USABILITY STUDY IN THE DEVELOPMENT OF HUMAN-MACHINE INTERFACES: IMPROVEMENT OF PRODUCTS IDENTIFICATION AND ACCESSIBILITIES

Tomé Canas[1], Tiago Girão[2], Jorge Sales Gomes[1]
[1]Brisa Inovação e Tecnologia SA, tome.pereiracanas@brisa.pt; jorge.gomes@brisa.pt
[2]TGDesign Lda, tiagogirao@netcabo.pt

Keywords: Innovation, Industrial Design, Interface Design, Payment Machine, Paper Prototyping

ABSTRACT

Complex technological systems are present in many aspects of our everyday life. The functionality of these systems can be improved by analyzing the phenomena involved between the users and the machine's interface. Usability issues have become more recognized in recent years as companies see the benefits of researching and developing their products with a user-oriented approach (outside to inside), instead of more technology/equipment oriented methods (inside to outside). Understanding the interaction between user and product in the real environment of operation, it's possible to identify some needed functionalities or design flaws that were not anticipated by traditional market researches.

This paper presents the development stages of a service providing machine, focusing on its user interface. Observing the target users, the interface is evaluated and redesigned, improving incrementally the effectiveness (fit for purpose) and the efficiency (work or time required to use) of the overall systems operability. The case study presented here shows how visual communication can improve the use of complex systems, reflect on the importance of interface design.

INTRODUCTION

This paper presents the development stages of a service providing machine, focusing on the user interface design. By observing target-users operating the machine, the interface is evaluated and redesigned to improve incrementally the effectiveness (fit for purpose) and the efficiency (time required to complete tasks) of the overall systems operability.

The case study presented illustrates the importance of the design at interface level. The process of development involved several technical skills in numerous areas, such as electronics, mechanics, software and metalworking. To improve the product's overall purpose, an effort was made to focus on how the machine's functionalities were perceived by the user.

By involving the users and clients during the development stages (EUI – Early User Involvement), one can do double duty: in the early stages of product development (PD), one can gather information about the specific needs of targeted market, so to structure a more formal market research. Secondly, the solutions being developed can be tested often, with users, through the various stages of PD. Thus, the work is being continuously addressed to the target sector [5].

In order to achieve a more user-friendly interface the product changed its internal and external configuration through several stages of evolution, as presented in the case study.

The continuous process of design improvement, focused in the final user, will have a direct impact/contribution on the quality of the service provided [1].

The interface of a machine has an important role in the way its manipulation takes place. With all the internal functions working with the desired performance, errors can only occur outside, in the way users operate the machine. To reduce errors done by the user, the interface must guide them through the set of action needed to complete the desired operation. The design of the interface must organize the requested information in a simple, quick and universal structure [6].

Testing is performed on prototypes to further develop the design, gather data to optimize the design, determine reliability and satisfactory operation under specified operating conditions [4]. Little emphasis is placed on the "look and feel". As presented further, paper prototyping [6] was a key tool for quick testing new interface layout solutions in a real environment of operation [3].

BRISA CASE STUDY

In 2008, Brisa, the main Portuguese highway operator, developed an automatic payment machine to install on the manual lanes of the toll plazas in order to operate in periods of lower traffic and also contributing for the increase of the number of lanes available in the toll plazas.

The machine, called E-Toll, Electronic Toll (Fig. 1), uses some of the equipments already operating in the lanes and new ones related with money control and man-machine interface.

Fig. 1 – *Early Laboratory Development Prototype*

Fig. 2 – *E-Toll user operation procedures*

This new machine is composed by a metal frame, with two levels, for cars and trucks, which houses a set of equipments. Some of these equipments are standard products available from international suppliers and others are Brisa's own products, developed and produced internally.

This machine has the following operation procedure (Fig. 2):

1 · The driver inserts ticket in the reader;
2 · Pays with possible payment means;
3 · Collect eventual exceeding cash;
4 · Receive a receipt.

One of the innovative aspects of this machine is the remote assistance made by human remote operators, observing and follow remotely all the operation (classifying the vehicle and helping the users operate the machine), using video cameras and communication via Voice over IP (VoIP).

The development process of E-Toll was based in two main issues:

- Mechanical design and creation of the metal structure;
- Software integration of all equipments with the toll management system

Consequently the design process involved several technical skills in numerous areas, such as electronics, mechanics, software, industrial design, materials, ergonomics and metalworking.

Fig. 3 – *E-Toll first produced layout*

One component is the user interface, which, as we saw earlier, is of enormous significance. This interface, like the rest of the project has undergone various changes during the development period. In a first phase, the interface of the equipment had the following layout (Fig. 3):

The development process first approach was based on an inside-to-outside methodology [2]. So the modules were arranged internally according to engineering requisites and internal module functionalities, leaving little freedom to develop the user interface. Only in a late development stage the concern with the user interface appeared.

The time to complete tasks by internal componentes was stable and made at an acceptable speed, though some improvements were needed. It was on the user side that was urgent to improve interface with the machine.

As stated, the operation of these machines was assisted by a remote monitoring system. This remote monitoring help identified a number of difficulties that users were having in using E-Toll, including:

- Difficulty in understanding the start operation; leading users to insert the title in the bank card readers
- Difficulty in following the sequence due to the non-linear path between operation areas and the large distance between the diverse modules in the interface area, forcing users to move the vehicle forward between tasks
- Trouble of access to the lowest area “Collect Change”, causing drivers to open the vehicle’s door to reach for the change
- Placement of “Via Verde” and “Information Request” buttons inside the major functional areas, causing users to use them improperly
- Lack of visibility over the machine’s interface delays the understanding of the logic sequence of tasks.
- Anthropometric pitfalls due to the vehicle’s window constraints. User’s amplitude of movements are substantially reduced (Fig. 4), which cause some to be uncomfortable using this type of systems

Fig. 4 – *Operation constraints*

Fig. 5 – *Several users contribute to define zone of reach*

Fig. 6 – *Using paper prototyping techniques*

The machine has a broad range of users, rather heterogeneous, which reinforces the need for an ergonomic and simple to use interface. This heterogeneity is reflected not only in the anthropometric distribution population [7], but also the degree of familiarity in the general use of interfaces man/machine.

Following this monitoring workload assessment tests were conducted, which attempted to reach an advantageous area of interface operations. In this empirical study were tried diverse users with different anthropometric dimensions, and various classes of vehicles, cars and vans in order to obtain a zone of reach (Fig. 5).

During the study several prototyping techniques were used including paper prototyping, to help the interaction process and the position of the different modules (Fig. 6).

The anthropometric testing information was collected for further refinement on the interface dimensions. For visualizations of man-machine relationship engineering principles were applied [7] and the complex bone structure was simplified in an anthropometric interactive table.

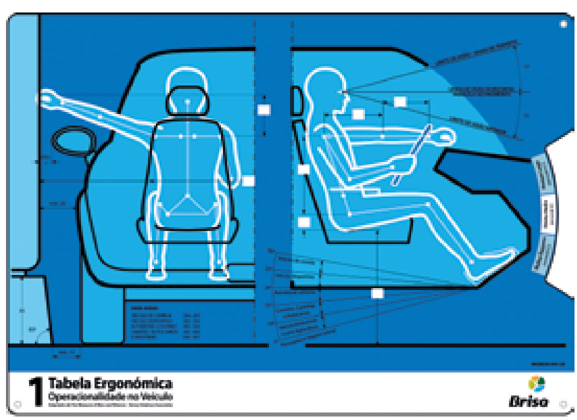

Fig. 7 – *Vehicle ergonomics chart made with empirical data and scientific data*

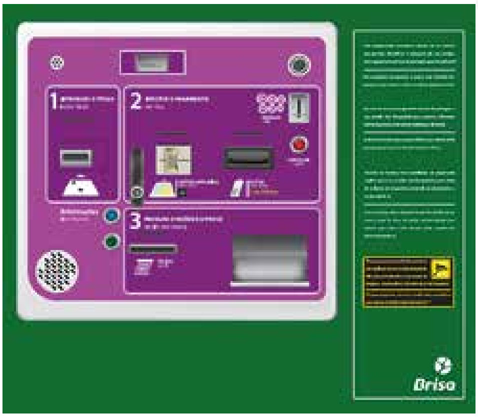

Fig. 8 – *New E-Toll interface layout*

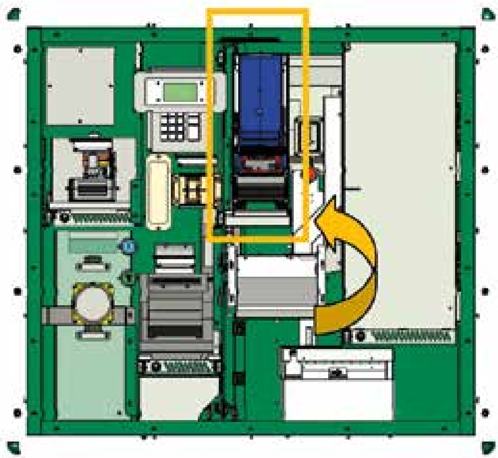

Fig. 9 – *E-toll internal view, showing the bill-validator 180˚ rotation solution*

Based on these tests and empirical work a new interface was developed (Fig. 8):

This new interface shows several improvements over the old one:

- Reduction on interface area – smaller area of operation was set and internal components followed the necessary adjustments. Due to limitations in terms of internal storage modules, the redesign process required ingenious solutions. One modification went through the 180˚ rotation of the bill-validator (Fig. 9) and repositioning of coin-storages, which enabled to optimize the overall internal space and allowed a closer interaction of the different components. This conversion has produced huge advantages in terms of interface area reduction and positioning;
- New information structure: a maximum of three major operations was set (1-title insertion; 2-payment; 3-collect both change and bill). These three major areas identified by big top left aligned numbers give, at a first glance, information about the complete sequence of user operations and where to start. By convention, a sequence is better perceived if organized in a straight line (vertical or horizontal). This way, the identification of the trigger operation, the initial task, was improved;
- In this special case, where the user is a driver operating the machine without stepping out of the vehicle, the sequential structure was designed to follow the easiest path of the extent user's left arm;
- White characters on a dark background worked better in the toll place environment, especially at night, where lighter surfaces tend to produce undesired reflections of artificial lights;
- Additionally, in top of every interface elements, blinking led bars were placed to give immediate feedback and to guide through the next operation;

- Introduction of a pre-recorded voice helper, showing the sequence of operations;
- Human-remote assistance made easy, clear and integrated with video-surveillance.

Fig. 10 – *Cardboard prototype*

Fig. 11 – *Model fitting test in production floor*

Fig. 12 – *E-Toll Machine*

A cardboard layout (Fig. 10) was made and tested, including at the production facility (Fig. 11).

The tests were conclusive and the new interface was employed in the renewed machines (Fig. 12).

Several improvements were identified:

- Ease of use for a wide range of heterogenic users;
- Reduced time of operation by the users. The most important feature because the introduction of this machine represents a disruptive innovation in toll payment services in Portugal which could generate user resistance in using it in comparison with the old manual operated system;
- Less intervention of remote operators helping new users;
- Fewer printed instructions needed in the layout surface;
- The new aesthetic appellative user interface help enhance the positive attitudes towards the machine by the users [8].

The project is now on the production installation phase, and it's expected to install over 200 machines in the Brisa's network until the end of 2010.

CONCLUSIONS

This project demonstrates the need to be concerned with the user interface from the initial phase of projects, not leaving this concern for the final stages, when the ability to influence the disposition of the internal modules is much smaller and its costs higher.

The development phase also shows the constructive use of different prototyping techniques, many of low cost, such as cardboard and paper prototyping, in selecting the most appropriate layout for the interface.

Another important point to be noted is the need for monitoring use of new equipment by the user, in a continue learning process. The E-toll project, due to the implications of the process itself, had this need clear from the beginning. This monitoring has brought major gains not only in improving the engineering component of hardware and software but also in observing users behaviors when using the new equipment, identifying difficulties that occur during the operation.

The development team has been heavily involved in the redesign process, congregating the areas of engineering and industrial design together, looking through a join process of experimentation and learning to improve the bond to the end user, through an improved functional and aesthetic machine interface.

ACKNOWLEDGMENTS

The authors would like to thank Rui Dias and Antonio Veiga from Brisa Inovação e Tecnologia, for the information and knowledge provided about the E-Toll project.

BIBLIOGRAPHY

[1] S.C. Wheelwright and K.B. Clark, Revolutionizing product development: quantum leaps in speed, efficiency and quality. New York: Free Press, 1992.

[2] K.T. Ulrich and S.D. Eppinger, Product Design and Development. McGraw-Hill, Singapore, 1995.

[3] S.H. Thomke, .Managing experimentation in the design of new products., Management Science, vol. 44, no.6, pp. 743-762, 1999.

[4] Shrage, Michael; Serious Play - How the World's Best Companies Simulate to Innovate, 1999

[5] Smith, Preston G., Let prototyping drive your product development process, 2003

[6] Moggridge, Bill., Designing Interactions, MIT Press, 2007

[7] Tilley, Alvin R., The Measure of Man and Woman – Human Factors in Design, Whitney Library of Design, (2002)

[8] Norman, D. A., Emotion and design: Attractive things work better. Interactions Magazine, ix (4), 36-42, (2002)