Evaluation of Car Navigation Systems: On-Road Studies or Analytical Tools

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Abstract. In-car navigation systems are an example of how multimodal technologies are increasingly becoming part of our everyday life. Their usability is important, as badly designed systems can induce errors resulting in situations where safety may be compromised. There are different ways to assess the usability of car navigation systems, including expert-based usability evaluations and on-road trials. In this paper we discuss the kind of insight they offer the evaluator with regard to the usability of the system, in terms of both the type of usability problems and the scope of issues identified. We examine those issues that can only be discovered by an on-road study and discuss the challenges of on-road usability evaluation.

Keywords: usability evaluation; in-car navigation; empirical evaluation; on-road trials; analytical evaluation

1 Introduction

Car navigation systems are designed to guide the driver through a generated route toward a selected destination. Any activity that distracts drivers or competes for their attention whilst driving has the potential to impair driving performance and has serious safety implications. Drivers interact with such devices when programming the destination and whilst driving when receiving instructions from the device (using maps, visual cues and auditory instructions). The usability of navigation devices is a contributing factor to the overall safety of car driving; as the tasks on the navigation device become more difficult, drivers will concentrate for more time on the device and less on the road ahead [1].

The dynamic environment in which the user navigates can also have a great impact on the successful and safe use of such devices. The various stimuli and the unpredictability of the environment pose challenges to designers and evaluators of such systems [2, 3].

2 Study

In order to determine the scope and type of usability problems of navigation systems we conducted a study where such devices were evaluated both analytically, using a set of HCI techniques, and empirically by carrying out an on-road study. More detail about this study is provided in [4].

The analytical methods selected are characterised by a varying degree of formality, with each advocating a different approach to user interface evaluation. Each method has its own potential merits in the evaluation of this device: Cognitive Walkthrough for Operating Procedures [5]; EMU (Evaluating Multi-Modal Usability) [6]; UAN (User Action Notation) [7]; Leveson's design guidelines [8].

The empirical evaluation (on-road study) helps us capture important properties of the interaction, as it is taking place in a dynamic environment, where users are expected to follow guidance instructions from a location-aware application while driving their cars, with various unpredictable and difficult to control environmental variables. Thus, the empirical part of the study gives us an important insight regarding issues of context of use that analytical methods might fail to capture.

3 Results

During the analysis of results we had two different foci. Firstly with regard to the type of issues identified and secondly with regard to the scope of each approach. The differences in the types of issues identified are discussed in [9]; in summary, usability issues identified empirically were attributed to phenotypes [10], overt and observable manifestations of an incorrectly performed action, whereas issues identified analytically were attributed as genotypes, the underlying likely cause. As a result, a combination of analytical and empirical techniques can offer a richer insight into the usability of the system and give the analyst greater argumentative power.

The analysis of results helped us also identify the scope of empirical and analytical approaches. We focussed on the kind of problems that were captured during the study solely by the on-road trials. The trials helped us understand user models and strategies; observe system failure and user reaction; assess user trust in the system; evaluate error recovery and rerouting. The gravity and scope of these issues confirms the importance of on-road studies, as such issues would have been missed if we relied solely on analytical techniques. This does not underestimate the value of analytical tools, but merely outlines the importance of user involvement and in particular on-road studies in the evaluation of such systems.

The use of analytical methods and the on-road trials gave us an insight into a wider spectrum of usability issues of navigation systems. Nevertheless, the design of a navigation system is determined by the extent to which it presents information that matches what the driver sees on the road, at an appropriate pace [11]. As the study has demonstrated the use of on-road trials is an indispensable step toward the evaluation of such a system with location-aware properties within a dynamic environment. We observed how users managed with the use of the system, as they also had to cope with driving the car and responding to stimuli from the surrounding environment.

4 Challenges of on-road studies

On-road studies do not come without a significant cost. The design, setup and collection of empirical data during the empirical part of the study are challenging. Obtaining ethics clearance was an arduous procedure, because of the safety risks involved with on-road studies. The ethics committee demanded evidence that the whole empirical design was sound (mainly safety concerns), and they required significant changes to the empirical design in order to improve safety.

In order to improve safety, users were required to familiarise themselves with the device for a week before taking part in the experiment. As a result the experimental sessions had to be spread out to allow time for each participant to become familiar with the system. The participants were also required to navigate in their own cars during the experiment, with appropriate insurance, as they would be in a more comfortable and familiar environment. This process made it significantly more difficult to recruit participants for the experiment.

As each user was navigating in their own vehicles, we had to move equipment between the cars, which included the navigation device, the GPS antenna, video equipment, and a laptop computer in order to capture the display of the navigation device. As a result the setup of the experiment for each vehicle was more difficult than using a single instrumented car for all participants. The use of an instrumented car would have reduced significantly the time need to set up the equipment and increase the quality of the data.

Finally, the quality of the video can be seriously affected by the location and installation of the camera. It was sometimes very difficult to capture the surrounding environment, because of the various weather conditions and the reflections on the windscreen and the windows. Although cameras have quite powerful microphones, the combined noise coming from the car engine and the surrounding environment also had a detrimental effect on the sound quality of the auditory instructions and users' comments.

5 Conclusions

Analytical and empirical techniques employed in this study offer a different perspective into the usability evaluation of interactive systems and identified distinct sets of issues. We focused on the type and scope of usability problems reported from the analytical and empirical techniques.

In particular we were interested in the set of problems that can only be identified empirically, thus making the empirical approach a necessity to the evaluation of this type of systems. We need to examine closer problems that cannot currently be captured by the analytical techniques and experiment with how to modify the techniques to cover such issues. This will minimise people's exposure to systems with poor usability during an empirical evaluation, as many issues would have already been addressed. This could lead to a combinatory approach where empirical and analytical techniques are used in tandem to tackle the problems of this type of systems. Further investigation is needed into the appropriateness of analytical

methods when using such devices in a constantly changing environment and where the goals of the users are not preconceived, as they were in this study.

We have also demonstrated that although analytical techniques give a great insight into the usability of navigation systems, user studies retain a pivotal role in the evaluation. They provide us with different insights that are not currently captured in the analytical evaluations. Empirical results helped assess how the severity and multitude of usability problems create difficulties for users, worsen driving behaviour and potentially compromise safety. This makes a case for the design of safer and more usable systems: a confused and angry user is evidence that something is wrong with the current design. It has more persuasive power than an expert's report suggesting problems are likely.

Finally, we discussed the many challenges encountered in order to carry out on-road trial and demonstrated how the benefits clearly outweigh the effort needed. The use of on-road experimental trials should be an integral part of any evaluation of such systems. It is a technique that can capture issues pertinent to the dynamic environment and location-awareness of the device, which cannot be captured by any other approach.

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325