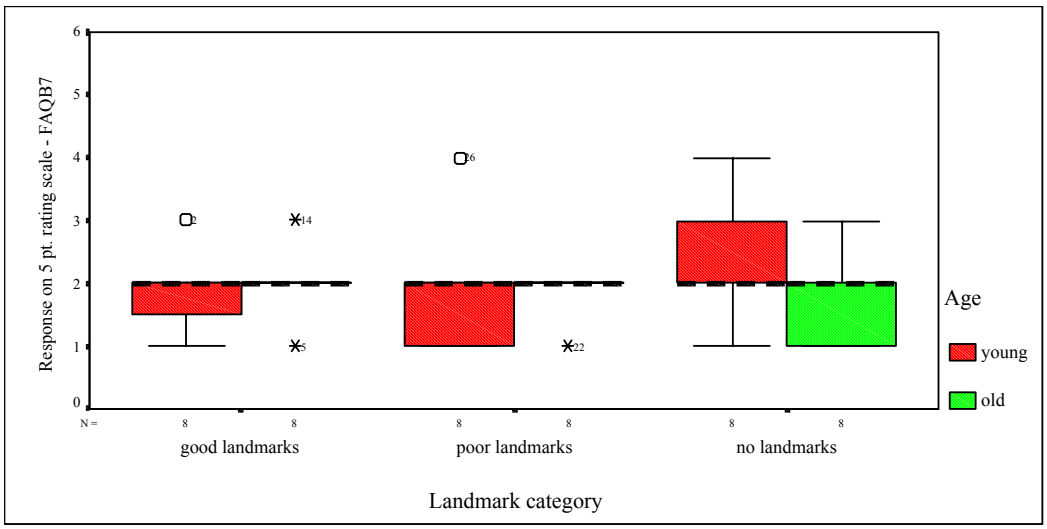
Graph 127. FAQB4 - The navigation system always gave me information when I needed it



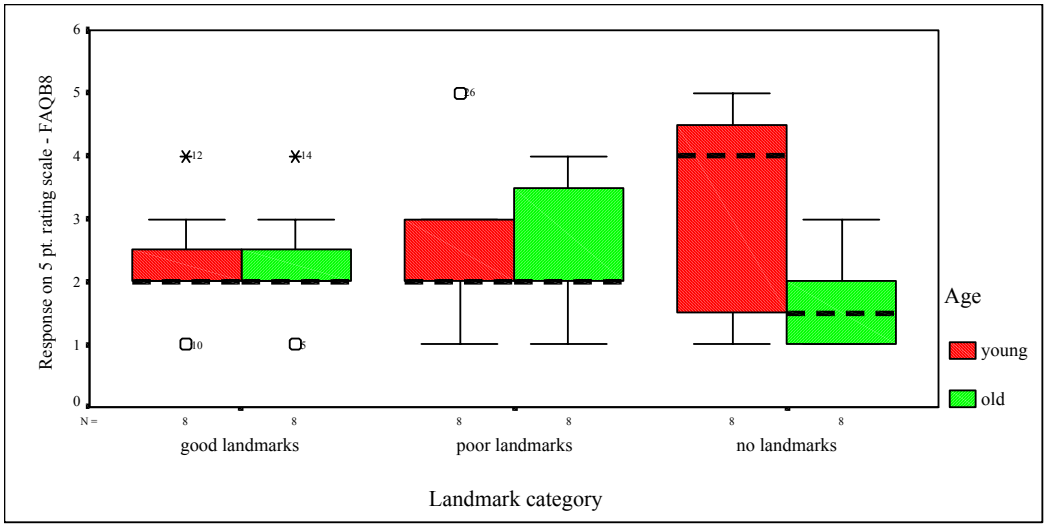
Graph 128. FAQB5 - The map overview told me exactly where I needed to turn



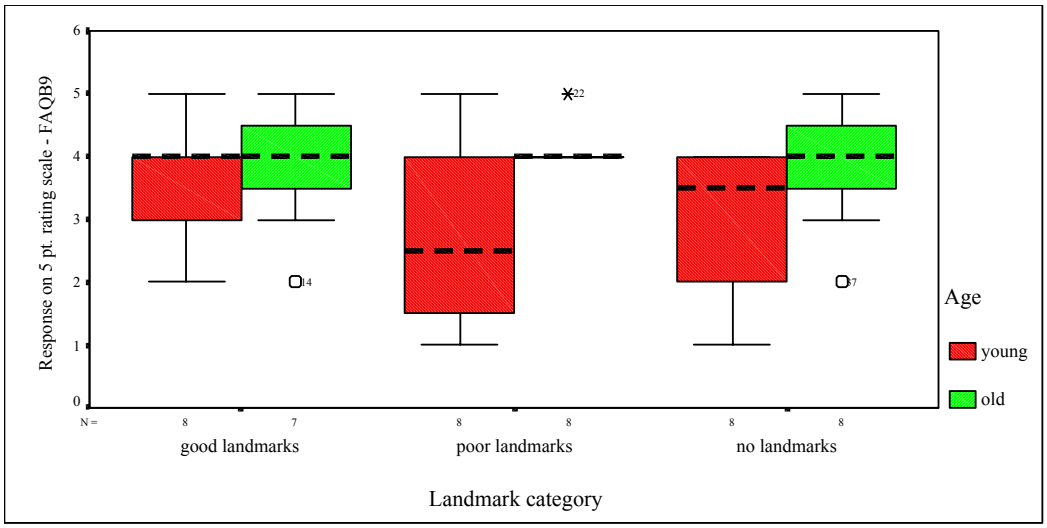
Graph 129. FAQB6 - I listened carefully to the voice messages when driving round the route



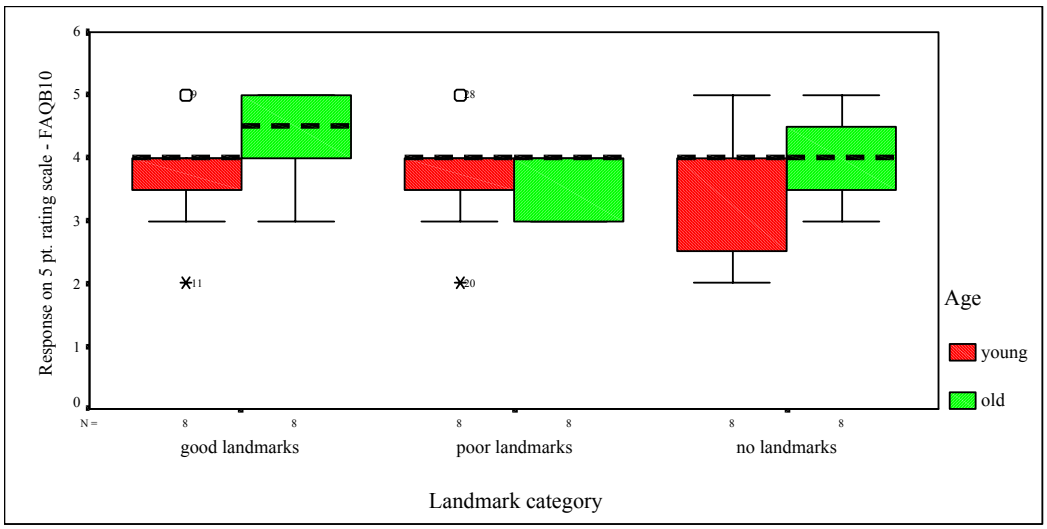
Graph 130. FAQB7 - The navigation system usually gave me information too late



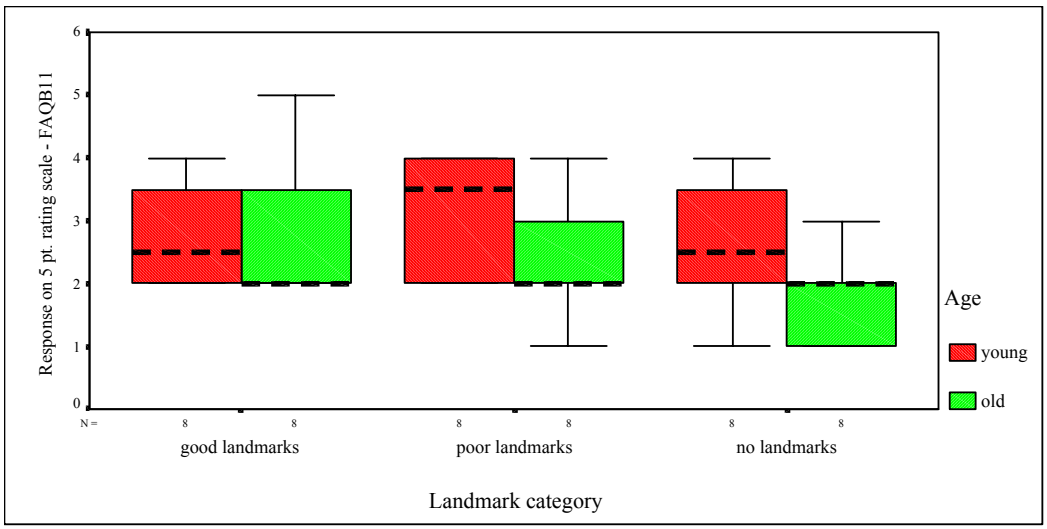
Graph 131. FAQB8 - The navigation system did not give me enough information



Graph 132. FAQB9 - The voice messages told me exactly where I needed to turn



Graph 133. FAQB10 - The diagram of each junction help me identify where to turn



Graph 134. FAQB11 - The navigation system usually gave me information too early

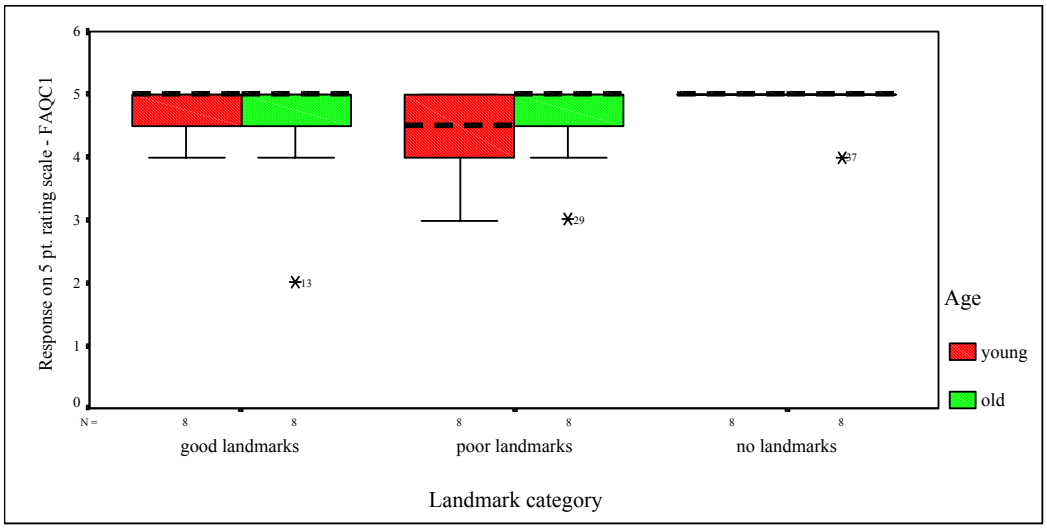
11.5 Final Acceptance Questionnaire Part C (usefulness of information)

The following graphs present box plots of the results from the 5 questions within the Final Acceptance Questionnaire split by LANDMARK condition, and participant AGE.

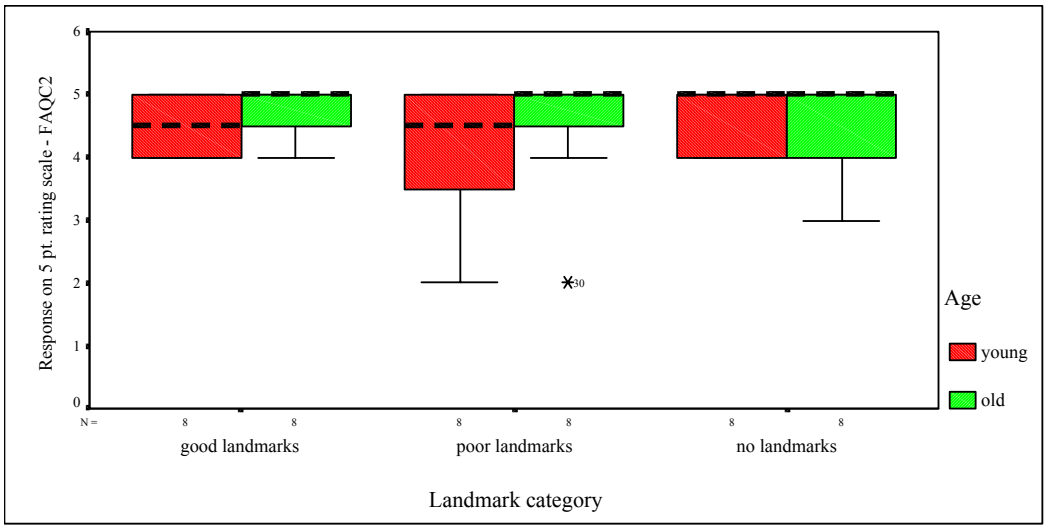
Note that a box plot is a summary plot based on the median, quartiles, and extreme values. The shaded box represents the interquartile range, which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A dashed line across the box indicates the median.

Participants were asked to indicate how useful different information elements were. The rating scale used for this section was the following.

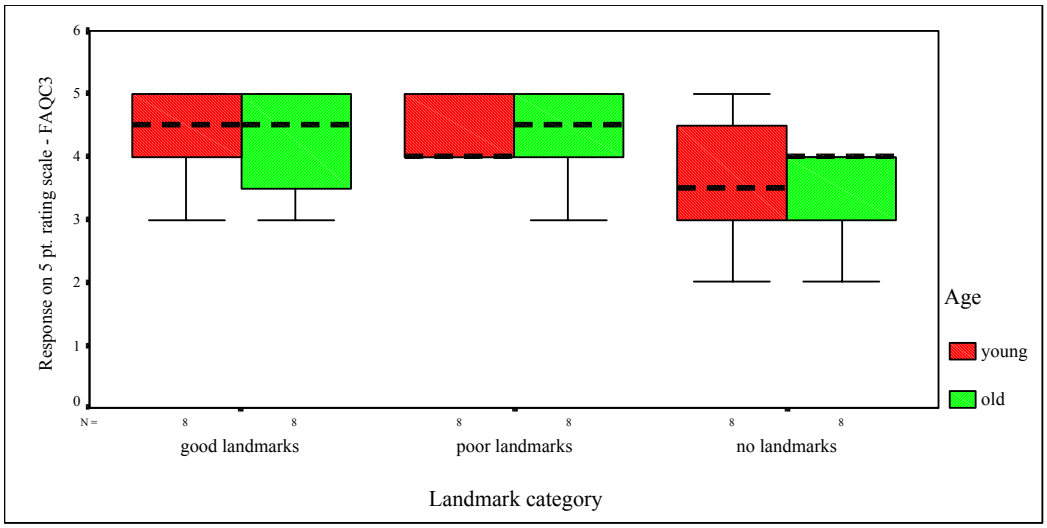
Not at all useful	Not very useful	Neutral	Quite useful	Very useful
1	2	3	4	5



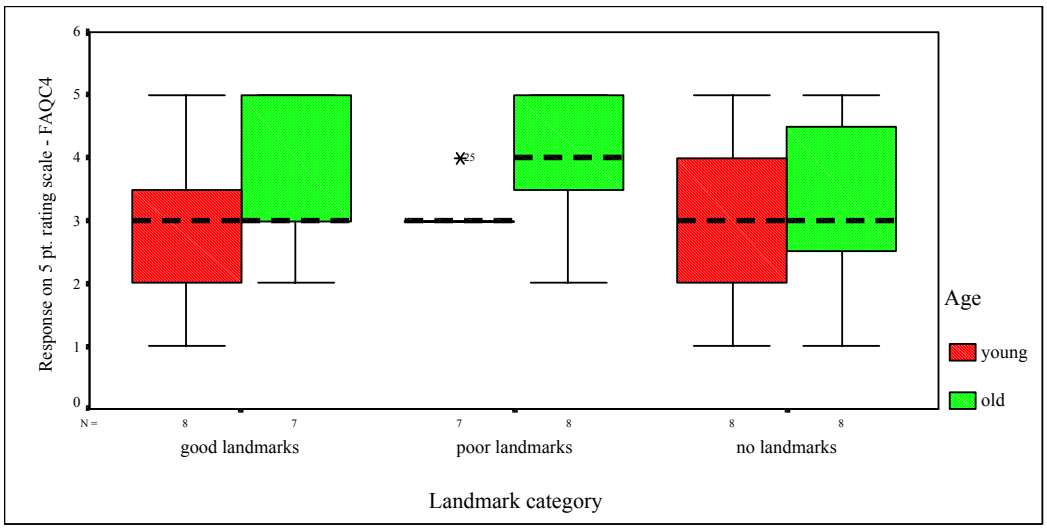
Graph 135. FAQC1 - The distance countdown bar (lhs)



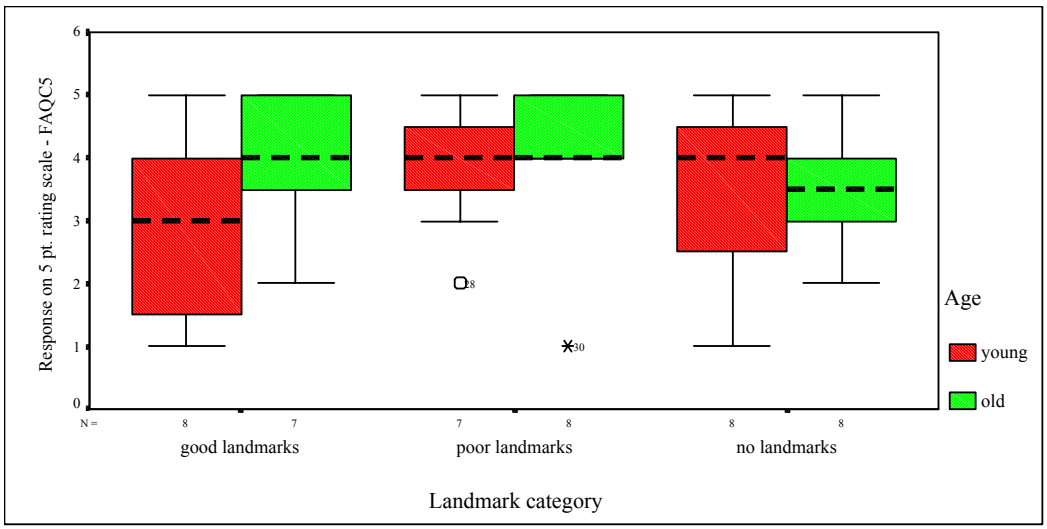
Graph 136. FAQC2 - The voice instructions



Graph 137. FAQC3 - The map overview

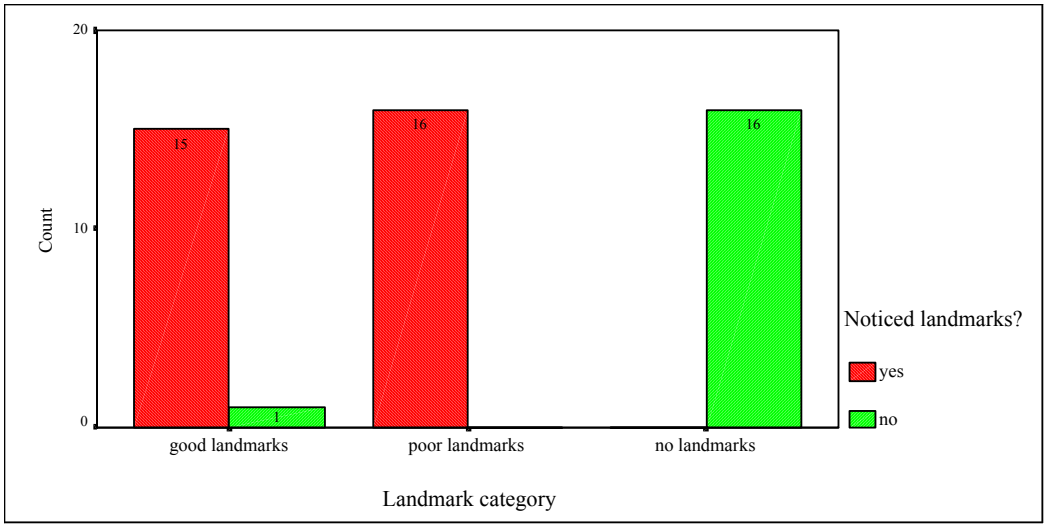


Graph 138. FAQC4 - The distance to destination indicator



Graph 139. FAQC5 - The road names (top and bottom)

All participants were also asked whether they noticed landmarks being used in the voice instructions. For Good and Poor the answer should have been 'yes', for No Landmarks it should have been 'no'



Graph 140. Did you notice that the navigation system used landmarks in its voice instructions?

11.6 Final Acceptance Questionnaire – statistical analysis

A Kruskal-Wallis test for 3 independent samples (LANDMARK condition: good, poor or none) was applied to the results for each of questions FAQA1 to FAQC5.

There was a significant effect of LANDMARK condition for question FAQB4 'The navigation system always gave me information when I needed it' ($\chi^2 = 6.475$, df = 2, $p = .039$), mean rankings: good landmarks 31.09; poor landmarks 20.09; no landmarks 22.31.

There was a significant effect of LANDMARK condition for question FAQC5 'How useful were the road names? Not at all useful – Very useful scale': ($\chi^2 = 7.551$, df = 2, $p = .023$), mean rankings good landmarks 21.70; poor landmarks 27.17; no landmarks 21.75.

The results for all other questions within the Final Acceptance Questionnaire were insignificant for LANDMARK condition.

11.7 Final Acceptance Questionnaire - qualitative results

Subject responses to the qualitative/free response section to the questionnaire were content analysed and results presented in this section. For each question, a frequency count was calculated according to participant group, and either the system feature being commented on (FAQD1 to 3), or whether positive or negative views were expressed (FAQD5).

FAQD1: Was there anything about the navigation system (e.g. the way it worked, what information it provided, when it gave you instructions) that you particularly *liked*?

	What referred to / instances of					
	Landmarks	Instructions	Distance countdown bar	Display overall	Voice	Map
Good LM	2	3	10	2		2
Poor LM		3	5		3	3
No LM		2	9		2	2

Table 12. System features liked by participants

In general participants within the good landmark condition gave positive feedback on the landmarks, voice instructions and distance countdown bar, with the greatest number of comments relating to the distance countdown bar. Typical comments were:

> '[I liked the] use of landmarks i.e. pubs and petrol stations, very reassuring! Overall [I liked] the combination of voice, map and distance countdown.'
>
> 'I used a combination of all things to obtain accuracy in turning. I found the distance to destination particularly useful.'
>
> '[The navigation system] referred to landmarks like real people do, very useful.'
>
> 'The distance countdown bar is very useful.'

Reactions from the poor landmark condition participants were more varied and less positive in general. None of the poor landmarks group stated that they particularly liked the landmarks; the features this group particularly liked were the clarity of the instructions and the distance countdown bar, with typical comments:

> '[The] instructions and countdown bar were most useful, especially in the busier, smaller streets"'.
>
> '[I liked the] countdown bars and map'.
>
> '[I liked it] giving information more than once'.
>
> '[It was] a very good tool to use. I would buy one if the price was right. Very clear and concise'.

Participants in the no landmark condition were generally positive towards the distance countdown information and the voices instructions in general, with typical comments being:

> '[The] countdown bars were very useful'.
>
> '[There were] good clear instructions. Distance countdown excellent idea'.
>
> '[I liked the] voice system, [and the] distance bars'.

FAQD2: Was there anything about the navigation system (e.g. the way it worked, what information it provided, when it gave you instructions) that you particularly *disliked*?

	What refereed to / instances of					
	Landmarks	Instructions	Distance countdown bar	Display overall	Voice	Map
Good LM		3		2	2	4
Poor LM	5	3		1		1
No LM					1	5

Table 13. System features disliked by participants

Negative comments about the navigation system comprised two main themes. The participants who received either good landmarks or no landmarks were critical of the map view given by the system, as this was not always consistent with the actual road layout and the view seen by the driver. In particular, some mini-roundabouts and side roads were not shown which caused some navigation uncertainty. None of the participants in the good landmarks category stated they disliked those landmarks. Typical comments from these two groups were:

> '[There was a] lack of information about mini-roundabouts and one-way [streets]'.
>
> '[The] street plan had roads missing from it, directions were misleading'.
>
> '[The] large scale maps were confusing in residential areas where not all street/roads are indicated'.
>
> '[The map] didn't show side roads"

In contrast, the participants in the poor landmark condition tended to be more critical of those landmarks than the map overview, with difficulties in actually identifying the required turning.

> '[There was] confusion on my part when turning and two roads very close together, no time to read map screen. [I did not like] references to post boxes, telephone boxes an similar items which could be obscured by parked cars.'
>
> '[I did not like] the use of objects such as post boxes that you don't see until the last minute'.
>
> '[I] could not always see where it meant me to turn.'
>
> '[I did not like it] telling me to turn after letter boxes, bridges and pubs that I initially could not see'.

FAQD3: Do you have any suggestions for *improving* the way it worked?

	What refereed to / instances of					
	Landmarks	Instructions	Distance countdown bar	Display overall	Voice	Map
Good LM	1	2				1
Poor LM	3	5				1
No LM	2	4		3		2

Table 14. Suggested improvements to system

There was a range of opinions regarding potential improvements to the navigation system. Few suggestion for improvement came form the participants in the good landmark condition, although one commented that:

> '[The] names for landmarks [were] OK, as long as no one changes them!'

The poor landmarks category participants actually suggested using better landmarks:

> '[You could improve it by] using easily recognisable landmarks.'
>
> '[You could improve it by using] roundabouts, pedestrian crossings, traffic lights as markers.'

Comments from the no landmark category generally referred to the need for more detail on the map, the use of a counting strategy within the voice instruction, and the inclusion of landmarks:

> '[It could be improved with] more map detail and a higher level of quality'.
>
> '[It could be improved with] more voice instructions to stop me over-looking at display'.
>
> '[A way to improve it would be to] use landmarks, more description, e.g. 3rd right.'
>
> '[A way to improve it would be to use] speed related instructions, use landmarks, give indication of size of road you are entering.'

FAQD5: What did you think of the landmarks?

	Participant perceptions		
	Positive	Negative	Indifferent
Good Landmarks	12	2	2
Poor Landmarks	5	7	4

Table 15. Opinions on landmarks

Table 15 clearly shows the perceived differences between the good and poor landmark conditions, with a greater number of positive comments arising from the good landmarks condition, and more criticism of landmarks by the participants in the poor landmarks category. However, there were mixed responses to this question from participants. From participants in the good landmark category, positive comments included:

‘Brilliant’.

‘[They were] useful as you can spot them [the turns] easier’.

‘[They were] useful information to help identify turns’.

‘[They were] informative and accurate’.

Negative feedback was related to the amount of information presented, potential impacts on driving, and concerns about reliability, e.g.:

‘[They] could be better’.

‘[They are] not necessary. The system is good enough with out them (telephone box – not useful – worried about reliability).’

‘Sometimes it [the landmark] was useful. When the landmark came into view I found that I was concentrating too much on finding the landmark’.

Comments on landmarks from the participants in the poor landmarks category was mixed; some participants in this group were positive:

‘[They were a] good idea’.

‘[They were] very good’.

‘They gave you something to check on’.

Some participants were very critical of them:

‘[They were] distracting’.

‘[They were] terrible.’

‘You spent too much time looking for them and so less time concentrating on the road’.

However, many of poor landmark category participants were positive towards the concept of using landmarks in the navigation instructions, but tended to be critical of their implementation, with comments including:

‘[They were] good but you had to keep an eye out to see where they were’.

‘[They were] good but you could not always see them. Could give more detail e.g. pub on right, not just turn left after pub.’

‘[They were] generally good e.g. pubs and buildings but other landmarks post boxes etc could be obscured’.

‘[They were] mostly good but sometimes too obscure and not always quickly spotted.’

11.8 Age and gender differences

A Mann-Whitney test for 2 independent samples was carried out for each of the questions within the Initial Perceptions, Limited Exposure and Final Acceptance questionnaires. These tests investigated the effects of AGE (young, old) and GENDER (male, female), with each of these independent variables equally balanced across the LANDMARK condition.

Significant results for the independent variable of AGE are shown in Table 16below. In all cases, a higher mean ranking indicates a higher mean agreement with the statement.

Question No	Statement	Mann-Whitney U	N (young)	N (old)	Sig. (2-tailed)	Mean rank: young	Mean rank: old
IPQ7	I would prefer using a navigation system to my usual way of navigating in a car	197.5	24	24	$p = .042$	28.27	20.73
LEQ5	A navigation system is an easy method of finding my way in an unfamiliar area	198.5	24	24	$p = .05$	20.77	28.23
LEQ9	I am looking forward to using a navigation system (again)	202.5	24	24	$p = .042$	20.94	28.06
FAQA7	The navigation system always did what I expected	178.5	24	24	$p = .017$	19.94	29.06
FAQA8	I always paid attention to the road when driving round the route	165.5	24	24	$p = .008$	19.4	29.6
FAQA14	The navigation system exceeded my expectations	153.0	24	24	$p = .004$	18.88	30.13
FAQA17	I always thought the navigation system was working properly	184.0	24	24	$p = .017$	20.17	28.83
FAQA22	I am disappointed with the performance of the navigation system	190.0	24	24	$p = .032$	28.58	20.42
FAQA23	I felt happy when I was using the navigation system	185.5	24	24	$p = .024$	20.23	28.77
FAQB2	The information from the navigation system was always accurate	177.0	24	24	$p = .012$	19.88	29.13
FAQB4	The navigation system always gave me information when I needed it	163.5	24	24	$p = .005$	19.31	29.69
FAQB5	The map overview told me exactly where I needed to turn	165.5	24	24	$p = .009$	19.4	29.6
FAQB9	The voice messages told me exactly where I needed to turn	168.0	24	23	$p = .013$	19.5	28.7
FAQB11	The navigation system usually gave me information too early	198.0	24	24	$p = .047$	28.25	20.75

Table 16. Questionnaire statements with significant effect of age

11.9 Changes in attitudes between the Initial Perceptions and Final Acceptance Questionnaires

Table 17 identifies the questions that were common across the Initial Perceptions Questionnaire, Limited Exposure Questionnaire, and Final Acceptance Questionnaire.

Initial Perceptions Question No.	Final Acceptance Question No.	Question wording
IPQ1	FAQA15	A navigation system reduces the amount of stress during driving
IPQ2	FAQA1	Using a navigation system is a fun way of navigating
IPQ3	FAQA19	I am looking forward to using a navigation system (again)
IPQ4	FAQA24	Using the navigation system makes driving more difficult
IPQ5	FAQA4	A navigation system is an easy method of finding my way in an unfamiliar area
IPQ6	FAQA6	With a navigation system, I think I would be less likely to get lost
IPQ7	FAQA21	I would prefer using a navigation system to my usual way of navigating in a car

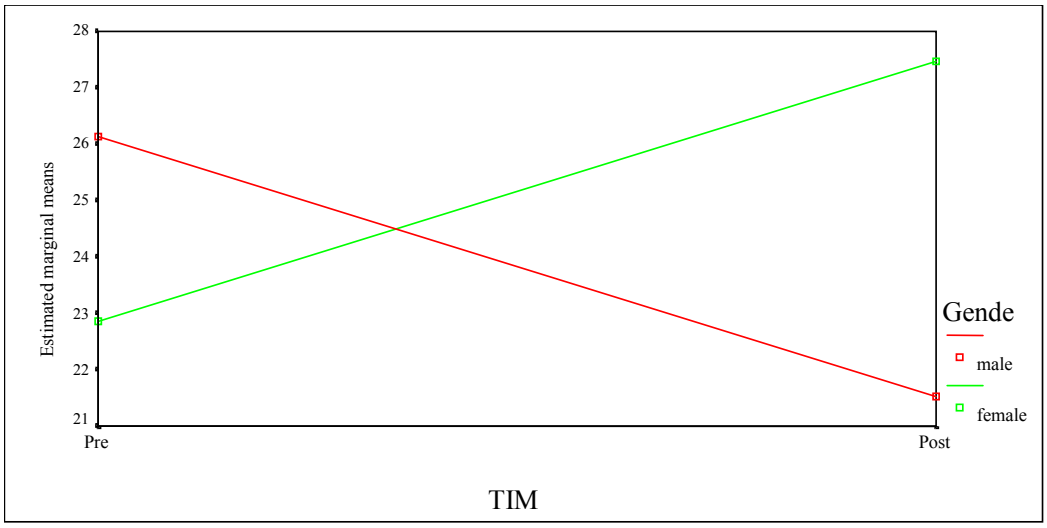
Table 17. Statements common to initial perceptions and final acceptance questionnaires

To analyse changes in opinion between the Initial Perceptions Questionnaire and Final Acceptance Questionnaire, two types of analysis were carried out. A Wilcoxon Signed Ranks test for two related samples was undertaken independently for each of the LANDMARK conditions. There were no significant results for any of the comparisons. However, there were some trends apparent

An additional analysis was carried out on ranked data for the questions common to the Initial Perceptions Questionnaire and Final Acceptance Questionnaire. A repeated measures ANOVA was performed, with TIME as a 2-way within-subjects factor, and LANDMARK, AGE and GENDER as between subject factors. All results are reported using Huynh-Feldt epsilon where there is a significant result for Mauchly's test of sphericity.

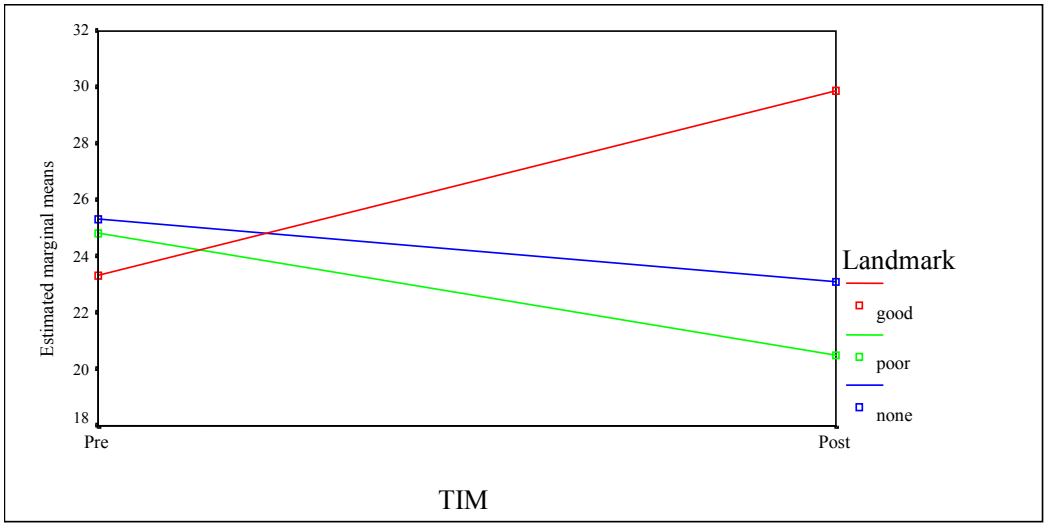
Graphs are presented in numeric order by FAQA.. number.

(NOTE No significant main or first order interaction effects were found for the following questions, so no graphs are shown: Change in attitude over time for FAQA4 and IPQ5 'A navigation system is an easy method of finding my way in an unfamiliar area')



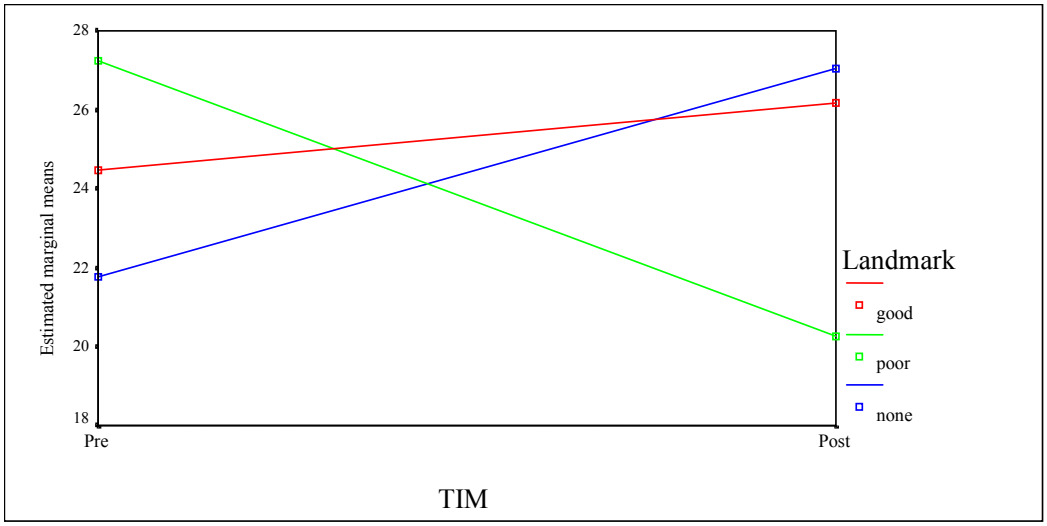
*Significant effect for TIME*GENDER F(1,36) = 5.250, p = .028*

Graph 141. Change in attitude over time for FAQA1 and IPQ2 'Using a navigation system is a fun way of navigating'



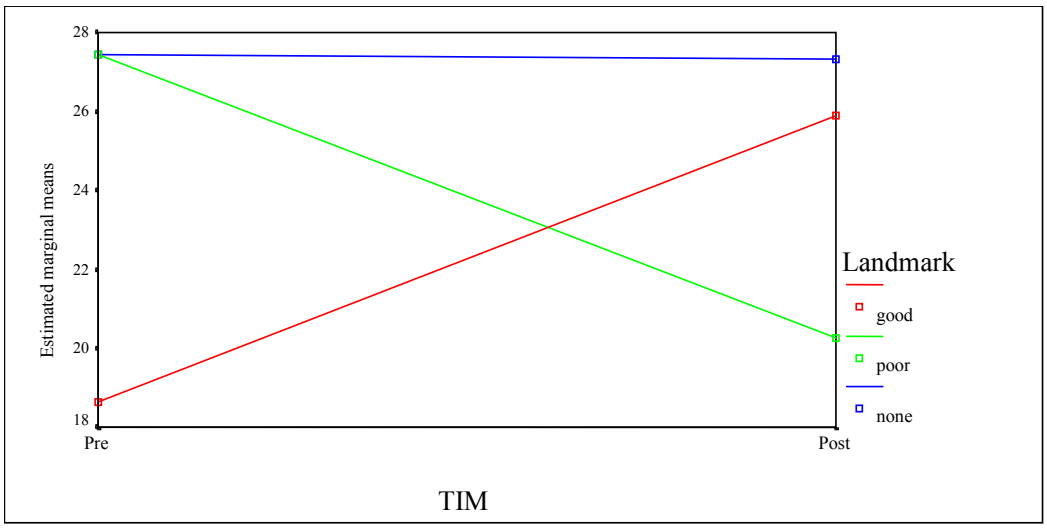
*Significant effect for TIME*INFO F(2,36) = 3.702, p = 0.035 (using hF epsilon)*

Graph 142. Change in attitude over time for FAQA6 and IPQ6 'With a navigation system, I think I would be less likely to get lost'



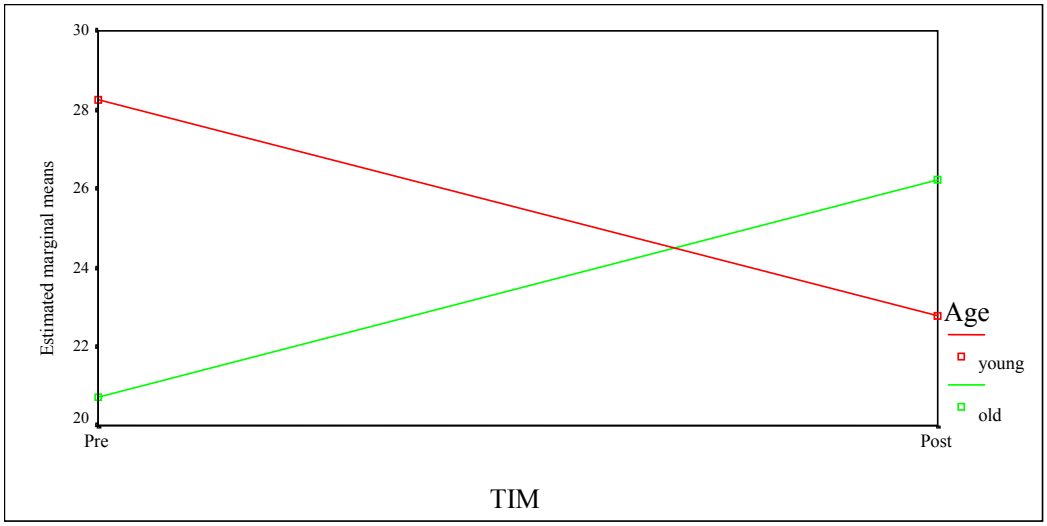
*Significant effect for TIME*INFO F (2,36) = 3.864, p = 0.030 (using hF epsilon)*

Graph 143. Change in attitude over time for FAQA15 and IPQ1 'a navigation system reduces the amount of stress during driving'



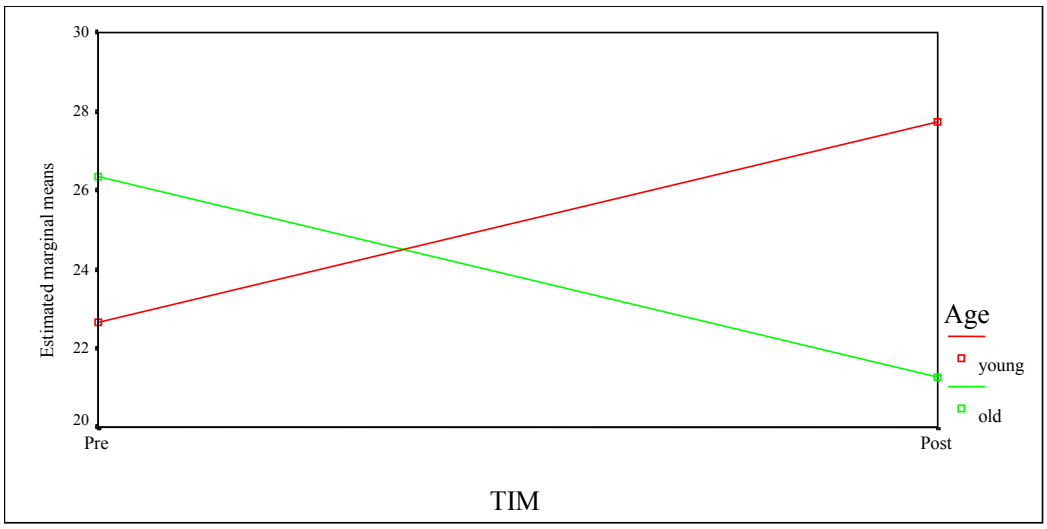
*Significant effect for TIME*INFO F (2,36) = 3.415, p = 0.044 (using hF epsilon)*

Graph 144. Change in attitude over time for FAQA19 and IPQ3 'I am looking forward to using a navigation system (again)'



*Significant effect for TIME*AGE F(1,36) = 9.453, p = 0.004*

Graph 145. Change in attitude over time for FAQA21 and IPQ7 'I would prefer using a navigation system to my usual way of navigating in a car'



*Significant effect for TIME*AGE F(1,36) = 4.634, p = 0.038 (using hF epsilon)*

Graph 146. Change in attitude over time for FAQA24 and IPQ4 'Using the navigation system makes driving more difficult'

12 RESULTS – CORRELATIONS BETWEEN PERFORMANCE MEASURES AND LANDMARK VALUES

12.1 Analysis

One of the aims of the road trials reported within this deliverable was to determine the extent to which there was a relationship between the value of the landmark as calculated by the model described in Figure 1, and driver behaviour as measured by the range of dependent variables described in section 3.7. It was expected that at manoeuvres where the landmark value was high (i.e. where a 'good' landmark was being used within navigation instructions), driver performance would be better than where the landmark value was low.

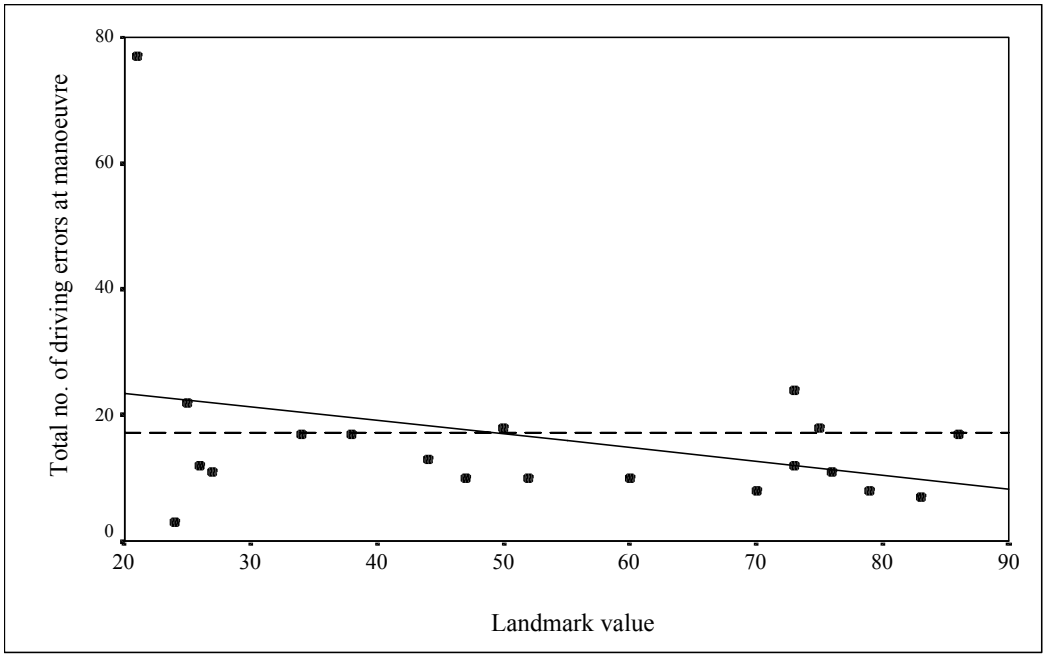
Each of the target manoeuvres (10 in total) was selected on the basis that there was a 'good' and a 'poor' landmark that could be incorporated within navigation instructions. Due to the between subjects design of the study, 16 participants completed manoeuvres based on using the 'good' landmarks, and a different 16 participants completed those same manoeuvres using 'poor' landmarks. Therefore for each landmark, there was data according to all of the dependent measures from the 16 participants who used that landmark for navigation at a particular manoeuvre.

For analysis purposes, an aggregate value for each dependent variable was calculated for each landmark, across the 16 participants who used each of those landmarks. In addition, for each landmark, their value was calculated according to the model described in Figure 1. The value for each landmark can be found in Appendix 2. Correlation plots were then generated, based on plotting each dependent variable in turn against landmark value, for each of the 20 landmarks used within the study. These are shown in section 12.2 below, with each point on the plots representing a single landmark. On all plots, a dashed horizontal line shows the equivalent aggregate value of the dependent variable for the participant group who undertook the no landmarks condition.

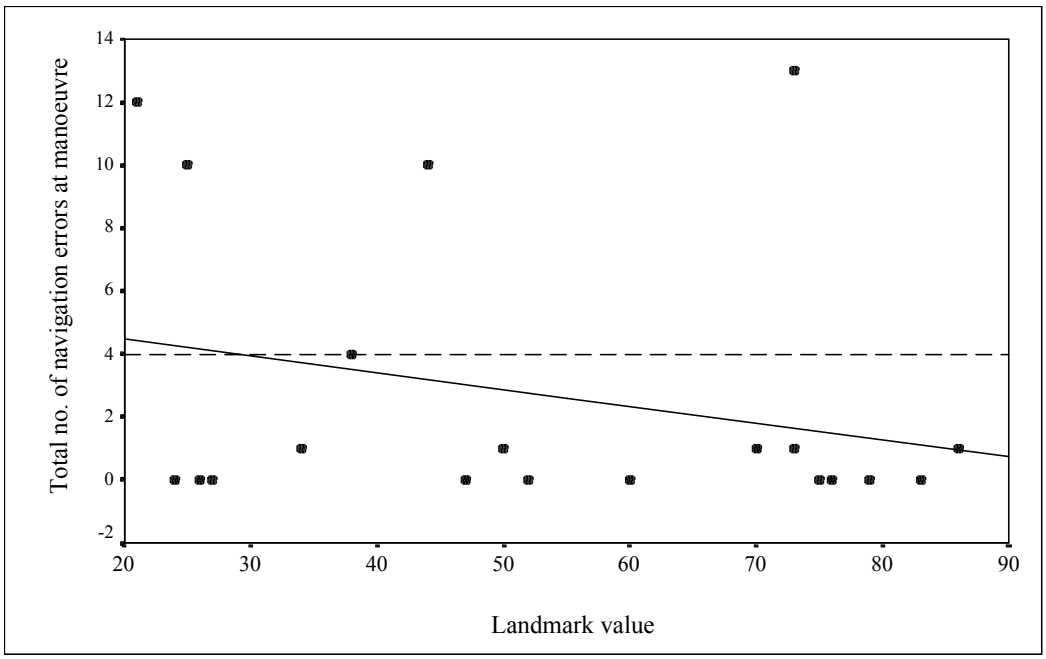
The dependent variables plotted against landmark are:

- Total number of driving errors made at that manoeuvre
- Total number of navigation errors made at that manoeuvre
- Average percentage of moving time spent looking at the display at that manoeuvre
- Average number of glances towards the display at that manoeuvre
- Average confidence at the preview 1 point at that manoeuvre
- Average confidence at the preview 2 point at that manoeuvre
- Average confidence at the final point at that manoeuvre
- Average confidence at the post manoeuvre point at that manoeuvre

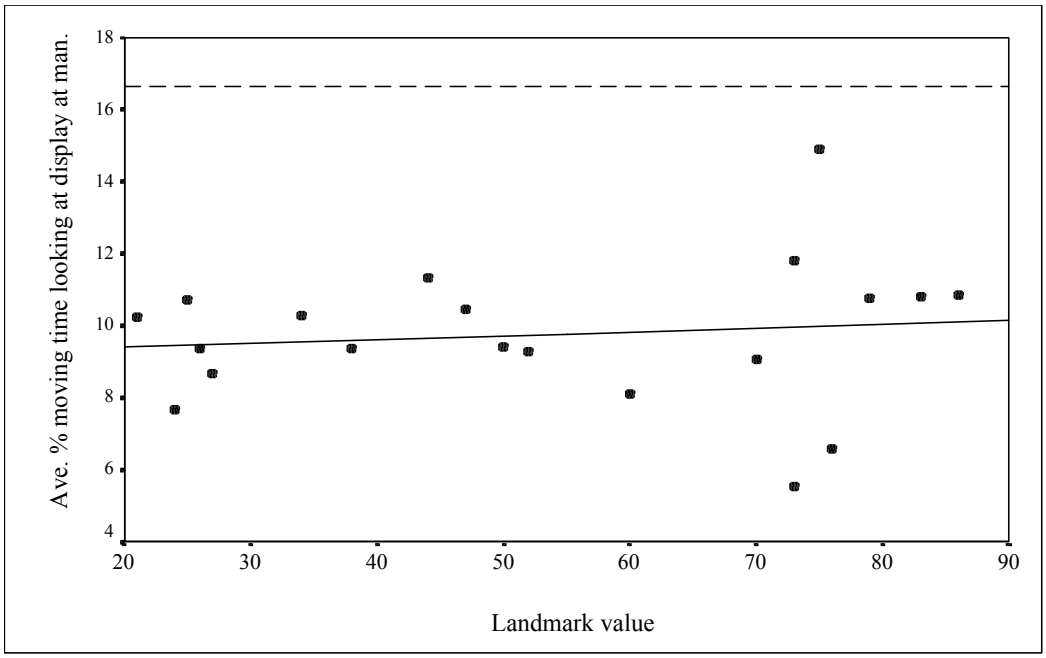
12.2 Correlation plots



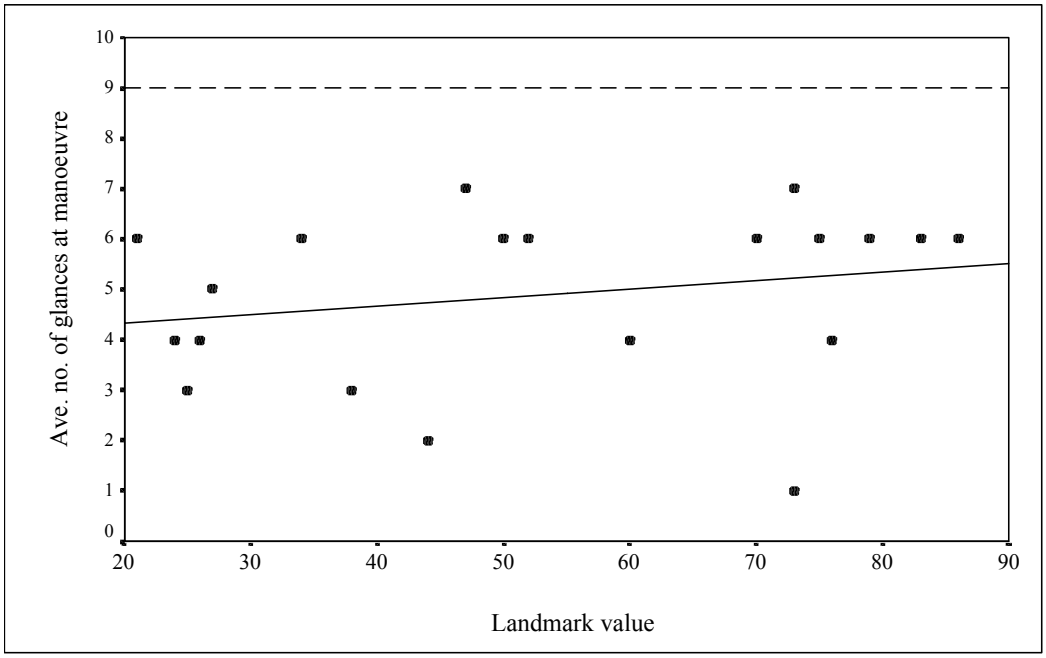
Graph 147. Correlation plot for total number of driving vs. landmark value, for each manoeuvre



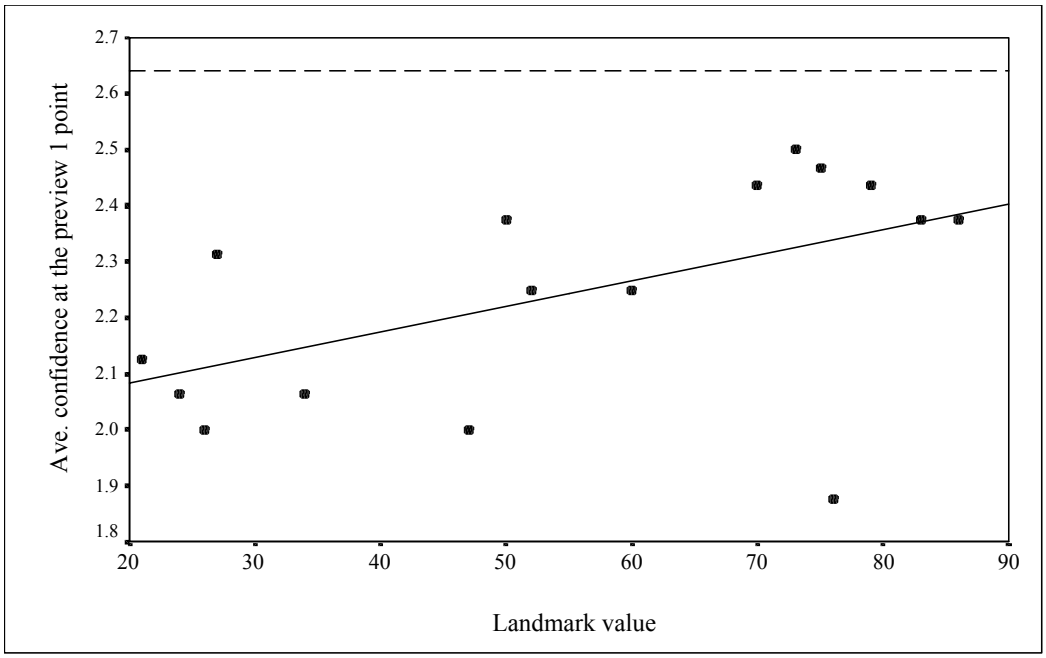
Graph 148. Correlation plot for total number of navigation errors vs. landmark value, for each manoeuvre



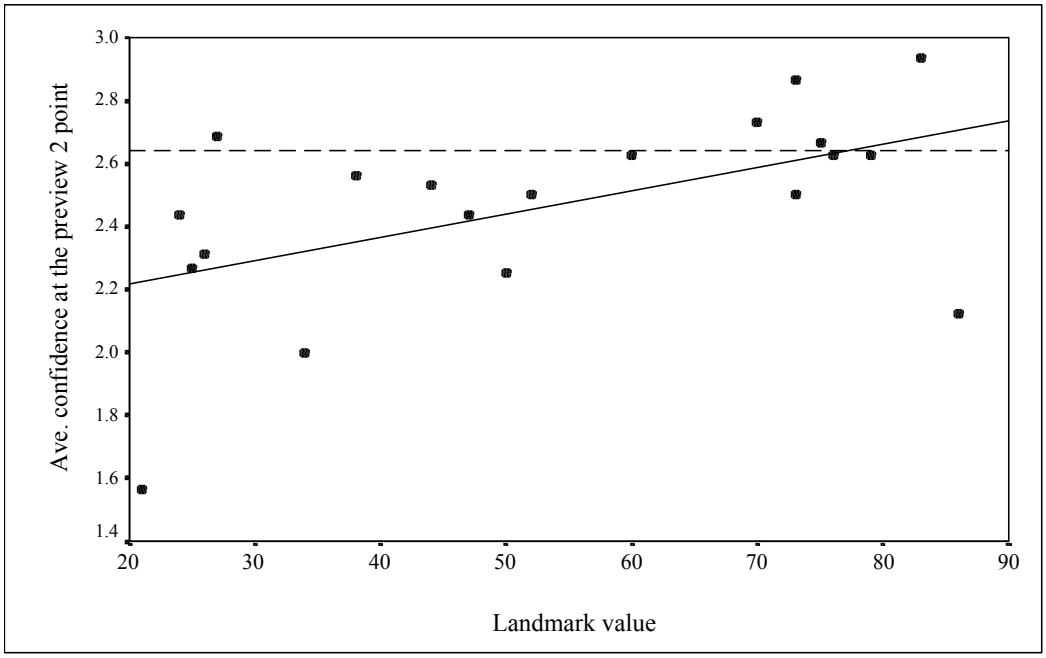
Graph 149. Correlation plot for average percentage of moving time looking at display vs. landmark value, for each manoeuvre



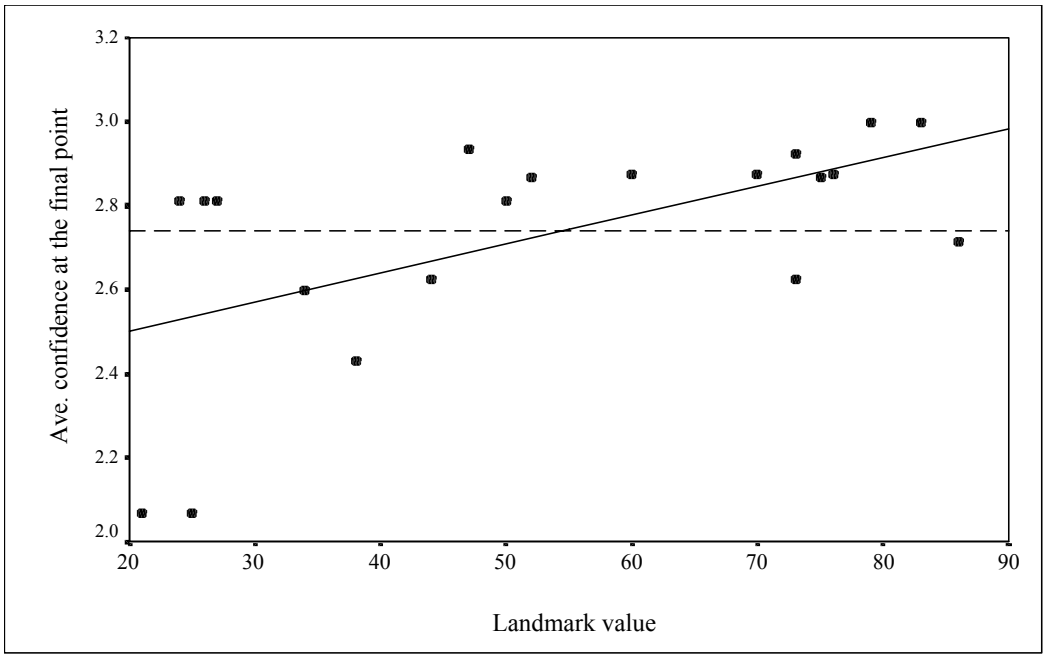
Graph 150. Correlation plot for average number of glances toward display vs. landmark value, for each manoeuvre



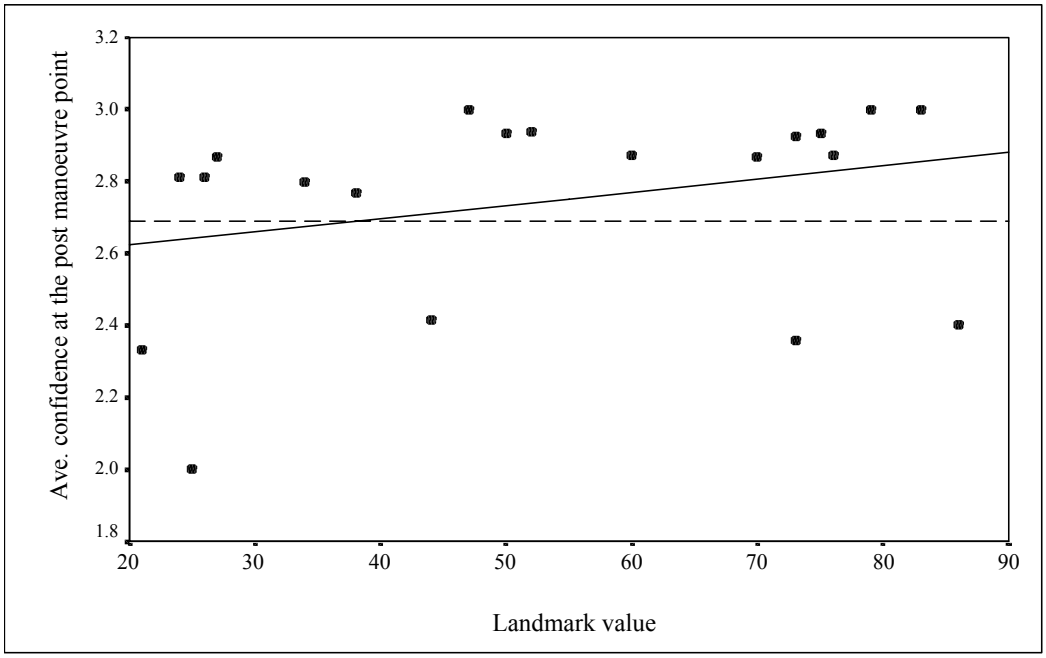
Graph 151. Correlation plot for average confidence at the preview 1 point vs. landmark value, for each manoeuvre



Graph 152. Correlation plot for average confidence at the preview 2 point vs. landmark value, for each manoeuvre



Graph 153. Correlation plot for average confidence at the final point vs. landmark value, for each manoeuvre



Graph 154. Correlation plot for average confidence at the post manoeuvre point vs. landmark value, for each manoeuvre

13 RESULTS – CORRELATIONS BETWEEN PERFORMANCE MEASURES AND COMPONENT FACTORS

It was considered valuable to investigate any relationship between the driver behaviour measures and the ten original component factors used in the regression analysis. The ten components are (inclusion in regression model indicated by *):

- Visual Characteristics (VISCHAR*)
- Visual Effort for Scanning (VISEFF)
- Pre-Warning (PREWRN)
- Familiarity (FAM)
- Ease of Naming (ESNAME)
- Influence of Surroundings. (SURR)
- Similarity of Appearance (SIMAPP)
- Usefulness of Location. (USELOC*)
- Level of Task Demand (TSKDEM)
- Degree of Interaction. (DEGINT*)

An additional, objective measure was included in the correlations. This was the distance, prior to the manoeuvre, at which the landmark (and any associated label) could be seen (to the nearest 50m). This is termed 'VISIBILITY DISTANCE'.

To include scatter plots for all factors and measures would run to 88 graphs, therefore a summary of the significant relationships only are shown in Table 18. Also shown, for comparison is a repeat of the correlations for overall Landmark Value. (level of significance is indicated by * $p \leq 0.05$ or ** $p \leq 0.01$). A blank cell indicates no significant correlation.

	Component factors (* indicates inclusion in model)											
	* VISCAR	VISEFF	PREWRN	FAM	ESNAME	SURR	SIMAPP	* USELOC	TSKDEM	* DEGINT	VISIBILITY DISTANCE	LM VALUE
No. of glances												
% time looking at display												
Driving errors									-.579 **			
Navigation errors											-.480 *	
Confidence at Preview 1	.542 *		.660 **							.630 **		.535 **
Confidence at Preview 2	.631 **					.567 **					.555 *	.501 *
Confidence at Final	.525 *	.445 *	.565 **			.542 *			.473 *	.619 **		.616 **
Confidence post-manoeuvre			.445 *						.610 **	.476 *		.478 *
Range of ratings (majority range)	75	70	75	80 (30)	55 (25)	75 (30)	65	65 (35)	40	90	350	70

Table 18. Correlations between driver performance measures and landmark factors

14 DISCUSSION

14.1 Effect on visual behaviour

For the majority of manoeuvres, the effect only partly matched the expected findings. Providing no landmarks consistently resulted in more glances to the display as drivers had to rely on glances to the distance countdown bar to identify the exact position of the manoeuvre (Graph 7). However, it was expected that the good landmarks would reduce glances to the display more than poor landmarks (i.e. negate the need to use the countdown bar or, possibly, any visual information) and this was not the case. In fact, for most manoeuvres, poor landmarks resulted in less glances to the display. Although the difference between the good and poor conditions was not statistically significant, it is interesting to consider possible reasons for it. One possible explanation for this behaviour is that, for the poor landmarks, the drivers' gaze was directed to the periphery of the road, searching for landmarks that may have been more difficult to find and therefore reducing the opportunity for glancing towards the display. Unfortunately, project resources did not allow visual behaviour analysis beyond 'glances to the display', so this theory cannot be proven, but would be an interesting topic for future research. No effects of age or gender were identified across manoeuvres or for landmark condition (Graph 8, Graph 9, Graph 10 Graph 11).

Glance duration was not affected by landmark condition (Graph 12). This is a result that would be expected, as glance duration is usually a factor of the complexity or design of a visual display. In this trial, the visual information was identical in each condition, only the verbal information changed. Glance duration was affected by age (Graph 13, Graph 15). The older participants, as a whole, spent significantly longer on each glance. This is a function of declining visual ability with age. Particularly it relates to a decrease in speed of accommodation (re-focusing) when moving from a far image (the road) to a near image (navigation display). Many authors have reported the increased visual demand experienced by older drivers using visual displays (see section 1.2)

One other interesting finding was that glance duration decreased over time (i.e. from manoeuvres 2 to 33) from $\geq$ 0.95sec to $\leq$ 0.9sec, with no apparent plateau occurring. This was consistently the case for both age groups and males and females (Graph 12, Graph 13, Graph 14). It is likely that increased familiarity with the system makes information uptake more visually 'efficient'. That is, drivers learn the position and format of relevant information and do not need to see so much of the detail (for example, it may not be necessary to read the distance to turn but merely to glance at the size of the countdown bars). The reduction in some cases was up to 0.2seconds, which is quite a substantial change. This change took place over quite a limited exposure time (50 minutes of driving) and is likely to plateau at some stage. It would be interesting to further investigate this change with longer-term exposure.

One of the most indicative measures of safety is the total amount of time spent looking at the display as a proportion of total driving time (here referred to as 'percentage moving time'). The results here are similar to those for number of glances (being a function of that measure). Providing no landmarks significantly increased the time looking at the display compared with using good or poor landmarks (Graph 20). However, the difference between good and poor landmarks was not enough to be statistically significant and the direction of the change differed according to the manoeuvre. Again, there was no effect of age or gender (Graph 21, Graph 22, Graph 23, Graph 24).

The effects of landmark condition on visual behaviour showed the following main results:

- Providing landmarks (whether good or poor) decreased the number of glances to the display and percentage moving time looking at the display
- There was no consistent difference in visual behaviour between the good and poor landmark conditions
- Glance duration was not affected by landmark condition but older drivers (over 55years) had longer glance durations than those under 40 years.
- Glance duration decreased over time (50 minutes) irrespective of age or gender

The lack of consistent results for good and poor landmarks suggests that the manoeuvre itself has some effect and this was shown statistically. Possible reasons for this are discussed in section 14.9.

14.2 Effect on driver confidence

The study enabled investigation of the effects of landmark condition on overall confidence for each manoeuvre as well as changes over the course of the route. Approach confidence (the mean of confidence ratings at Preview 1, Preview 2 and Final messages) was significantly lower for the poor landmarks condition than for either good landmarks or no landmarks (

Graph 28). The difference between the latter conditions was not significant and the direction of change varied (half of the manoeuvres had higher confidence ratings in the good landmarks condition and half in the no landmarks condition). This implies that the addition of poor landmarks within a navigation system may be detrimental to driver confidence but that good landmarks do not have a consistently positive effect. Although this contradicts the findings of Alm et al (1992), the non-landmarks condition in the cited study provided drivers with simple left/right/straight-on information, hence the difference between conditions was more marked. A more comparable study was conducted by Allerton (2000) with similar voice instructions (but no visual information) and here there was no difference between the landmarks and no landmarks conditions. In the current study there was also a significant interaction effect of manoeuvre number, suggesting that factors other than landmarks may be influencing confidence (see discussion of this in section 14.9).

The lack of higher confidence ratings for good landmarks (in comparison to none) is surprising, as previous studies have found landmarks to be beneficial. It is likely that this is due to the effect in this study being diminished by the comprehensive visual information provided on the display. The hybrid mode (detailed junction layouts at manoeuvres and a map overview between manoeuvres) was chosen specifically in this study as it was felt to be more representative of real use. Previous studies have tended not to use a real navigation system but to *simulate* visual information. This often means that a very simplified junction layout or a direction arrow alone is used and the landmark is either overlaid on this visually or provided in the verbal message. Hence the difference between conditions is more marked, and drivers are likely to find it significantly more difficult to make decisions when the additional information provided by the landmark is not present.

Over the course of the route (from manoeuvre 2 to manoeuvre 37), approach confidence increased for all conditions as follows (1=low, 2=medium, 3=high):

- Good landmarks: 2.33 to 2.84 (an increase of 0.51)
- Poor landmarks: 2.15 to 2.64 (and increase of 0.49)
- No landmarks: 2.65 to 2.76 (and increase of 0.11)

This indicates that the initial confidence and improvement of confidence was similar for good and no landmarks. Poor landmarks, however, resulted in significantly lower confidence levels at the beginning of the route but a steeper increase in confidence over time. It could be that driver's initially anticipated that the poor landmarks would by their nature (bus stops, post box) be more difficult to see. As time progressed, they knew that there were no 'tricks' in the trial and that the landmark was always present, even if at a late stage, so confidence may have increased. The general increase in confidence over time for all conditions is probably also explained by drivers' increasing confidence with the vehicle, the experimenters and the tasks they were carrying out.

What seems to have happened in this study is that driver confidence has been the same in good and no landmark conditions but to the detriment of safe visual behaviour. That is, confidence is high with good landmarks and drivers also have less eyes-off-road time whereas, for no landmarks, confidence is still high but this benefit is counteracted by increased glances to the display to use the countdown bar to identify the turn.

A significant interaction effect was also found between landmark condition and gender (Graph 32): for poor landmarks males and females had similar confidence levels; for good landmarks males' confidence was higher; for no landmarks females had higher confidence ratings. This finding contradicts other studies that suggest that landmarks are preferred and used more by females than males. This study can offer no explanation for this effect.

The results also enable consideration of changes in confidence across the three verbal messages and the post-manoeuvre rating, i.e. changes over the course of each manoeuvre (Graph 54). Poor landmarks resulted in the lowest confidence at Preview 1, Preview 2 and Final messages. Confidence with good landmarks was generally lower than for none at Preview 1 and 2 but rose to be better than for none at the Final message. Good landmarks resulted in slightly higher

confidence post-manoeuvre than the other two conditions but this was not statistically significant. There seems therefore to be little benefit to including poor landmarks in verbal messages at all. Good landmarks do seem to improve driver confidence beyond Preview 2 messages (i.e. approximately 200yds before the manoeuvre) but have little benefit before this. This is probably due to the fact that, at Preview 1 (approximately 500yds), the driver: (a) does not yet need to precisely locate the manoeuvre and (b) is unlikely to be able to see the good landmark in most cases. Indeed, for the good landmarks used in this study, none were visible prior to 350yds before the junction (and 7 out of 10 were not visible until 200yds). The lack of any effect post-manoeuvre is probably due to the fact that, at this stage, drivers are using other information than landmarks to confirm that they have made the correct turn (i.e. that road sign matches that on the display or, if the display quickly changes to the map, that they still seem to be on the highlighted route).

Age also had an effect on confidence ratings, with the older age group showing higher confidence ratings at Preview 1 and 2 with a reduced increase at the Final message, but no difference post-manoeuvre (Graph 55). Again, the cause of this effect is unknown. There was no effect of gender (

Graph 56).

When each manoeuvre is considered separately, other trends in confidence can be seen (Graph 61 to Graph 70). For the majority of manoeuvres, confidence increased from Preview 1 to Final message for both good landmarks (8 manoeuvres) and poor landmarks (7 manoeuvres). In the less favourable cases, where confidence remained the same or decreased when using landmarks (manoeuvres 2, 4, and 33), the no landmarks condition performed equally badly with confidence falling. There were only 4 manoeuvres (no. 7, 9, 15 and 19) where using no landmarks resulted in an *increase* in confidence over time and in these cases the good/poor landmark conditions also showed a rise. There were some instances where confidence dropped from Preview 1 to Preview 2 and then rose at the Final message. This happened once for the good landmarks (manoeuvre 2), three times for the poor landmarks (manoeuvres 2, 8 and 37) and twice for no landmarks (manoeuvres 2 and 9). Overall, when considering approach confidence, using landmarks seemed beneficial over none at manoeuvres 2, 8, 22, 33 and 37 but had no benefit for manoeuvres 4, 7, 9, 15 and 19. Good landmarks did seem to increase post-manoeuvre confidence at manoeuvres 4 and 33 only. Both of these manoeuvres were quite similar (very narrow streets that you wouldn't be expecting to take as there were other, more noticeable roads just afterwards). It seems that factors other than the navigation information provided are affecting confidence. This is discussed further in section 14.9.

14.3 Effect on driver errors

The total driver error scores for each landmark condition (1=minor, 5=serious, 10=dangerous) showed that poor landmarks resulted in the highest score, followed by no landmarks, with least errors occurring for good landmarks (Graph 71). Although the difference across landmark categories was not statistically significant it does indicate a safety benefit associated with using good landmarks. Three other studies have measured the effect on driving errors of including landmarks in navigation instructions. Bengler et al (1994) found that landmarks reduced the numbers of indicator errors and Philips (1999) found that landmarks improved turning accuracy and indicator accuracy for older drivers. Both of these results were based on simulator studies (and hence a less realistic task than the study reported here) so should be treated with caution. Allerton (2000) used the same method as in the current study (i.e. a driving instructor recording minor, serious or dangerous errors for the same types of error). However, only a count of number of errors was reported (rather than a calculation based on seriousness. She found no difference between the landmark/no landmark conditions. This difference to the current study maybe due to Allerton's landmarks covering a range of both 'good' and 'poor' and therefore diluting the benefits of landmarks. However, the actual value of the landmarks cannot be assessed form the thesis.

When considering the type of error (Graph 74), indicator errors were the most common (confirming the results of Bengler et al, see above) and there was a significant difference between conditions, with poor and no landmarks resulting in an error score twice that for good landmarks. This lends support to the benefit of good landmarks to identify manoeuvres. Most indicator errors were due to confusion over which turn to take resulting in early, late or no use of indicators. Other types of error did not seem to be influenced significantly by landmark condition.

14.4 Effect on navigation performance

There was a significant reduction in navigational errors associated with good landmarks (n=17) compared with poor (n=37) or no (n=40) landmarks (Graph 75). The maximum number of errors possible for each landmark condition was 160 (10 manoeuvres x 16 subjects). The poor and no landmarks condition therefore showed a 25% chance of an error whereas the good landmarks presented only a 10% chance of taking a wrong turning. This benefit of (good) landmarks replicates the findings of other studies including Alm et al (1992) and Bengler et al (1994). One study contradicts these findings. Allerton (2000) did not identify a difference between navigation errors for the landmark condition versus no landmarks.

The findings of the current study are quite significant for future navigation systems. The aim of a navigation system is to *reduce* such errors and make driving more efficient. The *absolute* error rates above would probably not be replicated in a realistic route as the target manoeuvres on the test route were chosen to be quite challenging. However, the *relative* benefits of good landmarks should still be present.

14.5 Effect on driver workload

The NASA-RTLX scores showed no first order effects of landmark condition (Graph 76), age or gender. This is an interesting methodological finding as many other driver behaviour studies have found this to be a sensitive measure. It is proposed that the reason for this is a combination of the small differences between the overall conditions (10 out of 37 manoeuvres having landmarks present or not in the verbal instructions) and the influence of other factors on perception of workload (traffic and weather conditions for example). Most driving studies that have reported an impact on NASA-RTLX have had more marked differences between conditions (e.g. map-following vs. turn-by-turn instructions, or manual vs. voice input methods). In the case of one navigation study (Alm et al. 1992), where mental workload was lower when including landmarks, the no landmarks condition included only limited left/right/straight-on instructions. Although the current trials were all performed out of peak hours and in daylight, differences in traffic and weather are inevitable in a real road study. This combined with the fact that the NASA-RTLX ratings are given at the very end of the trial is likely to dilute any influence that the different landmark conditions may have had at particular manoeuvres and this is better reflected by the measures discussed in sections 14.1 to 14.4. Future studies may wish to assess the value of using the NASA-RTLX when the difference between conditions is so small.

14.6 Effect on driver attitudes

14.6.1 Introduction

The participants completed three attitude questionnaires: Initial Perceptions (completed when the participants arrived), Limited Exposure (after the participant had completed a practice session with the navigation system, and then the first four manoeuvres within the trial) and Final Acceptance (completed after finishing the route).

The purpose of the Initial Perceptions questionnaire was to record peoples opinions and attitudes prior to using any system. Therefore, although the results from this questionnaire are interesting as they identify initial attitudes, their main purpose was to enable a comparison of pre- and post-trial attitudes (this is reported in section 14.6.6). With matched subject groups there should theoretically be no difference in responses to the Initial Perceptions questionnaire, between participants in the three landmark categories. However, one of the seven questions (IPQ3 - I am looking forward to using a navigation system) did showed significant difference across the matched groups, with a more negative response to this question arising from the participant group that would undertake the good landmark condition. There is no logical explanation for this difference. The matching criteria for the between subjects factor did take into account the main factors considered important (see Table 10 for participant demographics), the inclusion of additional criteria would have increased the homogeneity of the whole participant group.

The intended use for the Limited Exposure questionnaire was to help identify any changes in attitude over the course of the trial (i.e. to compare results across the Initial Perceptions, Limited Exposure and Final Acceptance questionnaires. However, during the course of the trial, it became apparent that participants were not being consistent in the experience they were using to answer the Limited Exposure questionnaire: some participants were incorporating experiences gained during the practice session, whilst others were basing their answers on their limited exposure to the

system within the actual trial (as was the intention with this questionnaire). Therefore the answers to the Limited Exposure questionnaire were considered to be unreliable, and although presented in the results for completeness, they are not analysed or discussed further.

The Final Acceptance questionnaire was used to investigate any effects of the independent variables: landmark condition, age and gender (see sections 11.3, 11.4 and 11.5). Also the results were compared with those from the Initial Perceptions questionnaire (see section 11.9)

The final questionnaire on driver attitudes covered three areas: general opinions on using the navigation system (questions FAQA..), specific questions on the information provided (questions FAQB..) and detailed questions on the information components that drivers found useful (questions FAQC..). Each of these is taken in turn, first the general opinions of using the system.

To enable understanding of the results, for these questions the responses were on the following scale.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

To avoid confusion between questions *phrased* positively and negatively, responses are discussed in terms of whether participant opinions were positive, neutral or negative (i.e. agreement with a positive statement is a positive opinion as is disagreement with a negative statement). The relevant graphs can be found in Sections 11.3, 11.4 and 11.5 in alphanumeric order by question code.

Throughout section 14.6 statistically significant results for any question are indicated by asterisks as follows: * $p \leq 0.05$, ** $p \leq 0.01$.

14.6.2 Final acceptance questionnaire – part A

Responses to the following question were, for the majority of participants, wholly positive with no change across landmark condition and no effect of age:

FAQA1 **Using a navigation system is a fun way of navigating**

FAQA3 **The navigation system had an overall feeling of 'quality'**

FAQA9 **I liked the visual display for the navigation system**

FAQA16 **I liked the voice instructions from the navigation system**

FAQA26 **At the end of the drive, I felt relieved that the ordeal was over**

The next set of questions again showed no effect of age or landmark condition but opinions were more neutral:

FAQA2 **The way the navigation system worked fitted in with how I would normally navigate**

FAQA5 **I always trusted the navigation system to give me the right instructions**

FAQA10 **I found using the navigation system distracted me whilst driving**

FAQA12 **I sometimes got messages from the navigation system that I was not expecting**

None of the questions indicated a statistically significant difference between landmark conditions. However, plots for the three questions described below did seem to indicate some trends across conditions:

FAQA20 **Using the navigation system felt like a 'natural' thing to do**
There was a lot of variation in response to this question (1.5-4). There was also a trend for good landmarks to generate a positive response, poor landmarks neutral and no landmarks a neutral/negative response.

FAQA21 **I would prefer using a navigation system to my usual way of navigating in a car**
Responses to this question were mostly positive but this was less so for the poor landmarks.

FAQA22 **I am disappointed with the performance of the navigation system**
Again, most respondents were positive but this was reduced to neutral for poor landmarks.

Many of the questions showed a difference across the two age groups.

Many questions elicited a more positive response from the older group across all conditions

FAQA8** **I always paid attention to the road when driving round the route**
Responses neutral/positive, old more positive towards all conditions.

FAQA14** **The navigation system exceeded my expectations**
Young were neutral to negative, old were neutral to positive, across all conditions.

FAQA11 **I found it frustrating using the navigation system**
Generally positive, old emphatically so (median=2 for all conditions)

FAQA13 **The navigation system seemed to operate consistently**
Generally positive with a very strong consensus for the old group (median=4 for all conditions)

FAQA17** **I always thought the navigation system was working properly**
A consistent increase in agreement across all conditions for the old group (positive) compared with young (neutral).

FAQA18 **I drove safely at all times when driving round the route**
Responses were positive, more so for older drivers across all conditions

FAQA24 **Using the navigation system makes driving more difficult**
The older group were generally more positive and there was a wide variation in opinion for the no landmark condition in the young group

Response to the following questions was generally positive but younger drivers were more negative about the poor landmarks conditions.

FAQA4 **A navigation system is an easy method of finding my way in an unfamiliar area**
Generally positive, young more negative towards poor landmarks.

FAQA6 **With a navigation system, I think I would be less likely to get lost**
Generally positive, young more negative towards poor landmarks

FAQA15 **A navigation system reduces the amount of stress during driving**
Quite a variation in opinion (2-4.5) with young more negative towards poor (median=2) than good or none (median=4).

FAQA21 **I would prefer using a navigation system to my usual way of navigating in a car**
The majority of respondents were positive but the young group were neutral about the poor landmark condition.

FAQA22* **I am disappointed with the performance of the navigation system**
Most respondents were positive (i.e. disagreed with the statement) although there was a wide variation for the young group for the poor landmarks

There was neutral response to one question and it is the only one where the good landmarks condition elicited a more negative response (from the younger group)

FAQA7** **The navigation system always did what I expected**
Neutral response, young more negative towards good landmarks

For two questions the younger group showed a preference for the no landmarks condition.

FAQA19 **I am looking forward to using a navigation system (again)**
Responses were very positive, particularly for the young drivers in the no landmarks condition (median=5)

FAQA23* **I felt happy when I was using the navigation system**
Mostly positive, especially for the old group. Younger drivers were most positive about the no landmarks condition.

Only one question had a negative response and this was less negative for the older drivers in the poor landmarks condition.

FAQA25 **I looked at the display a lot when I was driving round the route**
Most respondents agreed with this statement (median=4), which is a negative outcome. The old group were more neutral for the poor landmarks condition.

14.6.3 Final acceptance questionnaire – part B

The second set of questions were phrased to elicit opinion on the information components of the system and identify whether these were affected by the landmark condition.

The following questions showed a positive response from the participants with no effect of landmark condition or age:

FAQB1 **The distance countdown bar told me exactly where I needed to turn**

FAQB6 **I listened carefully to the voice messages when driving round the route**

FAQB10 **The diagram of each junction helped me identify where to turn**

The following statements showed an effect for age. Question FAQB4 also showed an effect for landmark condition.

Two statements elicited a more marked positive response from older drivers.

FAQB5** **The map overview told me exactly where I needed to turn**
Responses varied from 2-4.5 for this statement, with older drivers consistently more positive (by 1-1.5 scale points) across all conditions.

FAQB7 **The navigation system usually gave me information too late**
Most respondents were positive (i.e. disagreed). This was more marked for the older group.

Three statements showed a more negative response for the poor landmarks condition in one age group. In two cases this was the young group, in one it was the older group.

FAQB4** **The navigation system always gave me information when I needed it**
There was quite a lot of variability in response to this question (2-4.5). The good landmarks condition resulted in a significantly (p=0.05) more positive response than the others. The older group were less positive for the poor landmarks condition.

FAQB9** **The voice messages told me exactly where I needed to turn**
Responses were mainly positive with younger drivers more negative in the poor landmarks condition.

FAQB11* **The navigation system usually gave me information too early**
Response to this statement was mostly neutral but the young group agreed more for the poor landmarks. (i.e. a negative response)

The remainder of the statements indicated mixed views from different age groups on landmark condition.

FAQB2** **The information from the navigation system was always accurate**
Responses were neutral to positive with the young group more neutral for good and poor landmarks.

FAQB3 **The navigation system gave me too much information**
Respondents disagreed with this statement, with the older group having a strong consensus in the good and poor landmarks conditions.

FAQB8 **The navigation system did not give me enough information**
The majority of responses were positive, except for younger drivers in the no landmarks condition (median=4)

14.6.4 Final acceptance questionnaire – part C

The next section of the question was a slightly different format. Participants were asked to indicate how useful different information elements were. The rating scale used for this section was the following.

Not at all useful	Not very useful	Neutral	Quite useful	Very useful
1	2	3	4	5

The information items rated were:

FAQC1 **The distance countdown bar**
A strong positive response (all medians 4.5 or 5). No effect of landmark or age.

FAQC2 **The voice instructions**
A strong positive response (all medians 4.5 or 5). No effect of landmark. Greater variability in a negative direction for the young group in the poor landmarks condition.

FAQC3 **The map overview**
Positive response (medians 3.5 to 4.5). Both age groups found the map overview less useful in the no landmarks condition although this was not statistically significant. There was no effect of age.

FAQC4 **The distance to destination indicator**
Response was mostly neutral with all medians at rating 3 except for the older group in the poor landmarks conditions (median 3)

FAQC5 **The road names (top and bottom)**
Quite a positive response (medians 3 to 4) with a statistically significant effect (p=0.05) of landmark condition - participants in the poor landmarks condition found road names more useful that those in the other conditions. The younger group seemed to find it less useful in the good landmarks condition.

Overall, the voice instructions and distance countdown bar were considered the most useful, followed by map overview and road names. Respondents were neutral about the distance to destination indicator, which is to be expected as it had little purpose in the trials (it only indicated distance to the next waypoint). One interesting finding is that drivers in the poor landmark condition found road names to be more useful. This could be due to the poor landmarks often being difficult to see until the last minute, and the drivers relying more on road names both for identifying the manoeuvre and confirming that they had taking the correct turn.

The high rating for the distance countdown bar suggests that it was heavily used which is not ideal in respect of maintaining visual attention to the road.

14.6.5 Final acceptance questionnaire – subjective comments

Part of the questionnaire, post-trial, provided the opportunity for free text comments on aspects of the system liked/disliked, suggested improvements and views on landmarks (see Section 11.7).

Positive comments related mostly to the voice instructions, landmarks and distance countdown bar. Most participants seemed to enjoy their experience with the navigation system.

Negative remarks were linked to what was perceived as 'missing' or misleading information. A particular example of this was the omission of any mention of mini-roundabouts within the verbal or visual information. Another frequently mentioned feature, particularly in the poor landmarks condition, was that the first message was presented too early, when the landmark could not be seen.

Suggested improvements included: specify lane, give an idea of distance between landmark and turn, count number of roads to turn, indicate mini-roundabouts.

With regard to the usefulness of landmarks for navigation, more positive responses were given in the good landmarks condition but negative comments were also made (that they could be improved or that they were redundant). Some positive comments were made on the poor landmarks but the majority of respondents were negative or indifferent (e.g. that they were distracting or confusing).

14.6.6 Final acceptance questionnaire – change in attitudes

The analysis also investigated whether opinion changed after use, compared with opinions before use (the latter based on a verbal description of the navigation system which did not mention landmarks). It was possible to ask seven of the questions before and after the trial (the rest would have been meaningless before use). Graphs showing the direction of change are provided in section 11.9.

FAQA1* **Using a navigation system is a fun way of navigating**
Females agreed more after use. Males agreed less.

FAQA4 **A navigation system is an easy method of finding my way in an unfamiliar area**
No change over time.

FAQA6* **With a navigation system, I think I would be less likely to get lost**
Agreement increased for those using good landmarks. Agreement reduced for those using poor or no landmarks.

FAQA15* **A navigation system reduces the amount of stress during driving**
Agreement increased for no landmarks with a slightly smaller increase for good landmarks. Agreement reduced for poor landmarks.

FAQA19* **I am looking forward to using a navigation system (again)**
Opinion remained the same for no landmarks, improved for good landmarks and worsened for poor landmarks (NOTE: this results should be treated with caution as the matched IPQ3 question showed a significant effect of landmark condition – see section 14.6.1)

FAQA21** **I would prefer using a navigation system to my usual way of navigating in a car**
The older group agreed more after use. The younger groups agreed less.

FAQA24* **Using the navigation system makes driving more difficult**
The younger group agreed more after use. The older groups agreed less.

Generally, where there was a significant change over time, the good landmarks condition increased peoples opinions favourably. Conversely, poor landmarks had a negative effect on opinions. For the condition where no landmarks were used, the effect on opinion varied. The no landmarks

condition was associated with a bigger improvement in opinion than good landmarks for one question (FAQA15)

14.6.7 Final acceptance questionnaire – summary

Nearly all statements elicited positive responses from the participants. This was unanimous for enjoyment in using the system, feelings of quality and liking the visual and voice information. More neutral (but not negative) responses were given for finding the system natural to use, trusting it, meeting drivers' expectations and believing it did not distract attention from the road. Only one negative response was found with regard to looking at the display a lot.

The lack of any significant difference in opinions between landmark conditions contradicts some other studies where use of landmarks often results in more positive responses (see Alm et al, 1992; Green et al, 1993 and Allerton, 2000)

Where a significant change of opinion was found from before system use to after, good landmarks improved opinion and poor landmarks worsened opinion. Using no landmarks had a varying effect on opinion, sometimes detrimental, sometimes not.

The older group (55+) were more positive on several questions relating to driving safely and the system working properly and consistently. The younger group were often more negative of the poor landmarks condition, especially relating to improvement of the driving experience. The only other study to have found an age effect on opinions was a driver survey (as opposed to a road trial) by Burnett (1998) where older drivers rated most of the proposed navigation information types (including landmarks) as more useful than did younger drivers.

Few gender differences were found, which is surprising when considering the fact that most research suggests that females use/prefer landmarks and left/right directions and males use/prefer distances, compass directions and road numbers. The lack of a difference in the current study may be due to the fact that the navigation system used in the trial presented a whole range of information (see section 3.3), thus showing no particular benefit of landmarks when used by female drivers.

The information components considered of most use were the voice instructions, the countdown bar and the junction layout. Road names proved more useful in the poor landmarks condition than for good or no landmarks.

14.7 Predictive value of regression model

In addition to comparing driver performance across the good, poor and no landmarks categories, the trial also aimed to validate (or otherwise) the regression model developed within REGIONAL. This model enables an object to be given a value that indicates its usefulness for navigating a particular manoeuvre. The model uses ratings on three factors (Visual Characteristics, Usefulness of Location and Degree of Interaction) to compute this value.

The trial aimed to show that as this computed Landmark Value increases so does driver performance as measured by:

- Number of glances to the display (predicted decrease)
- Percentage of moving time looking at the display (predicted decrease)
- Confidence ratings at Preview 1, Preview 2, Final and Post-manoeuvre (predicted increase)
- Driving errors (predicted decrease)
- Navigation errors (predicted decrease)

There was a significant, positive relationship between confidence ratings (for all four points) and landmark value. All other measures did not correlate with landmark value.

Taking confidence ratings first, the strongest relationship was at the Final message point (a 'beep' at 50yds) with a correlation coefficient of 0.616 ($p=0.01$). This is the point at which the driver must commit to the manoeuvre that will be taken. Any lack of confidence at this point could result in an indecisive approach and improper indication to other drivers of the action to be taken. The fact that the model can predict driver confidence at this point is a positive outcome of the research.

Significant correlations were also found at Preview 1 (0.535, $p=0.05$), Preview 2 (0.501, $p=0.05$) and post-manoeuvre (0.478, $p=0.05$). However when considering confidence for the no landmarks condition (i.e. that which represents current, 'standard' navigation instructions), landmarks are only of value where confidence with landmark inclusive instructions exceeds that for instructions

without landmarks. The landmark value at which this benefit begins varies for each point of rating as follows:

Message/rating point	Distance from manoeuvre	Landmark value at which confidence increases above no landmarks condition (maximum value possible = 100)
Preview 1	500m	Increase does not occur
Preview 2	200m	77
Final	50m	55
Post-manoeuvre	after	38

Table 19. Landmark values at which use becomes beneficial

This finding is interesting when considering at which point to provide landmarks within the navigation instructions. It seems that there is no benefit to providing any landmarks at Preview 1, but by Preview 2 there is an advantage to providing only the best landmarks. Landmarks with a lower value are beneficial at the Final message and even the poorer landmarks seem to increase confidence after the manoeuvre has been completed.

The fact that landmarks do not have an advantage at Preview 1 is probably connected to the visibility of landmarks. There are very few objects in the urban road environment that are visible at 500m (all landmarks in the trial were only visible at 350m or less). Any increase in confidence at Preview 1 would only be due to an 'expectation' that a landmark will be useful. It seems that this expectation did not occur. The benefit of including landmarks at Preview 1 could be increased if landmarks could be presented in an appropriate way on the visual display. This should increase driver confidence that the landmark exists and pre-warn of its precise location. This should be a topic for further research as additional visual information could adversely affect drivers' visual attention to the road. The findings from the current study can provide useful guidance for verbal-only landmark information.

An increase in landmark value was not always associated with an increase in driving performance. All other measures of visual behaviour, driving safety and navigation performance did not correlate with landmark value. This could be due to the behaviour measures used not being sufficiently discriminating to show a correlation. However, it may also be possible that, if the measures were taken as a whole, i.e. combined into some overall 'driver behaviour' measure then a different result may be found. Earlier stages of analysis showed that measures could not be taken in isolation. For example, visual behaviour alone indicated that poor and good landmarks had little difference between them and using no landmarks was significantly worse. When taking driver confidence into consideration, good landmarks had an advantage over both poor landmarks and no landmarks. If both of these measures are considered, good landmarks 'score' well on both measures and the other conditions do not. With only one measure, an incomplete picture is given. A combined measure could be created but this would be quite arbitrary and the validity of results would be questionable.

14.8 Predictive value of regression factors

Although the regression model does seem able to predict effect on driver confidence, it was not validated for the other measures (i.e. landmark value does not predict changes in visual behaviour, driving errors or navigation errors). It was considered valuable to consider the ten original component factors used in the regression analysis to see if any of them, singly, showed a strong relationship with driver performance. The ten components are (inclusion in regression model indicated by *):

- Visual Characteristics (VISCHAR*)
- Visual Effort for Scanning (VISEFF)
- Pre-Warning (PREWRN)
- Familiarity (FAM)
- Ease of Naming (ESNAME)
- Influence of Surroundings. (SURR)
- Similarity of Appearance (SIMAPP)
- Usefulness of Location. (USELOC*)
- Level of Task Demand (TSKDEM)
- Degree of Interaction. (DEGINT*)

An additional, objective measure was included in the correlations. This was the distance, prior to the manoeuvre, at which the landmark (and any associated label) could be seen (to the nearest 50m). This is termed 'VISIBILITY DISTANCE' and can be considered a component of VISEFF).

Table 18 in the results section provides a summary of significant correlations. Again, there was little relationship between ratings on each factor and measures of driving errors, navigation errors and visual behaviour. One exception was a significant ($p=0.05$) correlation coefficient of –0.579 between driving errors and task demand. This seems logical but is likely to be a factor of the road environment itself rather than the choice of landmark.

Driver confidence again seemed to be predictable based on several of the factors. It was reassuring to see that two of the three components of the regression model (Visual Characteristics and Degree of Interaction) did, individually, have some predictive ability for driver confidence. This was not the case for the third component, Usefulness of Location, but this may be due to the majority of landmarks in this study covering a small range of ratings (i.e. the data was range-limited).

Other factors, which were not components of the model, did seem to have a link with confidence ratings. 'Pre-warning' of the landmark seemed to have a relationship with 3 of the confidence ratings. 'Influence of Surroundings' and 'Level of Task Demand' correlated with 2 confidence measures.

The confidence rating that correlated with the most factors was that given at the Final point. This reflects the findings for correlations with overall Landmark Value. Most of the factors that had predictive abilities at this point reflected the visual components of the landmarks i.e. Visual Characteristics, Visual Effort for Scanning, Pre-Warning, Influence of Surroundings, and Degree of Interaction. One exception to this was Level of Task Demand, but the small range of ratings (at the high end) on this factor means that these results may not be applicable where task demand is low.

It is probably not valid to assume that the factors that showed little, or no, correlation with behaviour should be ignored when identifying the value of landmarks. The landmarks in the study only covered a very small range of ratings for these factors, which were: Familiarity, Ease of Naming, Similarity of Appearance and Usefulness of Location. This was due to limitations on the availability of appropriate landmarks within a real driving environment.

14.9 Manoeuvres not matching the trend

When considering the plots of behaviour against regression factor (summary reported in section 13, graphs not replicated in this deliverable), there are several cases of outliers that suggest that there may be something other than the landmark (factors) influencing behaviour. This could be due to experience with the system, the junction layout, surrounding junctions, speed of approach, traffic, weather or user effects.

Where a trend was shown on a plot, outliers were those points that were, on visual examination, disassociated with those trends. Therefore, where there is no trend there can be no outliers. The maximum number of times that any manoeuvre (in each landmark condition) could result in an outlier was 88 (10 factors plus 'Visibility Distance', times 8 behaviour measures). The table below shows the manoeuvres where there were outliers and the number of outliers, (+n) indicates the number of times there was an outlier on the 'Landmark Value' correlation plots in Section 12.2 (maximum = 8).

	Good Landmarks		Poor Landmarks		All Landmarks
Man no.	Outliers where performance was better than the trend	Outliers where performance was worse than the trend	Outliers where performance was better than the trend	Outliers where performance was worse than the trend	Total outliers for Confidence measures only
2		10 (+1)		53 (+5)	41 (+4)
4		16 (+1)		33 (+3)	27 (+2)
7	8	7 (+1)			7 (+1)
8					
9				1	1
15		11			
19					
22					
33	1	21 (+2)	10 (+1)	21 (+2)	20 (+2)
37					

Table 20. Correlation outliers for each manoeuvre

Table 20 indicates the outliers for all regression factors; however, the outliers for *confidence measures* (shown in the last column of Table 20) are those for which some conclusions may be drawn. This is because confidence ratings were the only measures that showed a significant relationship with landmark value. The results above show that manoeuvres 2, 4, 33 and, to a lesser extent, 7 seem to induce behaviour that is outside that which is the norm (i.e. which can be predicted by Landmark Value or a component factor) and this consistently resulted in lower confidence ratings. Users, weather and overall traffic level were as consistent as possible throughout the duration of the trial. Therefore the possible factors affecting behaviour include:

- Experience with the system
- Junction layout
- Surrounding junctions
- Usual traffic density
- Likely speed of approach

Knowledge of the route and experience within the trials enable the following factors to be identified as those that caused worse performance for each manoeuvre:

Manoeuvre 2: - early in the trial (participants generally had not got into the habit of using the distance countdown bar)
- previous crossroads similar in layout would be an equally likely route
- dual carriageway, lane choice required, busy environment

Manoeuvre 4: - early in the trial (participants generally had not got into the habit of using the distance countdown bar)
- minor road, very narrow and partially concealed
- subsequent mini-roundabout in view which would be a more likely route

Manoeuvre 7: - several right-turns in central reservation as possible prior manoeuvres
- dual carriageway, lane choice required, busy environment

Manoeuvre 33: - the last of 3, stacked manoeuvres
- minor road, very narrow, concealed by parked cars
- subsequent, wider road in view, which would be a more likely route

In contrast, the other manoeuvres were all visible, did not have other junctions nearby that would seem a more 'likely' route and had a lower workload (i.e. no lane choice, less traffic pressure).

These finding have some implications for landmark choice. The early manoeuvres (2 and 4) had more outliers with worse performances in the poor landmarks condition. This was not the case for the later manoeuvres, probably because the participants were using the distance countdown bar to better identify the manoeuvre.

The results also suggest that junction representations could support the driver further by providing some indication of road 'size' and showing prior/subsequent junctions that could be confused with that intended. For instance, the screens below show what the driver sees, comments below each picture indicate improvements that could help at that junction

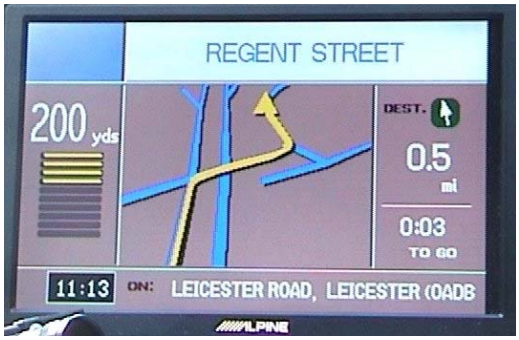
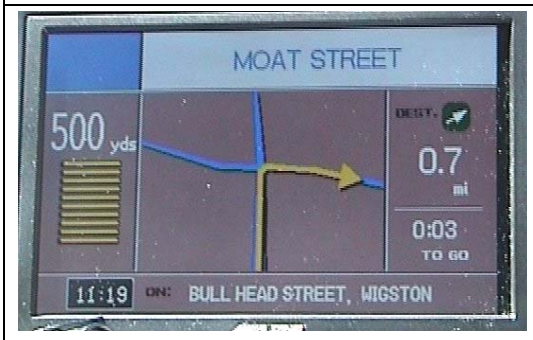
Manoeuvre 2	Manoeuvre 4
	
Show the prior crossroads.	Show the subsequent (more expected) turn as a mini-roundabout and that the target turn is narrower than all surrounding roads.
Manoeuvre 7	**Manoeuvre 33**
	
Indicate other potential right turns through the central reservation.	Show that the target turn is much narrower than the subsequent left turn.

Figure 4. Potential improvements to visual display for problem manoeuvres

For all manoeuvres, an indication of landmark position on the visual display may also assist the driver. This issue was discussed earlier in this section (with regard to further research being required before any firm guidelines could be given).

15 CONCLUSIONS

15.1 Landmark condition and driver behaviour

When comparing good, poor and no landmarks, several of the behavioural measures indicated a clear difference between landmark categories. However this was not always in the direction expected. The assumption was that good landmarks would always result in better performance than poor, with no landmarks being the least advantageous conditions. It is interesting to look at a high level summary of findings. Table 21 shows the landmark condition(s) that produced the best performance (√ √), the second best performance (√) and the worst performance (X). For some measures no difference was found, these are indicated by '-'.

	Good landmarks	Poor landmarks	No landmarks
No. of glances	√	√ √	X
Glance duration	-	-	-
% time looking at display	√	√	X
Workload	-	-	-
Driving errors	√ √	X	√
Navigation errors	√ √	X	X
Approach confidence	√	X	√
Confidence at Preview 1	√	X	√ √
Confidence at Preview 2	√	X	√ √
Confidence at Final	√ √	X	√
Confidence post-manoeuvre	-	-	-

Table 21. High-level summary of findings

From this, the main conclusions are:

- Good and poor landmarks resulted in less glances to the display
- Good landmarks produced less driving errors
- Good landmarks produced the least navigation errors
- Good and no landmarks resulted in higher driver confidence (except post-manoeuvre where there was no difference)
- Workload was unaffected by landmark condition

The two main, reported age effects were that older drivers had longer average glance durations (expected, due to reduce speed of visual accommodation with age) and generally reported themselves to be more confident.

One unpredicted finding was that, for all conditions, glance duration decreased over time (from manoeuvre 2 to 37) from $\geq$ 0.95sec to $\leq$ 0.9sec, with no apparent plateau occurring.

15.2 Driver attitudes

Driver perceptions of the system were generally positive with very few opinion statements showing a significant difference across conditions. The majority of participants enjoyed using the system, perceived it to be of high quality and liked the information that was presented. Where

opinions after the trial differed from those prior to system use, good landmarks generally improved driver attitudes, poor landmarks were detrimental to opinion and no landmarks had a mixed effect.

The main age effects were that older (55+) participants were generally more positive about use of the system.

The information that participants found helpful in all conditions was the voice instructions (including the landmarks), the distance countdown bar and the road layout. Those experiencing poor landmarks also found road names particularly useful.

Suggested improvements were:

- the addition of mini-roundabouts on the display
- indication of the most appropriate lane
- counting of roads (e.g. take the second left)
- identification of distance between landmark and manoeuvre.

Several participants felt that (particularly for the 'poor' condition) landmarks were given too soon (mostly because they were not yet visible).

15.3 Regression model

A further aim of the study was to validate the model developed by the REGIONAL project to determine the navigational value of a specified landmark. It was hoped that increasing landmark value would be associated with an improvement in driver behaviour and confidence (as indicated by the measures in Table 21). The model correlated well with measures of driver confidence. In addition, it was possible to identify the landmark value at which confidence increased above that for the no landmarks condition for each stage. These were: 77 for Preview 2, 55 for Final and 38 for Post-manoeuvre.

An increase in landmark value was not always associated with an increase in driving performance. All other measures of visual behaviour, driving errors and navigation performance did not correlate with landmark value. This could be due to the behaviour measures used not being sufficiently discriminating to show a correlation. However, it may also be possible that, if the measures were taken as a whole, i.e. combined into some overall 'driver behaviour' measure then a different result may be found (as for the findings summarised in Table 21, considering one measure alone does not provide the whole picture). A combined measure could be created but this would be quite arbitrary and the validity of results would be questionable.

15.4 Correlation with landmark factors

When considering correlation with the individual components of the regression model (and other components excluded during the regression) again, there was little relationship between ratings on each factor and measures of driving errors, navigation errors and visual behaviour. However, driver confidence once again seemed to be predictable based on some component factors as shown in Table 22 (an asterisk indicates inclusion in the REGIONAL model)

Correlation with driver confidence?	
Yes	No
Visual Characteristics (*)	Familiarity
Visual Effort for Scanning	Ease of Naming
Pre-Warning	Similarity of Appearance
Influence of Surroundings	Usefulness of Location (*)
Level of Task Demand	
Degree of Interaction (*)	
Visibility Distance	

Table 22. Factors showing a correlation with driver confidence

15.5 Manoeuvre effects

Particular manoeuvres caused behaviour outside the norm (namely manoeuvres 2, 4, 7 and 33). These manoeuvres had one or more of the following features: were early in the trial, had other, equally/more likely manoeuvres nearby (e.g. roundabout, more major road), were concealed in some way, were in a busy traffic situation. These results suggest that junction representations could support the driver further by providing some indication of road 'size', showing prior/subsequent junctions that could be confused with that intended and indicating position of the landmark on the display.

15.6 Comparison with predicted findings

Based on previous studies in the literature, 4 findings were predicted (in section 4). It is useful to provide a summary of the conclusions in relation to these predictions:

Good landmarks will result in better driver performance than Poor landmarks, which will, in turn be better than No landmarks

Clear behavioural differences were found between the three landmark categories of good, poor and no landmarks: the good landmarks condition was the one that most consistently resulted in safer and more effective driver behaviour. Poor landmarks performed equally well on reducing the amount of time looking at the display. No landmarks resulted in driver confidence equivalent to that for good landmarks Participants' attitudes varied little across landmark condition:

An increase in landmark value will lead to better driver performance

The REGIONAL regression model for landmark value could predict driver confidence but could not predict other measures of driver behaviour. Driver confidence also showed a relationship with the component factors of Visual Characteristics, Visual Effort for Scanning, Pre-Warning, Influence of Surroundings, Level of Task Demand, Degree of Interaction and Visibility Distance

There will be no effects of age on driver performance

Older drivers had longer average glance durations and were more positive about system use. There were no notable effects of interaction between age and landmark category.

There will be no effects of gender on driver performance

There were no notable effects of gender

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18 APPENDICES

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Appendix 1. Navigation information provided at target manoeuvres

Man no.	Display	Condition	Preview 01	Preview 02	Final preview
02		Distance	500 metres	200 metres	50 metres
		Good	right turn at the 2nd set of traffic rights	right turn at the 2nd set of traffic lights, then left turn	Beep
		Poor	right turn at the sculpture	right turn at the sculpture, then left turn	Beep
		None	right turn ahead	right turn ahead then left turn	Beep
04		Distance	No message given at this point	200 metres	50 metres
		Good		right turn before the church	Beep
		Poor		right turn after the police station	Beep
		None		right turn ahead	Beep
07		Distance	500 metres	200 metres	50 metres
		Good	right turn after the Texaco petrol station	right turn after the Texaco petrol station	Beep
		Poor	right turn opposite the Horse and Trumpet pub	right turn opposite the Horse and Trumpet pub	Beep
		None	right turn ahead	right turn ahead	Beep
08		Distance	300 metres	200 metres	50 metres
		Good	left turn after the pedestrian lights	left turn after the pedestrian lights	Beep
		Poor	left turn after the bus stop	left turn after the bus stop	Beep
		None	left turn ahead	left turn ahead	Beep

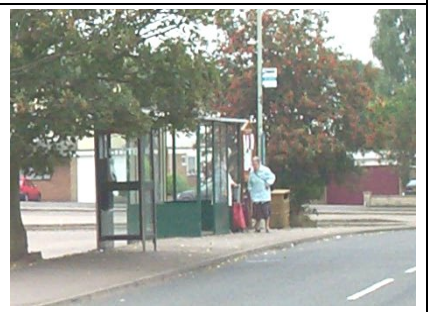
Man no.	Display	Cond.	Preview 01	Preview 02	Final preview
09		Distance	500 metres	200 metres	50 metres
		Good	left turn after the Vikings Tun pub	left turn after the Vikings Tun pub	Beep
		Poor	left turn after the bus stop	left turn after the bus stop	Beep
		None	left turn ahead	left turn ahead	Beep
15		Distance	500 metres	200 metres	50 metres
		Good	left turn after the pedestrian lights	left turn after the pedestrian lights	Beep
		Poor	left turn opposite the post box	left turn opposite the post box	Beep
		None	left turn ahead	left turn ahead	Beep
19		Distance	500 metres	200 metres	50 metres
		Good	right turn before the pedestrian lights	right turn before the pedestrian lights	Beep
		Poor	right turn after the bridge	right turn after the bridge	Beep
		None	right turn ahead	right turn ahead	Beep
22		Distance	500 metres	200 metres	50 metres
		Good	right turn after the pedestrian lights	right turn after the pedestrian lights	Beep
		Poor	right turn opposite the post box	right turn opposite the post box	Beep
		None	right turn ahead	right turn ahead	Beep

Man no.	Display	Cond.	Preview 01	Preview 02	Final preview
33		Distance	No message given at this point	100 metres	50 metres
		Good		left turn at the phone box	Beep
		Poor		left turn after the Jet garage	Beep
		None		left turn ahead	Beep
37		Distance	500 metres	200 metres	50 metres
		Good	right turn before the 2nd set of pedestrian lights	right turn before the pedestrian lights	Beep
		Poor	right turn before the phone box	right turn before the phone box	Beep
		None	right turn ahead	right turn ahead	Beep
Over view					

Appendix 2. Target manoeuvres and landmarks

<table>
<tr><td>Man. 02</td><td colspan="2">Good Landmark: The Traffic Lights (value = 86), visible at 150yds</td><td colspan="2">Poor Landmark: The Sculpture (value = 21), visible at 0yds</td></tr>
<tr><td></td><td>Position</td><td>Appearance</td><td>Position</td><td>Appearance</td></tr>
<tr><td></td><td> 
</td><td>  </td><td> 
</td><td>  </td></tr>
<tr><td></td><td colspan="2">Comments: Required lane change, previous set of traffic lights also with right turn</td><td colspan="2">Comments: placed quite far to right of junction and quite difficult to see against background</td></tr>
<tr><td>Man 04</td><td colspan="2">Good Landmark: The Church (value = 38), visible at 200yds</td><td colspan="2">Poor Landmark: The Police Station (value = 25), visible at 100yds</td></tr>
<tr><td></td><td>Position</td><td>Appearance</td><td>Position</td><td>Appearance</td></tr>
<tr><td></td><td> 
</td><td>  </td><td> 
</td><td>  </td></tr>
<tr><td></td><td colspan="2">Comments: Vary narrow road (i.e. unexpected), with a mini-roundabout in sight ahead</td><td colspan="2">Comments: ‘Police’ sign is small and difficult to see</td></tr>
</table>

Man. 07	Good Landmark: The Texaco Petrol Station (value = 76), visible at 350yds		Poor Landmark: The Horse and Trumpet Pub (value = 24), visible at 100yds	
	Position	Appearance	Position	Appearance
				
	Comments: Located on corner, visible from far away		Comments: Set back quite far from roadside	
Man 08	Good Landmark: The Pedestrian Lights (value = 70), visible at 150yds		Poor Landmark: The Bus Stop (value = 34), visible at 100yds	
	Position	Appearance	Position	Appearance
				
	Comments: Just after a mini-roundabout (not indicated as such on display)		Comments: Just after a mini-roundabout (not indicated as such on display)	

Man 09	Good Landmark: The Vikings Tun Pub (value = 52), visible at 0yds		Poor Landmark: The Bus Stop (value = 47), visible at 100yds	
	Position	Appearance	Position	Appearance
				
	Comments: The building itself is set back quite far from the roadside, there is a separate sign for the pub located at the corner of the junction		Comments: Quite cluttered environment	

Man 15	Good Landmark: The Pedestrian Lights (value = 84), visible at 300yds		Poor Landmark: The Post Box (value = 26), visible at 150yds	
	Position	Appearance	Position	Appearance
				
	Comments: Most drivers are accelerating away from the previous roundabout at this point		Comments: Not in direct line of driver's sight, on opposite side of dual carriageway	

Man 19	Good Landmark: The Pedestrian Lights (value = 73), visible at 100yds		Poor Landmark: The Bridge (value = 60), visible at 150yds	
	Position	Appearance	Position	Appearance
				
	Comments: Easily visible landmark and junction		Comments: Less noticeable as a bridge, no change in gradient	
Man 22	Good Landmark: The Pedestrian Lights (value = 83), visible at 250 yds		Poor Landmark: The Post Box (value = 27), visible at 150yds	
	Position	Appearance	Position	Appearance
				
	Comments: Visible and located close to junction		Comments: Set back from roadside	

<table>
<tr><td>Man 33</td><td colspan="2">Good Landmark: The Phone Box (value = 44), visible at 0yds</td><td colspan="2">Poor Landmark: The Jet Garage (value = 73), visible at 100yds</td></tr>
<tr><td></td><td>Position</td><td>Appearance</td><td>Position</td><td>Appearance</td></tr>
<tr><td></td><td> 
</td><td>  </td><td> 
</td><td> 
</td></tr>
<tr><td></td><td colspan="2">Comments: Although potentially a good landmark (located next to the target junction), it was often obscured by parked vehicles. The target road is very narrow.</td><td colspan="2">Comments: Opposite the target junction which was a very narrow road (with a subsequent, more likely turn, in view.</td></tr>
<tr><td>Man 37</td><td colspan="2">Good Landmark: The Pedestrian Lights (value = 79), visible at 200yds</td><td colspan="2">Poor Landmark: The Phone Box (value = 50), visible at 50yds</td></tr>
<tr><td></td><td>Position</td><td>Appearance</td><td>Position</td><td>Appearance</td></tr>
<tr><td></td><td> 
</td><td>  </td><td> 
</td><td>  </td></tr>
<tr><td></td><td colspan="2">Comments: Pedestrian lights visible quite far away</td><td colspan="2">Comments: Cluttered environment for the landmark</td></tr>
</table>

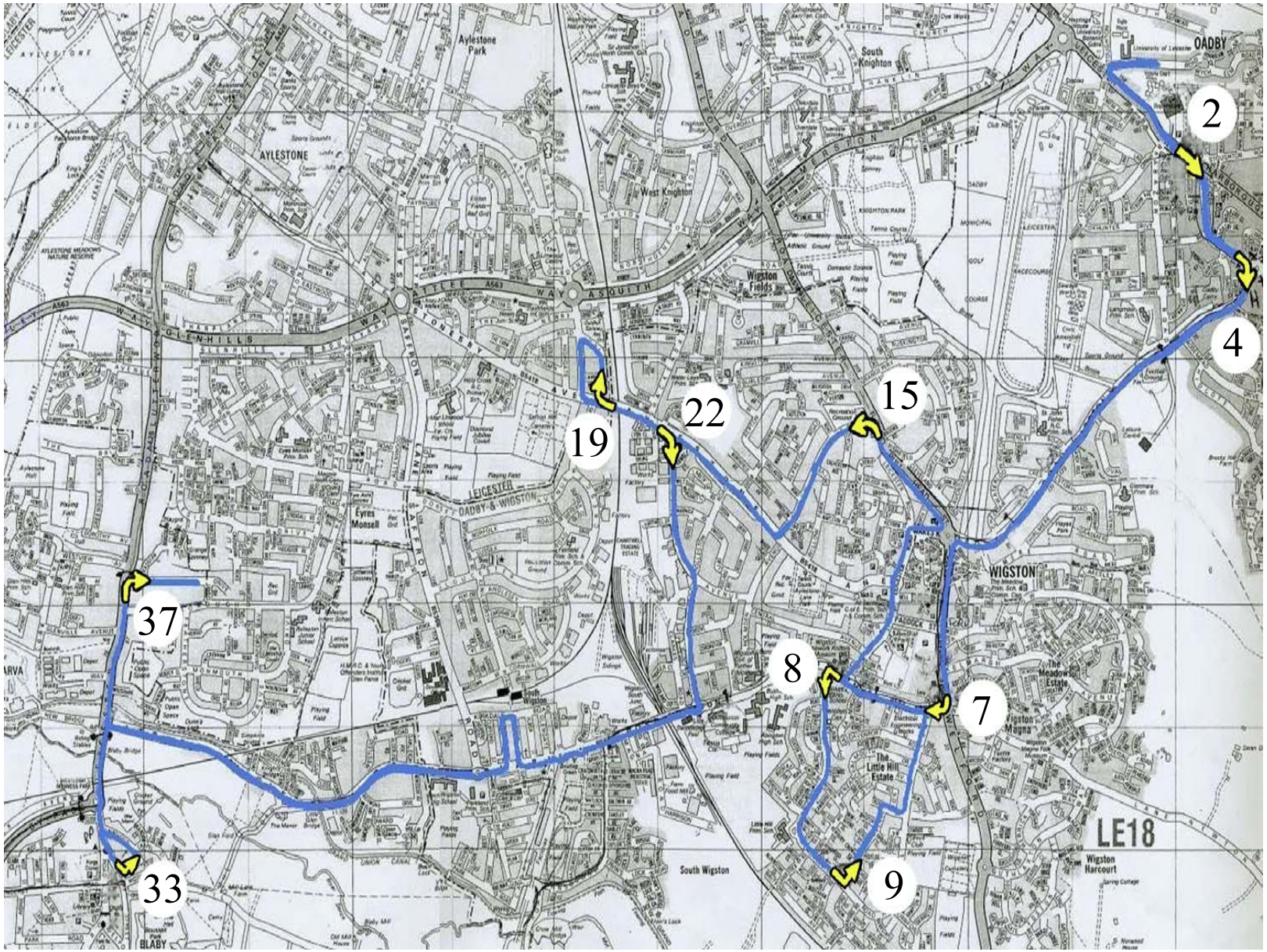
Appendix 3. Route overview

KEY:

Blue line: test route

Yellow arrows: location and direction of target manoeuvres

White circles: target manoeuvre number


OADBY
2
4
15
22
19
37
8
7
9
33
WIGSTON
LE18
AYLESTONE
Aylestone Park
South Knighton
West Knighton
Wigston Fields
Eyres Monsell
South Wigston
The Meadows Estate
Wigston Magna
The Little Hill Estate
Wigston Harcourt
BLABY

Appendix 4. Driving errors score sheet

Safety checklist (driving instructor)

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

Sub name…….. No…… Date……... Time…….

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 Parade' (Oadby)																		
3	proceed on Leicester rd road (road bears left)																		
4	right by the church, Wigston 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
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																		
19	right onto Goldhill																		
20	left onto Windley rd																		
21	left onto Stonesby Ave																		
22	right onto West Ave																		

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
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 5. NASA RTLX rating sheet

NASA-RTLX – Introductory materials, factor definitions and rating scales

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 instances, one has 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

Appendix 6. Confidence ratings & navigation errors score sheet

Confidence Ratings & Navigation Errors - Subject Ratings Sheet

Subject Name: **Date:**
Subject No.: **Start Time:**

18.1.1.1 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					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

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					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

6 - 1st exit off Wigston roundabout (onto Bull Head street)

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

7 - right onto Moat Street

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

8 - left onto Launceston rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.2 ON MOVE – Next Waypoint

9 - left onto Bodmin ave

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.3 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					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

11 - left onto Moat street

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

12 - right onto Long street

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.4 ON MOVE – Next Waypoint

13 - right onto Wakes Rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.5 ON MOVE – Next Waypoint

14 - 1st exit off Wigston roundabout

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

15 - left onto Carlton drive

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.6 ON MOVE – Next Waypoint

16 - right onto Chellaston rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

17 - left on Exeter rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

18 - right onto Aylestone rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

19 - right onto Goldhill

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.7 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					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

21 - left onto Aylestone rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

22 - right onto West Ave

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.8 ON MOVE – Next Waypoint

23 - right onto Pullman rd

	Low	Med	High	Comments/Reasons for rating				
Preview 1								
Preview 2					Navigation Error			
Final					Too soon	Too late	No turn	Other (state)
After man.								

24 - right onto Station rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

25 - right onto Fairfield rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.9 ON MOVE – Next Waypoint

26 - left onto Kirkdale road

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

27 - left onto Leopold rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

28 - right onto Blaby rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

29 - proceed onto Little Glen rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

ON MOVE – Next Waypoint

30 - left onto Leicester rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

31 - 1st exit off Blaby roundabout

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

32 - left at mini roundabout

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

33 - left onto Home close

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

18.1.1.10 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	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

35 - right onto Leicester rd

	Low	Med	High	Comments/Reasons for rating	Navigation Error			
Preview 1								
Preview 2								
Final					Too soon	Too late	No turn	Other (state)
After man.								

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)

18.1.1.10.1 END – Drive back to Sainsbury's

Appendix 7. Driver attitude questionnaires

Initial perceptions questionnaire

The following are some general questions about navigation systems. Please read each statement, and circle the number that best reflects whether you agree or disagree with each statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	A navigation system reduces the amount of stress during driving	1	2	3	4	5
2.	Using a navigation system is a fun way of navigating	1	2	3	4	5
3.	I am looking forward to using a navigation system	1	2	3	4	5
4.	Using the navigation system makes driving more difficult	1	2	3	4	5
5.	A navigation system is an easy method of finding my way in an unfamiliar area	1	2	3	4	5
6.	With a navigation system, I think I would be less likely to get lost	1	2	3	4	5
7.	I would prefer using a navigation system to my usual way of navigating in a car	1	2	3	4	5

Limited Exposure Questionnaire

The following are some general questions about navigation systems. Please read each statement, and circle the number that best reflects whether you agree or disagree with each statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	Using a navigation system is a fun way of navigating	1	2	3	4	5
2.	The navigation system always did what I expected	1	2	3	4	5
3.	I liked the visual display for the navigation system	1	2	3	4	5
4.	The navigation system had an overall feeling of 'quality'	1	2	3	4	5
5.	A navigation system is an easy method of finding my way in an unfamiliar area	1	2	3	4	5
7.	I would prefer using a navigation system to my usual way of navigating in a car	1	2	3	4	5
8.	The navigation system seemed to operate consistently	1	2	3	4	5
9.	I am looking forward to using a navigation system (again)	1	2	3	4	5
10.	Using the navigation system makes driving more difficult	1	2	3	4	5
11.	With a navigation system, I think I would be less likely to get lost	1	2	3	4	5
12.	The navigation system exceeded my expectations	1	2	3	4	5
13.	A navigation system reduces the amount of stress during driving	1	2	3	4	5
14.	I liked the voice instructions from the navigation system	1	2	3	4	5
15.	The information from the navigation system was always easy to understand	1	2	3	4	5

Final acceptance questionnaire

The following are some general questions relating to your use of the navigation system. Please read each statement, and circle the number that best reflects whether you agree or disagree with each statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	Using a navigation system is a fun way of navigating	1	2	3	4	5
2.	The way the navigation system worked fitted in with how I would normally navigate	1	2	3	4	5
3.	The navigation system had an overall feeling of 'quality'	1	2	3	4	5
4.	A navigation system is an easy method of finding my way in an unfamiliar area	1	2	3	4	5
5.	I always trusted the navigation system to give me the right instructions	1	2	3	4	5
6.	With a navigation system, I think I would be less likely to get lost	1	2	3	4	5
7.	The navigation system always did what I expected	1	2	3	4	5
8.	I always paid attention to the road when driving round the route	1	2	3	4	5
9.	I liked the visual display for the navigation system	1	2	3	4	5
10.	I found using the navigation system distracted me whilst driving	1	2	3	4	5
11.	I found it frustrating using the navigation system	1	2	3	4	5
12.	I sometimes got messages from the navigation system that I was not expecting	1	2	3	4	5
13.	The navigation system seemed to operate consistently	1	2	3	4	5
14.	The navigation system exceeded my expectations	1	2	3	4	5
15.	A navigation system reduces the amount of stress during driving	1	2	3	4	5
16.	I liked the voice instructions from the navigation system	1	2	3	4	5
17.	I always thought the navigation system was working properly	1	2	3	4	5
18.	I drove safely at all times when driving round the route	1	2	3	4	5
19.	I am looking forward to using a navigation system (again)	1	2	3	4	5

20.	Using the navigation system felt like a 'natural' thing to do	1	2	3	4	5
21.	I would prefer using a navigation system to my usual way of navigating in a car	1	2	3	4	5
22.	I am disappointed with the performance of the navigation system	1	2	3	4	5
23.	I felt happy when I was using the navigation system	1	2	3	4	5
24.	Using the navigation system makes driving more difficult	1	2	3	4	5
25.	I looked at the display a lot when I was driving round the route	1	2	3	4	5
26.	At the end of the drive, I felt relieved that the ordeal was over	1	2	3	4	5

The following are some specific questions relating to the information that the navigation system gave you – both the information on the visual display and the information given to you in the voice instructions. Please read each statement, and circle the number that best reflects whether you agree or disagree with each statement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	The distance countdown bar told me exactly where I needed to turn	1	2	3	4	5
2.	The information from the navigation system was always accurate	1	2	3	4	5
3.	The navigation system gave me too much information	1	2	3	4	5
4.	The navigation system always gave me information when I needed it	1	2	3	4	5
5.	The map overview told me exactly where I needed to turn	1	2	3	4	5
6.	I listened carefully to the voice messages when driving round the route	1	2	3	4	5
7.	The navigation system usually gave me information too late	1	2	3	4	5
8.	The navigation system did not give me enough information	1	2	3	4	5
9.	The voice messages told me exactly where I needed to turn	1	2	3	4	5
10.	The diagram of each junction help me identify where to turn	1	2	3	4	5
11.	The navigation system usually gave me information too early	1	2	3	4	5

Think about knowing where to turn and using the system easily. Please rate how useful the following features were to you by circling the appropriate number:

		Not at all useful	Not very useful	Neutral	Quite useful	Very useful
1.	The distance countdown bar (lhs)	1	2	3	4	5
2.	The voice instructions	1	2	3	4	5
3.	The map overview	1	2	3	4	5
4.	The distance to destination indicator (rhs)	1	2	3	4	5
5.	The road names (top and bottom)	1	2	3	4	5

1. Was there anything about the navigation system (eg the way it worked, what information it provided, when it gave you instructions) that you particularly liked?

……
……
……

2. Anything that you particularly disliked?

……
……
……

3. Do you have any suggestions for improving the way it worked?

……
……
……

4. Did you notice that the navigation system used landmarks in its voice instructions?

Yes ❑

No ❑

5. What did you think about them?

……
……
……

Appendix 8. Participant consent form

I _____ understand fully the procedures in this experiment, which have been explained to me.

I understand that as a participant I am guaranteed complete confidentiality and anonymity and although a record will be kept of my participation in the study, all data will be identified by number only. Therefore I consent to the written publication of results.

I have been informed that there is no known expected discomfort or risk involved in my participation in this study (other than the task of driving), and have been asked about any medical conditions that might create a risk for me when I participate.

I have been informed that there are no "disguised" procedures in this study.

I have been informed of the purpose of the study and understand that after the experiment, the investigator will answer any questions regarding the procedures of this study.

I understand that whilst in control of the vehicle I am responsible for observing the Highway Code (and therefore speed limits). I accept liability for any traffic offences or violations, and take full responsibility for the consequences. I am aware that the vehicle provided is comprehensively insured by Loughborough University.

I have been informed that I am free to withdraw from the study, at any time without penalty of any kind.

I am aware that concerns about this study can be referred to the principal investigator Mrs Tracy Ross or her superior, Mr John Richardson.

I therefore give my consent to be a participant in this experiment.

**I give my consent for videos of my trial to be used in future presentations

**I do not give my consent for videos of my trial to be used in future presentations

*(** please delete as appropriate)*

Signed;

_____ Participant

_____ Date

_____ Investigator

Appendix 9. Demographics questionnaire

I will now go through a few simple questions with you, these are about you and driving.

1. Name ……..

2. Gender

Male ❑

Female ❑

3. How old are you? ……

4. What is your occupation?……..

5. What type of vehicle do you normally drive?

Make (e.g. Ford) ……
Model (e.g. Mondeo 1.6) ……
Year or registration letter (e.g. 90, G reg)
……

6. How long have you have held a clean driving licence?……

1. How many accidents have you had which were wholly or partly your fault in the last 3 years?……..

8. How many days per week do you normally drive?…….

9. Approximately how many miles have you driven in the last year?……..

10. Approximately how many unfamiliar journeys do you do each month?…….

11. Do you have knowledge of the following areas in Leicester. Please tick yes or no:

	Yes	No
Oadby	❑	❑
Wigston	❑	❑
Glen Parva	❑	❑
Blaby	❑	❑

12. How do you rate your navigation ability (please tick one) ?

Very poor	Poor	Average	Good	Very good
❑	❑	❑	❑	❑

13. When you are going to an unfamiliar area, do you use (1) a Map or (2) Turn-by-Turn Instructions (go onto MI, then get off at J23, take third exit to A512, etc.) to plan your route. Please tick the one that is most applicable.

Always use maps	Mostly use maps	Use both equally	Mostly use directions	Always use directions
❑	❑	❑	❑	❑

14. How is your distance judgement ability (please tick one) ?

Very poor	Poor	Average	Good	Very good
❑	❑	❑	❑	❑

15. Do you have knowledge of any vehicle Navigation Systems (not including the brief description we have just given you) ? See below and please tick appropriately.

	Yes	No
I know what one is	❑	❑
I have actually used one	❑	❑

If you have used one, what was the make and model?……

16. How confident are you in general when using new technology (please tick one) ?

Not at all confident	Not very confident	OK	Confident	Very confident
❑	❑	❑	❑	❑