Usability as a Challenge in Precision Agriculture – Case Study: an ISOBUS VT

H. E. S. Haapala[1)], L. Pesonen[1)]and P. Nurkka[1)2)]

[1)] MTT Agrifood Research Finland, Vakolantie 55, FI-03400 Vihti, Finland,

hannu.haapala@mtt.fi

[2)] University of Art and Design Helsinki, Hämeentie 135 C, FI-00560 Helsinki, Finland,
piia.nurkka@mtt.fi

ABSTRACT

Taking products into practical use tends to be a bottle neck in the innovation chain of agricultural engineering. Usability is a major factor when customers consider if a new product or method is taken into wide use or not. Usability in agricultural engineering is a complex issue since the context of use in agriculture is variable and complex machine combinations are common. Furthermore, mobile work is typical to agriculture. Thus, usability of new technology is an important research theme in agricultural engineering.

The research themes were:

1. Usability as a challenge. How great a challenge is usability in Precision Agriculture (PA)? Is it the cause for poor market penetration?
2. Usability evaluation methods. Which usability evaluation methods are applicable to PA?
3. Usability of a Virtual Terminal. Which kind of usability problems can be detected with one selected method (heuristic evaluation)?

Themes 1 and 2 were studied in literature. According to literature usability issues have not been a central issue in electronics development in agriculture. Poor experiences of unacceptable operation could be one reason for the customers not relying on new electronic control systems such as those of PA. There are multiple potential usability evaluation methods for agricultural engineering. Some methods are suitable both for mobile applications and stationary ones as well.

Theme 3 was evaluated in a case study. The results show that heuristic evaluation, where there is no real user interaction, is a suitable method for detecting coarse design deficiencies in HMI software such as ISOBUS Virtual Terminal software. User inquiry could be a better method if real mobile working situations of the terminal were evaluated.

Keywords: Usability, Acceptability, Agricultural Engineering, Precision Agriculture, ISOBUS, Virtual Terminal

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1. INTRODUCTION

One of the primary goals of applied research is to apply the newest potential results into practice. The philosophy of utilitarism seems to lead technological research (Airaksinen 2003). Recently, introducing new technologies has become more challenging for the engineers since technologies have become complex. Successful product development requires joint input from several groups of experts such as research, engineering, ergonomics, design and marketing.

1.1 The Need for Usability Design in Precision Agriculture

User acceptance is a distinct limiting factor for applications of new technology in agriculture. Farmers are very conservative in their choice of technology so that they reduce risks and tend to choose traditional techniques. Because of all this, completely new applications have not penetrated to the market as presumed.

New technology aims to better control and monitoring. In order to do it, new measurements must be introduced. As human capacity to handle simultaneous information is limited new intelligence has been developed between the user and the system to be controlled. The intelligent layer decides which kind of information is passed on for the user and which part is used for other purposes. Design of such a layer and its Human-Machine Interface (HMI) is challenging since it has to be user-centric. (Fig. 1)

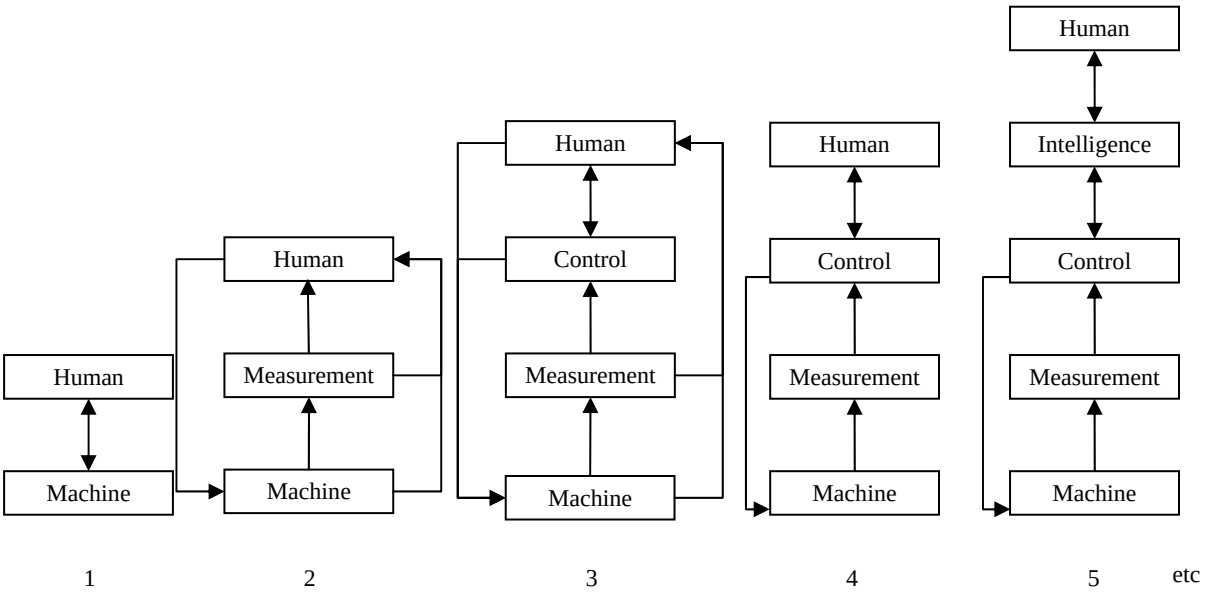

Figure 1. Development stages of the Human-Machine-Interface (HMI).

Performing navigation tests in 1993 with a laser beam based drive assist system was the starting point of usability considerations in the Finnish research team of Precision Agriculture (PA). Navigation results were excellent: a skilled driver could quite accurately (±20 mm) follow the desired straight path. However, when interviewed, the driver replied that he had to be under constant mental pressure when keeping the accuracy at this required level. (Haapala 1995)

1.2 Research Themes

In AGRIX project in 2003 the group needed a method for evaluating ISOBUS compatible Virtual Terminal (VT) software to be developed. As PA is quite a new application the design included usability tests with various methods. (Nurkka 2005, Oksanen et al. 2005)

To succeed in this the aim of the study was to concentrate on following three research themes:

1. Usability as a challenge. How great a challenge is usability in Precision Agriculture (PA)? Is it the cause for poor market penetration?
2. Usability evaluation methods. Which usability evaluation methods are applicable to PA?
3. Usability of a Virtual Terminal. Which kind of usability problems can be detected with one selected method (heuristic evaluation)?

2. MATERIAL AND METHODS

Themes 1 and 2 were studied in literature. Theme 3 was evaluated in a case study where prototype AGRIX Virtual Terminal (VT) software of a combined drill was evaluated using one selected usability evaluation method (heuristic evaluation).

Combined drilling (Fig. 2) is a potential application of PA since the technique itself is accurate. The method enhances the initial phase of plant growth especially where there is shortage of water during the sowing season. Emissions of nutrients are lower than with the use of separate operations or surface spreading techniques. An environmentally sound technique could be achieved if site-specific control would be added to combined drilling. (Haapala 1995)

Combined drilling is a challenge for usability design since the work is mobile and still the quality of drilling and seeding processes needs to be monitored and controlled by the user. If site-specific control is added the task of the user gets more complicated. A good HMI is needed.

a. b.

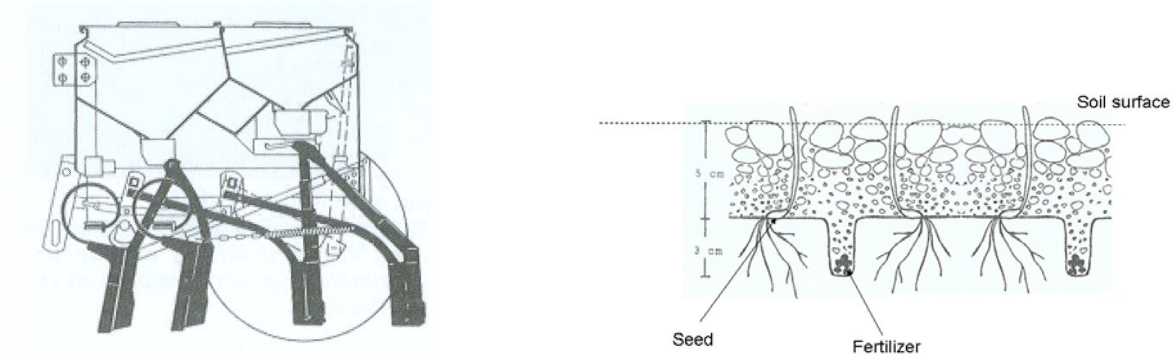

Fig 2. (a) A typical combined drill. There are separate hoppers and coulters for fertiliser and seed. (b) Fertiliser is incorporated some 3 cm´s deeper than seed. Row spacing is typically 12.5 cm for seed and 25 cm for fertiliser.

The aim was to uncover HMI deficiencies in the AGRIX VT software before field testing. The heuristic evaluation proceeded as described in next figure (Fig. 3).

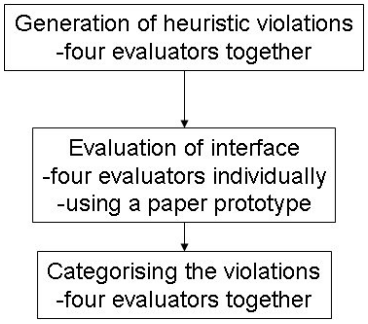

Fig. 3. The sequence of heuristic evaluation.

There were four evaluators who first generated a list of heuristic violations based on Jacob Nielsen's list of heuristics (Nielsen 1993). Different modes of the interface were presented to the evaluators as screen shots on paper (paper prototype), with a navigation map as a supplement. Then the evaluators tested the interface individually. Finally, the violations were categorized according to their severity on the scale of 5 to 1. Severity ratings depended on the obtained frequency, impact for the user and persistence of the problem.

3. RESULTS

3.1 Usability as a Challenge

According to ISO 9241-11:1988 standard (ISO 1998): ´Usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.´

Nielsen (1993) claims that usability includes several layers whereupon ease of use, efficiency and subjective pleasure are considered as central elements (Fig 4).

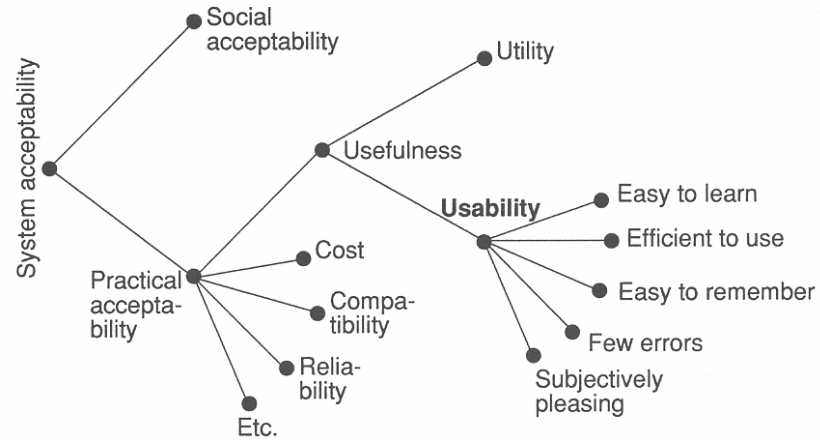

Fig. 4. A model of the attributes of system acceptability (Nielsen 1993).

The role of automation should be designed so that automation helps the individual user to simultaneously avoid stress, and increase efficiency of work. Thus the interaction between human and machine as well as the work context need to be studied (Hollnagel & Bye 2000).

Combined drilling is a mobile work so the VT software faces the challenges for usability design of mobile computer device listed by Dunlop and Brewster (2002):

1. Design for mobility
2. Design for widespread population
3. Design for limited input/output facilities
4. Design for (incomplete and varying) context information
5. Design for user multitasking

As farmers are conservative, trust has first to be formed in order to have a breakthrough of new technology. Kaasinen (2005) concludes that trust is a very important issue in successful mobile appliances. Trust is built when the user has a clear conception of the functionality of the appliance even though (s)he does not know all the details. The user also needs to trust on the reliability and accuracy of the information available.

3.2 Usability Evaluation Methods

Usability evaluation methods can be divided into three different main categories: usability testing, inspection and inquiry (Nielsen & Mack 1994, McLeod 2003, Folmer & Bosch 2004).

The usability testing approach requires representative users to perform given tasks with the product. The results are assessed to see whether the product supports the user doing the tasks and meets a set of usability criteria. Test settings are controlled, so variable factors are eliminated.

Usability inspection means examining the product according to established usability principles, e.g. heuristic evaluation, by usability specialists with no user involvement. Inspection methods take no consideration on the work environment.

The usability inquiry approach aims at detecting information about the users in general and about their interaction with the system in real work settings and context.

Because of their differences the methods apply for different phases of product development. The users and the real context of use also have an effect on the feasibility of methods (Riihiaho 2000, Kaasinen 2005).

3.3 Usability Evaluation of a Virtual Terminal

At the heuristic evaluation of AGRIX VT software (Nurkka 2005, Table 1) altogether 74 violations were found. The number of violations considered urgent to fix (catastrophic and major usability problem) were 39. The largest amount of them, 29, was found relating to the heuristic ´Simple and natural dialogue'. The second highest amount of violations, 10 examples, related on the heuristic ´Speak the users' language'. Context awareness was also a problem because of the violations in ´Visibility of system status – feedback´.

Table 1. Results of heuristic evaluation of the Virtual Terminal of a combined drill. Number of violations to different heuristics.

Heuristic	5 = usability catastrophe - must be fixed	4 = major usability problem - important to fix	3 = Minor usability problem - worthwhile to fix	2 = Cosmetic problem only – fix if you have time	1 = This is not a usability problem at all	violations: total number / level 5,4,3 / level 5, 4
Aesthetic and minimalist design	1	13	6	7	2	29/20/14
Match between system and the real world – speak the user's language	1	3	5	1		10/9/4
Recognition rather than recall – minimise the user memory load	1	2	1	2		6/4/3
Consistency and standards		1	3	1		5/4/1
Visibility of system status - feedback		9	1	1		11/10/ 9
User control and freedom – clearly marked exits	1	1				2/2/2
Flexibility and efficiency of use - shortcuts			1			1/1/0
Help users recognize, diagnose, and recover from errors – good error messages		2				2/2/2
Error prevention		3	3	1		7/6/3
Help and documentation		1				1/1/1
total	4	35	20	13	2	74/59/39

4. DISCUSSION

4.1 Usability as a Challenge in PA

When considering PA according to Nielsen's model (Fig. 4 above) we can quite easily pinpoint usability as a probable cause for problems in acceptance. Other features can be more or less excluded. Social acceptance of PA has developed positively lately. There have been enquiries and interviews of specialists and decision makers showing quite positive attitude of using new technology in quality management of agriculture generally (e.g. Rikkonen 2004). Benefits of PA are widely agreed. Features connected to practical acceptability of equipment such as price, compatibility and reliability have lately been improving. Only usability seems to be negative.

Farmers, farm workers and contractors are challenging users. Generally, they are very much business oriented and do not want to deal with complex techniques. McBratney, Whelan & Ancev (2005) conclude that drive assist systems are the only success products in PA since they are not requiring the farmer to make additional decisions but help her/him to reduce them. Drive assist systems give benefits for the farmer since they are easy-to-use and they solve actual important problems, and they return investment costs immediately.

When following the list of Dunlop and Brewster (2002) above some specialties in PA can be found. User environment can be far from ideal and the environment may change drastically as the user moves. Input/output facilities (screens, keyboards, pointing devices etc.) have to be usable during agricultural work. However, their physical properties (size, touch, number of keys, sensitivity etc.) limit the design of user interface software. Eventually, mobile users, such as farmers in field work, face more interruptions than desktop users since they perform multiple tasks at the same time.

Kaasinen´s (2005) issue of trust is a challenge in PA. In agriculture there are lots of bad experiences of prototype (electronic) products for agriculture that have not been reliable or easy to control. Thus, all new technology is easily considered as potential trouble.

Complex machine combinations are central in PA. In spite of increased complexity and abundance of data, all relevant pieces of process information should be communicated to the driver. It is a challenge then to choose what is relevant and which are suitable formats and forms for the presentation of each piece of information.

4.2 Usability Evaluation Methods for PA

In conventional design of human-machine systems the designer takes an external position outside the interactions between the human and the machine. The task is to design optimized interaction between the two based on a technology-centred idea. However the interaction is often too complex to be predicted at the design stage. Therefore, a user-centred approach is advised to be applied (Hall 2001). Usability evaluation is needed in such an approach.

Heuristic evaluation was chosen as the method to evaluate the Virtual Terminal of the combined drill because the method has proven to be effective, it can be used early in the design process and it is suitable for iterative design process (Nielsen & Mack 1994, Riihiaho 2000).

4.3 Usability Evaluation of a Virtual Terminal

Evaluation methods of different categories all give different views on usability. The usability inspection approach (heuristic evaluation) used detects issues concerning information presentation pointing out the major areas in need of improvement. This was just what was needed in the particular phase of AGRIX VT design. In other phases of development other methods could be more efficient. Real user involvement should be present when the VT is nearer to a practical product.

In this study, the observations of violations on heuristics concerning memory load and feedback were inaccurate. A paper prototype gives only visual feedback. In real usage situation the feedback of an action is gained through other senses than visual.

5. CONCLUSIONS

5.1 Usability as a Challenge in PA

Development of new agricultural engineering technology, such as PA, should be more user-centred to be able to meet all the requirements of usability. As PA is implemented the traditional and adopted ways of interaction between the user and the machine system has to be changed.

It can be concluded that poor user acceptance could be the core reason for PA not being widely adopted in practice. Usability of PA products is not on an acceptable level. There is a clear need to evaluate the usability of new PA devices to meet the user requirements.

Technically, PA is challenging since there are lots of sensors and actuators needed. The usability design, however, is even more challenging. Multitasking situations can not be avoided since farmers are working with multiple simultaneous tasks in their mind. Mobile work in hard environment limits the features of electronics that can be applied.

5.2 Usability Evaluation Methods for PA

Different evaluation methods emphasize diverse dimensions of usability. Thus, in product development, multiple methods for usability evaluation are needed. The selection depends on the phase of development, complexity of user interaction and the available resources.

5.3 Usability Evaluation of a Virtual Terminal

HMI (Human-Machine Interface) is a central part of usability design. Eventually, the HMI is the only part of the system that the user communicates with. In order to give confidence for the user, the HMI has to be easy to use and reliable.

In Virtual Terminals more attention has to be pointed at the information presentation and used icons. Only the information needed to carry out a task should be displayed and the information should be presented in a logical order. The icons should be designed to better symbolize the task at hand and the use of standard icons is advisable. Inconsistency and indistinctness as well as the choice of icons and language were found to be sources of possible problems in the interaction.

The results show that heuristic evaluation is a suitable method for early detection of coarse design deficiencies. Other methods such as user inquiry need to be used if real mobile working situations are to be evaluated.

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