# Integrating Production Workers into User Interface Design for Diagnosis Devices in Automotive Production Environments: Field Experiences and Lessons Learned

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**Abstract.** In this paper, we present an exploratory case study regarding user interface design for test and diagnosis devices in automotive production environments. We report workers´ opinions concerning existing user interfaces and devices, as well as the use of innovative user interface and interaction concepts. Finally, we derive requirements for future use of modern interaction concepts and present a set of possible devices for future evaluation.

**Keywords:** Industrial production context, test and diagnosis, user interface design, user machine dialogue.

## 1 Introduction

Today's requirements for human-machine interaction should consider central aspects of human factors/ergonomics, usability, reliability, human-machine cooperation and a human-centered design. Innovative and future-oriented concepts to achieve an unambiguous interaction between humans and machines are furthermore needed in industrial production context in which they have been often neglected [1]. The purpose of the present study is to investigate the existing user interfaces and devices in an automotive production environment and to formulate requirements for future development. The challenges was the necessity of applying test benches for quality controls to improve existing user interfaces without radically changing existing workflows and induce negative side effects on the production process.

The study has been accomplished on production lines at two different automotive production locations. At these production lines, a car passes through several quality control stages where workers use mobile and stationary devices for checking certain electronic car features. The test duration depends mainly on the vehicle's configuration and the requirements of the countries they are exported to. Usually, the testing sequence begins with connecting a diagnosis device to the vehicle. Then, the worker starts the test sequence, which consists of automatic testing routines without interventions by the worker, as well as manual test procedures the worker has to carry out manually in and around the car. These manual test procedures contain visual examinations and/or interaction with the test device to confirm the well function of certain

C. Stephanidis (Ed.): Posters, Part II, HCII 2013, CCIS 374, pp. 469–473, 2013.

electronic car components by pressing a button on the device. All vehicles with at least one encountered error are sorted out and returned to overhaul, followed by a further quality check after resolving all errors. All cars leaving the production line have successfully passed all quality checks.

## 2 Methodology

We conducted a human factors centered exploratory case study based on semi-structured interviews with 36 production workers accompanied by field observations that were conducted in two production sites of a large German car manufacturer. The two sites used similar but not identical hardware concepts and thus also testing software. The working experience (tenure) of the workers varied from a few days up to 40 years. The interview was specially designed for being conducted in the field: at production lines during running production. Overall, each worker was asked 19 questions. Each question was rated on a 5-point scale from -2 (very negative) to +2 (very positive), and a zero as a neutral option. Topics addressed in the interviews were personal experiences with the existing equipment, especially their performance, software design and forms of assistance. In addition, workers were asked about information on non-functional elements, such as the use of multimedia stylistic elements. Finally, we proposed alternative user interface concepts to the workers, such as compact and handy sized terminals, headsets, head-mounted-displays, and gesture control. The workers were also asked about their requests and suggestions for new innovative diagnosis devices in the near future.

## 3 Results

The insights from the interviews with the workers at both production sites demonstrated the importance of user integration into the design process. According to our observations at two different locations with different diagnosis systems we encountered that the current diagnosis systems in use were primarily designed for diagnosis specifications and industry standards. The criterion of "user experience" was widely neglected. Analyzing the transfer of this assumption with regard to the definition of usability [2] we came to the conclusion that existing diagnosis systems were effective in terms of fulfilled specifications but not always efficient in terms of ease of use.

For example, diagnosis devices are very versatile with many features and many keyboard buttons providing a default layout. This can result in higher error rates by accidently pushing a wrong button, which may lead to the cancelation of the whole diagnosis process. Nevertheless, the interviewed workers have accustomed themselves to the current diagnosis system and use it properly and efficiently. We think that this is the reason for the low rating of proposed alternative devices presented to the workers, which show better condition concerning usability requirements. Other reasons for this negative outcome were difficulties of workers' ability to image the use of such devices and the work environment. For instance, wearing devices on the body foster hygienically problems and thus were rejected as a possible new class of devices. Furthermore, workers have no intention to use innovative interaction concepts unless there is a chance to increase ergonomic and usability aspects at the same time.

Below, we list important requirements and challenges for alternative diagnosis devices for production lines we gained from our exploratory case study:

- Compliance with the industry standards: heat resistance, stability, shock resistance, long battery life, mobility, short maintenance and service intervals, Safety and health aspect
- Compliance with company philosophy: Effectiveness and efficiency, high Availability and replaceable
- Flexibility: adaptable user interface on workers experience or cultural background
- Ergonomics and satisfaction, e.g. social acceptance, motivation, emotion, Communication features

### 3.1 Alternative and Innovative Diagnosis Devices

In this chapter we want to introduce various diagnosis devices and reactions to these alternatives, accompanied challenges arising from discussions with workers. Based on this study, the following results from interviews were obtained for devices with visual information representation with haptic controls, and alternative user interfaces such as gesture control, head mounted display and auditory input and output (i.e. headsets).

*Handy sized terminals:* These devices are usually equipped with touch screen and haptic controls. The great advantage of these devices is the common use of multimedia on graphical screens and audio capabilities. The haptic controls give also a better feedback feeling and safety versus touching screens. They can also be worn attached to an arm or pocket, hence it is in reachable range to read information and confirm incoming orders. Workers can interact with these devices only one-handed and use the other hand for interaction with the inspected vehicle. Graphical screens allow also customization and personalization for visual data representation due to user experience.

Negative aspects of such devices are a poor heat resistance, additional heat produced by operating a device, and current short battery life what is unsuitable for shifts up to 8 hours in production. To get further instructions during diagnosis process, a worker has to toggle his view between vehicle and diagnosis device, which implies high level of concentration.

*Gesture-based interaction:* For gesture-based interaction, devices such as sensor gloves should be used [3]. Thus, both hands can be used freely to interact with vehicle. If gloves are personalized for each worker also hygienic requirements are met. Furthermore, visual sensors can recognize workers' gestures without using any gloves or other wearing sensors for interaction [4].

But this kind of interaction has some challenges. The handling of such devices is not intuitive and workers would need to train available interaction commands [4]. Additional devices (i.e. acoustic, graphical interfaces, sensors) for input processing and incoming instructions are required.

*Head-mounted displays:* Devices such as Google Glasses [5] are at first glance one of the best alternatives which combines various technologies (i.e. display, camera, speaker and microphone) in one device. Workers do not need to toggle sight between vehicle and device. Visualized order and further information are always in focus without restrictions to the field of view and allows using a customizable graphical user interfaces.

Based on the workers statements, head-mounted displays are unsuitable for using on production lines. Head-mounted displays are predestinated to carry them on the body respective on the worker's head. Particularly, in summer and very hot temperatures of about 30 degrees Celsius (86 degrees Fahrenheit), this would be very unpleasant. The built-in computer devices would produce additional heat. Another issue is the hygienic of this device class. A further aspect is the heavy weight of many head-mounted displays, which may cause eyestrain and health problems [6].

*Headset-based interaction:* Interaction via headset also offers many possibilities for customization and personalization. To improve communication between workers and computer interface it is possible to create for each user own profile for voice input or language. Similarly, the output can be also adjusted to the user experience and language. Interaction with such devices is done by special acoustic signals and voice commands. Workers have both hands free to interact with a vehicle and the viewing direction must not be toggled anymore between diagnosis device and vehicle [7].

The main challenge of headsets would be to achieve a clear speech comprehension in noisy environment. Further, this kind of interaction depends on learning of correct pronouncing and encoded words to achieve a smooth interaction. Another unpleasant side effect of using such devices would be health and psychological aspects caused by permanent repetitive acoustic signals through excessive use.

On both production sides was confirmed that current used mobile devices are usable but are so far not ergonomically designed. All introduced alternative devices have also their challenges. Furthermore, the interviewed workers have confirmed that haptic controls were preferred over the touch-interfaces due to better physical feedback. Due to social acceptance and privacy violation, cameras are generally not possible. Therefore it is strongly recommended to carry out further studies to elaborate alternative diagnosis devices and further challenges for automotive production environments.

### 3.2 Software Challenges

In this case study we determined some usability issues in software design caused by overloaded screens with textual information and no use of multimedia elements, which may be important for less experienced workers. We also missed a feature to support workers on machine failures. On the production lines the diagnosis program is working very simple. Workers getting an order from the program what to do next (i.e. start engine, push button X, open/close doors, visual inspection of light sources, etc.), understand it and finally execute and/or confirm it. But once an error occurs, for example lost diagnosis communication to vehicle or important precondition due to accident prevention was not occurred. The worst case is when display still showing the same order, even if worker successfully finished or confirmed the order and nothing happens, because the diagnosis program lost connection to the vehicle. At this point, we need additional kind of software logic to compensate such situation by starting to report helpful user instructions after elapsed time for a task without noticed any user interaction. Among others, a very crucial insight was that workers constantly need an overview about what and why the software is doing what it does at a certain point in time and that support is needed to predict subsequent process states in accordance to workers' mental process model.

## 4 Conclusion

It was not easy to perform this study with interviews directly on the production line under time pressure. The quality of the survey can therefore be improved on outside of the production line. However, more important was to plan the worker integration in this study from the outset. Based on these experiences, we will develop a new approach of applying a human factors centered, worker-oriented approach of modeling user interfaces for human-machine interaction in automotive production environments. This modeling approach will be based on prior work in user interface modeling [8] and accompanied with the design of a new handy and versatile mobile interface, which will be developed comprehending production workers resulting in a structured and novel design for ease of use accordingly to the requirements revealed in the interviews and in ongoing case studies.

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