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This paper firstly describes the development of a method that allows in-car device designers to conduct their own usability studies, early enough in the design lifecycle to inform design; secondly looks at the way the method was formalised and thirdly considers its applicability in the wider automotive design industry.

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

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Introduction

The number and complexity of in-car devices is increasing due to competition for sales, and consumer demand for greater entertainment, comfort and convenience. Many of these devices are secondary (*i.e.*, not necessary for the primary task of driving) and their operation while driving contributes to motor accidents. Hence, increased entertainment, comfort and convenience may be at the expense of decreased driving safety. Chen, Scrivener and Woodcock (2004) argue that since consumer demand is unlikely to disappear, at least in the short term, ways must be found of designing in-car devices such that driving is maintained within acceptable safety limits. The creation of a designer-centred ergonomically informed method for in-car design is described in Chen et al. (2004)

A key goal of the method is to introduce user-informed evaluation into the early concept design stage. Criteria for the proposed evaluation method were that it should uncover and characterise usability problems in a form that supports design and directs the designer towards ergonomics knowledge that might contribute to problem resolution. To test the method in this respect, it was used to evaluate the user performance of an existing in-car climate control device. On the basis of the problems identified, the device interface was redesigned (by a member of the research team) drawing on relevant ergonomics knowledge contained in texts and guidelines. The resultant design was then re-evaluated, in the expectation that user performance on the revised design would be enhanced compared to the original design. Subsequently, the method was formalised and used by a designer to evaluate an in-car device interface design of his own construction. This example was then presented to in-car device designers practising in the automotive industry, who were asked to assess the method in terms of usability, usefulness and practicability.

The paper firstly introduces the evaluation method, including objective and subjective measures, and explains how the evaluation environment, including in-car interface concept and driving simulator, was constructed and configured. Secondly, the evaluation, analysis, redesign and re-evaluation process is described. Finally, the method itself is evaluated in terms of its usefulness, usability and practicality.

Usability toolset

The usability toolset consisted of objective measures (learning time, task completion time, errors) and subjective ones (a usability questionnaire and an ergonomics audit form). The usefulness of these measures for uncovering usability problems and informing redesign was tested through applying the toolset to the evaluation of an existing in-car stereo interface in a stationary car, together with a distraction task (the participants needed to count the pedestrian and cars passed when they were using the in-car system) to simulate the driving situation.

The results showed the value of combining objective and subjective evaluation methods for uncovering and triangulating usability problems, for example the ergonomics audit form revealed items which the users disliked. Problems with individual features were reflected in high task completion times and operational errors. As, measuring learning time did not provide useful or reliability usability information, nor could it be related directly to the problems uncovered by the other evaluation methods, it was removed from the toolset. Although the questionnaire did not specifically support results achieved with the other measures, it did provide a general impression of the participants' feelings about usability and indicated directions for redesign. The ergonomics audit form clearly showed the drawback of some functions and elicited valuable redesign suggestions. Overall, information derived from the subjective measures supported the objective ones and generated useful insights for design refinement. The toolset (minus the measuring of learning time) was therefore considered to include sufficient methods to capture user requirements and provide information for the redesign of in-car interfaces.

In terms of system operation, the participants spent a long time looking at and conducting the in-car tasks without reference to the road or the distraction task. None of the measures employed captured this phenomenon. Since, this might be an indicator of usability problems, it was proposed to incorporate measures of glance frequency and duration in the revised toolset. A criteria set by Zwhalen *et al*. (1988) was employed to assess the acceptability of glance frequency and duration when conducting in-car control operations.

The distraction task, counting cars and pedestrians, was not found to be satisfactory. Participants missed a lot of cars and pedestrians, resulting in error rates at around 20%. This may indicate that the distraction task did not simulate the real driving situation. Therefore, a logical alternative, to this, and one that could be used on concept designs, was a driving simulator. Previous studies have shown that there is good correspondence between task performance on a simulator and on the road (*e.g.*, Reed and Green, 1999).

In conclusion, the testing of the initial usability toolset revealed that most methods provided useful information for redesign. In the subsequent refinement of the method "learning time" was discarded ,"glance behaviour" introduced, and distraction task was replaced by driving on a low cost simulator.

The validity of the simulated in-car interface

The main aim of the research was to develop a usability method for designers producing in-car device concepts. Once way of testing the usability of interface concepts would be to mock them up, or simulate them if 1) this did not add a significant time burden to the process, 2) designers had the presrequisite skills to make such simulations and 3) that the usability results produced from the evaluation of the simulation would be valid and reliable (ie the same as could be expected from the evaluation of the corresponding real system).

In order to establish whether the simulated interface performed similarly to a 'real' system from a user's perspective, an existing 'typical' in-car climate control system was selected and simulated. The development of the climate control system simulation was divided into two stages, understanding the system functions using task analysis and implementing the interaction of buttons and feedback in Macromedia Director. The climate control system encompasses a lot of controls (*i.e.*, screen and push buttons) and information displays (*i.e.*, different interface screens and LCD display), therefore, task analysis was applied to reveal the operation of each function in preparation for constructing the simulated interface.

The simulation was constructed as a real size computer graphic in-car system touch screen interface with fully interactive simulated graphic control buttons and simulated feedback of system functions, which acted and responded to user input in the same way as the selected real system. Hence, all of the 'hard' buttons of the real system were transformed to 'soft' buttons in the simulated interface,

Both the simulated interface and the original system were evaluated in a comparative study of user performance. Additionally, questionnaires were used to collect subjective opinions about the extent to which the simulated interface replicated the real one. The results from the questionnaires were used not only to improve the simulated interface but also to provide recommendations for generating valid simulations.

The results showed that the participants performed similarly on both systems with no marked difference in the error rate or distribution across function. Few tasks showed significantly different completion times. Therefore, the objective measures indicate that the simulated interface had good validity with the real system. For subjective measures, the participants agreed that the presentation of the simulated interface was clear, understandable and easy to use, however, some participants were not satisfied with its speed and visual feedback.

Overall, both the objective and subjective measures indicated that the simulated interface performed and appeared similar to the real one. This indicates that such in-car system interfaces, even when fitted with hard button controls, can be effectively simulated using a touch screen and validly employed in in-car interface design to assess user performance.

Low-cost in-car usability evaluation

The simulation was then subjected to a usability evaluation using the revised toolset, in conjunction with a “low-cost” and “easy to use” driving rig. This was seen as a practical alternative to the real driving situation, which is not realistic or possible in the early design stages, when the designs are not fully operational. Additionally the use of a driving rig built, in this case, with reference to the layout and dimensions of the original car, would potentially allow in-car devices to be easily evaluated independently of the vehicle they are intended for. Thereby increasing parallelism in design activities.

The simulator (shown in Figure 1) comprised four parts, a simulated driving environment displayed on a computer screen located in front of the participant; a “computer game” steering wheel and pedals (accelerator and brake) for controlling the ‘vehicle’; an adjustable car seat; and a touch screen showing the simulated in-car interface being tested. Participants “drive” the simulator whilst using the simulated in-car interface (See Figure 1).

A lab-based study brought together the three main resources of the proposed usability method – the toolset, simulation display and driving rig – for assessing the usability of the interface and providing information for redesign.

Figure 1: Low-cost in-car usability evaluation

Enhancement of user performance

The information derived from the usability evaluation supported the iterative development of the system and led to the production of a refined interface, informed by actual usability problems and ergonomics guidelines and information. Since ergonomics information is seen a primary part of the proposed method, ergonomics principles and guidelines from the ergonomics literature and textbooks were assembled to assist in the resolution of the usability problems uncovered from the evaluation of the simulated in-car climate control system. This information will be a component of the proposed method for general application in in-car control and display design.

The revised interface was tested using the same toolset, and showed a reduction in the number of usability problems measured by both the objective and subjective measures. This indicates the value of integrating existing ergonomics guidelines and outcomes with user testing in ergonomically informed design. It has also shown that both information types (i.e. guidelines and results from usability studies) support each other to assist decision-making in redesign.

Formalising the method

The method was formalised as a handbook for designers to use in concept design, which detailed the steps required to implement the usability method including developing the simulated conceptual interface, conducting the usability study and incorporating ergonomics information into redesign.

In order to understand whether the method could be used by practicing designers, an industrial designer used it to design and test an in-car interface concept. The designer was observed throughout the process and interviewed. The observation revealed a few places where the method needed to be refined, but generally demonstrated that the designer could undertake the usability studies without the need for further instruction and could feed the information through into his own practice. This provides further evidence of the method's value in uncovering usability problems in the concept stage of the design process.

A follow up interview with the designer indicated that he was satisfied with the method and found it easy to use. However the data analysis and need to search through ergonomics information appeared initially disconcerting. Given this, more explanation was added to the data analysis and the presentation of the ergonomics guidelines was redesigned. In conclusion, the designer was able to apply the method to a real design task. The study demonstrated that designers could actually use the method and that the method it was useful.

Feedback from automotive industry

One of the most important development goals of the method is that it should be applicable within the automotive industry. Given that the method could be used by industrial designers to guide the usability of initial concepts, two designers, currently in charge of in-car interface design in their respective companies, were interviewed to determine the current role of ergonomic evaluation and computer simulation in concept design. Following a demonstration, they gave their views on the potential acceptability and practicability of the proposed method for current design practice.

Consistent with the literature (*cf.*, Woodcock and Galer Flyte, 1998), the designers indicated that ergonomics is used as part of current automotive design practice but not usually in a systematic manner. In particular, no method is used for evaluating design concepts using ergonomics information. Concept designs are evaluated informally in terms of personal experience and managers' requirements. Additionally, almost all designers are capable of using computer graphics software. Both designers also thought that the current design process could accommodate the time spent using the method. They also confirmed that the method might even shorten the development time by identifying usability problems early in the design process. Hence the need and room for such a simulation based usability evaluation method in concept design was confirmed.

However, one designer felt that data analysis would be challenging for designers. This corresponds to the designer's comments in previous study – in general designers do not like to do data analysis. Apart from this uncertainty, both designers interviewed were positive about the toolset.

In conclusion, the designers agreed that the method was a useful and practical method for mocking up design concepts as computer simulations and evaluating the usability of their designs. The current early design lifecycle lacks an appropriate method for ergonomics evaluation and the proposed method is likely to be effective, efficient, and practical at this stage of the design life-cylce.

Conclusion

The primary aim of the research described in this paper was to develop a method for designers to evaluate the ergonomic performance of in-car interface designs during the early stage of the design process. This was achieved through a series of studies, from the development and validation of the elements of the proposed method, to the formalisation and potential practicability of the method.

On the basis of the results of these studies, the paper makes the following claims that:

1. The objective and subjective measures employed in the evaluation method support each other in revealing in-car device usability problems;
2. In-car devices interface concepts can be readily simulated using commonly available CAD design software;
3. The evaluation environment demanded by the method can be readily constructed in a studio-like space;
4. The application of the method led to enhancement of performance;
5. An independent designer was able to apply the method unassisted by a researcher or ergonomists, and was satisfied with it, in terms of both process and outcome;
6. The in-car device interface designers interviewed regarded the method as useful, usable and practicable.

In this research, only one designer used the method and two practicing designers commented on its potential usefulness in the automotive design process. Thus, although the results are supportive, it remains to be determined whether the method would be applicable in different automotive company. Obviously, future research should focus on testing the method with a larger sample of designers. Furthermore, the method should be tested in an automotive design company to confirm its validity for industry.

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