

INTERACTION DESIGN ISSUES FOR CAR NAVIGATION SYSTEMS

Paul Curzon
Middlesex University
Interaction Design Centre
London N14 4YZ
p.curzon@mdx.ac.uk

Ann Blandford
University College London
UCLIC, 26 Bedford Way
London WC1H 0AB
a.blandford@ucl.ac.uk

Richard Butterworth
Middlesex University
Interaction Design Centre
London N14 4YZ
r.butterworth@mdx.ac.uk

Ravinder Bhogal
Middlesex University
Interaction Design Centre
London N14 4YZ
Ravinder.Bhogal@eslo.co.uk

ABSTRACT

We describe a study on the interaction design of in-car navigation systems. It focused on a commercial product. Critical incident analysis was performed based on natural use of the system by a usability analyst. A cognitive walkthrough was then performed based on actual scenarios from the natural use. This is a non-classic application of cognitive walkthrough. It allowed anecdotal critical incidents to be theoretically grounded. We draw conclusions about the interaction design of car navigation systems.

Keywords

In-car navigation systems, cognitive walkthrough.

1. INTRODUCTION

Car navigation systems are safety critical systems that are put in the hands of novices. If they distract the driver they can cause crashes. A common use is in hire cars where drivers are likely to be total novices in their use. They must be very easy to learn and be very simple to use whilst driving. It is also important that an apparent ease of use does not lull drivers into a false sense of security. Previous studies on the use of in-car interfaces have found that danger arises from their use [7]. Manufacturers of the systems have recognised the importance of usability and much effort is put into their ergonomic design. As noted by Egenhofer [4], an important requirement is that information displayed on a screen can be understood at a glance. Audio messages need to be kept short to aid comprehension though, as noted by Lai *et al* [5], listening to audio does not appear to degrade driving performance. However, other aspects of human factors may not have been fully appreciated. For example, the instruction manual of the Toyota system we studied states

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“Learn how to use this system and become thoroughly familiar with it before attempting to use it while driving. Read the entire Navigation System Manual to make sure you fully understand the system” [9]. Whilst possibly having use in discharging legal liability, it is unrealistic to assume that this advice is followed. It is also debatable whether reading a manual equates to understanding a system.

Recent work has looked at navigation in the context of pedestrian tourist guides [1][3]. The focus of the work is not strictly about providing timely navigation instructions, however, and the problems for pedestrian systems are not identical. Some researchers consider the human factors problems of car navigation systems essentially solved. For example, Baus *et al* [2], note that they are widely accepted and have *“simple and well-designed interfaces for the specific task of providing multi-modal...route description to a car driver”*. It is argued that, unlike pedestrian navigation systems, car drivers have simple well-defined tasks. The purpose of this work was to perform a preliminary investigation into whether car navigation systems are a solved problem and, if not, suggest general lessons for their design. The study is limited and focuses on a single system. As such, care has to be taken in interpreting the results. However, the work suggests that general lessons about the design of car navigation systems can be drawn, and that their context of use is more complex than suggested by the above quotation.

2. THE STUDY

Our study was based upon the Toyota Navigation System as installed in a Toyota Avensis hire car in 2001/2002. It is part of the radio/CD system of the car using the same controls. It provides a variety of ways to set destinations and way-points, such as by address, postcode and name of point of interest. During navigation to a destination it determines its location using GPS signals and other information such as distance travelled. It then uses a mixture of voice, text and diagrams to give timely turn-by-turn instructions to travel to the destination set. The study consisted of three stages. The aim was to obtain wide ranging qualitative usability experience with the system, together with more formal results based on a

critical analysis with a theoretical basis. This allowed us to theorise about the informal results.

In the first stage, the system was used in a natural situation on two separate occasions. On the first occasion the system was used for a weekend during a trip from London to the north of England. This was followed by further use for a week as part of a holiday, again to the north of England. The system was used when travelling to/from the destinations and on day-to-day trips to local tourist attractions. A passenger was available to assist in the navigation. Neither driver nor passenger had previously used an in-car navigation system. Both were familiar with car navigation in general. Some roads driven were well known. Others, including the destinations, were unfamiliar. After the trips critical incidents in the use of the in-car navigation system were recorded.

Finally, a cognitive walkthrough [10] of three tasks using the system was performed. The first was a navigation task, assuming a destination was already set in the system. The second involved setting a destination. The final task, to switch the system from the radio to the navigation system, was identified for further investigation during the first walkthrough. Each task was chosen based on actual scenarios of use. Cognitive walkthrough was used as it has a theoretical foundation and was designed to analyse the learnability of interactive systems. The latter was identified as an important issue for navigation systems. The final two tasks correspond to classic tasks analysed using cognitive walkthrough of a user working directly with an interactive system. The first task, however, is non-classic as the user is interacting with the wider world and only indirectly with the system. Cognitive walkthrough proved to be appropriate for this but leads to different relative importance of the cognitive walkthrough questions.

3. RESULTS

Initially, the navigation system was found to be very useable. The voice instructions were given exactly when needed in a very natural voice – almost as though a passenger was speaking. Often instructions came just as the driver started to think that they were needed. The navigation display gave very clear guidance that was easily seen and absorbed at a glance. The ergonomics of the device were thus excellent. These issues are those identified as of importance for car navigation systems by Egenhofer [4]. Despite this, many critical incidents occurred.

3.1 Critical Incidents

Here we summarise major incidents. Some are considered in more detail when we discuss the cognitive walkthrough.

1) When travelling to the destination cottage, approach instructions along a given road were given by the cottage owner. However, it was not clear whether the navigation system had chosen that route. The instructions included landmark detail such as to “go past a red brick house then turn down the track by the large hedge”. It was important to follow them.

2) On several journeys a particular route was desired, but the system picked other routes, leading to confusion. On one journey, the system gave directions to turn right when the destination was to the left. Its route was to go round the block to go in the other direction. A car following ignored this turn and went the more obvious way, arriving first.

3) When taking day trips, locations were planned over breakfast with other members of the group based on tourist leaflets and atlases. On deciding to leave, the other cars were then forced to wait many minutes while the navigation system was programmed. There was social pressure just to go.

4) Several times turnings were missed or taken when they should not have been, especially at junctions on bends in the road (see below).

5) On leaving the holiday cottage the driver often had to guess which way to turn onto the main road before any guidance was given. This led to the “round-the-block” problem noted above.

6) When the driver decided to change route mid-journey, the navigation system repeatedly asked for left turns to be taken to return to the planned route. There was no obvious way whilst driving to turn it off.

3.2 Cognitive Walkthrough

The cognitive walkthroughs of the system gave explanations for many of the critical incidents that occurred, suggesting that they correspond to usability problems that ought to be addressed. For example, incidents related to the programming of the system were explained due to: actions not being visible (the unlabelled volume knob of the radio being used to move between menu items); the correct action not being easily identified (keys labelled with up and down arrows that are not used to move up and down a menu); and poor feedback (such as there being a delay between moving the dial and the movement of the cursor). Other similar problems were noted that had not occurred during actual use. Whilst of potential interest to the designers of the particular system, such problems are of less interest in general. A general lesson is that even with a high degree of ergonomic design, problems can still arise from parts of the system beyond the high profile instructions. Such problems are equally critical if they cause confusion or mistakes while driving.

The above problems were rarely to do with goal formation. In contrast, for the cognitive walkthrough of the navigation task, the problems identified were invariably related to incorrect goal formation. There were fewer problems in the areas of actions and feedback. To illustrate this we describe the walkthrough of an action that led to a critical incident.

The required action was to: *Follow the road round a sharp left bend (with a road coming in sharp right on the bend).*

The interface is defined as follows for this action: *The distance counts down on the screen in tenths of a mile towards the bend. It shows a large left bending arrow. A quarter of a mile before the junction, the voice says "In a quarter of a mile, left turn". The screen switches to a line plan of the junction. An arrow shows your moving position. As you near the junction, the system says "Left Turn". After the junction, it switches immediately to the large arrow screen for the next destination.*

Q1: Will the users try to achieve the right effect? *The instruction may be misunderstood due to a mismatch between the physical and logical (road-markings) structure of the junction.*

Q2: Will the user notice the correct action is available? *Yes.*

Q3: Will the user associate the correct action with the effect trying to be achieved? *Yes, if goal correctly formulated.*

Q4: If the correct action is performed, will the user see that progress is being made towards solution of the task? *Yes, but only if the user formed the correct goal. If they took the action by default, only following the road because there was no junction, then the feedback is confusing.*

This leads to a failure scenario, where a person coming to the junction believes they must turn left, but no left turn materialises. They could take a wrong turn immediately after the bend if there was one, or simply be confused into believing they missed the turn. Attention may be diverted from the road to the navigation screen whilst on a bend for longer than is safe as the driver tries to understand what happened.

The walkthrough showed that other actions result in potentially failed goal formation too: for example when first starting a journey, before initially moving to a road on the route insufficient directions are given.

4. DISCUSSION

Navigation systems differ from many other interactive systems in that the environment is an integral part of the system. Consequently, when navigating, the person interacts with the navigation system indirectly. In terms of the questions of a cognitive walkthrough,

this means that seeing whether an action is available is generally outside the control of the navigation system itself. The actions correspond to taking turns (or not) onto particular roads. The second question about visible actions is therefore not as relevant, as roads are not generally hidden. Goals correspond to taking a particular series of roads. The aim of the system is to ensure the person forms the "correct" sequence of goals that correspond to the route chosen. Unlike other applications, the person does not always enter the interaction having a sequence of such goals. Indeed having preconceived goals can be problematic: there is a tension as the person may have formed some of those goals using other forms of information. Matching actions to goals involves realising that the goal road corresponds to a particular turn. Traditionally a driver uses the road signage or personal knowledge to achieve this. The analysed system does this purely using commands to take turns. This corresponds to how a passenger navigator would work though anecdotally in that situation dialogue based on signage is also used. Feedback consists of confirming that the person is on the road as planned.

When the user is interacting with the world *correct goal formation* is the main issue. To do this they rely on a combination of cues from the world, the navigation system, their knowledge and passengers. It is therefore important that the system is consistent in its messages with those from these other sources.

Guidance should be based on the logical structure of junctions (road markings) not the physical layout as otherwise goal formation can be confused. However, at sharp bends on junctions additional guidance is needed couched in physical terms such as "Follow the road round to the left".

Communication, between system and driver, of the route chosen would help to match the user's model of the route with the system's route. This helps if they are to draw on existing knowledge when forming goals that correspond to those required by the system. It also aids with understanding the feedback and instructions of the system. If the user deviates from the route, a dialogue to negotiate whether it was intentional or not would help.

Navigation systems should provide explicit feedback that an action was correct or not. In the system studied this was indirect – moving to the next instruction. It would do this (after re-routing) even if a mistake had been made. Voice feedback would help: "OK. Now..." as positive feedback and "That was not the turn I intended, I am rerouting" for an immediate indication of a wrong turn, for example.

A navigation system should make use of existing road signage to avoid ambiguity with goal formation and tap into existing ways people navigate. This is a

very rich source of information for ensuring that correct goals are formed (though its shelf-life may be an issue). People may conceive roads in terms of their numbers (the M25) or the destination precisely because this is how they are labelled. In fact, the labels are there specifically to give a standard way to articulate them. The navigation system we investigated presents such information about the current road, so the information is available. That information should be used in helping goal formation as that is how the actions (such as turn left) are labelled in the real world. Instructions could be given that explicitly then match the goal to the action: eg "Take the first left, onto the M25".

The above points highlight a general problem with navigation systems (for the blind, pedestrians, etc). The cues that the system must give to aid goal formation depend on the signs/landmarks available in the world and the user's knowledge. The goal may be an abstract one (being on "the road to Leeds" without knowing anything more about it). The goal may alternatively be concrete (knowing the road due to having driven on it many times before). Abstract formulation of goals could result from information on other navigation aids such as tourist leaflets.

The above discussion concerns goal formation for each action. We now turn to the overall user goal. Baus *et al* [2] suggest that pedestrian navigation systems are harder to design because goals vary widely. An example is given of the different goals of a person wishing to get to a station and a tourist who wishes to see interesting local sights. However, a similar variety of goals must be supported by car navigation systems. A driver may wish to get to the station or be a tourist wishing to tour a city. Even in the tourist context, we encountered many different sub-contexts when using the system: leaving a town centre, going to a tourist site, to a holiday home with explicit instructions, etc. Furthermore, tourists form goals opportunistically, such as diverting for lunch when a journey takes longer than planned. A dialogue would be useful when planning routes. If user preferences and preconceptions are captured, then mismatches are less likely to occur during the journey. This is related to a point of Rogers *et al* [6] that users have various route planning preferences. Using simple criteria such as "shortest" is likely to be unsatisfactory. Scott *et al* [8] show that people can interactively optimise vehicle route choices, though in the context of multiple trucks delivering goods.

5. CONCLUSIONS

Even when the high profile ergonomic issues of car navigation systems are solved, problems remain. In particular, it is important that correct goal formation is

supported by the system, and that the user and system models of the route coincide. Car navigation is not a single well-defined task, but encompasses a wide variety of tasks depending on context of use. The combination of empirical data and theoretical analysis has yielded insights and understanding that neither would have delivered alone.

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