A Designer-Centred Method for Ergonomically-Informed In-Car Device Design.

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A DESIGNER-CENTRED METHOD FOR ERGONOMICALLY-INFORMED IN-CAR DEVICE DESIGN

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A gap has been identified in evaluation methods that can be used by in-car device designers to capture the usability problems of representative end users, during concept design. Usability information has a vital role to play in design, yet all too frequently, this information is only gathered once concepts are stable and mature. At this stage ergonomics information and recommendations cannot have a major role in influencing the final design. Additionally many evaluation methods fail to evaluate in-car devices in their context of use, i.e. as a secondary task. An evaluation method is needed for concept design, that can be used by designers, and that provides them with useful, usable information relevant to their current design problems. This paper outlines the features, and development process of a designer-centred, simulation –based evaluation method tailorable to the evaluation of in-car interfaces.

Introduction

When the automobile was first introduced it was seen as a functional device for getting people from one location to another. In-car instruments and displays were concerned exclusively with the driving task, and driving was uncomfortable, dirty and dangerous business. Cars have come a long way since these early days and today driving is, relatively speaking, comfortable, clean and safe.

However, today there is little to differentiate between vehicles in the same class in terms of primary controls and displays. Those necessary for driving safely and legally, have been developed to the point where they are generally satisfactory. Consequently, motor manufacturing companies are looking to gain competitive edge by re-conceptualising the motorcar as an object of desire and pleasure (Peacock, 1993). Facilitated by advances in computer and communication technology, increasingly vehicles come fitted as standard

with devices (*e.g.*, navigation, climate control and entertainment systems) designed to reduce stress and increase comfort, pleasure and enjoyment of driving,

The operation of these devices is secondary, or not essential to the task of driving, requiring the driver to shift mental and visual attention from the road to the interior of the vehicle. Hence, we might expect that the time spent while driving during which the driver is not attending to the road will increase as the number and complexity of in-car devices increases. This will have serious implications for road safety. Indeed, there is much evidence to suggest that a significant number of road accidents occur while driver attention is focussed on the operation of in-car devices (Wierwille and Tijerina, 1996).

Producing in-car devices that can be operated within acceptable safety limits is an ergonomic issue (Galer Flyte, 1995). It is also a design issue, for whilst ergonomics might have the responsibility for determining operational criteria and for identifying when and why devices fail to meet such criteria, design is responsible for envisioning devices that satisfy ergonomic constraints (Galer Flyte, ibid). However, notwithstanding ergonomic and design advances, particularly in relation to human-computer interaction, automobile design research (Woodcock and Galer Flyte, 1995) has revealed that the boundary between the two disciplines remains to a large extent a “no man’s land”.

Many factors have been identified to account for this gap, including poor communication and the failure to integrate ergonomics information and evaluation into the early stages of design (Woodcock and Galer Flyte, 1998; Porter and Porter, 2000).

Although some methods have been developed to evaluate in-car systems (e.g., Rapid Prototyping, Green, 1990), these may have limitations in revealing usability problems of complex in-car HCI interfaces or in providing detailed design information. For example, these interfaces comprise various soft buttons (in addition to conventional hard buttons) and graphical displays, which may produce different and additional usability problems than conventional in-car systems. Additionally, the primary driving task is not considered in most usability evaluation methods even though, in-car secondary controls and displays are mainly used while driving. This means that there may be undiscovered usability issues that only become apparent during dual operation.

Therefore, current ergonomically informed methods have their limitations and should be enhanced to identify the problems arising from the use of in-car HCI devices in driving, so that the particular and relevant ergonomics information can be provided to designers.

Given the above, this paper presents a method for ergonomically informed in-car device design and describes how it was developed and evaluated.

Context of the development of the proposed method

Designers problems with ergonomics information

Designers are unable or reluctant to apply ergonomics information contained in the literature. Relevant ergonomics information should be presented in a form that designers can naturally locate, easily understand and apply to their current activities. If designers are responsible for the gathering of usability information, they will be stakeholders in the usability testing and the information they gather (in terms of requirements and guidelines) will be directly relevant to their task.

Usability evaluation of advanced in-car interfaces

To ensure that the in-car interface is easy and safe to use, *i.e.*, requiring little of the driver's visual attention to conduct the in-car tasks, thereby allowing him/her to reserve most of their attention for the road, it is essential to uncover potential usability problems and to present both the problem and relevant ergonomics information in a suitable form for design decision making. To achieve this, an in-car usability evaluation toolset was proposed that combines objective and subjective evaluation methods to assess user performance and preference during the concept design stage. Such a method used standard HCI evaluation methods applied in the context of a simulation of the driving task. This allowed the specific problems that arose from the use of in-car displays in a driving situation to be uncovered.

Simulation in concept design stage

To support ergonomic design of in-car interfaces, it is crucial to investigate the usability of the in-car device early in the design process. Focussing on concept design ensures that ergonomics is factored into design from the outset. Most in-car usability studies have been conducted in the real driving situation (or simulation), with a fully instrumented vehicle. However, if interface/device evaluation moves upstream, this may occur before or in parallel to the design of the rest of the vehicle. In such circumstances, vehicle mock ups (in which the seating and major control positions are correct combined with rapid computer simulations of in-car device concepts may be a useful/usable approach.

Practicality for designers and current design process

Automotive design is a complex and distributed process, in which a large amount of time, financial costs and manpower are invested. This takes place against a need for shortened lead times. In such an atmosphere, designers may not have the time, ability, training or inclination to conduct complicated experiments to evaluate early designs and their design rationale. For example, the location and size of buttons may never be subject to user testing. Without an easy-to-use, tailorable method, designers will either follow previous designs or design on the basis of their own preferences. The development of an ergonomically informed evaluation method, which requires

little time and cost, and which could be integrated into the design process, could not only remove this subjectivity but also provide a way for designers to incorporate ergonomics information in their design and become ergonomics champions.

Given this context, a three-part method was developed to inform the concept design and iterative development of in-car control and display design. This comprises

- Usability toolset
- Interactive simulation of the object to be evaluated (in this case a touch screen control)
- Low cost driving simulator (mock up)

The development of the method

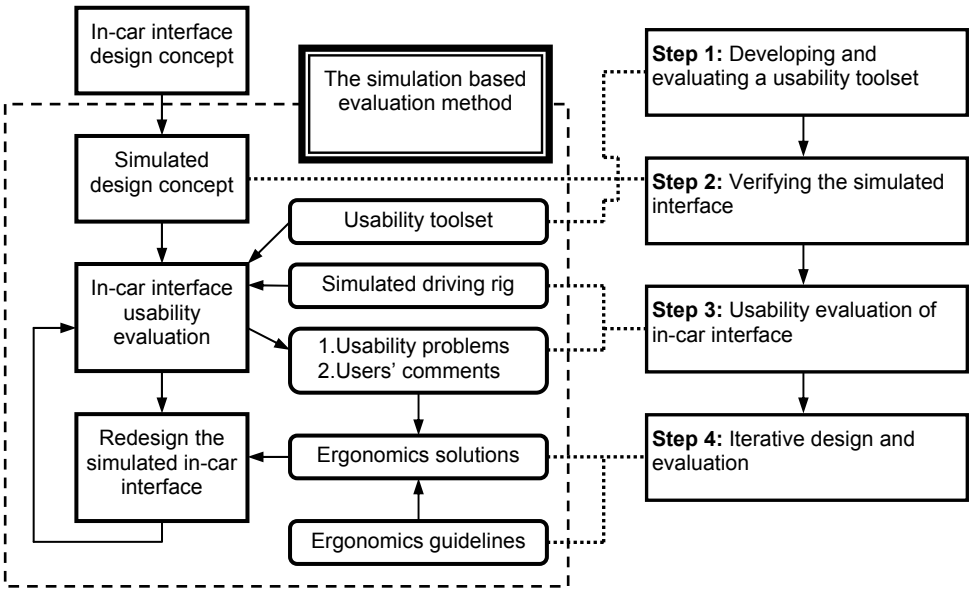

Figure 1: The development of the simulation based evaluation method

Given the context outlined above, this section presents the tasks of the development process of the method, and the approach to achieving its development (see Figure 1).

Developing and evaluating a usability toolset

The primary aim of this step was to establish and test methods for evaluating the usability problems of in-car displays. The chosen methods were evaluated in terms of their usefulness for uncovering problems and providing information for redesign. In this way productive methods were identified and those that did not uncover problems or failed to support the other methods were excluded to ensure the quality of the toolset.

Verifying the simulated interface

The key element of the proposed method is to use computer simulation at the mock up stage to help designers evaluate the usability of their design. In order to determine whether the simulation was a good approximation to the real system, this part of the research needed to establish the validity of the simulation from a user perspective. An existing in-car interface was simulated and its performance and appearance compared to the original. The results indicated that a good standard of simulation could be achieved quickly using readily available software, and that designers themselves might have the prerequisite skills to use software in this manner.

Usability evaluation of in-car interface

After demonstrating that the simulated interface represented the real system, a low-cost driving rig for simulating driving was developed, and in conjunction with the usability toolset was used to determine usability issues of the simulated in-car system. This part of the research was conducted to demonstrate the effectiveness of the method (the simulation, driving rig and usability toolset) in uncovering usability problems and generating redesign information.

Iterative design and evaluation

The evaluation revealed usability problems that could be solved by the application of ergonomics information and design guidelines. This guided the redesign of the in-car system. The simulated, ergonomically redesigned interface, was then retested using the same method with the expectation being that user performance would be better using the new interface, thereby demonstrating that the method yields improvements in design.

The evaluation of the method

Through the studies indicated above, the proposed usability method was iteratively developed and demonstrated its validity/usefulness for uncovering usability problems and for ergonomically informed iterative design. Once the method had been tested in the laboratory it was formalised into a toolset that could be used by designers for evaluating their concept designs. The formalised method was tested by asking a designer to use it on a realistic design task. This was followed by assessing the practicability by interviewing in-car interface designers from industry (see Figure 2).

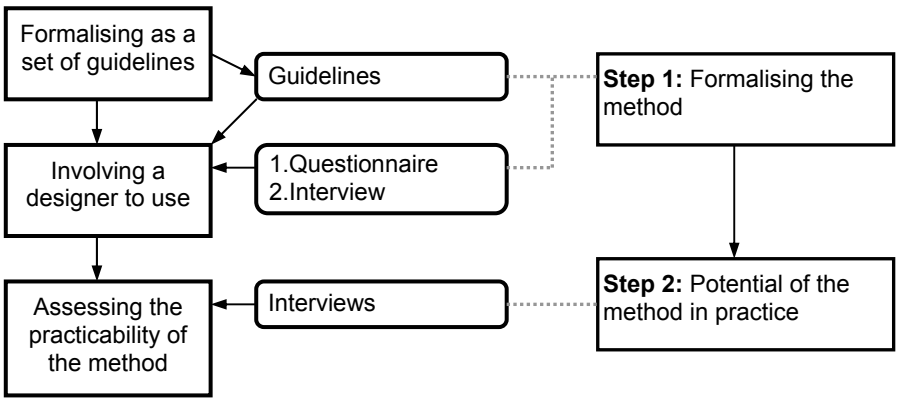

Figure 2: The evaluation of the simulation based evaluation method

Formalising the method

Having confidence in the ability of the method to produce useful results, this stage of the work focused on formalising the method into a set of guidelines for designers to use in the concept design stage. The usefulness of these guidelines was demonstrated in a design study in which a designer followed the guidelines to design, simulate and evaluate the usability of a new interface. The feedback from the designer was used for iterative development of the method and to increase its acceptability to designers.

Potential of the method in practice

In order to determine whether the method could be of value to automotive companies, it was shown to representatives of two leading automotive companies for their comments. The results from this show that not only would the method be useful in early design, they confirmed that currently an equivalent method is not available to them.

Conclusion

This paper concerns the development of an ergonomically informed method to support in-car interface design in the early stage of design process. From previous studies, it has been argued that poor ergonomically designed in-car controls and displays can have a negative impact on driving safety. However, the literature and interviews with representatives of the automotive design companies, both show that the early stages of the design process are poorly supported by ergonomics; existing tools and methods for evaluating in-car interfaces either necessitates the use of complicated research skills that practicing designers do not possess or do not take into account both primary and secondary tasks.

Therefore this research has identified a need for a new method to assist designers in their early evaluation of in-car control and display concepts, which in turn will lead them to adopt a more user-centred approach at this critical design stage. The method developed to fill this gap relies on the

simulation of the interface and the driving task, augmented by a set of research methods that designers can use for themselves to evaluate early concepts.

Most of the research reported in the paper has addressed the validity, practicability and usefulness of this approach for practicing in-car interface designers. It is argued that the research makes a contribution to knowledge by advancing methods for ergonomically informed in-car interface design. Specifically, it contributes to prior work in automotive design in the following ways:

1. By focussing on concept design, it ensures that ergonomics is factored into design from the outset;
2. By shifting the onus for ergonomically informed design toward the designer, it ensures that the designer plays a key role in accessing relevant ergonomics data, integrating it into design, and the ergonomic evaluation of design ideas;
3. By framing an evaluation method, that engages both the primary (*i.e.*, driving) and secondary (*e.g.*, climate control) tasks it ensures that the dual task demands are considered, and provides a framework for assessing performance against driving safety criteria;
4. By employing low cost simulation of both the driving context and the in-car device concept, it ensures that the potential user contributes to the process from the outset
5. By careful consideration of the nature of in-car vehicle design in the industrial context, the likelihood of the method being incorporated into professional automotive design is increased.

The novelty of the research resides not in the individual components of the method produced, the value of which have been demonstrated in other related contexts, but in their refinement, development, integration and validation. The result is a method that is useful to, usable by, and practicable for, in-car device designers operating in the automotive industry.

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