# Assistance Needs in Production Environments: A Contextual Exploration of Workers' Experiences and Work Practices

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**Abstract.** This paper presents assistance needs in production environments for assembly processes from a workers' perspective, i.e. what kind of assistance assembly workers would need to enhance their everyday work experience and to better cope with challenges coming along with an increasing digitization in these work environments. Within a large-scale empirical field study in central Europe, we interviewed assembly workers and observed everyday work situations in different production environments (e.g., automotive domain) to understand workers' experiences and work practices in increasingly connected and automated production environments. Based on the insights gained in this study, we describe several assistance needs for assembly workers that serve as a guidance for future worker-centric designs of assistance systems in production environments.

**Keywords:** Assistance needs · Assembly work practices · Experience with technology · Production environments · Automation

## 1 Introduction

Production environments are often characterized by a strong focus on technologies and machinery that they are equipped with. While this is certainly important when it comes to productiveness, efficiency, and competitiveness, this emphasis on technological systems may overshadow those that work with them, such as assembly workers. Although it has been widely recognized that humans are essential in "all phases of factory operations from the planning through the operation to the maintenance and repair services" [15, p. 136], little is known of the workers' needs and practices.

To address this gap, we investigated such needs and practices, aiming to answer the following research questions: *RQ1: What are humans' work practices*


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*and work experiences in assembly work contexts?* and *RQ2: What assistance needs to they have?* Our work is positioned at the intersection of smart factories (and in particular assembly work), system design, and Human-Computer Interaction (HCI).

Influenced by this positioning, we contribute a perspective on humans working at assembly lines to (a) provide insights into everyday work practices and workers' assistance needs, and (b) inform the design of future assembly systems and processes. The paper starts by providing a brief overview of the background to this work, including challenges of increasingly digitized work environments. Afterwards, we describe the approach and methods used to explore situated practices in three different factories and continue by depicting the results of the study. In particular, we detail assistance needs for assembly work and discuss how they could be met.

## 2 Background

Assembly work requires workers to conduct a set of physical and mental operations [11] in which they may or may not need support. To provide such support, various attempts exist (either in form of concepts, prototypes, or implemented systems) and are referred to as assistive systems, i.e., technologies aiming to support employees within their working tasks [3,13]. Examples for these developments are collaborative robots operating alongside human workers [4], exoskeletons aiming to reduce physical workload [8], (mobile) information and communication technologies showing assembly instructions [1], or mixed reality applications using projections to provide work instructions [6]. In assembly work, technologies such as Augmented Reality (AR) or collaborative robots seem to be particularly promising [13] to reduce the physical and mental burden for the workers, and of course to enhance efficiency and productivity as well. Consequently, these systems increasingly invade factories. However, there are only a few studies that reveal how they actually assist assembly workers during their everyday work (e.g., [14]).

This is even more timely since increasingly digitized work environments bear several challenges that influence the way of working in such environments. For example, due to the growing demand to customize products, assembly work is accelerating and tasks become more complex. Furthermore, interacting with digital technologies on the shop floor becomes a challenge in itself, being demanding for human workers, who are surrounded by more and more automated and connected systems [9]. These systems have the potential to assist workers, but also to shape everyday work practices [14]. Designing successful assistive technologies implies first to meet user needs, which can be ensured by adopting a user-centered design approach [12].

To contribute an understanding of the needs of assembly workers, that can inform the development and implementation of assistive technologies of the future, this work is positioned within the realm of HCI, a field that engages with humans in their situated interplay with technology in a particular context.

The approach we are pursuing in this study, which is described in the following, starts from empirical observations of assembly work in three factories to draw conclusions for the design of interactive systems to support assembly workers within their daily working routines.

# 3 Approach and Methods

## 3.1 Context of Research

The research at hand was conducted within the national flagship project *MMAssist II*[1] in Austria, Europe. The goal of this project is to explore the characteristics of assistance in production contexts and develop modular assistance systems for workers in future factories. The outcomes and insights, we report in this paper, were part of a large-scale empirical field study aiming to identify assistance needs from a workers' point of view, which provides the basis for the conceptualisation and implementation of assistance systems. Besides assembly work, the project also explores other domains of industrial work: service and maintenance of machines as well as operating autonomous machines. In this paper we only report on the insights related to assembly work.

Within the empirical field study, we investigated three use cases of assembly work in three different factories: (a) assembly of powertrains, (b) assembly of construction machines, and (c) assembly of battery charging systems. In the first two use cases, the workers are working on assembly lines. Cycle times vary between 1,5 min for the powertrains and 20 min for the construction machines. In use case (a) the powertrains are carried on automated guided vehicles (AGVs) that are constantly moving and connected with the tools and control system. In use case (b) the construction machines are carried on carriages that need to be manually pushed by the workers to the next work station after a cycle time has expired (a sound signal indicates the end of each cycle time). In use case (c) each worker assembles an entire workpiece at her/his work station. In all three use cases, connected tools like smart screwdrivers are used.

## 3.2 Methods and Procedure

The overarching goal of this study was to identify and describe workers' assistance needs for assembly work to provide a basis for the implementation of future assistance systems. Following a worker-centered approach, putting workers' experiences and work practices in the center of attention, we conducted a field study exploring workers' everyday work in real assembly work contexts (see Fig. 1 for an overview of the research process). The field study mainly aimed at: (a) understanding current work practices and work experiences in the context of assembly work, (b) identify challenges and problems assembly workers currently have to deal with, as well as (c) how they cope with these challenges.

[1] https://www.mmassist.at.

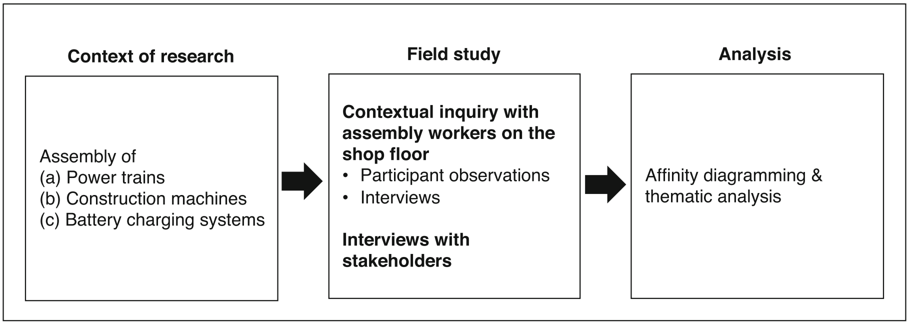


**Fig. 1.** Procedure of the field study and applied methods.

**Data Gathering.** To address our research goal, we conducted participant observations on the shop floor and qualitative interviews with assembly workers. Additionally, we conducted interviews with stakeholders that are familiar with the shop floor but not directly performing assembly tasks (e.g. shift leaders). These stakeholder interviews mainly focused on challenges and assistance needs for assembly work. Our data gathering approach was following the principles of "contextual inquiry" [7], a well-established approach in HCI, the technique of "shadowing" [10], as well as qualitative interviewing [5].

During the participant observations, two researchers slipped into the role of a trainee and accompanied each assembly worker as if she/he was their instructor, i.e., observing them and asking questions about their work. To document the observed work practices, the researchers were taking field notes as well as pictures. Each assembly worker was accompanied for half a day and during or after the observations, a qualitative interview was conducted with each worker. The interviews with workers took about one hour, the interviews with stakeholders about 45 min, and the informants gave their informed consent. The researchers used an observation and interview guideline to guide the focus of observations and (interview) questions.

**Study Participants.** We stayed for two days at each factory and observed and interviewed 11 assembly workers in total. Five of them were male and six female, their age ranged from 22 to 57 and they had been working at the observed shop floor between just recently and 23 years. Additionally, we conducted 14 stakeholder interviews with people working as shift leaders, production managers, IT personnel, as well as members of the works council. 13 of them were male, one female (representing the gender imbalance in these positions), and they were between 23 and 43 years old.

**Data Analysis and Interpretation.** After the field notes were digitized a team of two researchers (one of them was involved in gathering the data, the other one supervised the study) applied an affinity diagramming technique [7] to structure and analyze the data gained from the participant observations and interviews with assembly workers. The analysis was guided by the goal to describe assembly work practices and experiences, as well as related assistance needs.

Within several affinity diagramming sessions the field notes, as well as pictures from the shop floor, were clustered in order to reveal themes (i.e., patterns within the data) [2], that describe work practices and experiences as well as related challenges of the assembly work we have observed. In parallel, another team of researchers analyzed the interviews with stakeholders. Finally, within a joint interpretation session, a team of four researchers contrasted the insights gained from exploring the assembly workers with the ones from the stakeholders in order to come up with a merged set of assistance needs for assembly work as well as how they can be addressed. In the next section we describe the results gained from this process (see Fig. 2 for an overview of this process and the gained results).

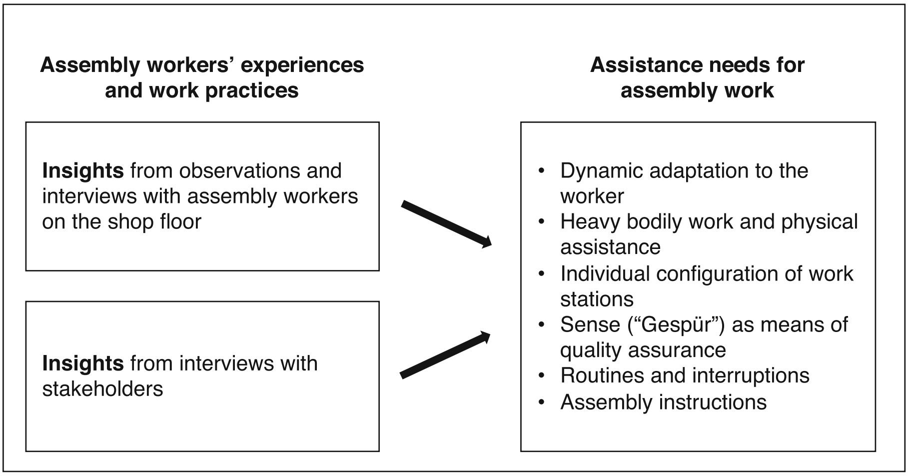


**Fig. 2.** Overview of the field study results.

## 4 Results

### 4.1 Assembly Workers' Experiences and Work Practices

In this chapter, we describe the assistance needs for assembly work that we have identified based on the observed work practices and related experiences of assembly work.

In a first step and as a basis for further interpretation, we generated themes from studying the assembly workers as well as stakeholders. The themes - relevant aspects for assembly work - gained from the observations and interviews with assembly workers reach from work experiences, challenges related to assembly work, to current work practices. In total, our analysis revealed 15 themes. These themes are concerned with: *Organisation of the work station, work environment, tools, work material, customizing the work station, time, work practices, training, routines and workarounds, static information, dynamic information, documentation, dealing with errors, social setting at the workplace, and relation to the product.* Within the scope of this paper, we will not discuss each of the themes in detail but focus on the revealed assistance needs (see below). The insights gained from interviewing the stakeholders, mainly centered around assistance needs and comprised the following issues: The *mental workload and time pressure* due to short cycle time, which is very demanding and stressful; the *physical challenges* due to high physical load, e.g., standing in the same position, unhealthy body posture, or carrying heavy loads; the *need for digital assembly manuals*; as well as that already *a lot of optimization is happening* on the shop floor. Based on these themes and issues related to assembly work, we further interpreted the data and identified the following assistance needs for assembly work.

### 4.2 Assistance Needs for Assembly Work

**Dynamic Adaptation to the Worker.** We observed that an individual organization of the work station is crucial for the assembly workers. Especially as different workers are working at the same work station (e.g. in different shifts), the workers adapt and customize their work station based on personal needs. Often this is done to improve the ergonomic position, e.g., placing tools and materials in best reach for the worker. Due to time pressure (e.g., short cycle times) this isn't always possible or just inconvenient and cumbersome. Consequently, the lack of time to adapt the work station leads to ergonomic problems and increased physical workload over time, e.g., as workers are standing on tiptoes over a longer period of time because the workpiece is positioned slightly too high, or they are repeatedly tiptoeing because of fixed working heights, as well as that different assembly steps would require different working heights.

For these reasons, dynamic and automated adaptations to the worker would be beneficial for enhancing the assembly workers' experiences. Adaption and customization could be done, for example, related to body size or arm length. It would also be beneficial to allow the workers to actively adapt and change ergonomic settings and positions to avoid one-sided physical strain. This could be supported by smart and adaptive assembly lines, e.g. concerning working height, or with customized physical assistance.

**Heavy Bodily Work and Physical Assistance.** Assembly work is heavy physical work. Depending on the specific assembly work environment, the intensity of work can vary based on different circumstances, such as assembly workers might have to lift or position heavy materials and workpieces. Further, we observed that unergonomic activities and body posture, that are performed over a longer time, are quite common and additional reasons for the increased physical workload. Often, this comes along with standing for a long period at the same place, performing constantly the same movements (often related to lifting some more or less heavy load), or working in a bent-over posture. These issues can also increase the risk of injuries or physical complaints.

Therefore, physical assistance to support assembly workers performing heavy bodily tasks would be beneficial. Further, assembly workers would also benefit from the reduction or even avoidance of unergonomic activities as well as from variations of body postures. Smart assistance systems could provide assistance for heavy physical tasks (e.g., fixing screws that are difficult to reach and therefore require an unergonomic posture, or ergonomic assistance for lifting workpieces). Smart and adaptive assembly lines and work stations (e.g., concerning working heights) might also address these issues. Additionally, assembly manuals could be extended with instructions and guidance for better or varying body postures.

**Individual Configuration of Work Stations.** Our observations showed that an individual configuration of the work station is essential for assembly workers to increase their efficiency and to cope, for example, with the cycle times and required speed of work. This is especially relevant for repeated and timed activities and movements (e.g., on assembly lines with short cycle times). A customized configuration of the work station is concerned with the handling of different kinds of stuff, e.g., tools, work materials, and equipment, but also with the handling of the water bottle for hydration purposes. Constantly changing work stations (e.g., due to shift changes and job rotation) even supports these practices and needs. Further, we observed that some assembly workers are definitely motivated to optimize their work station for the longer term. This is done, for example, by organizing specific tools or equipment that is not contained in the standard setup of the work station (e.g., a worker organized a vacuum cleaner for his/her work station).

To support these practices, assembly workers should be assisted in easily configuring their work station in order to set up a comfortable workstation as well as to allow practical handling of the work materials and tools. Therefore, assembly work stations should allow customization, or at least to customize parts of the work station. Additionally, this could be supported by participatory approaches as well as by providing incentives for workers to innovate and optimize their workplace.

**Sense ("Gespür") as Means of Quality Assurance.** Assembly workers, especially very experienced ones, have developed a certain sense ("Gespür") and skillfulness ("Geschicklichkeit") related to the product, the materials, the tools, as well as their handling. For assembly workers, it is crucial to develop this sense to subjectively assess the quality of the assembled product and parts of it. Further, it is essential to cultivate this sense of skillfulness for a variety of manual activities, such as handling and assembling small and filigree pieces, or to fix and adjust certain pieces (e.g., with a certain pressure or tension, such as chains in powertrains). This set of skills is further applied for haptic checks of surfaces (e.g., to check that there are no scratches), to attach labels, and to position wires. Sense and skillfulness evolve based on bodily experiences of working on the shop floor over time.

As this specific set of skills is hard to grasp and often not-well acknowledged or overseen, the first step to support it is to admit it and explicitly acknowledged it as an important part of assembly work. To make skillfulness and sense explicit, assembly workers could be provided by the possibility to feed-back their subjective sense of a certain piece, e.g., trough a system capturing the subjective haptic sense. Further, assembly workers should be assisted in developing certain useful senses and skillfulness, e.g., by providing reference objects to get a sense for a certain skillful assembly activity.

**Routines and Interruptions.** For assembly workers, it is crucial to develop routines and to internalize activities and movements to cope with time pressure and cycle times. On the other hand, routines are constantly broken and have to be shaped anew, e.g., with each product change. Assembly workers have to deal with these interventions and the need to constantly (re)shape routines. Thereby, routines are developed on a cognitive as well as motoric level. Currently, there are different ways of dealing with this issue. For example, we observed the deployment of pick-by-light assistance systems to guide the workers to grab the required part that needs to be assembled for the current product (if there are several containers with similar pieces). This top-down approach should reduce the mental load for the workers. However, we also observed work practices developed by the workers themselves (bottom-up) in order to deal with this issue of intervening routines. For example, a worker covered certain components of tools - a single bit within a bit set, that is currently, and for this specific product, not used - with tape, so that she/he restricts him-/herself to accidentally grab this bit when changing bits.

From the perspective of enhancing assembly workers' experiences, the workers should be supported in preserving autonomy, which might have positive impacts regarding compliance as well. The deployment of assistance systems should not only allow workers to passively react to interruptions of routines, e.g. related to top-down deployed systems. Assistance should be a choice for workers and they should have the possibility to opt-out from receiving support. Workers could be further supported by offering varying and alternating multisensory ways of intervening routines.

**Assembly Instructions.** Assembly instructions and manuals are an essential source of knowledge for assembly workers. Due to the increasing complexity and variety of products, it becomes more and more relevant to assist assembly workers with appropriate assembly instructions. Within our study, we observed that assembly instruction, as well as interactions with them, are currently very different concerning depth and quality. For example, current assembly instructions reflect the discrepancy between standard and "real-world" procedures not sufficiently. Thus, existing assembly instructions are currently rather inflexible, mainly representing standard-ideal cases and procedures. This is reasonable, as assembly work is mainly characterized by standardized procedures. However, assembly work is at the same time also diverse and characterized by (sometimes minor) deviations from these standardized processes. Related to that, we observed the usage of digital assembly instructions that are guiding the worker through the assembly process also by enabling or disenabling the usage of connected smart tools (e.g., screwdrivers). However, the system does not reflect deviations from standard assembly procedures, e.g., as it is the case for repair cases, where disassembling and re-assembling procedure slightly differ from the standard assembly procedure. Therefore, the workers developed practices of circumventing and hacking the instruction system.

To support assembly workers, digital instructions should be flexible and dynamically adapt to different assembly procedures. This could be the case by providing situational instructions, e.g., representing standard vs. repair case; or by providing instructions based on experience, i.e., inexperienced workers might need more (in-depth) information compared to experienced workers. Further, assembly workers should have the possibility to feed back to the system, e.g., through annotating instructions and creating experience-based instructions the workers would be supported in learning from each other, additionally, the assembly instructions would become interactive. Assembly workers would also benefit from an assistance system that combines required and suggested assembly steps. Based on that, smart and adaptive assembly instructions systems could learn the most frequently used assembly steps to extract and provide the most common needed assembly steps.

## 5 Conclusions and Discussion

With this study, we contribute a worker-centric understanding of assistance needs of assembly workers based on everyday work practices and experiences. The aforementioned assistance needs point to a variety of opportunities for the design of future systems, environments, and work practices. Assistance may relate to physical assistance (such as to support ergonomics and heavy work), to workplace preparations (such as individual configurations of equipment), to the development of skilfulness (such as for quality assurance), or to the way that assembly instructions are presented.

What the identified assistance needs unanimously highlight is the individuality of the human worker. If we take assistance at the workplace seriously, we need to take individual characteristics, needs and levels of experience into account - both as an offer for the human worker to individualize their workplace on their own and as "automated" customization by technological systems to adapt to the worker.

Apart from these design opportunities, there are several further conclusions to be drawn from the insights we gained from our investigations of assembly work. First, in assembly work, lacking individualization may often be an issue due to missing time. Thus, if possibilities for individualization were provided, they will only be helpful if there is sufficient time to carry them out - or if they won't require extra time at all. The benefit of facilitating individualization may be twofold: first, individualization may positively impact work efficiency, since it may build upon workers' experiences and knowledge that potentially have been gained over the years. Second, creating an atmosphere that encourages individualization may, at the same time, motivate to share thoughts and ideas for advancing the overall assembly line, contributing to innovation.

Another aspect that seems to be of utmost importance for workers is the requirement to preserve autonomy, to not lose control of one's work. This includes autonomy in regard to work practices, workplaces, and interaction with technologies and machinery. Thus, future systems may be designed in a way to not overtake as much as possible, but provide a balance for the worker to remain in control of crucial activities and decisions.

Finally, it is to be emphasized that workplaces are dynamic both in terms of workers and technology. This may be relevant, for instance, in the development of assembly instructions, in which workers can adapt to the specific needs of the situation in order to account for the particular conditions of a given situation.

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