Deploying Robots in a Production Environment: A Study on Temporal Transitions of Workers' Experiences

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Abstract. Understanding a worker's perspective when introducing robots at humans' workplaces is crucial to improve human-robot interaction in production environments. Taking a temporal perspective on workers' experiences with robots, we explored expectations and general attitudes as well as actual feelings and reflections regarding the deployment of robots in a semiconductor factory. To evoke reports on workers' experiences, we applied a narrative interview technique with 10 workers. To characterize the temporal transition of workers' experiences, we distinguished between three phases in the deployment process: expectations before the deployment of the robots, familiarization with the robots, and experienced consequences of working with the robots. We present characteristic experiences of each phase and describe how these experiences change over time regarding the perceived functional value of the robots, work organization, feelings, social environment, and attitudes. Overall, our research contributes leverage points towards a more positive experience of workers when deploying robots in a factory.

Keywords: Temporality, Experience, Factory, Human-Robot Interaction

1 Introduction

Introducing robots at humans' workplaces is a critical endeavor. Specific expectations, attitudes, familiarization processes and experiences may be relevant as they presumably influence actual, future human-robot interactions. In particular, workers' experiences with interactive artifacts, i.e., user experience (UX), are crucial as they influence the course of actions in a factory [22]. Robots represent such interactive artifacts and thus can be a focus of UX research in a factory.

To facilitate a better collaboration between humans and robots, it is important to understand the temporal process of deploying a new robot from a worker's point of view, ranging from workers expectations before the introduction of robots to their actual experience of working together with such a robot. Previous work already showed that time can be a crucial factor regarding workers' experiences in human-robot interactions [5]. Initial experiences positively changed with prolonged interaction and remained stable after one year. To extend the contribution of Buchner and colleagues, details about temporal influences at different stages in the deployment process of a robot regarding the workers' experience would be beneficial, as this could provide important hints on how to improve human-robot collaboration in general.

By explicitly taking a process-oriented perspective (beginning from expectations to familiarization issues up to long-term consequences) on workers experiences regarding robots, we extend the current state of the art. In particular, we were interested in the characterization of workers' experiences within the deployment process of robots in a semiconductor factory. Further, we aimed to find out how the workers' experiences changed across different stages in the deployment process of the robot.

In the following, we motivate our research aims that led to the research questions, then we present related work on human-robot interaction (HRI), user experience (UX) and temporal aspects of UX. Next, we point out the objective of our study, the study set-up, participants and procedure, as well as our approach. We then explain the data analysis process and present our findings on workers' experiences at different stages of the deployment process of a robot. Finally, we discuss transitions of workers' experiences over time as well as leverage points for potential interventions during the deployment process.

2 Background

2.1 HRI & UX

UX comprises all aspects of how people interact with a product: the way it feels in their hands, how well they understand how it works, how they feel about it while they are using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it [1]. Interactions – with systems or individuals – are key elements in many working environments, e.g., in factories. Obrist et al. [22] emphasized that research on workers' experiences in a factory is important, as UX aspects like collaboration and reliability, usability or even emotions influence working routines in the factory. The experiences that result from these interactions in turn may influence motivation, compliance and performance and are, thus, relevant to investigate in order to improve them. This work was extended by Wurhofer et al. [30], who explored workers' everyday experiences and contextual influences on it in a semiconductor factory.

In general, industrial contexts pose a variety of challenges and restrictions, for instance, fieldwork must not impact work practices [3], [27]. The challenges of these contexts led to a limited number of studies. In particular, introducing robots in a factory is a critical endeavor. A recently conducted quantitative study in the cleanroom of a semiconductor factory focused on how UX of industrial robots with and without safety fences changes over time [5]. By deploying a self-developed UX questionnaire consisting of five scales – cooperation, perceived usability, perceived safety, stress, and general UX - different facets of UX were measured at different points in time. Results showed that time can be a crucial factor in human-robot interaction, as initial experiences positively changed with prolonged interaction. In order to understand the reasons for this change, however, more details about what accounts for these changes, i.e., what influences how a robot is perceived in the course of time, are needed.

There are studies on how to raise the workers' acceptance of industrial robots, for instance, by transferring anthropomorphic features to the industrial robot [8], [12]. Next to the appearance of the robot, other factors probably play a role regarding the acceptance of robots as co-workers. For example, in previous studies it was found that the fear of being replaced by a robot is crucial regarding how the robot is experienced and accepted [22], [28].

In contrast to industrial robots, investigations of service robots over a longer period became more frequent, e.g., in schools [6], or health care settings [7], [18]. In such studies, it was reported that the users' attitude towards the robot changed over time, e.g., became more accepted over time [7]. Further studies highlight that it is important to keep up the users' interest [9], to match the functionalities of the robot to its appearance [15], and to give feedback at the right time [20]. As Karapanos et al. [14] pointed out, usability becomes more important over time; studies in HRI have also shown that it is crucial to consider usability aspects for long-term human-robot interaction [18].

2.2 UX over Time

In recent years, research on UX over time has been intensified and became an important area of research within the HCI community (e.g., [14], [16]). However, the temporality of UX, i.e., how the quality of the users' experience develops over time [14], is still an area of research to be further explored [2]. As soon a new technology is deployed, acceptance becomes an issue (e.g., [10], [25]), and technology adoption is crucial. Technology adoption represents a process that ends with a user embracing a technology, i.e., accepting it [24].

Regarding UX over time with robots in an industrial context, we already pointed out the limited number of studies due to the challenges and restrictions of this context. The study of Buchner et al. [5] represents an exception, however, still leaves open some issues (see section 2.1).

In contrast to the industrial context, consumer contexts are better researched. For example, Karapanos et al. [14] contributed a five-week study with six participants purchasing an Apple iPhone. They found that prolonged use was motivated by different qualities than the ones that provided positive initial experiences. According to their results, early experiences seemed to relate mostly to hedonic aspects of product use, whereas prolonged experiences became increasingly more tied to aspects reflecting how the product becomes meaningful in one's life. Their findings showed that many different kinds of experiences may take place during the same day, but their distribution changes over time, starting from an orienting learning phase to a final emotional attachment phase. They identified three phases of how the experience with a product develops over time: (1) orientation, (2) incorporation, and (3) identification.

Recent research in the consumer context further demonstrated that the factor usability is becoming more important with increasing time [16]. In the study of Kujala and Miron-Shatz [16], emotions and experience episodes during real-life mobile phone use were examined over a five-month period. Their results indicated that both emotions and how people remember them had strong unique roles in the overall evaluation of the product. Positive emotions were mostly related to good user experience, whereas negative emotions were mostly related to low usability. Further, users seemed to focus on user experience in the early stages of use, whereas the importance of usability increased over time. The importance of usability as crucial factor for long-term interactions was also pointed out by Coradeschi et al. [7], who studied long-term human-robot interaction.

The decreasing importance of hedonic aspects with increasing time was also reported by Von Wilamowitz-Moellendorff et al. [26], who found that the perceived stimulation and other hedonic aspects of user experience of mobile phones seem to fade away during the first 20 months of use. Studies further showed that sustaining perceived attractiveness can be a differentiating factor in the user acceptance of personal interactive products such as mobile phones [17].

3 Method

3.1 Objective of the Study

In our study, we aimed to explore how people working in the production line of a semiconductor factory experience the deployment of industrial robots. Following Alben [1], Wright and McCarthy [29] and Karapanos et al. [14], we conceive experience broadly, including users' expectations and general attitudes as well as actual feelings and reflections. In particular, we addressed the following research questions:

- RQ1: How can the workers' experience be characterized within the deployment process of robots in a semiconductor factory (by taking a temporal point of view)?
- RQ2: How does the workers' experiences change at different stages in the deployment process of the robot?

The outcome from our research contributes leverage points for improving the introduction of robots in a factory environment (regarding workers' UX) as well as deepens the general knowledge on temporal transitions of UX regarding human-robot collaboration.

3.2 Study Set-Up

In order to understand how workers have experienced the introduction of the robots, one researcher conducted 10 narrative interviews on two consecutive days in a semiconductor factory. We aimed to assess how workers experience the interaction with robots and the transition to working together with robots (i.e., we sought to interview workers that witnessed the deployment of robots in the factory). The interviews were conducted in a quiet and comfortable atmosphere (i.e., a meeting room). Each lasted about one hour and all were audio recorded.

3.3 Narrative Interviews

By applying a narrative interview approach, we aimed to reveal workers' experiences, attributions and reflections regarding the robots. To get insights about the deployment process of robots, we adopted a retrospective method. Such an approach implies that people reconstruct personally meaningful experiences from memory [13], [29], representing one possibility to access experiences over time.

The set-up of our narrative interviews was based on Meneweger and colleagues' [19] classification of textual data specifically developed for accessing user experience. Using an open structured interview guideline, the interviewer encouraged the interviewees to report their personal experiences in form of stories and situation narratives. The focus of the interviews was based on the three main stages of the deployment process: Stage 1 – before the actual deployment of the robots; stage 2 – briefing, training and first interactions with the robot; stage 3 – daily work with the robots.

An exemplary question triggering personal experiences associated with stage 1 is the following: "Can you tell me about the situation when you got to know that you will work together with a robot? Please tell me about that." Regarding stage 2, an exemplary question is the following: "Can you remember the first day working with the robot? Please tell me about that." An exemplary question for stage 3 is represented by this one: "Can you tell me about specific events regarding your daily work with the robots? Please tell me about that." Thus, we collected episodes (situation narratives) of certain human-robot experiences, ranging from pre-expectations regarding the robots, first time experiences, to current experiences of workers.

Narrative interviews are open-structured qualitative interviews that aim to evoke reports of personal experiences by the participants [10]. The main task of the interviewer is to stimulate these reports by asking narrative trigger questions. Meanwhile the participants are reporting their experiences, the interviewer should be mainly a listener and her/his influence on the participant's story is limited [10]. By making use of people's reports about their experience of a certain process or an event, we considered a narrative interview technique to be appropriate for accessing the experiences of workers, who are directly interacting with industrial robots. In addition to narrative questions, Flick [10] proposes to additionally ask semantic questions, which are questions that do not trigger reports of personal experiences, but argumentations regarding the interviewee's assessments and ascriptions of meaning. These semantic questions aim at accessing additional information, which cannot be narrated, but which is nevertheless relevant (like subjective meanings). An exemplary semantic question was the following: "What does 'robot' mean to you?".

3.4 Participants and Procedure

The narrative interviews were conducted with people that are actually working together with the robots as they are directly affected by the transition from working without robots to working with them. Working with robots basically means that the product (i.e., silicon wafer) to be processed by the equipment is handed to the robot (by the workers). The robot then puts the wafers into the equipment and passes it back to the workers after the processing is finished.

The manager of the automation department recruited the participants. In the selection process, diversity was sought in terms of age, working experience, and role. In particular, we aimed for a sample of participants that ranged from novice participants (their first interaction/encounter with robots not being longer ago than one month) and advanced/expert workers (being familiar with the robot in their environment). Overall, seven operators, two shift leads, and one dispatcher were interviewed[1], all working in the same department. We interviewed eight male and two female workers, with a mean age of 40 years (SD = 12), ranging from 22 to 57 years. Their average working experience at the specific factory was 16 years (SD = 11), ranging from 0.5 to 30 years.

The procedure of the study was as follows. At the beginning the researcher introduced the participant to the study purpose and its goal. Each participant filled in the informed consent form as well as short demographic questionnaires. After the interview, participants were thanked for their participation.

3.5 Analysis Approach

The audio recordings were transcribed verbatim and analyzed in a team of two researchers following a thematic analysis approach [4]. This analysis approach is used to organize qualitative data sets by identifying different themes within the collected data. For our purpose we aimed to structure and describe the participants' reports about their personal experiences with the newly introduced robots by revealing the prevalent thematic issues regarding the different phases of the deploying process.

In a first step we selected relevant data with regard to our research questions. Then, taking a temporal focus, we structured the collected experience reports and assigned them to different (temporal) phases in the deployment process: (1) a*nticipated experiences before the deployment of the robots, (2) initial experiences immediately after the deployment of the robots, and (3) long-term experiences in the daily work with the robots*. As a next step, to further structure the data, we assigned initial codes to the data and searched for themes within the phases based on the codes. The identified themes aimed to describe commonalities and differences regarding the worker's experiences and assessments during the introduction process of the robots. Finally, based on the revealed themes, we aimed to identify changes and transitions regarding the participants' experiences of working together with the robots within the deployment process.

[1] In this paper, we refer to all of them as *workers*, as they are interacting with the robots during daily working routines.

4 Findings

4.1 Workers' experiences within the deployment process of robots

With our first research question we aimed to describe workers' experiences within the temporal process of deploying robots in a semiconductor factory. Based on the stages of the deployment process addressed in the interviews (see section 3.3), we distinguished between the following three phases from the workers' (experiental) point of view (see Figure 1 for an overview): Phase 1 deals with workers' expectations before the deployment of the robots. Phase 2 describes the workers' familiarization with the robots as a process, which is influenced by learning and training. Finally, phase 3 points out the experienced consequences of working with the robot. In the following sections, we characterize these phases with regard to workers' experiences in detail.

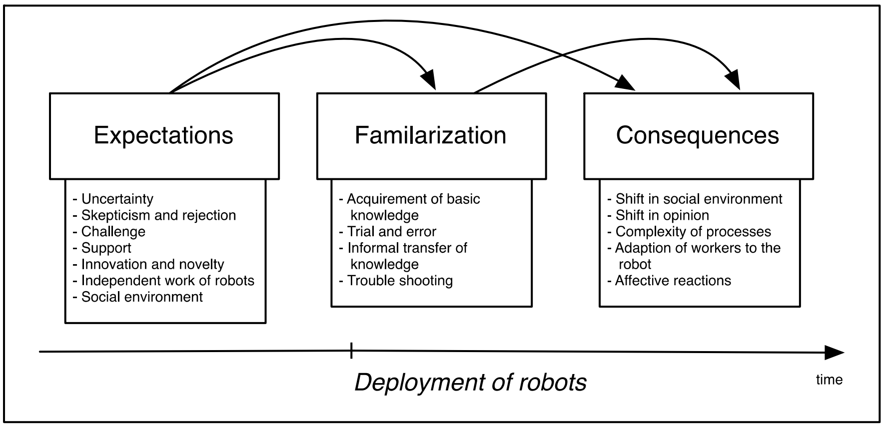

Fig. 1 Phases in the deployment of the robots and associated experiences of workers.

Phase 1: Expectations before the deployment of the robots.
When being asked about expectations they had before the robot was actually deployed at their workplace in the semiconductor factory, the workers experienced the following aspects to be crucial:

- Uncertainty
- Skepticism and rejection
- Challenge
- Support
- Innovation and novelty
- Independent work of robots
- Social environment

As the workers did not know how the future with robots will look like, **uncertainty** was a key issue. In particular, workers faced the fear of being replaced by the robot. For example, P1 wondered *"Are you going to be replaced, will you be supported, or will you be completely replaced?"* Workers were unsure how working with the robot will look like or did not recognize the benefit of the robot. P9 stated, *"How will this work out at all? How shall this work out at all?"*

Next to uncertainty, **skepticism and rejection** characterized this phase. Workers' negative attitudes or emotions towards robots led to negative expectations. *"In the beginning, no one actually wanted it* [the robot]*,"* stated P2. P4 said, *"Somehow, I wasn't happy about it… I did feel anger," while P8 claims that "In the beginning, everyone was shocked, for sure, because everyone fears losing their job.*"

Further, working with robots was considered as demanding or challenging by the workers. Thus, **challenge** was also a crucial expectation regarding the collaboration with robots. For example, P3 stated, *"It was challenging to work hand-in-hand with the robot. Let's see how it* [the robot] *will behave."*

Support in the sense that robots could relieve stress from factory workers by taking over work from them was another expectation. For example, P10 indicated, *"Maybe* [they introduced the robots] *to disburden the operators*." Introducing a robot was further associated with **innovation and novelty**. In this case, workers were looking forward to new developments due to the introduction of robots. This is illustrated by the following statement of P1; *"Well, at that time* [when the robots were installed], *I was in a positive mindset and also a bit happy. Just because it is something different, because it is innovative, because it is just new."*

Workers further expected that the robot was **working independently** and on its own, arguing that the human was not involved in the work. *P7 claimed, "The first few days I didn't have any contact with it* [the robot] *... I thought it would do everything on its own and we wouldn't have to do anything with it… gradually in the course of time, it* [working with the robot] *became more and more... fixing all the errors, moving* [the robot], *unloading."*

Moreover, workers' expectations were shaped by the **social environment**, as information from others, who already worked together with a robot, influenced their anticipations of future interactions. For example, P4 indicated, *"... thus they* [the colleagues, who already worked with the robot] *cursed. Because from time to time the robot did not work correctly and did not do exactly what they* [the operators] *wanted them* [the robot] *to do…you then get a negative image already in advance, which makes you think that if you also get such a robot, it will go crazy as well and not do what I want it to do."*

Overall, some of the expressed expectations indicate the workers' ambiguity towards robots: they are torn between positive and negative expectations regarding the collaboration with robots.

Phase 2: Familiarization as process which is influenced by learning and training. The time after actually deploying a robot in the semiconductor factory may be considered as a phase of reorganization for workers in terms of a change of the workflow and spatial rearrangements. When learning how to handle the robot after deploying the robot in the factory, we found the following aspects to be characteristic for workers' experiences in this phase:

- Acquirement of basic knowledge
- Trial and error
- Informal transfer of knowledge
- Trouble shooting

First, workers got a mini training in which they **acquired basic knowledge** to solve minor problems of the robot. This training took place on-site. The worker was explained the most important functions of the robot in the production line directly at the robot. If there were more severe problems, workers were instructed to call the technicians to get support. As P2 explained, *"We got a brief training over just the most important things, so if something happens, like small issues, they told us what to do. However, if there were more in-depth issues, then we had to inform these people* [technicians], *who had been previously here all the time* [during the installation of the robots]. *Therefore, we learned a little bit."* P8 also stated that, *"Training also happens within the cleanroom, on site and at the machine. Otherwise, it does not make any sense."*

Knowledge acquisition for handling the robot was often characterized by individually trying and exploring. Thus, when interacting with the robot, **trial and error** was prevalent in the early phase of human-robot interaction. This learning process took place on-site, next to the robot. The following statements point out this kind of knowledge acquisition. P1 had to *"learn 80% of it on my own; I had to deal with it by myself. Then you just tried it yourself."* "*I mean, I have to say, we found out a lot by ourselves, because at night no one is here and we are doing overnight shifts. This means we have to be able to find solutions by ourselves and, thus, we were able to fix some errors with the manual, the electronic one, thankfully. Also without the technicians,"* stated P10. Also P1 said, "*Exactly, that happened exclusively on-site. You can do it with learning by doing, that's clear anyway. Some error has to occur and then someone, who knows about it, can show it to you. If there is no one around, you just have to decide by yourself."*

Another important aspect of knowledge acquisition was the **informal transfer of knowledge**. This means that information about the robot and how to handle it was generated by asking or observing others. Informal information channels were important, e.g., information was passed on by other people (rumors). On one hand, knowledge was transferred from worker to worker, on the other hand, from technician to worker. This is illustrated by P1, "*It seemed there have been trainings, but most information had been shared from worker to worker." P3 agreed that* "*In case of an error, someone fixed it and you observed it. This person told you how it worked or that you only have to confirm* [at the robot's interface]. *Then suddenly you took that over."* P1 further stated that *"when you talked to them* [technicians], *when you stood next to them, when they installed it, they certainly showed you where to push, where it moves to the right, where it moves to the left..." "Not everyone got trained from the robots team… in each finger* [sub-department] *or in a department, only one gets trained from the robots team, maybe two, and they pass it on," stated* P8, while P10 claimed that "*when someone from the technicians was around, than you pepper them with questions. How is this? And how can I do that?*"

The main interaction the workers had with the robot was problem solving: Skills and knowledge regarding the robot were mainly needed for **trouble shooting**, i.e., in case of problems. The situatedness of the problem was also characteristic. This means that workers had the feeling that the robot will never be fully understood, as problematic situations are changing. For example, P1 stated that *"There are always new situations. Well, this will go on forever. You cannot say, I know everything about that."* P3 said, "*Confirming* [on the robot's interface], *moving* [the robot] *to its home position, or bringing back the wafers because there had been a problem… You handle all these things on the screen. We are not allowed to do anything else and we don't do it. Certainly, when you talked to them* [technicians], *when you stood next to them when they installed the robots, they certainly showed you where to push, where it moves to the right, where it moves to the left, but when something happened to please give them a call." "We never had a special training. It was just like this, that, ... when there is an error you have to push this button and if it does not help give us a call,"* recalled P10.

Phase 3: Experienced consequences of working with the robot.

After getting familiar with the robots and restructuring work routines, workers' predominately experienced the following aspects as a consequence of deploying the robots:

- Shift in social environment
- Shift in opinion
- Complexity of processes
- Adaption of workers to the robots
- Affective reactions (non-involvement, resignation)

The operators were faced with a **shift in their social environment**, as they got new working colleagues due to the introduction of the robot. These new working colleagues were, for example, technicians, who were responsible for the technical functioning of the robot. This change was considered as a positive one, as reported by P1, *"Yes, this had actually been a very positive aspect, that new faces occurred, young people, motivated people, who take care."* Introducing a new robot further attracted attention of other workers, who did not know the robot. Thus, workers from other working areas came and had a look at the robot or wanted to get information about the robot. An example for this was given by P3, *"In the beginning, it was interesting, people asked you whether you are in a finger with a robot because it had been the first finger with robots. People asked how is it with the robots and observed how it worked. Especially when they got to know that their finger would get a robot as well."*

Another issue we identified in this phase was a **shift in the workers' opinion**, as initial skepticism and rejection turned out to be arbitrary. For example, there was no reduction of staff due to the introduction of the robots as initially expected by the workers. This change of opinion was expressed by P2 in the following way, *"Yes,* *well, in the beginning, we were all a bit skeptical towards it, but over the time, we grew with this* [development] *and now it is as it is."*

A consequence related to the introduction of a robot was an increased **complexity of processes**. Due to the robot, some procedures were more complex than before, resulting in the perception that the robot was not as supportive as expected. Further, the deployment of the robot required an **adaption of the workers' behavior** in a way that the workers had to adjust their behavior to the robot's behavior. This means that workers' tried to anticipate or react to the robot's behavior in order to execute their work properly. For example, workers had to take care where to position things as the robots took physical space, which was not demanded before. P3 stated, *"To some extent, you have to be careful where to put the cart* [where the wafers are stored and carried]*."*

Affective reactions linked to the deployment of robots were, for instance, the feeling of **non-involvement, resignation,** or **malicious joy**. The feeling of non-involvement was characterized by the fact that workers saw no possibility to contribute or influence the introduction process, or that they felt excluded from the decision process. P6 expressed this, saying *"We have been confronted with an accomplished fact, it is as it is."* P8 indicated that *"At some point we were confronted… At some point, they installed tracks, and then it was there, and at some point we got angry. Yes, that's ho it is."* P10 confirmed the questionable reasonability of the robots, as they had not been asked about that: *"But no one really asked us, whether they would make sense where they installed them. That has been decided from the higher authorities and that's it."* Resignation means that workers got used to the robot as there was no other option. To conduct one's work properly, interacting with the robot was required. The following statement from P2 expressed the non-involvement as well as the resignation linked to the introduction of the robot, *"... it* [the robot] *was just there and we worked with it and tried to get the best out of it."*

Another reaction to the robot was related to a feeling of malicious joy. Workers felt joy or satisfaction when the robot did not work as expected. In such cases, workers often stated that they would have told the management about such problems beforehand, if they would have been asked. P10 illustrated such feelings in saying, *"However, yes, again we came up with a grin. We knew it anyway, but they have to recognize it themselves."* "*We certainly made a little fun of the company, because that did not work from the beginning,"* agreed P1.

4.2 Transitions of Workers' Experiences

Our second research question targeted changes regarding the workers' experiences across the deployment process of the robots. Therefore, we compared initial expectations and dominant themes before the deployment of the robots with actual experiences and prevalent topics of production workers who actually work together with the robot. We identified several substantial changes over time. In particular, we found changes regarding the attitude towards the robots, the functional value of the robot, work organization, feelings, as well as the social environment.

Change in the perception of the robots' functional value.
Before the actual deployment of the robot, workers expected that the robot would take over work and thus relieve them from stress. However, after actually working with the robot, the workers recognized that the robot led to an increased complexity of some working procedures. Thus, the robot turned out not to be as supportive as supposed, but to increase complexity in some working issues. For example, the robot's tasks are not fully automated so that the workers' assistance is needed, representing an additional task for the workers. Thus, initially expected support of the robots turned into the perception of increased complexity of processes.

Change in work organization.
Regarding work routines, workers expected that robots would work autonomously and independently from the workers, with no contact between human and robot. However, it turned out that this initial expectation was not true in their daily work. In fact, the workers had to interact with the robot and adjust their behavior to the robot's behavior, e.g., by providing (physical) space to the robot or adapting their work routines to the robot's routines, e.g., waiting until the robot finishes its task. Consequently, initially expected independent work of robots changed to the necessity to adapt to the robot.

Change in feelings.
The prospect of a robot being deployed in the production line was often linked to feelings of uncertainty, but also to feelings of challenge and novelty. This was closely related to the aspect that workers did not feel informed about the deployment process and the robots to be deployed. Whereas uncertainty is often manifested in fears (losing one's job due to the robot), novelty is connected to aspects of innovation (new developments due to the introduction of the robot). After actually deploying the robot, feelings of non-involvement, resignation, or malicious joy were in the foreground. Workers accepted the robot, but felt excluded from decision processes, thus resigned with their (new) working situation, or felt a kind of satisfaction in case the robot made a mistake. This change of feelings ranged from initial feelings of uncertainty and novelty to feelings of non-involvement and resignation. Although the feelings towards the robots were still ambiguous when actually working with the robot (i.e., both positive and negative), the workers' had a more differentiated picture of the robot.

Change in social environment.
Before the deployment of the robot, providing information about the robot was considered as the main social activity in relation to robots. This means that information regarding the robot and its introduction was passed on from other workers (i.e., in particular from those already working with a robot in the production line) and shaped the workers' expectations of future interactions with the robot. After deploying the robot in the production line, the social environment changed (e.g., new working colleagues due to the introduction). Further, the robot attracted attention from other workers, who came to look at the robot or requested information about it. Conse-

quently, the information provision function of the social environment was replaced by a change of the social context.

Change in general attitude towards the robots.
Before the deployment of the robots, rather negative attitudes and expectations were expressed. This was reflected in workers' statements showing skepticism and rejection before actually working with the robot. However, the experience of actually working with the robot changed the workers' attitude towards the robot in a positive way. Expected negative consequences due to the deployment of the robot did not occur (e.g., reduction of staff) and thus led to a more positive attitude towards the robot. As a consequence, initial skepticism and rejection turned out to be arbitrary, and robots were not perceived as negative as initially expected. These changes do not mean that the robot was considered as completely negative before its deployment and entirely positive after the deployment. Rather, the daily worklife with the robots was different than expected, leading to a refined perception of the robots.

5 Reflection and Discussion

The aim of this work was to investigate workers' experience when deploying robots in a production environment. In this chapter, we reflect on our results regarding potential interventions ("leverage points") during the deployment process. Further, we discuss benefits and limitations of our research.

5.1 Leverage Points

Through creating awareness of which aspects or themes are foregrounded in which phase of the deployment process, we point out potential interventions (i.e., leverage points) towards more positive experiences of workers regarding future human-robot interactions. Based on the insights from our study, we suggest the following leverage points. In general, these leverage points are feasible at all stages of the deployment process, although we suggest to apply them as early as possible.

Increased transparency and information.
Overall, workers reported uncertainties regarding the future deployment of robots that would not have been necessary, as they turned out to be arbitrary afterwards. Many of these uncertainties evolved because workers hardly had any information about the robots. In such situations, rumors from the social environment can reinforce negative expectations so that workers have negative associations regarding the robots. Informing the workers as much as possible about facts regarding the deployment of the robots represents a way to reduce some of these uncertainties and rumors. We therefore suggest giving workers a relatively realistic estimation of how the situation will change and inform about benefits as well as potential negative consequences. For example, informing the workers beforehand how the robot will look like combats

rumors and speculations about the robots' appearance (e.g., space requirements). Further, information about planned tasks of the robot and interactions with the workers would be beneficial. As negative aspects of robots seem to overshadow positive aspects especially at times when few facts are known, positive aspects of the robots' introduction should be foregrounded, but potential consequences should nevertheless not be neglected.

A platform for workers' thoughts and reflections.
Our study showed that both – positive as well as negative expectations and attributions regarding the forthcoming deployment of the robot – were mentioned by the workers. Fears and uncertainties as well as challenges and innovations were associated with the robots. Based on the workers' statements and the interviewer's reflections, we believe that the workers felt not being heard and taken seriously. On the one hand, the workers felt not involved in the decisions of the management regarding the introduction of the robot, although they knew the working context very well and felt that they could give advice. On the other hand, the workers showed a desire to talk and reflect about the robot in the interviews. Therefore, we think that providing a way to express thoughts and reflections continuously (and as soon as possible when the introduction of robots is discussed for the first time) can combat feelings like non-involvement or inferiority. We think that openly discussing positive and negative aspects of the deployment of robots (e.g., in workshops, via an online platform) reduces uncertainties and a-priori rejection regarding the robot

Improved training and enhanced competences.
In the interviews, workers expressed that they felt inferior, incompetent or helpless regarding the interaction with the robots. Workers reported that they wanted to understand the robot and strived for more training and skills regarding their handling of the robot. Some of them were even actively asking for information about the robots' handling, which, mainly consists of error handling. Not knowing how to handle the robot conveyed negative feelings regarding one's competences. In turn, providing workers with sufficient competences regarding the handling of the robot will support the avoidance or reduction of negative associations. Thus, adequate training and courses are crucial, especially at the beginning to allow positive first interactions. Successful initial interactions convey a feeling of competence in the workers and may impress future attributions and associations regarding the robot.

5.2 Benefits & Limitations

Overall, our interviews were appreciated by the workers as a platform for expressing thoughts and reflecting about the deployment process of the robots. Although the interviewees initially expressed a kind of astonishment that they were interviewed about the robots, they soon showed that they valued to be taken seriously as experts regarding the robots. Thus, we think that our interviews represent a positive intervention for workers towards a critical reflection on human-robot interaction in their daily work.

Our research is beneficial in several aspects. First, we want to highlight the peculiarity of our data. Our sample is exceptional in terms of experiencing the change from working without robots to working with robots. Interviewing workers about their personal experiences regarding this change provided us with valuable insights, which have not been reported in related literature so far.

Moreover, investigating workers' experiences from a process-oriented, temporal perspective in a factory extends the current state of the art, as long-term studies and in-situ investigations in production environments have rarely been conducted. This may be due to lacking accessibility, since such studies may interrupt the workflow, which, in turn, restricts access and possibilities. Our work thus extends knowledge on how workers' experience the changes in their daily work and experiences due to the deployment of robots from a long-term perspective. Taking such a temporal perspective allows to focus on experiental changes and how these changes evolved and developed. This knowledge provides leverage points for interventions (before and after the introduction), as discussed earlier in the paper.

Further, we showed that the workers' experience regarding the interaction with the robots already started before the deployment of the robot. Indeed, human-robot interaction at the workplace is more than just working with robots. Emotions and expectations are crucial. Attributions and interpretations of the robots' behavior play an important role, as workers aim to "understand" the robot. Thus, we also found the recently emphasized importance of expectations and anticipated experiences [23], [31] in a factory / robots context. Further, studying the transitions of the workers' experiences over time (i.e., relating the different phases of the deployment process as done in section 4.2) revealed valuable insights regarding workers' experiences, e.g., how initial uncertainties and fears turned into a still ambiguous but more differentiated picture of the robot.

In this study, we applied a narrative interview approach to access workers' thoughts and reflections regarding the (self-experienced) deployment process of robots – which is only possible retrospectively. Further, we had to consider not to interfere with the production itself, which was feasible by applying a retrospective approach. At the beginning of the interviews, it seemed that the workers were rather unaffected by the deployment of robots. However, in the course of the interview, the actions and experiences reported by the workers during the conversation revealed that the workers were indeed affected regarding the deployment of the robots. These insights were enabled by adopting a narrative approach, giving the interviewee the opportunity to extensively express his personal reflections and thoughts.

In our study, we specifically addressed the memories of the workers (after deploying the robots), as they represent the salient aspects kept in mind and which are associated with robots. Furthermore, the challenges that are inherent to the specific context of production environments require approaches that do not influence the production itself. Thus, the narrative interview approach was the most feasible and promising way to assess workers' temporal experiences in such a setting. Certainly, memory effects need to be taken into account in a retrospective approach on UX, relating to the question whether "memory” or “actuality" of an experience is more important [21].

With this work we addressed the change of workers’ experiences over time. Work that focuses on the temporal transitions of experience so far exists in the area of consumer products [14]. According to Karapanos et al. [14], the act of anticipating an experience results in the formation of expectations, happening prior to any experience of use. This corresponds to our phase 1, i.e., expectations before the deployment of the robots regarding anticipated human-robot collaboration. In line with Karapanos et al., this phase is characterized by both positive and negative anticipations. Their phase of orientation corresponds to our phase 2 (familiarization), dealing with users’ initial experiences with an interactive product. In both the consumer and the factory context, learning and familiarization characterize this phase. The last two phases – incorporation and identification – deal with the integration and meaning of the product in our daily life. This corresponds to our third phase considered as consequences of the robots’ deployment. Long-term usability and social aspects are crucial here. To this extent, our findings confirm the work of Karapanos and colleagues [14]. However, when going in-depth, differences reflecting the specific application context become significant. In particular, we found affective reactions, a shift in opinion, as well as a change in working routines to be further characteristic regarding long-term experiences in the factory context.

6 Conclusion

In which ways – if at all – does the deployment of robots affect workers’ daily experiences and routines? Our study showed that the workers were indeed affected. Information was sought actively from others, rumors were dispersed, routines were adapted, and affective reactions towards the robots were set. By taking an experience-centered perspective and focusing on the transitions of workers’ experiences in the course of the deployment of robots, such inherent actions and experiences became obvious.

We found different aspects of workers’ experiences to be foregrounded in different phases of the deployment process. Before the actual deployment of the robot, uncertainty as well as skepticism and rejection were predominant issues. Further, challenges as well as innovation and novelty were associated with the robots. Support as well as independent work of the robots was expected. Overall, the workers’ expectations were strongly influenced by their social environment. Immediately after deploying the robots, getting familiar with the robots and learning how to handle them was in the foreground. This included the acquirement of basic knowledge, learning to correct errors of the robots’ through trial and error, actively looking for knowledge regarding the handling of the robot, as well as trouble shooting as the prevalent kind of interaction with the robots. After getting familiar with the robots, workers experienced increased complexity, the need to adapt to the robots’ behavior, and affective reactions like non-involvement, resignation, or malicious joy in their daily work. This was accompanied by a shift in the workers’ opinion as some of their initial fears turned out to be arbitrary, as well as a shift in their social environment in terms of new colleagues. Regarding changes of the workers' experiences, we identified changes regarding the perception of the robots' functional value, work organization, feelings associated with the robots, the social environment, as well as the general attitude towards the robots.

In this paper we argued that it is crucial to understand workers' experience in the temporal process of deploying a new robot (ranging from workers expectations before the introduction of robots to their actual experience of working together with such a robot) to facilitate a better collaboration between humans and robots. By adopting such a temporal perspective, we were able to identify salient aspects of the workers' experiences and their changes during the deployment process of robots. Thus, this work contributes insights towards interventions for a better experience of workers in the interaction with robots.

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References

1. Alben, L.: Quality of experience: defining the criteria for effective interaction design. Interactions, 3(3), 11-15 (1996)
2. Bargas-Avila, J. A. and Hornbaek, K.: Old wine in new bottles or novel challenges: a critical analysis of empirical studies of user experience. In Proc. of CHI '11, p. 2689–2698, New York, NY, USA. ACM (2011)
3. Björndal, P. S., Ralph, M. B.: On the handling of impedance factors for establishing apprenticeship relations during field studies in industry domains. In Proc. NordiCHI '14, ACM, pp. 1107–1112 (2014)
4. Braun, V., Clarke, V.: Using thematic analysis in psychology. Qualitative research in psychology 3(2), 77-101 (2006)
5. Buchner, R., Wurhofer, D., Weiss, A., Tscheligi, M.: Robots in Time: How User Experience in Human-Robot Interaction Changes over Time. In ICSR International Conference on Social Robotics (2013).
6. Castellano, G., Aylett, R., Dautenhahn, K., Paiva, A., McOwan, P.W., Ho, S.: Long-Term Affect Sensitive and Socially Interactive Companions. In: Proc. of the 4th Int. Workshop on Human-Computer Conversation. (2008)
7. Coradeschi, S., Kristoersson, A., Lout, A., Von Rump, S., Cesta, A., Cortellessa, G., Gonzalez, J.: Towards a methodology for longitudinal evaluation of social robotic telepresence for elderly. In: 1st Workshop on Social Robotic Telepresence at HRI 2011 (2011)
8. Duffy, B. R.: Anthropomorphism and the social robot. Robotics and Autonomous Systems. 42, 177-190 (2003)
9. Fernaeus, Y., Hakansson, M., Jacobsson, M., Ljungblad, S.: How do you play with a robotic toy animal? A long-term study of pleo. In: Proc of the 9th int. Conf. on Interaction Design and Children, p. 39-48 (2010).
10. Fink, J., Bauwens, V., Kaplan, F., & Dillenbourg, P. (2013). Living with a vacuum cleaning robot. International Journal of Social Robotics, 5(3), 389-408.

11. Flick, U.: Episodic interviewing. In Qualitative researching with text, image and sound, M. W. Bauer and G. Gaskell, Eds. Sage London, 75–92 (2000).
12. Hinds, P. J., Roberts, T. L., & Jones, H. (2004). Whose job is it anyway? A study of human-robot interaction in a collaborative task. Human-Computer Interaction, 19(1), 151-181.
13. Karapanos, E., Martens, J., Hassenzahl, M.: Reconstructing experiences with iScale. Int. J. Hum.-Comput. Stud. 70(11), 849-865 (2012)
14. Karapanos, E., Zimmerman, J., Forlizzi, J., Martens, J.: User experience over time: an initial framework. In Proc. of CHI '09, p. 729-738 (2009)
15. Kidd, C.D.: Designing for Long-Term Human-Robot Interaction and Application to Weight Loss. PhD thesis, Massachusetts Institute of Technology (MIT) (2008)
16. Kujala, S., Miron-Shatz, T.: Emotions, experiences and usability in real-life mobile phone use. In Proc. of CHI '13, ACM, New York, NY, USA, p. 1061-1070 (2013)
17. Kujala, S., Roto, V., Väänänen-Vainio-Mattila, K., Karapanos, E., Sinnelä, A.: UX Curve: A method for evaluating long-term user experience. Interact. Comput. 23(5), 473-483 (2011)
18. Lee, M.K., Forlizzi, J.: Designing adaptive robotic services. Proc. of IASDR ‘09 (2009)
19. Meneweger, T., Wurhofer, D., Obrist, M., Beck, E., Tscheligi, M.: Characteristics of Narrative Textual Data Linked to User Experiences. In CHI EA ’14, ACM, New York, NY, USA, 2605–2610 (2014)
20. Mutlu, B., Forlizzi, J.: Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction. In: Proc. of HRI ‘08, 287-294 (2008)
21. Norman, D. A.: The way I see it: Memory is more important than actuality. Interactions, 16(2), 24-26 (2009)
22. Obrist, M., Reitberger, W., Wurhofer, D., Förster, F., Tscheligi, M.: User Experience Research in the Semiconductor Factory: A Contradiction? In Proc. of INTERACT 2011 p. 144-151 (2011)
23. Olsson, T.: Layers of user expectations of future technologies: an early framework. In CHI EA '14. ACM, New York, NY, USA, 1957-1962 (2014)
24. Renaud, K., Van Biljon, J.: Predicting technology acceptance and adoption by the elderly: a qualitative study. In Proc. SAICSIT 2008, ACM, 210-219 (2008)
25. Venkatesh, V., Bala, H.: Technology Acceptance Model 3 and a Research Agenda on Interventions. In: Journal of Decision Science, 39(2), 273-315 (2008)
26. von Wilamowitz Moellendorff, M., Hassenzahl, M., Platz, A.: Dynamics of user experience: How the perceived quality of mobile phones changes over time. In User Experience - Towards a unied view, Workshop at NordiCHI ‘06. 74-78, (2006)
27. Weiss, A., Buchner, R., Fischer, H., Tscheligi, M.: Exploring human-robot cooperation possibilities for semiconductor manufacturing. In Int. Workshop on Collaborative Robots and Human Robot Interaction, (2011)
28. Weiss, A., Igelsböck, J., Wurhofer, D., Tscheligi, M.: Looking forward to a “Robotic Society”? - Imaginations of Future Human-Robot Relationships. Special issue on the Human Robot Personal Relationship Conference in the Int. Journal of Social Robotics (2010)
29. Wright, P., McCarthy, J.: Experience-centered design: designers, users, and communities in dialogue. In: Synthesis Lectures on Human-Centered Informatics 3, 1 (2010).
30. Wurhofer, D., Buchner, R., Tscheligi, M.: Research in the Semiconductor Factory: Insights into Experiences and Contextual Influences. In Proc. of HIS ‘14, 123–128 (2014)
31. Yogasara, T.: Anticipated user experience in the early stages of product development. PhD thesis, Queensland University of Technology (2014)