Applying Human-Centered Design Methods in Industry – a Field Report

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ABSTRACT
Human-centered design methods are nowadays widely used in the design of consumer products. These methods aim at designing products with a high usability and a positive user experience (UX). However, in the domain of the design of industrial machines, design is often driven by functional requirements mostly neglecting the usability and user experience of products. Together with a medium-sized manufacturer of industrial laundry machines we applied the human-centered design process in an industrial context. In this field report, we describe the human-centered design methods applied in the project, the adaptations we had to make in the process and the challenges and opportunities for applying human-centered design in an industrial environment in general.

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INTRODUCTION
Human-centered design methods are well established for designing and developing new end-user products. However, the development of industrial machines often follows waterfall-like models, focusing on engineering core functionality of machines, but not putting huge emphasis on usability and user experience. Due to the increase in complexity and interconnectivity of machines, which are currently being developed under the heading 'Industry 4.0' [5], we predict that there will be a need to focus more on the user, the work task and the work environment. This new focus would consequently bring human-centered design into the aforementioned domain.

In cooperation with a mid-sized manufacturer of industrial laundry machines we applied the human-centered design process into this industrial domain. The system developed in the context of our project is a mobile device for the support of problem-solving and maintenance work within the laundry. We consider our case of industrial laundry machines as representative for other industrial machines as well. In this paper, we do not describe the system any further, but we will rather describe our development process and reflect on the methods applied. We will describe the challenges and opportunities of applying human-centered design in an industrial context. With this field report, we intend to start a discussion about the questions of the applicability of this design process in the context of the development of industrial machines.

RELATED WORK
There is a huge body of research on the topic of design methods. Zimmermann et al. characterize the role of a design researcher in the development of artifacts (models, prototypes, products and documentation) by reframing the problem statement through "*an active process of ideating, iterating, and critiquing potential solutions*" [13]. A lot of design methods have been developed to follow this iterative process of ideating and evaluation and there are numerous publications available that describe the methods, such as [3], [7], [8], [9] and [10]. These works describe methods and examples of how to realize a human-centered design process, but they focus on consumer products in general. Human-centered design itself is nowadays ubiquitous in product and software development, thus the concept made it into the ISO standard 9241-210 [4]. However, there are not many publications about the application of human-centered design in the context of industrial machines, even though industrial machines have special characteristics.

APPLIED METHODS
In this section we describe our methods applied in the project. As mentioned, those methods are known from human-centered design, but in some cases methods have been adapted to respond to the specific requirements of designing industrial machines.

Understanding the Context of Use
A first in-depth analysis was undertaken in order to understand the specific context of use of the machines,

comprising users, tasks, resources and the physical, social and technical environment that forms the context of use [8].

Review of Existing Documentation

As a first insight into the domain, existing documentation was reviewed. This method is usually not part of a human-centered design process, but rather known from the field of requirements engineering [11]. Contrary to the context of consumer products, the context of use in industrial settings is usually not known to the usability engineer or user experience designer from his or her everyday experience. Therefore the method was incorporated as a first step. The documentation provided by the industry partner consisted of printed service manuals and videos of maintenance activities that had been recorded for training purposes. The videos in particular were very useful in order to get a good comprehension of the new domain.

Identification of User Groups

User-group profiles were developed in a joint workshop. During a brainstorming session, various user types were collected. In the discussion that followed, the groups were defined and classified into direct and indirect users as well as into primary and secondary users.

Observation in a Laundry / Contextual Inquiry "Light"

In order to gain a deeper comprehension of the context, a laundry was visited and employees were observed in their daily work (see Figure 1a). While a contextual inquiry had been planned initially, after having talked to the manager of the laundry we had to adapt the planned method here and change to an observation with a limited possibility of asking interview questions to the employees. This change was done since only methods with a minimal impact on the productivity were allowed in the laundry. Conducting extensive interviews during the work was therefore impossible. In addition, the environment was very noisy, making a conversation difficult. Therefore, the users in the laundry were only asked few questions during observation, which we call contextual inquiry "light".

Figure 1. Impressions from (a) the observations of maintenance work in a laundry and (b) the sketching workshop.

Interviewing Users

In order to make up for the limited interviews during observation, we planned additional interviews with users about the way that people work with the systems. For confidentiality reasons, we recruited the interviewees among our industry partner's employees that regularly work with the systems during trainings or at trade fairs. Again, these kinds of interviews are usually not part of the human-centered design process and the recruitment of interviewees from among the partner's workforce was not the ideal case. However, the adaptation was necessary, since we had to find out more about the context of use with the given confidentiality.

Definition of Requirements

The definition of requirements was done in two joint workshops at which we discussed the consequences of the analyzed context of use. We defined and prioritized use-cases and related features that were the basis for the following design process.

Conceptual Design and Prototyping

The conceptual design was mainly done in three phases: first, a joint sketching workshop was held in order to get some first ideas about the general navigation structure. Second, the sketches were iteratively further developed to a digital clickable low-fidelity prototype. Third, an interactive prototype was developed based on a web application running on a tablet computer. During the development stages, intermediate evaluations were performed.

Sketching Workshop

We invited about 15 'Industry 4.0' experts and young professionals to a joint workshop for the development of the initial user interface (see Figure 1b). The aim of sketching user interfaces on paper is to start a fruitful discussion about the user interface with the various stakeholders. Sketches communicate their tentative and changeable character [10] to the participants of the workshop and were therefore considered as an ideal way to get first ideas about the navigation structure and user interface design.

Development of a Low-Fidelity Prototype

The ideas developed during the sketching workshop were discussed with the various stakeholders and combined into one 'clickable' low-fidelity prototype that shows the potential future application. The tool Balsamiq Mockups[1] was used to create the prototype. The finished low-fidelity prototype was iteratively discussed with various stakeholders and improved in accordance. However, actual users of the systems could unfortunately not be involved in the process for confidentiality reasons (see section Evaluation for details).

Development of the Interactive Prototype

Based on the concepts developed in the early prototyping phases, an interactive HTML5 prototype was developed. The aim of the second prototyping stage was to develop a prototype with a look and feel as close as possible to a future product. Therefore, the Yeoman[2] technology stack was used for the development, which includes JavaScript frameworks and tools like Bootstrap[3] and AngularJS[4] that

[1] https://balsamiq.com/products/mockups
[2] http://yeoman.io
[3] http://getbootstrap.com
[4] https://angularjs.org

allow the rapid development of responsive web applications. The navigation structure was taken over from the low fidelity prototype. However, the graphical user interface design was improved iteratively during the development stage.

Usability Evaluation

Inspection

Consistently to the challenges faced during the context analysis, an extensive user evaluation was not possible in this project. Instead, an inspection-based usability evaluation was done. An external usability engineer therefore iteratively assessed the interactive prototype during the development stages and identified a few usability problems that could be addressed in the following development stages.

Usability Test

Even though the iterative development and the multiple discussions with the stakeholders as well as the included usability inspection by an external expert target on a high usability, we consider a usability test in the field as an important and necessary step, before the prototype is further developed into a commercial product. However, we had the restriction of a very limited access to users for confidentiality reasons, which can be considered as typical in the context of the development of industrial machines. In the following sections we discuss, how this issue can be overcome.

CHALLENGES AND HOW TO MEET THEM

In this section, we will present the challenges that we observed when we applied the human-centered design process in a setting for the development of a system for an industrial context. We reflect on the challenges and describe how these challenges can be met.

Limited Access to Users

While recruiting users for usability tests is costly in general, it is a real issue when dealing with the design of industrial machines, since ideally people need to be recruited that have some previous training in the field of the work. According to our experience, mid-size companies producing industrial machines often do not have access to their clients' employees, which makes it difficult to recruit appropriate users for the application of human-centered design methods. Contrary to the development of consumer products, one cannot just recruit average people from the street as proposed in [12]. For human-centered design, end users are required especially in the context analysis and in the evaluation (both formative and summative). We had positive experiences in understanding the use context by observation and through interviews with partners that were not end users, but rather experts of the domain. However, we state that there should be an evaluation with end users when developing industrial machines despite the high costs and effort of recruiting them.

Confidentiality During the Development

The question of how to deal with confidentiality during the development is closely connected with the previous challenge. The development of new industrial systems often takes longer than the development of consumer products and it is usually an economic risk if information about the ongoing product development leaks. Our experience shows that it is important to deal with this risk and communicate openly with the management about this issue. In some cases, fears do not prove to be true, which is especially the case for the context analysis. Usually this context analysis can be done involving users without spreading information about the planned new development. If confidentially is an issue, a user evaluation is more critical. While in human-centered design user evaluations should be done as early as possible, in industrial projects one needs to find the optimal trade-off between confidentiality and early user involvement. In some cases, it can make sense to test at least selected features, while holding back on testing confidential features until a later point in the project.

Bias Towards Lab Studies

When deciding whether doing a laboratory or a field study, one might be biased towards laboratory studies since moving the new industrial system to the operation site might cause additional organizational efforts. However, we want to emphasize that the situation in the field might be totally different from a lab. Industrial machines are often installed in special environments that are for example characterized by noise, thermal influences, high humidity, special light conditions, etc. Doing lab studies might not catch all these environment factors and ignore specific requirements for the system.

Conflict of Interests Between Management and User

While user experience is an important factor for selling consumer products to customers and therefore a central requirement, there is a conflict of interests in the development of industrial machines: While end users have to struggle with usability issues in the case of bad design, buying decisions are usually not made by the users. This has two implications for the human-centered design process: First, people from the buying departments of representative clients should be involved in the human-centered design process in addition to the end users in order to cover their specific requirements. Second, it is not enough to focus on user experience only, but rather it is necessary to also consider the so-called customer experience, a larger concept that includes the satisfaction of users and customers with the product as well as within the communication with the whole company [6]. The human-centered design process therefore has to be integrated in a larger process that ensures a good customer experience.

OPPORTUNITIES

Even though there are some challenges when applying the human-centered design process in the industrial context, we see huge opportunities for human-centered design methods in the industrial context.

Complex Connected Machines Require Excellent Usability

Currently, industrial machines, production resources and products become more and more connected. Mobile devices are integrated to control machines and 'smart products' can communicate their state already during the production [5]. In German-speaking countries, this development is often referred to as 'Industry 4.0'. While the technological effects on this development are not clear yet, experts agree that humans will still be involved in the future of production [5]. However, controlling and maintaining machines will become a more difficult task with the growing complexity induced by the connected systems. We assume that better usability and a focus on human-centered design processes is a core requirement in the future of interconnected machines to deal with the high complexity.

Usability Issues Inexcusable due to Long Product Life Cycles

Contrary to consumer products, systems in industry usually have long product life cycles. Industrial machines are often used for multiple decades. Usability flaws that are built into a system today will cause problems, mistakes and costs in the decades ahead. The costs accumulated over this time make the establishment of a human-centered design process in the product development a reasonable decision.

Methods Available and Applicable (With Modifications)

When it comes to human-centered design, there is a huge body of well-established methods available. These methods have been successfully applied in numerous projects for the development of various products. While there had to be some modifications for the application in the industrial context, as described above, most of the methods have been generic enough and worked well in the industrial project.

New Interaction Technologies in Industry

With new interaction technology coming into industry, e.g. with the use of head-mounted displays or augmented reality projections for industrial production, such as [1] and [2], new development processes for such integrated systems will be required. While in past, machines often just had a minimal user interface consisting of a number of buttons and small displays, the integration of new interaction technologies shift the focus clearly to the user. We predict that industrial machines of the future will not be developed in waterfall-model-like processes anymore by engineers only, as it often happens today. Rather there will be a need for interdisciplinary iterative cooperation between engineers, industrial designers and UX experts, which will leverage human-centered design methods in this area.

CONCLUSION

With this field report, we documented our experience of applying the human-centered design process to the development of systems in an industrial environment. We showed that most of the methods are applicable and that only minor changes had to be made to the known design methods. We uncovered challenges and opportunities for future design processes in an industrial setting. Based on our experiences, we want to encourage 'Industry 4.0' researchers and practitioners to foster human-centered design methods in industry.

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