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Measuring work and workers. Wearables and digital assistance systems in manufacturing and logistics

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Abstract

The smart glove or smart data glasses: Digitalization of work means that technology is moving closer to the bodies of employees. It can make movements, vital signs and even emotions visible. Technologies which many people use privately to monitor their sporting activities or health opens up a new dimension of control in the workplace, but also the possibility of supporting employees in complex work processes. Based on case studies of companies in manufacturing and logistics as well as a survey of employees, this study provides insights into operational use cases of wearables and the assessments of employees. It reveals contradictory experiences and a high importance of co-determination and co-design of new technologies by employees and works councils as a condition for using new technologies for improving work quality.

Key words: Technological change, digitalization, manufacturing, logistics, work organization, skills, works councils

JEL Klassifikation: J51, J52, J81, O33

Die Vermessung der Arbeitswelt. Wearables und digitale Assistenzsysteme in Fertigung und Logistik

Zusammenfassung

Der intelligente Arbeitshandschuh oder die smarte Brille: Mit der Digitalisierung rückt Technologie eng an den Körper der Beschäftigten. Bewegungen, Vitalzeichen und selbst Emotionen können damit sichtbar werden. Was viele privat gerne nutzen zur Kontrolle von sportlichen Aktivitäten oder dem Monitoring der Gesundheit, eröffnet am Arbeitsplatz eine neue Dimension der Kontrolle, aber auch die Möglichkeit der Unterstützung der Beschäftigten in komplexen Arbeitsprozessen. Basierend auf Fallstudien von Unternehmen in der Fertigung und Logistik sowie einer Befragung von Beschäftigten gibt die Studie Einblicke in betriebliche Anwendungsfälle von Wearables und die Einschätzungen von Beschäftigten. Es zeigen sich widersprüchliche Erfahrungen und eine hohe Bedeutung der Mitbestimmung und der Mitgestaltung neuer Technologien durch Beschäftigte und Betriebsräte.

Schlüsselwörter: Technologischer Wandel, Digitalisierung, Fertigung, Logistik, Arbeitsorganisation, Qualifikationen, Betriebsräte

JEL Classification: J51, J52, J81, O33

Contents

1 Introduction

Martin Krzywdzinski, Sabine Pfeiffer

Wearables, such as data glasses and smartwatches, are a particularly visible element of Industry 4.0 applications and are rarely absent from any illustration symbolizing current changes in the world of work. Wearables are intended to connect employees with digital assistance systems in companies, serving as an interface that provides employees with situation-specific information and enabling them to work with both hands (Hobert/Schumann 2017a: 4276), while also feeding data about the work process into IT systems (Langer et al. 2016).

The use of wearables raises a number of key issues in the workplace. On the one hand, the technology promises an improvement in the quality of work, and on the other, streamlining effects. It also enables a new quality of monitoring of the work process and, ultimately, of employees, raising questions of data protection, among other things. Management and employee representatives (trade unions, works councils) have to develop regulation for the use of wearables under conditions of high uncertainty, as the technology is still in development.

Sociological research has so far focused primarily on the role of wearables as a means of surveillance and on the intrusion of "algorithmic management" (Schildt 2017; Wood 2021) into social processes in the workplace. As a result, so it is believed, there is pressure to improve performance and increased competition through employee transparency.

Our study takes a different perspective. We view wearables as a technology whose use is, by necessity, negotiated in the highly regulated arena of the workplace. This technology is fitted into existing production systems in manufacturing—mainly in lean production, in logistics in the established forms of warehouse management. Wearables reinforce management strategies to increase efficiency, but their introduction also requires acceptance by employees, and, in the case of the German economy, works councils. In addition, data collection via wearables and the recording of body-related data has to be compatible with general data protection and, in particular, employee data protection.

Indeed, the prominence of wearables in the Industry 4.0 discussion often belies the fact that this technology is still in a design and deployment phase. In this phase of the social genesis of the technology, the characteristics and usage scenarios are negotiated between actors such as solution developers and user companies but also management, works councils, and employees. Many company deployment projects are still pilot projects in which forms of use and their effects are being developed and tested.

Against this background, this research project addresses the following questions:

1. How do the technology's designers understand the working world and the usage scenarios of wearables?

2. Which usage scenarios for wearables are evident in operational reality?
3. How is the use of wearables negotiated and regulated in the workplace arena by management and works councils?
4. What are the effects of the use of wearables on (a) work content and skill requirements, (b) ergonomics, (c) employment, and (d) control of work?
5. How do workers evaluate the use and benefits of wearables in the workplace?

The analysis focuses on the use of wearables in manufacturing and logistics, i.e., in industry. The term wearables refers to devices that are networked with company IT systems, providing information in the work process while collecting data about the work process. We have not included technologies which neither provide nor collect data in our analysis, such as exoskeletons used for ergonomic purposes (Hensel/Steinhilber 2018). In addition to use in work processes, we separately consider cases in which wearables are used to train workers. By focusing on the industrial use of wearables, the project fills a research gap: While there are already initial studies how wearables are used in the private sphere (cf. Duttweiler/Passoth 2016), there has been little research to date on their use in the workplace and, in particular, in an industrial context.

Due to the novelty of various wearable technologies and the dynamic and open nature of both the technological development and the introduction of the technologies in work processes, we combined a qualitative and case study-based approach with a quantitative online survey. The first sub-project was based on case studies and focused on recording existing experiences in companies. We conducted expert interviews with technology developers and 16 case studies, based on a total of 48 interviews with 83 interviewees. The second subproject expanded the study's scope by conducting a quantitative survey. This survey focused on employees' expectations and attitudes toward the use of wearables and their regulation. It was based on a topic-centered representative sample of over 1,000 employees.

Our case studies showed how production systems and the workplace negotiation arena shaped wearables-usage scenarios. On the management side, strategies focused on achieving efficiency gains through standardization and flexibilization. Contrary to the arguments of some studies (Moore/Robinson 2016) this did not necessarily require a micro-analysis of the data generated by individual wearables. Rather, in the German context of co-determination, management was only able to implement these technologies in the workplace if it agreed to prohibit the use of individual data for individual behavior and performance control. This demonstrates the great value of co-determination and the need to develop it further as digitalization continues.

What were the consequences of the introduction of wearables for work content and qualification requirements? Here, it is useful to distinguish between usage scenarios in logistics and in manufacturing.

In logistics, the increased technical standardization and control through the usage of wearables led to a further reduction in employees' scope of action. When work processes were already highly standardized and digitalized, this step was relatively small. When companies jump from a relatively low level of digitalization (e.g., the use of paper lists) to the use of a digital assistance system with wearables, this step was larger. It is also noteworthy that the use of wearables was mostly positively received by employees. They emphasized that the number of errors was reduced and that work processes became more fluid because employees had their hands free and did not have to use mobile devices. Given the very high time pressure reported in many logistics case studies, wearables may even reduce work intensity.

Case studies in manufacturing show somewhat different patterns. Here, the use of wearables primarily leads to the flexibilization of labor deployment and a slight expansion of the responsibilities of skilled workers, and thus increased skill requirements. The goal here is not standardization, but the detachment of skilled workers from specific machines and the reduction of waiting times. Works councils view this positively, but there is a risk of this flexibility leading to an increase in work intensity. Negotiations between works councils and management therefore focus on issues related to the definition of performance standards and rules, such as the right to switch off wearables during break times.

Our findings show that the effects of the introduction of wearables depend significantly on how performance regulation is structured in the workplace. Co-determined systems aimed at balancing management and employee interests enable the human-centered design of digital assistance systems and wearables. Where understaffing and management-by-stress prevail, such design is rarely possible.

One notable finding of our study, however, is the relatively high acceptance of wearable technologies in general. Our company interviewees experienced them positively, even in very highly standardized processes. Employees in these processes work under very strong time pressure and want to avoid errors that would create additional time pressure. Assistance systems that use wearables to closely guide employees through the processes and make decisions reduce the stress level. We emphasize, however, that this acceptance by workers should not be taken per se as an indicator of a human-centered design. We use case studies to show what such a design could look like.

To understand how far we can generalize the findings of our case studies regarding the acceptance of wearables, we conducted a standardized survey. In view of the pilot nature of many wearables projects, we asked a large number of employees how they evaluated approaches to measuring movement, effort, or even emotion at work, and under what conditions they would accept them.

The acceptance of technical measurement of movements, physical signals, and emotions in the work process was surprisingly high in the survey. Only a quarter to a third of the employees surveyed had fundamental reservations, a surprisingly low level given the intrusive nature of these approaches. It is less surprising that employees who already used wearables privately were also more likely to accept their use in the workplace. However, there were very clear conditions associated with this general acceptance. Employees were willing to have their movements, physical states, and emotions measured if they retained control over the data and use and if this had a clear benefit for their work—especially in terms of making their work easier. All the individual and detailed questions on the conditions showed a consistent picture: People agreed to the use of wearables in the workplace, but only if the consistently very high demands regarding data handling and work benefits were also met. This demonstrates the value of guaranteeing the protection of employee data, co-determination during the introduction of the new technologies, and, above all, participatory introduction processes in which the demands and conditions can be negotiated and shaped by workers.

Our study provides a new perspective on the question of acceptance. In the discussion on wearables and self-optimization, reference is often made to the "gentle coercion" (Duttweiler/Passoth 2016: 19) exerted by institutions such as health insurance companies on the one hand, and discourses about self-optimization on the other. We do not want to play down these phenomena, but we have so far found a different situation in the workplace, in which the negotiation and co-determination and a focus on relief in the work process play a central role.

This research report begins with an introductory Chapter 1 and is organized as follows. Chapter 2 presents the state of research on the development of wearable technology and the study's theoretical framework. Chapter 3 presents the research design and data for the qualitative and quantitative approaches. Chapter 4 presents an analysis of the interviews with technology developers and their perspectives on the use of wearables. Chapter 5 presents an analysis of the case studies, and Chapter 6 presents and discusses the key findings of the quantitative survey. The report ends with overarching conclusions (Chapter 8). The report is accompanied by two appendices documenting the case studies (Appendix 8) and quantitative survey (Appendix 9).

2 Digital assistance systems and wearables in the workplace

Martin Krzywdzinski, Maren Evers, Christine Gerber

2.1 Wearables as digital assistance systems

Technical assistance systems have been an important means of analyzing and controlling work at least since the emergence of scientific management, or Taylorism, at the beginning of the 20th century (Nelson 1975; Merkle 1980). The standardization of work processes was one of the core pillars of Taylorism. It required the use of technical tools in the analysis of work processes and development of standards; these standards, in turn, would be communicated to workers and monitored. Even in the early days of Taylorism, stopwatches and camera recordings were used for analysis, and standard worksheets depicting the work process were developed to communicate standards. Foremen monitored work activity and repeatedly measured times to ensure compliance with the standards. These standardization processes were seen as key to ensuring an efficient workflow with the right load on the workforce (avoiding both underutilization and overutilization) and identifying errors and problems in the process (Adler 1995).

The standardization of work processes was further developed in the lean production approach (Dohse et al. 1985; Springer 1999). Adherence to standard processes and close monitoring of deviations are of central importance in lean production, as they are the way to identify problems, work out solutions, and establish new, better standards (Liker/Hoseus 2008). Under the name Poka Yoke (Japanese for "[avoiding] stupid mistakes"), a series of often relatively simple technical devices were developed to guide workers in work processes or detect and report errors. These included mechanical solutions to prevent incorrect assembly, such as designing components so that connectors only fit into each other in the correct configuration; sensor systems that ensured that presses or welding equipment only start when components are correctly inserted; automatic screwdrivers that are set to a certain torque, ensuring that screwed connections are screwed in by workers with the optimum force; or pick-by-light systems in order picking that informed workers of where to pick the required items (cf. Butollo et al. 2019; Krzywdzinski 2021).

In the 1980s and even more so in the 1990s, computer-based digital systems were introduced to provide workers with the information they need and in turn provide management with information on the status of work processes. In the 1990s, systems were implemented in automobile factories in which information about the respective vehicle was read out at each assembly station by scanning the barcode, with the required parts displayed on a screen (Krzywdzinski 2021). In stationary assembly, systems have been tested in various industries in which the assembly steps being performed are displayed on computer screens.

With the advent of mobile internet, it finally became possible to make these digital assistance systems mobile. There were new applications that networked mobile devices such as smartphones, tablets, laptops, or even wearables, which could be used both as a source of information about the work process and to convey information or even instructions to workers. In the industrial sector in particular, projects introduced wearables as digital assistance systems to "prepare work-related information in near-real time, provide decision-making support, or even issue work instructions" to workers (Niehaus 2017: 5).

As defined by Hobert and Schumann, wearable computers are "independent end devices that are permanently worn on the body and enable casual and hands-free use and interaction with the user at all times" (Hobert/Schumann 2017b: 4). These devices gain their relevance primarily through their connection to the IT systems used in operations and, in particular, digital assistance systems. This networking enables the flexible provision of information from databases, knowledge management systems, manufacturing execution systems (MES), and enterprise resource planning systems (ERP). At the same time, devices worn on the body make it possible to permanently localize and control movements and even measure bodily functions, which can in turn be linked to performance control systems. When using wearables, the employee literally becomes part of the network. Wearables are thus a specific manifestation of mobile assistance systems, considered a central element of Industry 4.0 concepts (Butollo et al. 2019; Evers et al. 2018; Niehaus 2017; acatech 2016). According to the definition presented here, we focus our analysis on wearables that provide and collect data; we exclude technologies such as exoskeletons (Hensel/Steinhilber 2018) as they do not have this function.

The development of industrial wearables dates back to the late 1980s. Baumann (2013) cited Boeing's 1989 project using augmented reality glasses to aid the assembly of wire harnesses for airplanes (cf. Mizell 2000) as the first relevant project in the industrial sector, though the technology was never actually used in operations. In the 1990s and 2000s, other projects were launched (mainly in the areas of product design and maintenance), but again without successful deployment in real operations (Regenbrecht et al. 2005; Barfield et al. 2001). In the WearIt@Work project (cf. Pezzlo et al. 2009), wearables were also tested in operational use cases in production (Skoda) and maintenance (EADS). These projects provided the initial experience with the technologies being developed today, especially data glasses and gloves equipped with sensors. However, as Regenbrecht et al. (2005) and Baumann (2013) have summarized, the available sensors and devices proved to be too error-prone, unergonomic, and expensive. This was especially true for data glasses, whose field of view, image display, and wearing comfort fell far short of the requirements of industrial workplaces. The wearables of the 1990s required users to carry heavy displays on their heads and heavy batteries and computing units on their bodies. Xybernaut, a company founded in the 1990s, which produced computers that could be worn on a belt and connected to data glasses or a small display, filed for bankruptcy in 2006 after the hoped-for market for wearables failed to materialize (Baumann 2013). In the following years, other companies (e.g., teXXmo or Knapp) developed wearables, but without major success. By the end of the 2000s, pick-by-voice was the only technology to have established itself (Baumann 2013). Pick-by-voice is a method of picking without paper lists. Orders are transmitted to workers via headphones, and the execution of orders is confirmed by the worker by means of speech (Föller 2008: 840).

Technological conditions for the use of wearables did not change until the 2010s. The miniaturization of computers, and especially of batteries, made them more comfortable to wear on the body, while prices fell continuously and the duration between battery charging increased. In the field of data glasses, new models came onto the market (e.g., Google Glass) that both reduced weight and had an improved field of vision and graphical display. The emergence of the Internet of Things created an infrastructure that enabled the embedding of wearables in corporate IT systems.

A new wave of development and testing of wearables for operational use began, triggered by the discussion on Industry 4.0 (cf. Pfeiffer 2017), the funding available through government support programs, and the increasing willingness of companies to invest. The most important wearables used in the industrial sector are data glasses, smartwatches, and smart gloves (gloves equipped with sensors and scanners). Data glasses can be distinguished depending on the approach they adopt: augmented reality (AR), mixed reality (MR), and virtual reality (VR). AR data glasses (like Google Glass) superimpose text and image information onto the field of view. MR data glasses (such as the Microsoft HoloLens) superimpose information onto the field of view in a 3D representation so that it appears embedded in the real world. VR glasses hide the real world altogether, creating a virtual reality (Ong/Nee 2013).

There are a number of different players in the market for wearable computing applications. There are developers of the hardware, such as Google or Vuzix in the case of data glasses. Google also supplies the Android operating system. There are also pure software developers integrating wearables for application scenarios, programming the corresponding software and implementing the application at the customer company. Some industrial companies, in collaboration with scientific institutions and startups, are developing their own hardware and software specifically designed for the industrial sector: for example, data glasses integrated into safety helmets (data glasses Zwickau UG 2018) or the "Glass@Service" research project for the development of data glasses and applications based at Siemens. Companies such as Microsoft with its “Hololens” also act as solution developers themselves.

Most solution developers are start-ups from the 2010s. They tend to have limited experience in an industrial context. The development of the business model is partly carried out via competitions of large corporations, where considerable start-up financing can be generated via prize money. A number of other technology developers are spin-offs from universities.

Capturing the number and range of projects and applications involving industrial wearables is very difficult. Based on an internet search of wearables application providers in March 2018 and an update in March 2021, we identified 87 (2018) and 80 reference cases (2021), respectively. The most common usage scenarios are (see also Niehaus 2017):

- Picking, pick-by-vision: The wearable (e.g., data glasses) displays information, such as the number of parts to be picked in connection with the corresponding shelf. Orders can be acknowledged using the wearable (e.g., with the help of the data glasses’ camera, or with a wristband equipped with an RFID chip).
- Worker guidance in production: The assembly sequence is displayed and checked via the wearable.
- Remote maintenance, service: An expert can be connected via the wearable in a conference call and can, for example, see the machine to be repaired via the device’s camera function and give appropriate instructions.
- Maintenance and servicing: The wearable shows when, and in which order, parts needs to be inspected. Here, too, the camera can be used, for example, to confirm that the required maintenance steps have been carried out.
- Occupational safety, ergonomics: Warnings on hazard protection are given directly to the employee via the wearable, for example if gas escapes.
- Training: training processes are supported with wearables.

Despite the increase in pilot projects introducing wearable technology in industry, this technology is still—at least at the time of writing this study—in an early development phase. The characteristics of the technology and its forms of use are being tested out and negotiated between solution developers, customer companies, and other actors. At the time of this study, the following development needs have emerged (see also Hobert/Schumann 2017a):

- Hardware: Despite the advances, the available data glasses still offer a relatively limited field of vision. Data glasses also often lack the robustness required in an industrial setting.
- Data security: Secure integration of wearables via Wi-Fi into company networks and relevant data structures has proven very complex, not least because of the lack of standards for operating systems, interfaces, and applications.

- Software: Software solutions for wearables are currently at an early stage. The solution providers are young companies that have only recently launched their first products into the market. In addition, the lack of standardization of operating systems and interfaces is hindering the development of overarching software solutions.

Hardware constraints, a lack of standardization, and market fragmentation still limit the technical maturity of most wearables applications, as one solution developer explained in an interview with us:

> "The hardware market [for wearables] is very reminiscent of the cell phone market 10, 15 years ago, when there was this transformation from these feature phones to smartphones. [...] There is this desire to develop some kind of wearable platform, [...] that always also behaves the same way, has the same specifications, that you can also control in a meaningful way. But at the moment, well, every manufacturer is always trying something new and learns relatively little from the experiences of other manufacturers [...]. And so almost every device from the smartwatch to the head-mounted display has a completely independent specification or feature set often coupled with relatively old operating systems." (IV5)

It is not only the limited level of technical maturity that leads to the assessment that wearable technology is still in the design stage. The field of actors and the "agora" of technology development (Pollock/Williams 2009: 98) are also still very much in flux. There is a lack of standard solutions and standard providers. Support for the customer-specific implementation of wearables solutions is often not yet offered by relevant consulting companies.

2.2 Digital assistance systems and wearables in the work process

What factors drive the use of wearables in companies and how can their effects be analyzed and explained? Our analysis focuses on both management strategies in the introduction of wearables and employee perspectives. In doing so, we connect to the concepts and discussion in labor process theory (LPT), in which the role of technologies in the work process was and is a central issue (Thompson 1983; Thompson/Smith 2010). In doing so, we discuss the role of technology developers, management strategies, the bargaining arena in the workplace, and employee perceptions.

2.2.1 Technology developers

Since wearable technology is at an early stage of development, it makes sense to include the role of technology developers in the theory framework. The role of actors in technology genesis is a classic theme of social construction of technology (SCOT) or science and technology studies (STS) approaches. Technology development is a process of negotiation and conflict between "relevant social groups" with different understandings of the technical problem situation, the technical solution methods, and the evaluation of the success or failure of the technology (Pinch and Bijker 1984). The form and mode of use of a technology is thus not predetermined. Rather, an “interpretative flexibility” prevails, which is limited at various stages by negotiation processes between actors. A “technological framework” develops, with a shared understanding of problems, goals, problem-solving strategies, organizational constraints, design methods, and ways of using the technology (Bijker 1987).

In the LPT tradition, Noble (1978) and Wilkinson (1985) emphasize the importance of “engineering ideologies.” Noble distinguished three phases of engineering genesis: design, deployment, and actual use. The design and deployment phases are shaped by the intentions and ideologies of powerful actors. Noble argued that the importance of the interest in controlling the work process and workers in technology development should not be underestimated:

> “Here the ideology of control emerges most clearly as a motivating force, an ideology in which human judgment is construed as ‘human error.’ But this ideology is itself a reflection of something else: the reality of the capitalist mode of production. The distrust of human beings by engineers is a manifestation of capital's distrust of labor. The elimination of human error and uncertainty is the engineering expression of capital’s attempt to minimize its dependence upon labor by increasing its control over production.” (Noble 1978: 30)

Industry 4.0 has revived interest in the analysis of “engineering ideologies,” However, so far, the literature only consists of overarching accounts that refer to the public discourse on Industry 4.0 (or digitalization in general). Morozov (2013) points to the influence of Silicon Valley’s understanding of technology, which he calls “solutionism”—that is, a way of thinking that assumes that all social problems can be solved by “smart” technologies and forms of control and incentives based on these technologies. Raffetseder et al. (2017) interpret the technology utopianism of the Industry 4.0 discourse as a return to cybernetic management concepts that rely on technical self-control. What has been largely lacking so far are concrete empirical analyses of the role of technology developers in the adoption of wearables or digital assistance systems.

To prepare our empirical analysis, we conducted a systematic search of specialized publications on the topic of wearables in the field of engineering and computer science in 2018. We considered a total of 61 publications from 1999 onwards, 51% of whose authors were from the fields of mechanical engineering, logistics or production, 33% from computer science, and 16% from other disciplines.

The publications identified six types of benefits of using wearables: (1) providing and processing information on demand, in real time, and individually, (2) guiding employees, (3) being able to work with free hands, (4) process optimization (higher working speed, better quality, simplified documentation of processes, higher flexibility), (5) improving acceptance and ergonomics, and (6) providing expert knowledge on site.

Characteristically, all publications promised significant rationalization potential through the use of wearables. This is clear, for example, in the research on the use of wearables in logistics (order picking). The focus is on examining the relationship between the use of wearables and the reduction of picking time and picking errors (e.g., Günther et al. 2009). Baumann (2013) came to the same conclusion as Günther et al. (2009) in a laboratory study but reported major acceptance problems of the technology. With regard to the understanding of work, the publications came to exhibit a pattern of thinking in which manual work requires close control. Employees should receive precise work instructions (e.g., in order picking) and the execution of their work should be controlled with the help of the device.

2.2.2 Management strategies

How do the conceptions of technology developers influence management strategies? In particular, Vidal (2020), in discussing LPT, emphasizes that management is confronted by contradictory requirements. On the one hand, it must ensure the recognition of the order, rules, and specifications in the company and the discipline of the workers. On the other hand, it has to guarantee the transformation of the commodity labor power into actually spent labor. This objective leads to management efforts to control work processes and staff. The control problem and the use of technology as an instrument of control have been the focus of a number of classical studies related to LPT (Braverman 1974; Noble 1978; Wilkinson 1985; cf. Hall 2010). These have discussed approaches to Taylorist control of the work process (using technology as a deskilling tool), as well as concepts such as relative autonomy (Friedman 1977) and bureaucratic control (Edwards 1979), forms that allow scope for upgrading skills and for self-organization.

Vidal (2020) argues that concepts such as relative autonomy are not simply another way of realizing control but result from a second central objective of management that may conflict with the control function: the need to ensure the efficiency (and quality) of the production process, which is a prerequisite for profitability. A large number of studies and research approaches have shown that companies can develop different product strategies (Freyssenet et al. 1998; Boyer/Freyssenet 2002). In particular, where high demands on process efficiency are combined with high demands on flexibility (such as product changes) and product quality, management often has to rely on approaches that invest in employee skills and grant well-qualified employees extensive scope for self-organization (Sorge/Streeck 2018; Krzywdzinski/Jo 2022). In contrast to Braverman and Noble scenarios, technology development and implementation in such contexts tends to lead to a further upgrading of skills.

Management can thus pursue different strategies in technology implementation. Depending on the context, the focus may be on control, but also on process improvement. This becomes entrenched in certain product strategies and production systems, creating path dependency.

There has been little research on management strategies for the introduction of digital assistance systems and wearables. Some studies argue that the use of wearables is mainly associated with control strategies that entail using technology for increased standardization of work processes, objectification of knowledge, and permanent monitoring of work (Wilson 2013, Lupton 2013, Moore/Robinson 2016; Delfanti 2019). Moore and Robinson (2016: 2781) argue that the use of wearables in the work process allows for the control of "microsocial and inner processes in open-ended working environments," in some cases even outside of working hours and the workplace.

It should be noted, however, that so far these studies have not been able to rely on any empirical research; they mainly use material from the press as evidence.

In contrast, Niehaus (2017) distinguishes between a Taylorism and an autonomy scenario, based on two case studies into the introduction of wearables in logistics. In the Taylorism scenario, the digital assistance system and wearables supply the employees with narrow specifications about the work process, with compliance with the work steps monitored by the wearables. Incidentally, this scenario may be associated with ergonomic improvements, as wearables free up employees' hands and allow them to work more safely and without interruptions (cf. also Butollo et al. 2019).

The autonomy scenario described by Niehaus (2017) focuses on a smartwatch that transmits information about orders to employees. It does not give them any mandatory instructions but is used only as a support. Niehaus's (2017) analysis does not discuss in further detail what factors drove management to choose the different strategies in the two cases, but based on our considerations, it is likely that different priorities in terms of control versus process optimization played a role.

2.2.3 Bargaining arena

In the next step of analysis, we consider how management strategies play out in a specific bargaining arena within the company. Especially in an industrial context, management is confronted with employee representation (trade union, works council) and with various legal and collective bargaining rules. Here, we mainly draw on the theoretical framework developed by Edwards et al. (2006) and Bélanger and Edwards (2007), which follows LPT. The authors assume that management strategies can be classified by how strongly they weight control of the work process on the one hand and the development of the productive forces of the company ("developmental concerns") on the other (see also Vidal 2020). Management is opposed by employee representation, which in turn has certain preferences with regard to (avoiding) control and the development of the company. Where management prioritizes the enforcement of control over the development of productive forces and the employees prioritize resistance, fierce "shopfloor battles" ensue (Edwards et al. 2006: 131). Where management prioritizes the development of productive forces and encounters an equal attitude from employees, productivity coalitions result. Depending on the specific configuration of the interests of both sides, a variety of intermediate forms are possible.

Thus, depending on the configuration of management's interests and priorities, different dynamics may emerge with respect to technology adoption. Bélanger and Edwards (2007) highlight three factors that influence these dynamics: the specific product markets of firms, which influence their product strategies and production systems; the technologies, which on the one hand are a result of actor strategies, and on the other hand also provide a framework for actors with their own materiality (Leonardi/Barley 2008); and the institutional frameworks, which structure rights and opportunities for action.

The special feature of wearable technology is that it can be used not only to transmit information to employees in a context-specific manner but also to collect data on the work process on a large scale. This raises the importance of data regulation. How this need for regulation is addressed in the workplace bargaining arena depends heavily on the institutional setting. Our case studies were conducted in Germany. The companies had a works council, and industry-level collective bargaining agreements concluded with trade unions applied. Though the strength of works councils and unions differed in the case studies, they all belong to the core of the classic "German model" (Weitbrecht/Müller-Jentsch 2003). While subject to considerable erosion tendencies (Addison et al. 2017; Bellmann/Ellguth 2018; Bispinck et al. 2010), this still exists, especially in industry. In the German case, employees possess specific "associational power resources" (Wright 2015) that influence power relations in the bargaining arena, though these power resources only take effect in the implementation process of the technologies, after the design phase of a technology. Moreover, co-determination shapes the strategic orientations of works councils and management, promoting the development of "productivity coalitions" (Edwards et al. 2006).

Concerning the legal regulation in Germany relevant to the implementation of wearables, at the most general level, §90 of the Works Constitution Act (BetrVG) only gives works councils the right to be informed and consulted in a timely manner about plans to introduce new technologies. In the case of digital assistance systems and wearables, however, they can also use other legal levers. First, §87 of the Works Council Constitution Act (BetrVG) gives works councils the right to co-decide on the introduction of technological solutions if they are "intended to monitor the behavior or performance of employees.". The potential for monitoring with wearables is obvious, and the regulation of this issue is at the center of most negotiations between management and works councils. Second, §5 of the German Occupational Safety and Health Act (ArbSchG) stipulates that employers must conduct a risk assessment if the design of workplace experiences can generate physical or even mental stress. The works council has a say in how it is carried out. If the risk assessment shows relevant stresses, the works council verifies that these are eliminated through appropriate measures. The use of wearables can result in both physical stress (for example, due to poor ergonomics in the devices) and mental stress (for example, due to monitoring). Accordingly, risk assessments are a frequent tool used by works councils in negotiations on the introduction of such systems. The new General Data Protection Regulation (GDPR) offers further opportunities. Although this does not specifically regulate the role of works councils in employee data protection, it does formulate specifications that works councils can use. If the company installs systems that enable employee monitoring, a data protection impact assessment must be carried out to show how employee privacy is guaranteed (cf. Körner 2019).

There are few empirical studies on the strategies of works councils during the introduction of digital assistance systems and wearables. Although the legal framework certainly gives works councils influence over the technology introduction process, some studies report significant difficulties. Matuschek and Kleemann (2018) argue that due to the complexity of new digital technologies, works councils struggle to assess their consequences. They also face the challenge of negotiating the future use of technologies with management, although both actors often cannot yet accurately assess this future use. Works councils often have insufficient knowledge of the technologies and must rely on the promises of management and technology providers. At the same time, they are confronted with a large number of decentralized digitization projects in companies, which generate enormous complexity. Overall, according to Matuschek and Kleemann (2018), works councils are often overwhelmed and react either passively or defensively to the introduction of technology, focusing in the latter case on warding off negative consequences, such as the monitoring of employees. Active co-design of new technologies is rare (see also Klippert et al. 2018; Falkenberg et al. 2020).

Some studies have looked at trade union initiatives to support works councils in co-designing digitization projects. The "Work 2020 in NRW" project (a collaboration between the German Trade Union Confederation and the trade unions IG Metall, IG BAU, NGG, and IG BCE) attempts to guide works councils in actively shaping digitization (Haipeter 2020). Mapping ongoing and upcoming digitalization projects in companies is at the core of the project. This mapping helps works councils engage with employees, develop demands, and negotiate with management. IG Metall's Transformation Atlas project takes a similar approach (IG Metall 2019).

2.2.4 The employee perspective

Finally, we want to include the employee perspective in our conceptual framework. At first glance, the situation seems clear. Employees view technologies that increase autonomy and expand capabilities as positive, while Taylorist approaches of standardization and control should prompt resistance. Indeed, studies have long reported such resistance (Noble 1978; Friedman 1977; Thompson 1983).

In the case of wearables and digital assistance systems, there is much to suggest that we should expect comparable conflicts over control and autonomy here. However, the situation is more complex. A number of studies have shown that the expansion of employees' scope for action can also be accompanied by stress and lead to work intensification (cf. Kalleberg et al. 2009; Batt/Doellgast 2005; Thompson/McHugh 2002). These studies mostly focus on team-based work organization and employee participation in continuous improvement processes. The findings suggest that while such participation gives employees more opportunities for action and responsibility, it is also often perceived as a stress factor. Time and organizational resources are often not made available for employees' expanded tasks, so time pressure and work intensity increase (Kalleberg et al. 2009).

Against this background, the question that arises is as follows: What effects of digital assistance systems and wearables can we expect? A conceptual framework that can also be used for sociological research is offered here by industrial and organizational psychology. The job-demands/control (Karasek 1979; van der Doef/Maes 1999) and job-demands/resources models (Bakker et al. 2004; Bakker/Demerouti 2007) analyze the relationships between the demands placed on employees, their resources for action, and the resulting job satisfaction. Rather than discuss all the different versions of these models, we limit our discussion to the job demands/resources model (JDR).

The JDR model distinguishes between demands and resources. Demands are the physical and mental (cognitive and emotional) tasks and requirements at work. What matters is their scope and their temporal compression. The concept of resources includes all those physical, psychological, social, and organizational factors that help employees perform tasks and meet specifications: technical devices (e.g., lifting aids for physical work), support from colleagues and superiors (e.g., emotional support and feedback) and also, as an organizational dimension, an interesting and clear design of the work tasks that grants room for maneuver and reduces uncertainties and ambiguities. The JDR model argues, first, that there is a direct relationship between demands and stress and resources and motivation (Bakker et al. 2004: 313; cf. also Hackman/Oldham 1976): the higher the demands, the greater the stress; the more extensive the resources, the greater the motivation. Second, however, the relationship also matters: Extensive resources can reduce the stress resulting from high demands. In terms of motivation, there is also an interaction between demands and resources, albeit in a complex way.

Based on the JDR model, we can now expect to find different effects of digital assistance systems and wearables on motivation. If the systems are introduced in the sense of Niehaus's "autonomy scenario" (2017), they should improve employees' job discretion, act as a resource, have a positive effect on motivation, and reduce stress. If, on the other hand, they are introduced in the sense of the "Taylorism scenario," it is possible, on the one hand, that they will reduce resources (for example, by limiting job discretion or reducing social contacts) and in this way increase stress and reduce motivation. On the other hand, it is also conceivable that the introduction of such "Taylorist" assistance systems will reduce resources in the sense of the JDR model, while also lowering demands and responsibility. By eliminating previous decision-making and planning tasks, employees save time. In addition, the pressure to bear responsibility for possible errors is potentially eliminated, which can be particularly important in systems where remuneration systems are strongly linked to performance targets. Depending on how employees view the impact of an assistance system on resources and demands, a Tayloristic system may also reduce stress levels.

Thus, when analyzing employees' perceptions of digital assistance systems, the effects of the technologies must be considered in light of the relationship between demands and resources. If employees have sufficient resources to fill the scope for responsibility, a preference for an "autonomy scenario" and a negative evaluation of Tayloristic approaches to the use of assistance systems can be expected. The situation becomes more complex when employees work in a highly stressful environment in which there is high performance and time pressure. Here, Tayloristic approaches to the use of assistance systems can also be perceived positively.

The limitations of the JDR model are that it assumes that workers use the assistance systems as prescribed by the management—that is, the model limits the agency of workers to the fulfillment of their work tasks. Both STS and LPT research have often found that employees actively appropriate the technologies they use in the work process, and in doing so, they can also develop strategies that can run counter to the plans of management and technology developers, by ignoring technologies or by using them differently than was originally intended (Boreham et al. 2007; Child 2000; Ball/Wilson 2000). Especially in the "Taylorism scenario," such resistant appropriation strategies are to be expected as a way for employees to regain autonomy margins (Knights/McCabe 2000; Bain/Taylor 2000).

So far, however, there are only a few studies on the actual use and work effects of digital assistance systems. Kuhlmann et al. (2018) studied assistance systems in the assembly of high-voltage systems. The work processes are highly standardized and conducted (untypically for assembly areas) by skilled workers, as work with high-voltage systems requires specialist electrical engineering training. Information from the digital assistance system is output via screens mounted at the workstations, with workers required to confirm the steps performed via the keyboard. Kuhlmann et al. (2018) find that the introduction of the digital assistance system hardly changed the work content and processes. It is noteworthy that the majority of employees rate the system positively:

> "By assisting with accurate and skilled work, it partially relieves employees from the risk of potentially consequential work errors, thus providing reassurance in the high-risk environment of the examined case. It is also helpful in managing the large workloads and considerable work assignment flexibility across different workstations and production lines. This aspect not only provides process security and flexibility advantages for the company, but is also highlighted by the employees in particular as an advantage, as it supports diversity, variety, and changes in workload [...]. Consistently emphasized are the benefits of digital worker guidance in learning new tasks as well as in returning to jobs after extended absences." (Kuhlmann et al. 2018: 186)

Kuhlmann et al. (2018) emphasize that not all workers view the assistance systems positively. Some employees perceive the assistance system as an annoying disruption of the work processes, mainly because of the obligation to confirm all individual work steps. However, workers find ways of circumventing this duty. Some workers simply ignore it, perform several work steps in succession without acknowledging each one, and then subsequently confirm all finished steps via the keyboard. This is perceived as annoying, but it allows the employees to continue their usual way of working. Accordingly, Kuhlmann et al. (2018: 187) conclude:

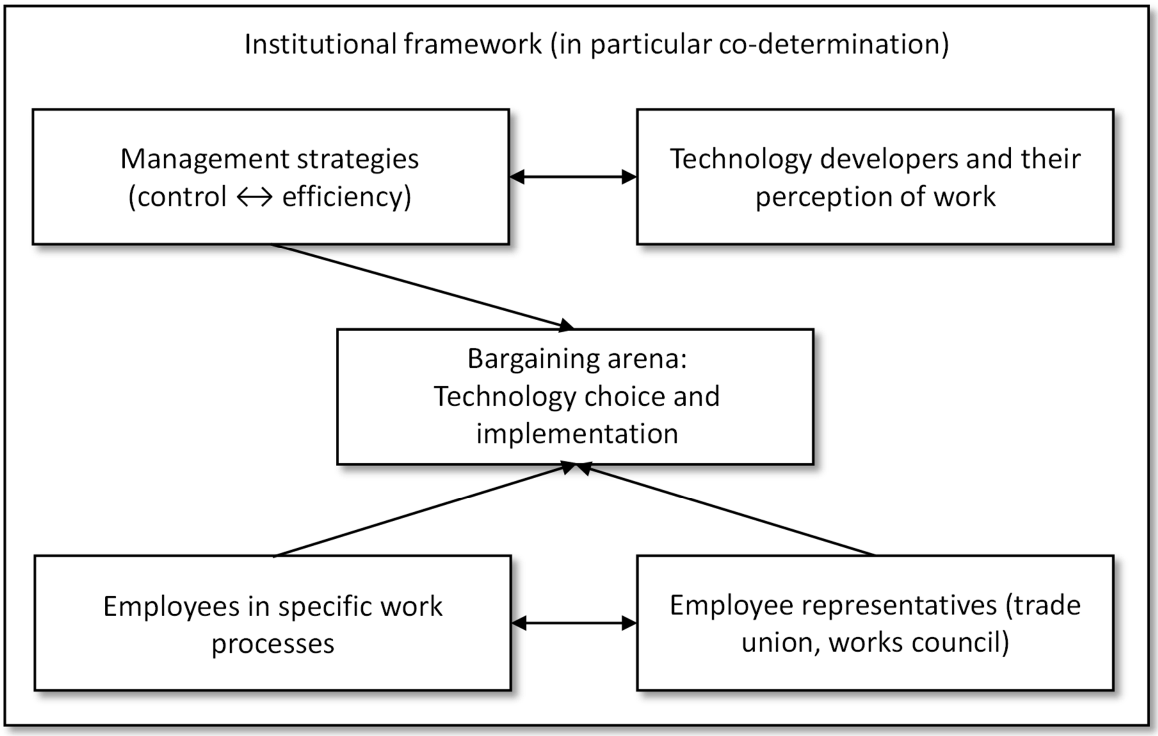
> "The thesis that digitization technologies lead to a more rigid determination of work and a stronger subordination of work to company control interests is not supported by our case study."

Potentials for conflicts in the introduction of digital assistance systems are more likely to emerge where assistance systems are to be used by skilled workers. Baethge-Kinsky et al. (2018) examined the introduction of an assistance system in the field of maintenance. In their case study, a simple system was implemented that sends automated fault messages and related information directly to workers' mobile devices. This system could be implemented because the maintenance staff did not see any risk of losing their competencies in the areas of problem diagnosis and problem solving. However, workers expressed reservations about the development of a knowledge database that, together with the malfunction information, would also provide guidance in problem solving. Baethge-Kinsky et al. (2018) refer to the special professional pride and high autonomy of maintenance workers, which they want to defend. The authors argue that the key position of these skilled workers in maintaining production makes it unlikely that an assistance system could be implemented against their will.

2.2.5 Summary

Figure 1 summarizes the heuristic model used in this study. We assume that the driver of development is management strategies, motivated by both control and efficiency objectives. Management interacts with technology developers in the development and implementation of technologies. In addition, the workplace (or the company) represents a negotiation arena where management faces employee representatives. Depending on the legal framework, the institutional or organizational structures, and ultimately also the specifics of the technology, this can result in dynamics that lead to fierce "shopfloor battles," but also productivity coalitions between management and employee representatives or various intermediate forms. It should be noted that although employee representatives take up the interests of employees, they are also an independent actor who, in turn, can also influence the positioning of employees vis-à-vis technologies.

Figure: Heuristic frame of the analysis



Source: Authors.

We assume that workers' perceptions and behaviors regarding technology adoption are significantly determined by how the technology affects (in terms of the job demands/resources model) the demands and resources in the work process. Workers may also develop modes of appropriation of the technology that run counter to management's intentions.

3 Research design and data

Martin Krzywdzinski, Sabine Pfeiffer, Maren Evers

The data used in this analysis were collected in the research project “Wearable Computing in Manufacturing and Logistics”, funded by the Hans Böckler Foundation (duration 2017–2021). Due to the novelty of various wearable technologies and the dynamics and openness of the technology development, we combined a qualitative and exploratory research approach with a quantitative online survey. The WZB team (Martin Krzywdzinski, Maren Evers, Christine Gerber) was in charge of the qualitative part and the FAU Erlangen-Nuremberg team (Sabine Pfeiffer, Bruno Albert, Marco Blank) was responsible for the survey.

The decision to combine a case study-based and qualitative analysis with a standardized survey was made with the aim of exploring a young and emerging field of inquiry. The case studies were intended to collect usage scenarios of wearables and experiences of corporate actors. Perceptions and experiences of employees were to be analyzed with a standardized survey.

3.1 Qualitative analysis

The qualitative part of the study is based on a total of 48 interviews with 83 interviewees. First, 16 one- to two-hour expert interviews (Gläser/Laudel 2010) were conducted with a total of 23 persons in the period 2017–2019, focusing on possible usage of wearables, the state of development of the technology, and the role of solution developers. We define solution developers as companies that develop wearables applications and offer them explicitly for use in the workplace.

The expert interviews were evaluated using qualitative content analysis according to Kuckartz (2016). A multi-stage procedure for the formation of categories was used. After an initial review of the material, we developed the main categories: “understanding of work”, “co-determination and participation”, “motives”, “data and content generation”, “solution developers”, and “wearables market”. In the next step, subcategories were developed inductively. Table 3.1 displays an overview of the categories and subcategories used.

Table 3.1: Categories for the analysis of the expert interviews

Main categories	Sub-categories
Main understanding of work	Relationship technology-body
	Work organization and skills
	Ergonomics
	Interaction
Codetermination and participation	Codetermination in the establishment
	Participation
	Introduction processes of new technologies
Motives	Rationalization
	Experimentation
	Development of IT systems
	Innovation
Solution developers	Experience and professional background
	Use cases

Source: Authors.

We conducted 16 case studies on the implementation of wearables and digital assistance systems in logistics and manufacturing. The case selection aimed to include as many of the wearables-usage scenarios identified in the literature review as possible (see Chapter 2). In the first step, we tried to identify the complete population of existing projects and applications of wearables in the industrial context. This proved very difficult as new projects are constantly being added and not all of them are made public. Based on an analysis of internet media (magazines, news sites, and solution provider sites) in 2018, we were able to identify 25 solution providers with a total of 87 reference cases. We contacted all these cases and completed 16 case studies, organized in three groups:

- Picking (mainly in logistics)
- Maintenance and remote maintenance, occupational health and safety (mainly in manufacturing)
- Training (both in manufacturing and logistics)

The case study results are summarized in chapter 4. All case studies are documented in detail in the appendix. We fulfilled our key success criterion—namely, capturing as many relevant wearables-usage scenarios as possible. The case studies are primarily from the automotive, electrical engineering, and automation industries, with individual cases from the transportation industry, the food industry, and retail logistics. In our experience, this corresponds to the actual distribution of cases, as the automotive industry, the electrical engineering industry, and also the automation industry are among the pioneers in the implementation of new technologies.

Almost all of our cases involved globally active corporations. Again, this is not surprising and probably reflects reality, as such corporations have the resources to implement new technology faster than small companies can. It should be emphasized that all of the companies studied have a works council structure and, as explained in Chapter 2, tend to belong to the core area of the

"German model" and its culture of co-determination. Despite our efforts, we did not succeed in conducting case studies of wearables use in companies without works councils. In our view, this is the most important limitation concerning the generalization of our findings.

In total, the case studies conducted in 2018–2019 involved 32 one- to two-hour interviews with 60 individuals. Typically, a case study consisted of an interview with managers responsible for the introduction of wearables, as well as works councils; in some cases, shop floor employees also participated in the interviews. Often, several people were involved in the interviews, each bringing different expertise. In the interviews with management representatives, different functions were often represented, such as the supervisors of the area in which the wearables were used and those responsible for the project; or supervisors from production and IT. In the interviews with works councils, several works council representatives often took part, frequently the works council chairperson and the works council members responsible for IT. Table 3.2 provides an overview of the interviews.

Table 3.2: Interviews

Number of interviews	Number of interviewees	Interviewed persons
9	10	Expert interviews with solution developers
2	4	Expert interviews with researchers
5	9	Expert interviews with representatives of industrial companies
14	31	Case study interviews with managers
12	23	Case study interviews with works councils
6	6	Case study interviews with workers
48	83	

Source: Authors.

The analysis of the case study interviews corresponded to the procedure for the expert interviews. The main categories of analysis were based on the heuristic model of analysis and were: "workplace characteristics," "state of digitalization," "management strategies," "negotiation arena," "employees," "work processes," "control," and "rationalization". Table 3.3 shows the categories and subcategories used.

Table 3.3: Categories of the case study analysis

Main categories	Sub categories
Basic information about the plant	Composition of employment (skills, age, and gender)
	Products and work processes
State of digitalization	Work processes before the introduction of wearables
	History and state of technology implementation
Managerial strategies	Motives for implementation
	Implementation process, involved actors
	Cooperation with solution developers
	Experiences in the implementation process
Bargaining	Demands of the works councils regarding the introduction of wearables
	Bargaining processes
	Bargaining results, collective agreements
Workers	Perceptions of the use of wearables in the work process
	Acceptance of wearables
Work processes	Impact of wearables on work processes
	Impact of wearables on ergonomics
	Impact of wearables on skill requirements
Control	Potential of technology for control
	Actual use of control potential (data recording, analysis, and optimization)
Rationalization	Rationalization impact of wearables
	Employment impact

Source: Authors.

3.2 Quantitative analysis

The qualitative interviews with technology developers and the qualitative company case studies were supplemented by a quantitative online survey (for the method, see Evans/Mathur 2018; Vehovar/Lozar Manfreda 2016). We originally planned to conduct this survey with employees from the case study companies. This did not prove possible. The qualitative studies showed that the number of employees already working with wearables is still very small and many of the projects are pilot projects. This forced us to choose a different approach for the quantitative analysis.

We decided to conduct a topic-centered representative survey drawn from an online access panel (Respondi). We surveyed more than 1,000 employees, asking them about their perceptions and expectations of wearables. The survey was conducted in early 2021 and the questionnaire was created using SoSci (see Appendix 9.1). While the access to the companies considered in the qualitative analysis was mainly through trade union contacts and mainly took place in companies with works councils, this approach also offered us the chance to reach employees from other sectors without trade unions or works councils. A possible bias in the sample must be considered, as online surveys tend to reach people with a greater affinity for technology who tend to be more open to wearable computing (Ray/Tabor 2003). The composition of the sample and the results of the analysis are explained in Chapter 6 and Appendix 9.

Since it was clear that a large proportion of the respondents had not yet worked with wearables, we decided not to focus on specific use cases and hardware variants (such as smartwatches and data glasses) as it was not possible to ask about specific experiences in this regard. The case studies also showed that wearables could be used for very different purposes and for recording very different data. Therefore, the survey focused on a particularly critical point in the use of wearables, namely the conditions for agreeing to the recording of individual employee data. Three dimensions were examined: the recording of emotions, physical states, and movements.

Accordingly, the quantitative analysis focuses on a different time horizon to the case study-based qualitative analysis. While the latter is concerned with the current state of wearables use, the former examines conditions for the long-term acceptance and use of wearables.

4 Engineering ideologies—the perspective of solution developers of wearables[1]

Maren Evers, Martin Krzywdzinski, Sabine Pfeiffer

Wearables are a highly dynamic technical subject area. How and where they will be used in work processes is still in an early phase of negotiation. Workplace discussions about it are strongly influenced by the dominant managerial discourse around Industry 4.0 and digitalization. Given the early stage of technology development and implementation, solution developers are a highly relevant player in the current processes of social negotiation of the technologies. We therefore begin our analysis with the interviews with solution developers and their perspectives and experiences, particularly relevant for the design of work. We initially consider the motives for client companies implementing wearables. We then show solution developers' understanding of the work process and how they understand the role of wearables in the workplace. Finally, we trace the expected impact on work organization and how solution developers view the role of employees' interest representation.

4.1 Motives for implementing wearables in the work process

Companies' motives for implementing wearables projects are perceived by solution developers as multi-layered. On the one hand, there are projects in which client companies clearly formulate

[1] This chapter is based on Evers et al. 2018.

rationalization motives with regard to work. The logistics sector, in which wearables are already used on a large scale with pick-by-voice technology, is paradigmatic for this approach. The key goals are to increase process speed while reducing error rates.

> “So when the logisticians come in, it has to pay off from the very first second.” (IV5)

A second recurring motive is to generate data about the work process and explore possible uses for this data for the purpose of process optimization.

> “That is also what customers actually already expect... They would like us to be able to simply optimize processes automatically. That we say, okay, now we're closer to the process than ever before, how could the process now be designed more optimally based on the data situation? [...] These are just data-driven solutions, i.e., analyzing the data and then deriving products, optimal processes, ergonomic recommendations, whatever you can think of.” (IV5)

However, solution developers often report that the motivations of client companies in many other projects are much vaguer and more open. In principle, this could leave considerable scope for alternative options of technology design and considerable “interpretative flexibility” (Pinch/Bijker 1984) of the technology. In many companies, there is experimentation with possible uses:

> “We're really open about it, we're trying it out. We don't know—are data glasses suitable for production? We are testing the use.” (IV29)

The companies are open to trying out different use cases because they see the implementation of wearables as a way to further develop the integration of different mobile devices into the IT architecture. So in this case, it is less about the specific devices (such as data glasses) and more about a mid-term overhaul of IT systems.

> “The most important thing is perhaps the middleware, because this is, after all, independent of a specific device. Even if we end up discarding the use of data glasses—at least for the time being—we do have the middleware, which we can also use with tablets, smartphones, or other devices.” (IV29)

From the company’s point of view, the motive to engage with new technologies and demonstrate innovative capability to the outside world also appears to be relevant:

> “At the beginning, this whole debate was also followed by our management in a somewhat benevolent manner, with the understanding that, well, this is now an innovative debate with an interesting topic, which makes good press and improves our external image. Our initial engagement does not have the focus at all on earning money with it, but rather that we are making ourselves more exciting, more interesting, and we are making ourselves more interesting for new employees, we are being noticed within and outside the group.” (IV42)

4.2 “Our goal is actually to make the worker's life easier.” How do solution developers perceive the work process?

The professional backgrounds of the solution developers we interviewed were diverse, but computer science and business administration dominated. What they had in common was that they rarely had any specific background in production technology or the areas in which they implement wearables. Our interviewees described the process knowledge required for the implementation of wearables in the workplace as something that solution developers can acquire as part of their job. Accordingly, solution developers did not refer to existing concepts from the field of work science in their assessment of the impact of technologies on work, but rather to their impressions and experiences.

In many interviews, solution developers emphasized that the use of wearables can have a positive impact on work due to the possibility of an ergonomic work design. They argued that wearables made it possible to work “hands free” and minimize the “tedious part of work”, such as information gathering or unnecessary walking. They described these as unloved activities and argued that employees were giving positive feedback regarding these aims. At the same time, however, this can also be seen as condensing “productive” parts of the work, and thus avoiding waste through lean production.

> “I think most of them actually perceive this as an improvement, because we are minimizing the tedious part of the work. The work itself doesn't change.” (IV5)

At this point, it is important to emphasize that our interviewees had a highly “atomizing” approach to the work process, focusing on individual tasks and how to optimize them. We discuss the implications of this with regard to work organization below. It should also be emphasized that in some of the interviews, solution developers described workers primarily as a potential source of error in the work process, a perception that is also dominant in the engineering literature. In this context, the optimization of ergonomics was also linked to eliminating potential sources of error.

In some interviews, however, solution developers did address the dangers of disempowering the workforce:

> “So from a business perspective, of course, you want to stabilize the processes, you want to minimize the degree of freedom somehow, because this degree of freedom, it just brings error rates and variances and all these problems. From a more humanistic perspective, of course, you sometimes think to yourself, what are you actually doing, would you want to work like that yourself?” (IV5)

4.3 New forms of control

From the perspective of solution developers, major gains in work ergonomics and production efficiency can be achieved when data from work processes are comprehensively recorded and evaluated. Our interviewees discussed situations in which the technology recognizes that a person is on their first day after vacation or is about to process a workpiece that has not been in the production program for a long time. Other examples relate to so-called "performance-impaired" employees (people who due to health limitations can no longer work at the required speed), where wearables could provide individualized support for these people during work processes.

> "If you look at the potential, about using [...] the data. I'm not even necessarily talking about vital data yet, but just about analyzing the location and a certain behavioral history of the employee. You can do a lot and you can also avoid a lot of superfluous activities that no worker enjoys. Information search, information clarification is always a topic that no one really talks about in practice. And here, of course, wearables offer a great deal of leverage. But I also have to use data that I can't use today and don't want to use. [...] [One could] completely individualize workplaces, always in parentheses, as long as individualization does not stand in stark contrast to productivity. But the workstation could adapt to your body: [...] the work area, which also adapts to my body height, which arranges the material [...] depending on whether I am left- or right-handed. The work speed could adapt a bit to my current situation. That could be my pulse now, but it can also be, I think, a little bit easier to implement the question of when I last worked on something like this, or whether I'm just coming back from vacation or have been there for a while, or whether I just had a mistake or not." (IV9)

Solution developers were very aware of the potential to use these technologies to control employees. However, the interviewees repeatedly referred to the opportunities for improving work ergonomics and the possibility of employees turning off the devices to escape control:

> "In a way, the company also benefits, but primarily the employee. It would be possible, for example, perhaps to store the value of when it was particularly stressful for him." (IV4)

With regard to the collection and evaluation of data, one interviewee drew a comparison with private smartphone use, in which most people already voluntarily disclose a large amount of personal data, either consciously or unconsciously. Accordingly, at the company level, better ergonomics would be exchanged for the provision of personal data, and one might expect a high acceptance of this data use by employees:

> "After all, we already have something that works more or less like this, and that's our smartphones, which collect so much information about us. In that respect, data glasses are not that different. People will adapt over time." (IV3)

The control possibilities are particularly high in cases in which wearables record the body functions of the employees, obtaining data about their fitness, performance, and even health. Technology developers discussed which functions they should develop and build in the devices:

> "We discuss in the team whether to include the heart rate monitor or not [...]. So is it really that useful, do the positive functions convince us so much that they outweigh the

negative functions? So the horror case is, the pulse rises when two workers meet; the pulse rises because one is in love with the other—and I can figure out that the one is homosexual. That's how I could interpret the data set. And that's a danger, it's kind of there. How can we prevent that? Do we not install the sensor there in the first place? [...] Do we encrypt the [data set] already, so that the customer will never see this data set or will never get it? Then we have a big responsibility over that data set. Do we want to face that responsibility or do we say to ourselves, 'oh, then we won't record the data at all' because that's just very personal?" (IV1)

It is clear here that the solution developers are well aware of the dangers of the technology they have developed but do not have a strategy to address these dangers.

4.4 Work organization—a nonissue

While the focus of solution developers lies in optimization and ergonomic improvement at individual workstations, they largely ignore questions of work organization and division of labor in work processes. Our interviews with solution developers show that wearables are primarily incorporated into existing work processes, with few attempts to introduce the technology alongside a fundamental redesign of work organization.

> "In the work scenarios that I have come across, [it is] just the case that the work process has been left as it was and the data glasses have now been poured in there as a new work tool. Sometimes that fits better and sometimes worse, sometimes you put a little more effort into the adaptation, sometimes a little less." (IV10)

However, when asked about the possible scope for redesigning work organization, the solution developers refered to the still immature state of wearable technology. The fundamental goal of technological development is seen as the enabling of employees to configure wearable applications according to their needs. The software systems must therefore become adaptable and usable by employees with different skill levels, process knowledge, and support needs. However, the interviewees emphasized that wearables-software technology is still far from having such adaptability.

> "We want to get to the point where you really assemble and configure everything yourself, from the machine to the individual software components, and it's all very, very simple. So really drag and drop. Unfortunately, we are not there yet, [...] we are in the middle of development." (IV4)

Technology developers also discussed the effects of the introduction of wearables on communication in the company. These effects were quite mixed. On the one hand, wearables enabled more communication:

> "[If] the message appears on the smartwatch, 'go back to the machine, insert a new part now', or whatever, but I can't go there right now, then I can also call for support via the smartwatch. In other words, I say I want support at the machine, press a button, then it is

> broadcast to the other smartwatches of the other workers and they can then accept or not accept the order. And so you practically have self-organization." (IV4)

At the same time, wearables could also isolate people because they limit opportunities for communication not controlled by the IT system:

> "Of course, now I don't have to walk all the way to the measuring room, and this means that I can't talk to my buddy in the measuring room; yes, actually that's an issue." (IV4)

4.5 Functional view of workplace participation

Almost all wearables' providers reported that they had to understand the rules of co-determination in companies, because the use of wearables affects works councils' co-determination rights according to §87 of the Works Constitution Act. The use of wearables can impact working hours as well as work breaks, as they are worn directly on the body and orders can reach workers even during their breaks. Wearables constitute technical applications that can monitor employee behavior and performance. They could increase the risk of workplace accidents and illnesses, for instance, if a smartwatch distracts an employee or data glasses lead to eye problems. Furthermore, wearables can change work tasks.

In principle, the solution providers we interviewed had relatively little contact with the works councils. This communication was mostly handled by the management of the customer companies.

> "Well, I usually do not speak with the works council, except when I'm there on site, then I can talk to them a bit more intensively. Now when I communicate with the company remotely, the works council is not one of the actors with whom I get in touch." (IV5)

In most of the interviews, the solution developers described the involvement of the works council (or employee representatives in general) in technology development as very important—a surprising finding. Works councils were perceived by the solution developers as quite supportive, particularly as works councils support ergonomic improvements. Those solution developers who had already carried out projects in industrial companies also emphasized that it was necessary to involve the works council right at the beginning of the projects to avoid jeopardizing successful implementation:

> "Well, I think it definitely makes sense to involve the works council [...]. In some cases, they have certain power and can bring a project to a standstill. In this respect, I think it's good to involve the works council right from the start." (IV5)

At the same time, in a number of the interviews we conducted, the solution developers complained that co-determination of the recording and analysis of data led to restrictions, making it more difficult to exploit the potential of technology:

> "I think we could record a lot more data, but there is a company agreement on this as to what data can and cannot be recorded. These are a few hurdles that restrict us greatly.

This is the kind of data that could be collected additionally in order to create added value. [...] For example, in production no one had any idea how often a worker actually goes into the warehouse to check whether parts are in order or not [...]. It would be an exciting thing to know this. Unfortunately, the works council is again trying to prevent the analysis of personal data, such as vital signs, as much as possible. Of course, you would have to have very personal data in order to know what has happened. Of course, that also entails risks." (IV4)

The solution developers' overall view of co-determination by works councils is ambivalent. The general approval for co-determination stands in contrast to the partially skeptical perception of works councils as "naysayers". At least in some interviews, this was related to a "functional" understanding of co-determination: The role of works councils was seen primarily as generating support for technology implementation, rather than shaping the technology itself.

4.6 Conclusions

Wearable technology is still in its nascent phase (at least with regard to its operational use) and a large number of design decisions still need to be made: Which sensors should be installed (e.g., heart rate monitors), which functionalities should be defined, and how should wearables be integrated into corporate IT infrastructures?

What positions do solution developers take in the process? Our interviews reveal a mixed picture. On the one hand, solution developers emphasized the importance of involving employees and their representatives in technology implementation and highlighted the potential for improving work. At the same time, a number of the interviewees revealed a more restricted perspective:

- This included, first, a perception of human workers as potential sources of error in the work process that need to be controlled technically—a persistent perception that is deeply rooted in Taylorist concepts of work design, despite having been repeatedly criticized in research and in practice (Kern/Schumann 1984).
- Second, solution developers emphasized the functionalities of wearables with a focus on optimizing individual jobs. There is a lack of a more holistic approach that takes an overarching view of the organization of work and the internal division of labor and considers which functionalities of the software are needed.

Solution developers' "engineering ideologies" regarding wearables are thus more varied than previously described. The classic contributions to LPT (e.g., Noble 1978) identified a dominance of managerial control interests. In our interviews, although control and rationalization interests were evident, there was also an emphasis on ergonomics and a clear view of the surveillance dangers associated with wearable technology. The views of solution developers here reflect the ambivalence of the public discussion on Industry 4.0, in which both utopian and dystopian elements can be found (cf. Hirsch-Kreinsen 2017; Butollo et al. 2019). Some solution developers echo the "solutionism" of Silicon Valley (Morozov 2013), focusing on technically solving social problems. However, the solution developers also clearly name the limits and dangers of the technology, likely because they are involved in a large number of development and pilot projects in cooperation with different companies in which the current restrictions of wearable technology are very clear.

Our interviews show that the development and usage of wearables in the workplace is still characterized by considerable openness, with a lot of experimentation in companies.

5 Wearables in the workplace—case studies

Martin Krzywdzinski, Maren Evers, Christine Gerber

The impact of wearables on work varies significantly depending on the specific processes in which they are used. In our case studies, we distinguished three major processes. First, there is logistics, and in particular commissioning, which is the major implementation field for wearables. Second, there is manufacturing, particularly machine operation. Third, there is the introduction of wearables in training processes.

5.1 Wearables-based assistance systems in work processes in logistics

Logistics work, and picking in particular, is a focus for the use of wearables and digital assistance systems in general. These work processes have been heavily restructured since the 1990s, as the reorganization of material flows (switching to the pull principle and just-in-time delivery; see Shimokawa/Fujimoto 2009; Krafcik 1988) is at the core of lean production as the dominant production system.

Since the 1990s, the triumph of lean production has brought about considerable upheavals in logistics. To reduce material inventories and accelerate material turnover, processes in logistics have been standardized and optimized by value stream mapping (Klenk 2013; Knössl 2013). The reduction of material inventories and just-in-time organization have put pressure on industrial contract logistics, as even small errors in the supply of production processes can lead to serious disruptions in production due to a lack of material buffers. Retail logistics has been similarly restructured by lean management, making its services more demand-driven and flexible (Jaehrling et al. 2018, Fernie/Sparks 2014, Mulholland/Stewart 2014). The pressure to reduce errors has also led to increasing technical control of logistical processes and picking in particular.

As early as the 1960s, databases began to be developed to enable companies to manage inventories with computers. This digitalization was boosted by the introduction of the first barcode systems in the 1970s, as information about material stock and material movements could now be digitally recorded directly on site (which is of central importance for the data quality in databases). The development of databases in logistics has evolved since the 1960s, but it received a boost in the 1980s with the proliferation of enterprise resource planning (ERP) systems and electronic data interchange (EDI), leading to the emergence of warehouse management systems (WMS) in the 1990s (Bonacich/Wilson 2008; Ten Hompel/Schmidt 2008; Cockburn 1988). ERP systems boosted the availability and manipulation of data for planning work processes in companies. They formed the umbrella under which the WMS operate. In this process, the WMS received information from the ERP system about the orders they process. They themselves managed information about the warehouse structure, material stocks, material receipts and issues, and much more.

In the everyday life of logistics workers, a combination of paper lists and barcode scanners was still prevalent in the 1990s. Workers received orders in the warehouse printed out on paper lists and acknowledged the work steps performed by scanning barcodes, which directly digitally recorded changes in the material inventory. However, further steps in automation began as early as the 1990s. On the one hand, there was the introduction of automatic recording of material movements, for example with the aid of RFID chips attached to material containers (Bonacich/Wilson 2008). On the other hand, efforts have been made to provide greater control of logistics workflows (for example, by prescribing work steps via computer screens) and to monitor them to reduce picking errors. The introduction of wearables in logistics continues these processes.

The increasing technical control of logistics processes has been accompanied by a focus on semi-skilled labor in the area of warehouse workers (Ortmann/Walker 2018; Ittermann/Eisenmann 2019), but this does not mean that particularly pronounced automation processes are taking place (Gutelius/Theodore 2019). Although planning and control processes are already highly automated, the picking of goods (gripping, loading, unloading, and assembling) relies on the dexterity of human workers. But how is this process changing with the introduction of wearables and digital assistance systems?

5.1.1 Overview of the case studies

A total of seven case studies were conducted in logistics. Detailed case study portraits can be found in the appendix of this report; we present a brief overview of the case studies here. The case studies come from a variety of industries, with the automotive industry being particularly well represented with four case studies. The case studies are almost exclusively about picking processes, in which different forms of wearables were used in conjunction with digital assistance systems: data glasses, pick-by-voice systems, smart gloves, and smartwatches. In five of our cases, the wearables were already in regular use in operations, while in two cases they were pilot projects, one of which (CarLog2) was considered a failure by the company and was not continued. In the case of one company (ElectroLog), it was unclear at the time of the study whether the company would implement the technology in regular operation beyond the pilot project.

Table 5.1: Overview of the case studies

Case	Industry	Employees (plant)	Employees (logistics area under study)	Use case
FoodLog	Food production	240	80	Pick-by-Voice in order picking
CarLog1	Automobile	2000	45	Data glasses in order picking
CarLog2	Automobile	>5000	– (pilot project abandoned)	Data glasses in order picking
CarLog3	Automobile	570	80	Smart gloves in order picking
CarLog4	Automobile	400	400	Data glasses in order picking
RetailLog	Retail	2000	2000	Smart gloves in order picking
ElectroLog	Electronics	1000	– (pilot project)	Data glasses and smartwatches for workers supplying SMD assembly machines

Source: Authors.

5.1.2 The implementation process: goals and experiences

Three types of motives and objectives can be distinguished for the implementation of wearables in logistics areas. The first objective is to streamline logistics processes. Companies introduce wearables to eliminate unnecessary handling of paper lists or hand scanners and to speed up logistics processes. This is accompanied by the second goal of improving the ergonomics of logistics processes. By improving ergonomic conditions, companies in turn hope to reduce disruptions and errors resulting from poor working conditions. Finally, the third goal is simply to try out the technology, test its use, and develop skills in the use of wearable technology.

Table 5.2: Motives for the introduction of wearables

Case	Motives for the introduction of wearables
FoodLog	Legal documentation duties; rationalization goals
CarLog1	Reduction of errors through better ergonomics; exploring the potential of wearables (data glasses)
CarLog2	Exploring the potential of wearables (data glasses)
CarLog3	Reduction of errors through better ergonomics
CarLog4	Rationalization goals; showing technological innovativeness
RetailLog	Rationalization goals; improvement of ergonomics
ElectroLog	Exploring the potential of wearables; reduction of errors

Source: Authors.

Not all wearable technologies were regarded as ready for use in normal operations at the time of the study. Some pilot projects with data glasses were abandoned. Only one company in our sample (CarLog1) rated data glasses technology as ready for deployment and implemented it in normal operations. After conducting pilot projects, three companies (CarLog2, CarLog4, and ElectroLog) decided that data glasses were not suitable for use in the work process for technical and ergonomic reasons. They were still too heavy, the display was too small (or too slow), the field of view too limited, and in some cases the batteries were not powerful enough. However, CarLog4 and ElectroLog decided to use IT systems developed in pilot projects with data glasses in combination with smartwatches or 'smart' wristbands with RFID chips.

5.1.3 Impact on job contents and skill requirements

There were patterns in the logistics case studies. In most cases, the introduction of wearables and their associated digital assistance systems had a limited impact on work contents and skill requirements. Logistics processes had long been highly streamlined, organized according to lean principles, and equipped with digital assistance systems. In these cases, the implementation of wearables continued long-running trends.

Where the introduction of wearables was accompanied by a digitalization push, entailing a switch from paper lists to completely digital systems, somewhat larger changes were observed (primarily in FoodLog, partly in CarLog4). Here, the introduction of digital assistance systems implied a reduction in work content. Previously, workers had to plan their picking routes themselves, but now the software took over and showed them the sequence of work steps and the locations of the goods or parts.

However, it was striking that workers had positive perceptions of digital assistance systems and wearables in the FoodLog and CarLog4 case studies. While wearables increased the technical control of the work process, they also reduced stress. Work regimes in the case studies were often characterized by very tight staffing (to the point of understaffing) and a great deal of time pressure when taking orders from internal or external customers. The clocking of customer orders was the central mechanism of performance regulation here. In this context, wearables enabled limited time savings that slightly reduced work intensity (at least while performance targets remained the same). In addition, as workers were guided in the work processes by the software, the system (rather than the workers) was responsible for completing the work in a very tight timeframe. Where delays occurred, workers were able to argue that they had simply followed the instructions of the system.

In the FoodLog case, a pick-by-voice system was introduced that guided workers step-by-step through all picking operations, taking over all the planning. It replaced a paper list system in which pickers were responsible for all the planning. However, this scope of action and responsibility was perceived as stressful given the time pressure. One picker argued:

> "If you want to talk about positive stress—not here. No, that was a strain, that was a tremendous strain. So we were loading, I think, products for around 400 customers a day. That was stress, that was really stress." (IV17)

Accordingly, the new pick-by-voice system was seen as a relief by the workers. The situation was similar in the CarLog1 case. Here, pickers worked on an assembly line, with call-offs from the line dictating the work cycle. A pick-by-vision system based on data glasses was introduced, replacing handheld scanners. Although the process had changed little, workers reported a reduction in workload:

> "I can work much more quietly with the glasses and have more time to take a breath. With the scanner, I sometimes lost time, had to walk twice to put the scanner down and pick it up again. [...] With the scanner, it was really psychological pressure, whether I will be able to finish my tour on time." (IV20)

Our case studies also illustrate the different ways in which companies can design systems. In the RetailLog case, the company introduced a wearables-based assistance system that explicitly gave employees discretion in how they use it. Employees were free to decide whether to follow the instructions of the digital assistance system or to plan the sequence of work steps themselves. As long as all steps were carried out and digitally confirmed, they could deviate from the system's suggestions. This design is certainly more human-centered than the relatively rigid systems we found in the other case studies (where workers had to follow the orders of the system), but it also presupposes a setting of performance targets that leaves employees time to plan their own work steps. The works council emphasized that the company set performance targets that could actually be achieved in the given time, at a pace that did not completely exhaust the employees.

5.1.4 Control and surveillance

There is no doubt that the use of wearables increases the potential for technical control at work. However, surveillance of workers was not one of the companies' goals. In four case studies, the use of wearables was regulated by company agreements that prohibited the storage of personal data and its evaluation for behavioral and performance monitoring. In two other case studies, such agreements had not (yet) been concluded for the sole reason that wearables were only used in pilot projects. The works council had only not yet concluded such an agreement in one case, where it had met with resistance from management.

This regulation of wearables points to the special framework offered by German co-determination law. As outlined in Chapter 2, the German Works Constitution Act gives works councils a right of co-determination regarding technologies that can be used to monitor performance and behavior. The pursuit of such goals is essentially barely possible without open conflict with the works council, and given the legal situation, it is even difficult when management is willing to engage in such a conflict. It should be noted, however, that our sample only included companies with works councils. We expect that the management of companies without works councils might use the potential of wearables to control workers, but there is no empirical evidence regarding the strategies of these companies.

Table 5.3: Agreements between management and works council on the use of wearables

Case	Agreements between management and works council on the use of wearables
FoodLog	Yes
CarLog1	Yes
CarLog2	No (as project only in pilot phase)
CarLog3	Yes
CarLog4	No; management does not consult technology introduction with works council
RetailLog	Yes
ElectroLog	No (as project only in pilot phase)

Source: Authors.

Certainly, despite strict regulation through company agreements, supervisors might still be able to access individualized data created by wearables—technically, this possibility certainly exists. However, works council members emphasized that company agreements preclude this data from being openly used in performance appraisals or other contexts. One works council member from RetailLog argued:

> "I will tell you about the actual practice in our company. Even if you could collect this data, if it was technically possible... There is also technical data that you can't fend off and where you say, 'ok, this has to be collected,' there is nothing you can do about it. But even then, this data will never be analyzed or used against workers." (IV28)

Several works council members also emphasized that analyzing wearables data to monitor performance would involve considerable effort without much added value for management, as the time pressure created by customer call-offs was sufficiently high and it was already easy for supervisors to see whether workers were keeping up with processing call-offs.

Nevertheless, the issue of data protection was not without problems. This issue was not always very visible to workers, and works councils had to mobilize workers to create support in the workforce for the regulation of wearables and the prohibition of individual performance monitoring. Workers' perceptions often focused on ergonomic issues. In many cases, moreover, employees already saw the introduction of a new technology such as wearables as an upgrade that they welcomed, without having privacy issues immediately in mind.

5.1.5 Impact on employment

Our case studies show that the use of wearables does create efficiencies by freeing up workers' hands and eliminating the need to handle lists, hand scanners, and devices to enter data. However, wearables only had real impact on employment in cases of companies which lagged behind in their digitalization and were now making the big direct leap from paper lists to paperless logistics guided by digital assistance systems (FoodLog, CarLog4). In the other cases, efficiency gains primarily reduced the time pressure on employees, minimizing disruptions and errors. One works council argued:

> "It probably only increases [productivity] by a few seconds, but if you extrapolate that..." (IV28)

The introduction of wearables did not lead to a tightening of performance norms in the short term, and the small gains in time were actually experienced by employees as making their work easier. Management saw the reduction of errors in the work process as the main impact of wearables. However, lean organizational concepts in logistics usually lead to regular (e.g., yearly) increases in productivity norms and often in situations already characterized by understaffing. It is likely that the time gains achieved through the introduction of wearables will be "recovered" in the medium term when productivity norms are increased.

In the two companies where wearables replaced paper lists, there were significant employment savings of between 17% and 50% of jobs. The employees in question were not dismissed, but rather reassigned to other work areas. It can be assumed that the other companies studied had already realized these efficiency gains when they had completely digitalized their logistics.

Table 5.4: Impact of wearables on employment and performance targets

Case	Impact on employment and performance targets
FoodLog	Reduction of employment in order picking by 50%
CarLog1	Small efficiency gains; no impact on employment and performance targets
CarLog2	– (pilot project)
CarLog3	Small efficiency gains; no impact on employment and performance targets
CarLog4	Reduction of employment in order picking by 17%
RetailLog	Small efficiency gains; no impact on employment and performance targets
ElectroLog	– (pilot project)

Source: Authors.

5.1.6 Role of works councils

The relationships between works councils and management in our case studies varied widely. In some cases (e.g., RetailLog, ElectroLog, CarLog3), the relationship was cooperative and no conflicts emerged in the regulation of the use of wearables.

In other cases, management was willing to find common ground with the works council, but exerted pressure by actively promoting the new technology to employees before an agreement was reached with the works council. Since employees were often very interested in trying out wearable technologies, works councils found themselves in the position of having to dampen employee approval while promoting their concerns about data protection and safeguards for employees (e.g., voluntary use and testing of ergonomics). This required both technical expertise from works councils and good communication skills.

In one case, the works council was relatively weak (due to weak unionization in the company) and was barely informed and consulted by the company with regard to technological changes. This certainly reflects the situation at a number of logistics companies. The priorities of the works council here were to increase union membership and the support of the workforce. The regulation of wearables was not a central priority, and the works council did not engage with it.

These examples illustrate the demands on works councils in regulating new digital technologies. Works councils must sensitize employees to the critical aspects of new technologies, even when employees themselves are eager to experiment—something that works councils welcome. This requires very good communication skills and a good knowledge of the technologies. As the case studies show, works councils are successful in these projects where they have motivated works council members who are committed to this communication with employees (FoodLog) and where they manage to change the way they work. Bargaining with management over digitalization projects (including the introduction of wearables) often requires project-based work in which works council members are involved from the very beginning, working with management and employees, developing and contributing their positions in the process (RetailLog). Such a way of working is time-consuming and also requires openness on the part of both works council members and management. Accordingly, it is also only possible in contexts in which there is a corresponding trust between the two sides.

5.1.7 Conclusions

The case studies in logistics show that management strategies are primarily driven by efficiency goals and the desire to try out new wearable technologies. While the use of wearables and assistance systems partially increased the technical control and standardization of the work process, the potential of wearables to individually track employees was not a direct goal in any case study. It should be noted that the German Works Constitution Act gives works councils the power to prevent such monitoring.

The assistance systems and wearables examined in the case studies were definitely able to tap into efficiency potential. In particular, where plants made the leap from paper-based picking to digital systems, efficiency gains were evident. Where pilot projects introducing wearables failed, this was mainly due to the lack of robustness and poor ergonomics of wearables (especially data glasses).

Two scenarios emerge in the case studies regarding the effects of wearables and assistance systems on work and the perceptions of employees. In the first (and most common) scenario, wearables and assistance systems were positively received, although they restricted the job discretion of workers and intensified technical control. However, these case studies took place in work contexts characterized by high time and performance pressure due to the clocking of orders from internal or external customers (and partly due to understaffing). By enabling more efficient work, wearables reduced work intensity. In the already highly standardized and controlled work environment in logistics, the increase in technical control for employees apparently weighed less against the (small) time gains. We were only able to observe a short time window, but in our case studies the introduction of wearables was not associated with a tightening of performance targets. However, it is quite possible that the small time gains achieved by wearables will be reversed during following rationalization rounds, common in lean production systems.

Only one case (RetailLog) showed a different, second scenario. In this case, the setting of performance norms for the employees is designed in such a way that the employees can do their work without being rushed. Here, the assistance system was also designed to be less rigid, so workers retained the ability to decide and plan the sequence of work steps themselves. This was rated positively by employees. A human-centered design of assistance systems and wearables that supports and preserves employees' scope for action and decision-making depends on employees also having time to plan and make decisions. In contrast, in contexts characterized by great time and performance pressures, rigid systems that efficiently guide workers through the work process are also experienced by workers as a relief.

5.2 Wearables-based assistance systems in manufacturing work processes

Manufacturing is another important application area for wearables and digital assistance systems, with our literature review revealing applications in assembly, machine operation, and maintenance and repair. The use of assistance systems also has a long history in manufacturing. For a long time, assistance systems usually took the form of written and pictorial representations of standard work procedures attached to the workplace or mechanical solutions, such as Poka Yoke (cf. Chapter 2.1).

In the 1990s, computers and computer screens began to be used to display information and instructions directly at the workplace. In the 2000s, the spread of the mobile internet enabled the use of mobile devices for assistance systems.

Manufacturing and logistics share similar goals in introducing assistance systems and wearables: standardizing processes, reducing errors, and increasing efficiency play an important role (Krafcik 1988; Springer 1999; Liker/Hoseus 2008). However, the implementation of wearables in manufacturing processes is also driven by the aim of increasing the flexibility of personnel deployment, especially in the areas of machine operation and maintenance and repair. According to lean production concepts, management should attempt to organize the work processes such that automated workstations do not require employees to permanently monitor the machines despite having nothing to do for a large proportion of their time. This "detachment" of people from machines has been previously attempted by installing large display panels, sound signals, and other solutions that are visible or audible far into the production halls, allowing workers to operate multiple machines (Sugimori et al. 1977). In the field of maintenance and repair, the flexibility problem also arises due to the problem of obtaining information. Resolving malfunctions often requires technical blueprints and instructions. Personnel deployment can be made more flexible if wearables can be used to communicate information about machine status, plans, and problem solving, regardless of location.

While making labor deployment more flexible may lead to an increase in the skill requirements of employees (for example, if they are to oversee a larger production area), there is also a risk of de-skilling associated with the use of digital assistance systems (Butollo et al. 2019; Baethge-Kinsky et al. 2018). Manufacturing sectors fundamentally differ from logistics in terms of workforce composition, as they are more heavily dominated by skilled labor. However, there are also differences within manufacturing. In assembly areas, there is often a mix between semi-skilled labor and skilled labor; in automated areas, the share of skilled labor is typically high (Kuhlmann 2004; Krzywdzinski 2021 and 2017); finally, maintenance and repair are almost exclusively skilled labor tasks.

From a business perspective, it may be useful to connect wearables and digital assistance systems with knowledge databases, thus supporting workers in machine operation or maintenance tasks. Technical information about individual machines could be objectively recorded in an assistance system, reducing the value of so-called "plant whisperers" who know specific machines so well that they can identify problems by sound or smell. We discuss below how far this goal was achieved by the wearables and digital assistance systems used in our case studies.

5.2.1 Overview of the case studies

A total of four case studies were conducted in manufacturing. Detailed case study portraits can be found in the appendix, so we will only present a brief overview of the case studies here. The case studies were again from different industries: the chemical industry, the electronics industry, and the steel industry. We were not able to conduct a case study in the field of assembly. Although references to the use of wearables in assembly processes are listed by several solution providers, our attempts to explore the field were unsuccessful for two reasons: In some cases, companies refused to cooperate; in other cases, the use of wearables in assembly processes was tried but eventually discarded. Our failed attempts to conduct case studies in assembly areas lead us to conclude that the use of wearables in assembly is not yet very widespread, primarily due to the immaturity of the technology. The use scenarios for assembly particularly emphasize data glasses as a technology to display assembly instructions to workers. Our study showed that, at least at the time of the study, data glasses were not yet technically robust and powerful enough for such use.

The use of wearables in machine operation and maintenance and repair appears to be making more headway. Our four case studies are from these areas. The main types of wearables used here are data glasses and smartwatches. In one case, wearables were already in regular use. In two cases, companies were conducting pilot projects that were considered relatively successful. One case represents an aborted pilot project. We do not consider this configuration to be a coincidence; rather, it represents the early stage of adoption of wearables in manufacturing processes, in which many companies are only exploring the possibilities of the technology in pilot projects.

Table 5.5: Overview of the case studies

Case	Industry	Employment (plant)	Area under study	Use case
ChemMain	Chemical industry	3,000	Maintenance	Data glasses + smartphones in maintenance
ElectroSup	Electronics	500	Maintenance, commissioning	Remote support via data glasses
ElectroMan	Electronics	1,000	Assembly (production)	Smartwatches for machine operators (pilot project)
SteelSafe	Steel industry	5,000	Maintenance	Data glasses for maintenance (abandoned pilot project)

Source: Authors.

5.2.2 The implementation process—goals and experiences

The motives and objectives for the introduction of wearables and associated digital assistance systems in manufacturing were very similar to those in the case of logistics. Here, too, the first objective was to streamline work processes. The main aim was to reduce employees' need to permanently monitor a specific machine, line, or manufacturing process, by using wearables to communicate information about the status of the process and any actions required to the employee. The second goal was the improvement of occupational safety. Some projects using wearables focused on monitoring the safety of employees and providing support in dangerous work situations. The third objective was simply to test wearables and digital assistance systems in manufacturing and gain understanding of their functioning and potential, without specific goals in mind.

Table 5.6: Motives for the introduction of wearables

Case	Motives for the introduction of wearables
ChemMain	Rationalization goals; work safety
ElectroSup	Rationalization goals; Exploring the potential of wearables (data glasses)
ElectroMan	Rationalization goals; Exploring the potential of wearables (smartwatches)
SteelSafe	Work safety

Source: Authors.

5.2.3 Effects on work content and qualification requirements

Because of the different usage scenarios, the effects on work content and skill requirements in manufacturing differed from those found in logistics. One goal of the projects was to deploy skilled workers in production and maintenance more efficiently and flexibly, completing a larger amount of work with the given number of skilled workers. Digital assistance systems and wearables reduced unnecessary information gathering times, waiting times, and travel times.

A typical example was the ElectroMan case. Here, a smartwatch was used on a partially automated production line, providing information about the status of the machines, status of order processing, material stock, and malfunctions. Employees could respond to messages on the smartwatch, for example, to confirm that they were taking on a task. The smartwatches were intended to enable employees to monitor multiple production lines. Previously, two skilled workers were responsible for one line. To monitor the line, they had to be close to it, even if this meant waiting times. With the help of the smartwatches, they could now also take on tasks that required them to be away from the line.

In the long term, some of the interviewees also considered it quite possible to link the digital assistance systems with knowledge databases, enabling less experienced workers in production and maintenance to perform complicated control or maintenance operations. This could raise anew the question of the skills requirements of employees. Today's systems already make it possible to locate malfunctions, call up blueprints, and other information, and even call in an expert via the Internet if necessary. Future systems could also automatically generate precise instructions for problem solving for different problem situations, though it is important to stress that today's technology is not yet that far advanced.

However, such automated problem-solving systems were not necessarily regarded as negative. Interviewees from both management and works councils considered the introduction of digital assistance systems to be sensible, even if they enabled workers with less experience to be deployed in complex jobs. In some cases (ChemMain), this was due to labor shortages and the urgent need to compensate for the impending retirement of many experienced skilled workers. In other cases (ElectroSup), managers and works councils emphasized the global footprint of the company and with it the need to locate production in countries where there is insufficient vocational training for workers.

Works council representatives underlined, however, that even elaborate digital assistance systems would not make skilled workers redundant. In some cases, such as the chemical industry, they pointed to specific legal requirements related to occupational safety. Automated equipment in the chemical industry can only be operated by workers with a high level of vocational training, regardless of the use of digital assistance systems. Here, wearables can support less experienced skilled workers but cannot replace specialized training. In other cases, works councils pointed to the expertise needed to work with highly automated equipment:

> "We will try to avoid having an electrical helper as a maintenance technician. [...] I have to have people pulling cables. They'll know they're pulling cables, and they'll get paid like cable pullers. And I can't let them, no matter how many google glasses I give them, operate the machines, because the wrong button pressed at the wrong time can have fatal costs and consequences." (IV31)

5.2.4 Control and surveillance

In the manufacturing case studies, surveillance of workers was not one of the companies' goals. Where the use of wearables and digital assistance systems had already moved beyond pilot project status, company agreements prohibited the use of data in monitoring individual behavior and performance; in one other case, such an agreement was planned once the pilot project was completed.

Table 5.7: Agreements between management and works councils on the use of wearables

Case	Agreements between management and works councils on the use of wearables
ChemMain	Yes
ElectroSup	Yes
ElectroMan	Not yet (pilot project), planned
SteelSafe	No, pilot project abandoned

Source: Authors.

A large number of issues had to be addressed in the regulation of data protection. One works council member described the major issues in discussions about regulating the use of smartwatches as follows:

> "We have to ensure hygienic conditions, so we have to make it clear that the watches are permanently assigned and not rotated. We need to make sure that people can turn off the watches at break time and not be interrupted. We have to make sure that there is no analysis of the data for performance monitoring, so that, for example, the data is deleted daily." (IV41)

5.2.5 Impact on employment

The use of wearables and digital assistance systems led to clear efficiency gains. These came primarily from the ability to detach production workers (such as machine operators) from specific machines or production lines and use their labor more flexibly. This led to a reduction in the waiting times during which employees had to be close to "their" machine to monitor it and were thus unable to take on other tasks. The use of digital assistance systems with wearables also allowed instant access to information in any work situation, reducing information retrieval times that occur when workers must first get information or instructions from a computer or manual.

The efficiency gains did not result in any employment losses, and no changes in performance targets were reported in the short term. However, the use of wearables and digital assistance systems had only recently begun in our case studies, or in some cases was still in the pilot stage. One works council member described his view as follows:

"We discuss this in the works council: will people be deployed more widely? Will jobs be cut? There is that danger. Our plant management promises that this will not happen. They want to use the time gains for people to work on new ideas, on improvements. We will see. In the past, we would have concluded an agreement at the beginning of such a process and try to fix rules for everything. Now we do it iteratively. We run projects and go with it. Everything is simply developing too fast for us to do it any other way. We're counting on building mutual trust." (IV41)

It is possible that after the introduction of the new systems, the organization of work will be changed, and employees will be assigned more extensive tasks to realize time efficiency gains. Depending on the scope of the changes, this may also be perceived as work intensification.

Table 5.8: Effects of wearables on employment and performance targets

Case	Impact on employment and performance targets
ChemMain	Small efficiency gains; no impact in the short term on employment and performance targets
ElectroSup	Efficiency gains; no impact in the short term on employment and performance targets
ElectroMan	Efficiency gains; no impact in the short term on employment and performance targets
SteelSafe	– (pilot project abandoned)

Source: Authors.

5.2.6 Role of works councils

In all of the case studies in manufacturing, the relationship between the works council and management was cooperative. The introduction of systems was negotiated, which enabled parties to identify a common line in terms of regulation. Management prioritized finding efficiency and flexibility gains rather than surveillance, facilitating the development of common positions with the works council. One works council (ChemMain) noted that the transparency about work processes established by the digital system was rather helpful for workers, making the huge workload and understaffing visible and rendering it easier for the works council to negotiate changes with management.

The wearables projects were also a considerable challenge for works councils. Many technology introduction processes had to be managed in parallel; it was often not clear at the beginning of the project what impact the technology would have. It was therefore necessary, as a works council, to enter projects with a certain openness and engage in a joint process with management, with the rules for the technology jointly developed step by step. One of the key prerequisites for this was a cooperative relationship between management and the works council.

5.2.7 Conclusions

In the case studies in manufacturing, we find management strategies primarily oriented towards efficiency and flexibility goals, as well as the desire to try out and test wearable technologies. We found that the surveillance potentials of wearables (in terms of individual tracking of employees) was not a goal in any case study. The corresponding potentials of the technology were addressed in negotiations between management and works councils, and solutions were found to rule out such use.

The assistance systems and wearables examined in the case studies were definitely able to tap into efficiency potential. The implementation of wearables in machine operation and maintenance showed a clear potential for more flexible and efficient personnel deployment. There is certainly a risk that the flexibility gained could be misused to intensify work, overstretching workers' areas of responsibility or undermining break times. In the case studies presented here, such dangers were addressed in negotiations between works councils and management. The extent to which the solutions found preclude future intensification of work could not be investigated, since three of the four cases involved pilot projects and had not yet been used in regular operations. For the same reason, no statement can be made about the employment effects of the new technologies.

Wearables and assistance systems had largely positive effects on work and employee perceptions, although most of our cases are only pilot projects. Works councils did raise the risk of the use of digital assistance systems leading to de-skilling in the long term. However, such risks were not seen in the short term. On the one hand, this may be because the primary goal of deploying wearables and digital assistance systems was to increase the flexibility of personnel deployment, which may also be accompanied by higher skill requirements. On the other hand, the limitations of the wearable technology itself may also explain this finding: the wearables can only convey a limited amount of information due to their (small) physical nature. Accordingly, the assistance systems used in our case studies were designed to provide quick access to basic information. They seem rather unsuitable for control and guidance in complex processes.

Human-centered design of assistance systems and wearables is clearly related to the work context. It is important to strike a balance between increasing the flexibility of personnel deployment and shaping performance norms and expectations to prevent work intensification.

5.3 Wearables-based assistance systems in training processes in manufacturing and logistics

In addition to the use of wearables and digital assistance systems in work processes, our research also encountered their increasing use in training processes. As Wu et al. (2013) argue, the use of data glasses in various AR, MR, and VR applications offers considerable potential for training. The new technologies can promote learning processes by enabling interaction with virtual objects to convey, consolidate, and test learning content. They can create new opportunities for knowledge transfer by enabling learning outside the classroom and in real-life contexts. Finally, wearables can be used to run simulations and teach learning content in a fun way.

However, while the new technologies have enormous promise, the reality was still modest, at least at the time of the study. The technology is still relatively new and applications are lacking. Creating training programs takes a lot of effort, often driving up costs and discouraging companies from using the technology (Wang et al. 2018). Accordingly, the use of wearables in training processes is in an initial and experimental phase. Our case studies report on these experiences.

5.3.1 Overview of the case studies

A total of five case studies were conducted on the use of wearables in training. Detailed case study portraits can be found in the appendix. The case studies are from the automotive, automation, electronics, and transportation industries. They are predominantly pilot projects for the application of data glasses in training processes in assembly and plant operation. Only one project (TransportTrain) goes beyond this application scenario and also includes modules used in vocational training.

Two of the four pilot projects were not continued by the companies, mainly because of the great effort and high costs of using the data glasses for training. These companies are waiting until the technology has reached a higher level of maturity with lower costs.

Table 5.9: Overview of the case studies

Case	Industry	Employees (plant)	Use case
AutoTrain	Automation	3,000	Data glasses for induction training in assembly (pilot project, abandoned)
ElectroTrain1	Electronics	1,000	Data glasses for induction training in assembly (pilot project, abandoned)
TransportTrain	Transport	-	Data glasses in vocational training and further training
CarTrain	Automobile	5,000	Data glasses for induction training in assembly (pilot project)
ElectroTrain2	Electronics	500	Data glasses for training on new equipment (pilot project)

Source: Authors.

5.3.2 The implementation process: goals and experiences

The central goals of using wearables were to facilitate and shorten training processes. Training processes generate two kinds of costs. Trainers are required and the training processes tie up their working time, and equipment is needed. At AutoTrain, the production line is slowed down for training processes, while in other cases, equipment must be taken out of regular operation to be used in training. The companies hoped that the use of wearables, and data glasses in particular, would result in savings. While instructors were still needed, workers could also perform certain training steps independently under the guidance of a program running on the data glasses. In addition, equipment could be simulated on the data glasses, reducing the need to remove equipment from productive operation.

Table 5.10: Motives for the introduction of wearables

Case	Motives for the introduction of wearables
AutoTrain	Shortening of training time, reduction of the required time of trainers, reduction of required equipment
ElectroTrain1	Shortening of training time, reduction of the required time of trainers, reduction of required equipment
TransportTrain	Shortening of training time, reduction of the required time of trainers, reduction of required equipment
CarTrain	Exploring the potential of wearables
ElectroTrain2	Shortening of training time, improving learning quality

Source: Authors.

5.3.3 Effects on the work contents of trainers and the training process

Potential changes to the work of trainers became clear regarding one point in particular. The design of teaching content for wearables and the support of training participants in their use became an important task. This required trainers to acquire new skills. First, technical skills, familiarity with the devices, and ability to develop content were required. Second, new pedagogical skills were also needed. In particular, the use of VR and MR glasses enable the simulation of work processes, which teaches workers how to cope with complex situations in a playful manner. Trainers must design and control simulation scenarios adapted to the level of knowledge of the training participants.

A distinction must be made between the use of VR, MR and AR solutions. VR and MR solutions were positively evaluated by both project managers and training participants. MR solutions enabled new forms of learning directly at the workplace, for example, by displaying information and explanations while working on real equipment. VR solutions enabled the simulation of complex processes, providing a learning experience otherwise only possible in real operations. Nevertheless, the MR solutions were not transferred from the pilot project stage to real operation, due to the effort and expense involved in developing training modules. There was a lack of flexible and easily applicable software for developing training scenarios, and this drove up effort and cost. The only solution studied that went beyond a pilot project and was used in real training processes was VR training at TransportTrain. This was a transportation company that needed to train large numbers of employees/staff for its trains on a recurring basis. Previously, real trains had to be taken out of service for these trainings, which was very expensive. The development of a simulation of trains in VR solutions required considerable effort, but realized great savings compared to the cost of shutting down a real train for training purposes.

The use of AR glasses was judged much more skeptically. These were tested in a case study (CarTrain) in learning processes for assembly. The content originally displayed on standard worksheets was simply output onto data glasses. Here, too, the training participants rated the use of the wearables positively, but tests showed that the use of the data glasses seemed to undermine learning success: Participants in the training without data glasses had better test results than participants with data glasses. This may be due to a kind of “navigation effect”. When the trainees follow the instructions on the data glasses, they do not have to take their eyes off the work object, they simply follow the instructions and rely on them. If, on the other hand, they work with the traditional representation on paper, they have to avert their gaze at least briefly from the work object, memorize the representation on paper, and then turn their attention back to the work object. This active memorizing could be responsible for the better test outcomes from those training without data glasses.

5.3.4 Control and surveillance, role of works councils

Wearables were not used to collect data on the participants in any of the training cases studies. The works councils ensured at the beginning of the projects that the use of the wearables was voluntary and that no one was obliged to participate in the pilot projects.

5.3.5 Conclusions

When using wearables (and in particular data glasses) in training processes, the focus is on reducing training time and effort, but in all case studies the content taught remained the same. The technologies certainly offer potential for efficiency improvements. They enable learning phases to be controlled independently by training participants and reduced the need to provide equipment and materials for training, especially when simulations can be used. However, the cost of developing training materials for data glasses was still very high, at least at the time of the study, which is why several of the pilot projects were not continued.

The potential of wearables in training processes lies primarily in VR and MR technology. In particular, the use of simulations and learning games has the potential to redesign training. The simple use of data glasses, on which the same information is displayed that was previously conveyed in the traditional way, appears to be relatively unpromising. Although this is simpler and cheaper, it does not lead to better training results.

Our case studies highlight the still early stage of development of the technologies. There is a great need for software development platforms that can create training content easily and quickly. In the ElectroTrain2 case, the company is working on developing its own platform and sees this as an important potential advantage.

5.4 Conclusions: Wearables in the workplace

Wearables are seen as an emblem of a new world of work. In utopian scenarios, they are envisaged as supporting employees in complex work processes, providing near real-time information about the work process, environmental conditions (e.g., hazards) and problem-solving paths. In dystopian scenarios, they are imagined as a means of comprehensively monitoring work by recording all work processes and the work environment via sensors and cameras, and even recording bodily functions such as temperature or pulse. Our study shows that wearable technology is still in the development phase and that companies experimenting with the technology are far from both the utopian and dystopian scenarios. This raises the question of which usage scenarios are emerging in everyday operations.

The analysis shows that the field of usage scenarios is narrowed down by two important factors. The first factor is the perspective of technology developers on wearable technology. These are primarily startups, founded by engineers and computer scientists, that are delivering initial applications for the industrial market. Our interviews show that technology developers' perceptions are characterized by a focus on optimizing individual jobs, with little concern for how work organization and the division of labor between different roles in the company could be redesigned. In addition, from the perspective of engineers and computer scientists, the human workforce is a potential source of error that must be controlled technically. Technology developers certainly see the danger that wearable technology could be used to monitor employees, but they also point to the potential of individualizing information for employees.

The second factor limiting the actual variety of usage scenarios of wearables is the impact of existing production systems and, in particular, lean production systems. Lean production is the dominant framework for management strategies (cf. Vidal 2020) and results in a focus on streamlining processes and increasing efficiency.

This focus leads to the following usage scenarios (research project question 2). In logistics, wearables are primarily used in the area of order picking, characterized by semi-skilled work. Wearables primarily guide employees in the work process, reduce job discretion, and standardize process flows. In manufacturing, on the other hand, wearables are used primarily in operating automated production lines and maintenance. They provide information, enabling more flexible use of labor on the shop floor. Workers can monitor larger areas with the help of wearables. As they receive all relevant information (such as material requirements and malfunctions), search times for information (such as localization of parts or machines in maintenance processes) are reduced. In both logistics and manufacturing, wearables are also being tested in training processes, in particular to reduce the time required for support by trainers. In all of the areas studied, wearables are leading to streamlining effects. Where processes were already highly digitalized before the use of wearables, the time gains are mostly small but still relevant. Where the introduction of wearables is associated with a major leap in digitalization, there are also employment savings.

Based on our theoretical framework, we expected that management strategies could go in two basic directions regarding the usage of wearables: a focus on efficiency improvement or a focus on surveillance and disciplining of workers. These two goals may or may not go together. Thus, achieving efficiency goals may not require or even rule out the intensification of surveillance of workers. Our case studies show that in industrial use cases, management focused on increasing efficiency. The efficiency gains from wearables were achieved through greater technical control of processes. What we did not find in our cases, however, were management strategies of surveilling employees in the sense of "control of microsocial and inner processes in open-ended working environments" (Moore/Robinson 2016: 2781). In all our case studies, agreements were reached between works councils and management that prevented technology from "rendering workers permanently visible to management" (Moore/Robinson 2016: 2779).

There are many reasons for the focus on efficiency gains and the lack of surveillance targets. Some of our case studies questioned the extent to which such monitoring could even provide management with new information that managers did not already have. What is more important, however, is the specific negotiation arena that shapes our case studies. All of the cases we studied can be assigned to the core area of the "German model" because they each have works council structures and are also regulated by collective bargaining agreements (even if, in some cases, unionization is low and the position of works councils is relatively weak). German co-determination law gives works councils leverage to exclude the use of wearable technologies for the monitoring of individual behavior and performance. Further opportunities for works councils to take action arise from occupational health and safety law as well as the EU's General Data Protection Regulation (for example, in the context of a risk assessment or a data protection impact assessment). Our cases, however, have a bias. We are unable to assess the extent to which companies without a works council use technologies such as wearables for surveillance goals.

While works councils have considerable influence on technology introduction, they also face huge challenges. The pace, variety, and experimental nature of current technology introduction processes require works councils to work on a project-by-project basis, monitoring many projects in an open-ended manner. This is only possible under specific conditions. The works council has to be large enough with the appropriate technical expertise. This also requires intensive communication with the workforce to understand their concerns and interests, and communicate the limits and dangers of the technologies. Some of our case studies show that some employees were very open to the use of wearables, as they expected them to make their work easier or saw the introduction of new technologies in their workplace as something interesting and a sign of appreciation. However, the potential dangers with regard to data protection were often not clear to workers, and works councils had inform the workforce of the problems inherent to the technology while avoiding being perceived as a "naysayer."

What are the consequences of the introduction of wearables for work contents and skill requirements? Here, it is useful to distinguish between the usage scenarios in logistics and in manufacturing.

In logistics, the increased technical standardization and control through wearables led to a further step in the reduction of employees' job discretion. Where work processes were already highly standardized and digitalized, this step was relatively small. Where companies jumped from a relatively less digitalized situation dominated by paper lists to the use of a digital assistance system with wearables, this step was larger. The use of wearables is also mostly positively received by employees. They emphasize that wearables help reduce the number of errors and improve the workflow, since employees have their hands free and do not have to handle mobile devices. Given the very high time pressure reported in many case studies, wearables reduce work intensity.

We can explain this perception using the JDR model we introduced in Chapter 2. In a highly standardized and time-pressured work process, wearables (and digital assistance systems) reduce work demands by relieving employees of planning tasks. At the same time, they can be perceived as a resource that helps in situations of uncertainty.

According to the JDR model, the relationship between requirements and resources is central to the perceived stress level. Wearables and digital assistance systems can be perceived as stress-reducing, even if they limit the job discretion of workers.

Employees do not passively adapt these technologies but can actively adopt them and also resist them. In the case studies we examined, however, criticism and resistance were primarily ignited by questions of the ergonomics (and in some cases the lack of functionality) of the wearables. Employees rejected working with wearables (and especially data glasses) where they were perceived as unergonomic or did not function robustly. We found no conflicts related to the role of wearables in standardizing and controlling work processes.

The findings of one case study (RetailLog) are worth highlighting. This case study deviates from the dominant pattern in logistics. While in all the other case studies the digital assistance systems used wearables to communicate instructions about work steps and their sequence to workers, in the case of RetailLog, the assistance system suggested a specific sequence of work steps for workers to complete the order, while the workers themselves decided how to proceed. This case study represents a human-centered use of wearables and digital assistance systems that stands out positively from the other logistics cases. However, the prerequisite was the appropriate setting of performance targets, giving workers time to plan their own work steps.

The case studies in manufacturing show somewhat different patterns to logistics. Here, the use of wearables primarily led to the flexibilization of labor deployment, a partial expansion of the responsibilities of skilled workers, and thus increased skill requirements. The goal here was not to standardize, but to detach skilled workers from specific machines and reduce waiting times. This was seen as positive by workers, but there is a risk that this flexibility could lead to an increase in work intensity. Negotiations between works councils and management on the introduction of these systems have therefore focused on issues related to the definition of performance standards, and the right to switch off wearables during break times.

Our findings show that the effects of the introduction of wearables depend significantly on how performance regulation is structured in the workplace. The German approach of co-determination, aimed at balancing company and workers' interests, facilitates the development of human-centered designs of digital assistance systems and wearables. Where understaffing and management-by-stress prevail, such design is hardly possible.

The limitations of our study lie primarily in the time period in which it was conducted. We captured an early phase of wearables adoption, where the technology is not yet fully mature and is only being tested in companies. While rationalization effects are evident in this early phase, negative effects of de-skilling and intensification of work are hardly evident. It should be emphasized, however, that this does not prejudge the long-term effects of wearables. Which path the adoption of wearables will take will depend on a number of factors: management strategies, the strength and strategies of works councils, and also the workers themselves. Emerging demographic shifts and changes in industrial employment will be important in this regard. In our case studies, management argued that wearables can be a support during skills and labor shortages. As population growth stagnates, and the attractiveness of vocational training and industrial work declines, companies cannot rely on skilled labor to the same extent as before. In this context, wearables and digital assistance systems can offer an opportunity to deploy less skilled employees and guide them in work processes. Such a scenario, however, carries the risk of a “self-fulfilling prophecy” if companies refrain from investing in training and rely on technological solutions. Securing investment in skilled labor therefore remains an important prerequisite for good quality of work.

6 Employees’ perspectives on wearables—online survey

Sabine Pfeiffer

In our case studies, the introduction of wearables in the workplace was still often at the pilot stage, with only a few employees working with this technology. Nevertheless, we were interested in the conditions under which employees are willing to accept the use of this technology and where the limits of this acceptance lie. Given the limited number of case studies already available, we decided to conduct a survey of employees beyond our case studies. The goal was to collect employees' assessments of the use of wearables on a broad scale. More than 1,000 employees were surveyed from various occupations and industries in which physical activity plays a role.

After introducing the sample and the considerations regarding the questionnaire design (for the questionnaire, see Appendix 9.1), we provide an overview of the general assessments of employees of the use of wearables in the workplace, complemented by the analysis of their opinions regarding the handling of data (Chapter 6.3) and the benefits of the wearable technology at work (Chapter 6.4). The aim is to investigate what trade-offs employees may be willing to make with regard to data protection, and the concrete possibilities of this technology to improve working conditions.

6.1 Sample and questionnaire design

The survey sample was drawn from an online access panel (Respondi). The survey was sent to persons in an employment relationship (we excluded persons looking for a job, or retired with secondary employment). As wearables are used in jobs requiring manual work, we focused on two major criteria to recruit people from the online access panel: “Do you work predominantly in the office (whether in a home office or in the company)?” and “Do you perceive your work as physically demanding?”. Only those who indicated that they were *not* working in the office or that they perceived their work as physically demanding were invited to participate in the survey. For example, we wished to separate people who work directly in nursing from those who undertake nursing in the office. On the other hand, we wanted to include academic occupational groups who have to be physically active (e.g., in field work in surveying or architecture). The goal of the topic-centered sampling was to focus on occupational groups potentially affected by the implementation of wearables.

1,124 people accepted the invitation for the survey, of whom 1,091 completed the questionnaire in full. After excluding persons who did not fit our criteria (e.g., retired persons) we ended up with 1,046 valid responses.

The sample was largely representative with regard to the geographic distribution of respondents. The average age of respondents was 45.2 years (SD 11.914; N=1,042). Compared to the employed population in Germany as a whole, the average age was lower for those aged 20 to 66, with a mean of 43.83 (SD 11.706; N=19,518). Online access to the survey evidently did not push the average age down (for an overview of all figures relating to the sample compared with representative data based on the 2018 BIBB/BAuA survey of employed persons and the extrapolation factor for the 2017 Microcensus, see Table 9.2 in the appendix).

Current occupation was queried in an open-ended field and initially coded in retrospect based on the Classification of Occupations (KldB 2010) at the 1-digit and 3-digit levels. Although the focus throughout the project was on the use of wearables in production and logistics, the quantitative study deliberately surveyed more broadly. This is because the interviews with technology developers also addressed, for instance, use cases in nursing and in the hotel/cleaning sector. Our two filter questions on office work and physically demanding work led to a deliberate oversampling in occupational areas 2 (+3.5%) and 3 (+2.7%), as well as to a more significant shift in favor of occupational area 8 (+7.9%) and to the disadvantage of occupational area 7 (-8.4%). For the analysis, we formed four groups of occupations:

- Manual (N=361, 34.5%) from KldB 1-digits 0=military, 1=agriculture/forestry, 2=raw material extraction, production, manufacturing, 3=construction, architecture.
- Trade/logistics (N=234, 22.37%) from occupational areas 5=transport logistics; 6=commercial services, trade, hotel industry, and tourism.
- Health/nursing (N=303, 29%), corresponding to 1-digit 8=Health, social services, teaching, and education.
- Nonmanual (N=148, 14.5%), formed by 1-digit 4=natural science, computer science; 7=business organization, accounting, administration; 9=language, literature, humanities, social sciences, and economics, culture, and design.

59.4% of respondents in our sample are male, 40.3% are female, and 0.27% indicated diverse as their gender. In comparison, the Microcensus indicates that 54.6% of the German labor force is male and 45.5% is female.

The overview of the sample (see appendix 9.2) shows the distribution by gender in the four occupational groups which we formed. The clearest male surplus is found in the material occupations with 84.2%, but men also predominate in trade/logistics occupations (64.1%). The health/nursing occupational group is mainly female (74.9% of women), and the most balanced distribution by gender can be found in nonmanual occupations, with 56.1% men and 43.2% women.

The respondents in our sample have significantly longer work experience than respondents in the representative Microcensus: Only 17.8% of our respondents state that they have been in their current job for less than five years (compared to 40.8% of the 20- to 66-year-olds in the Microcensus), and 16.4% of the currently employed respondents have been in their current job for more than 30 years.

Most of our respondents come from SMEs: 69.6% work in companies with fewer than 250 employees and only 10.2% in companies with more than 2,000 employees. This is consistent with data from the Microcensus.

The questionnaire was created with SoSci survey software. We did not address specific hardware variants of wearables (such as gloves, watches, and glasses), as these can be used for very different purposes and for recording very different data. Instead, a distinction was made between the three relevant recording dimensions that wearables in the workplace can typically target, namely:

- Emotions (E),
- Physical states (K), and
- Movements (B).

The main part of the questionnaire focused on the question of under what conditions wearables and the associated data recording are acceptable to employees. There were 12 questions focusing on the handling of data (e.g., whether employees can stop the recording, change the data, or use the data for other purposes) and 12 questions focusing on the benefits of using wearables at work (e.g., if it makes work easier to perform or plan, or if the quality of the work can be better documented). For these conditions, respondents were able to express their opinions using sliders on a scale of “does not matter to me” (0) and “is particularly important to me” (10). The higher the number (or the further the slider was moved to the right), the more important an individual condition is from the employee's perspective.

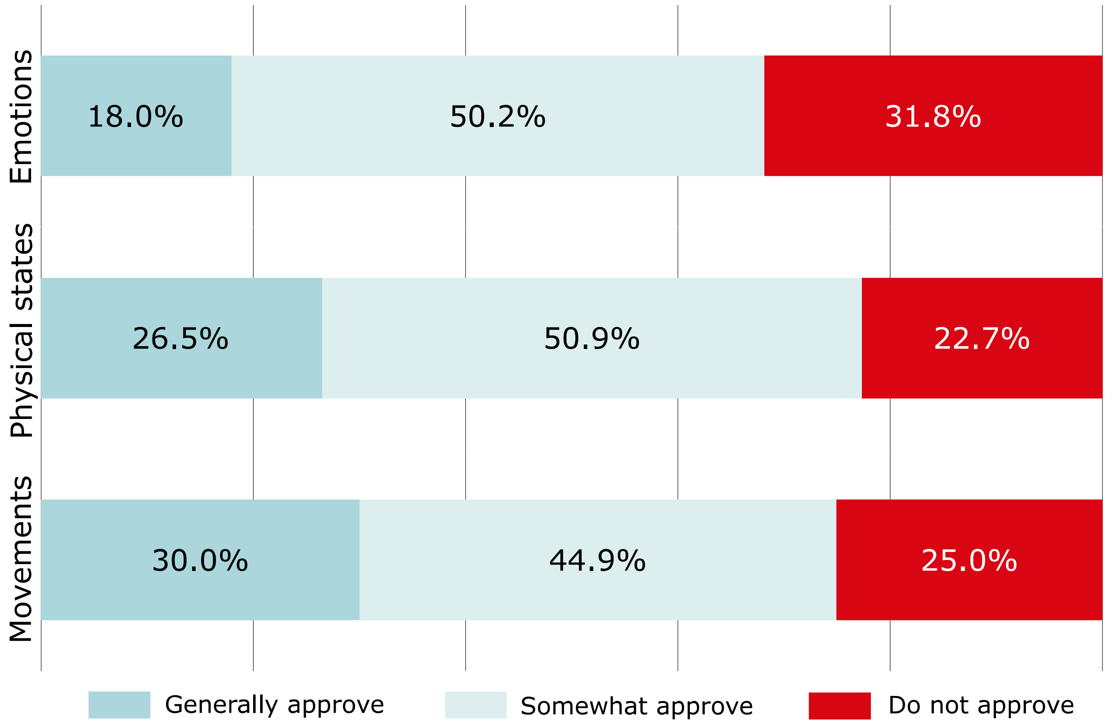
We used both clusters of questions about conditions for accepting wearables (regarding the handling of data and benefits for the work process) for three ways of using wearables: recording of emotions (e.g., via voice pitch), physical states (e.g., pulse), or movements (e.g., steps in high-bay warehouses or hand movements in assembly). Our initial expectation was that it would make a difference for employees what is recorded exactly and what happens with the data.

In addition to these specific questions, we also asked for a general attitude toward technical recording at the workplace. The question was: “Irrespective of your specific work situation or the technology used, what is your general opinion on recording your emotions/physical states/movements at the workplace?”. The response options were: a) fundamentally against it, b) would accept it under certain conditions or c) fundamentally in favor of it.

6.2 General assessments of the recording of emotions, physical states, and movements

Regarding employees' fundamental positions on the recording of emotions, physical states, or movements at the workplace, our analysis has two basic findings (Fig. 6.2a): Respondents are most skeptical regarding the recording of emotions: 31.8% are fundamentally opposed. 25% of our respondents fundamentally reject the recording of movements, and slightly fewer (22.7%) reject the recording of body signals. A quarter to a third of employees therefore have fundamental reservations regarding the potential usage of wearables. By contrast, 18% of respondents agree in principle with the recording of emotions, 26.5% with the recording of body states, and 30% with the recording of movements. In all cases, the majority choose the middle option, agreeing with recording under certain conditions.

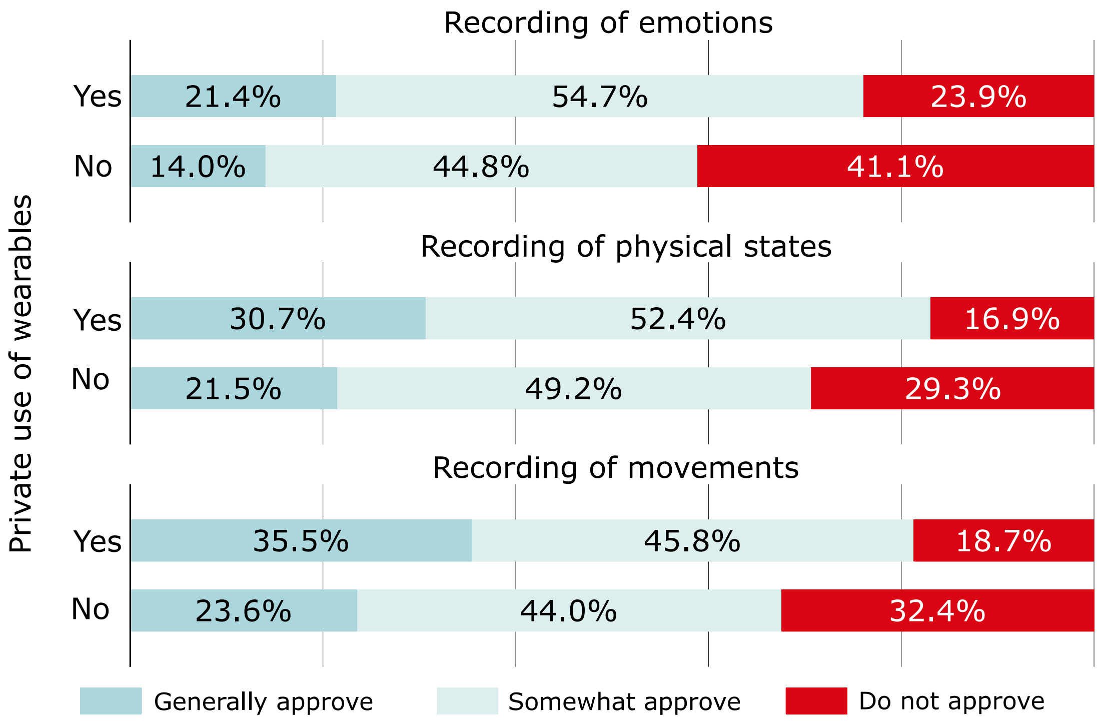
Figure 6.2a: General attitudes towards the recording of individual data at the workplace



Source: Authors.

These attitudes are clearly influenced by personal experience with wearables. We asked about the frequency of use of wearables in respondents' private lives with four options (very often—often—sometimes—never). Fig. 6.2b shows the answers using dichotomous coding (private wearables experience: yes or no). It shows that experience with wearables does not change general tendencies: the highest rejection is found for the recording of emotions, and the lowest for the recording of body signals. However, the rejection of data recording is stronger among respondents without experience with wearables in their private lives. This difference is most pronounced regarding the recording of emotions: 41.1% of those who do not use wearables privately disapprove, while among private users, only 23.9% disapprove in principle.

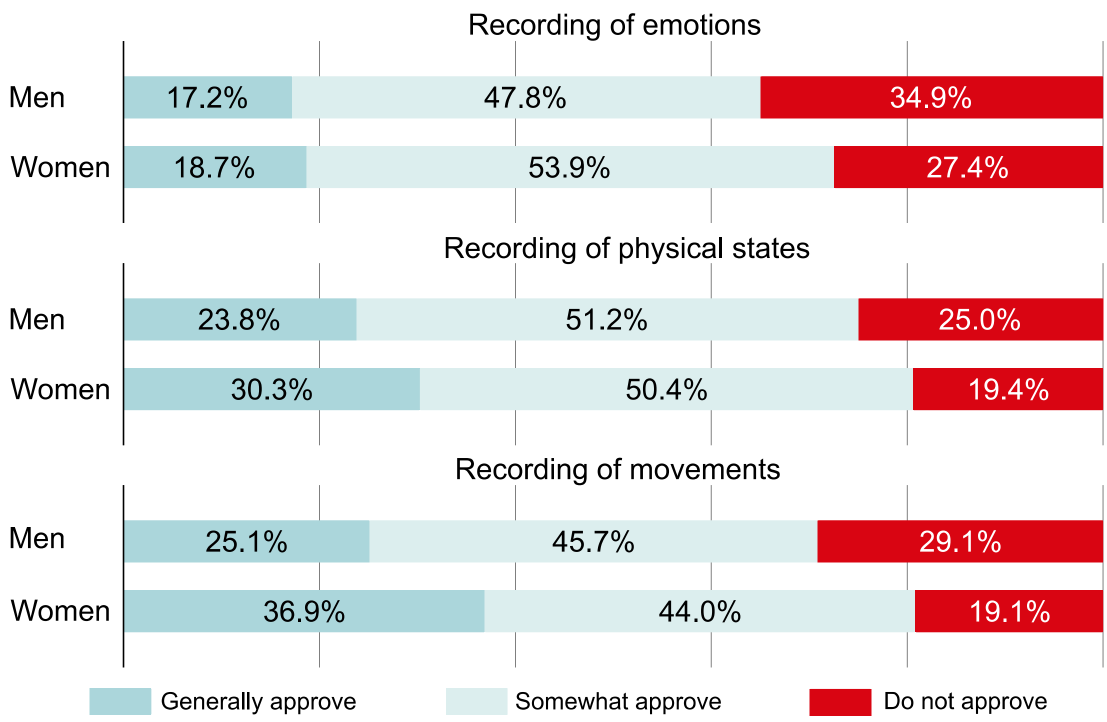
Figure 6.2b: Attitudes towards the recording of individual data at the workplace—employees who do and do not privately use wearables



Source: Authors.

Men are slightly more opposed to the recording of personal data than women (Fig. 6.2c). This difference is particularly evident for the recording of emotions and movements. In the case of physical states, there is hardly any difference between genders.

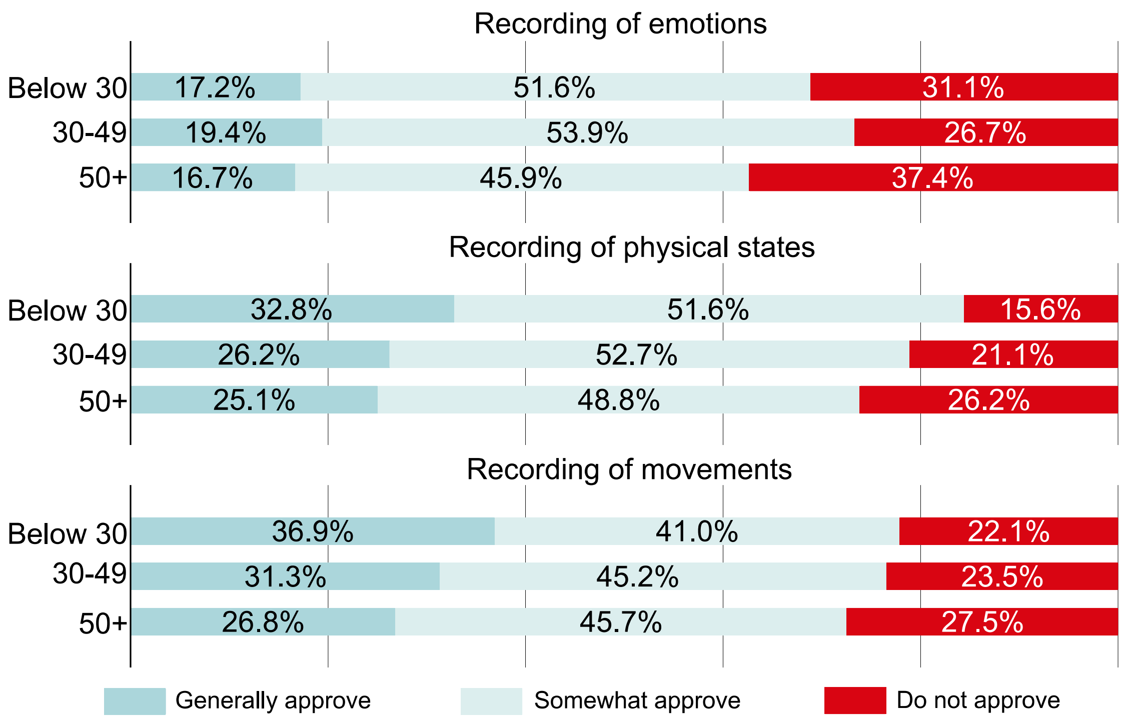
Figure 6.2c: Attitudes towards the recording of individual data at the workplace—differences by gender



Source: Authors.

It is generally assumed that younger people are more accepting of the collection of private data. We compared three age groups: under 30 years old, 30 to 49 years old, and more than 50 years old (Fig. 6.2d). Regarding the recording of physical states and movements, the findings correspond to our expectations. The share of opponents increases with increasing age, and those with a positive attitude decrease accordingly. When it comes to emotions, however, the picture is different. Here, younger people (31.1% fundamentally opposed) and older people (37.4%) are both much more skeptical of recording than those in the middle age group (26.7%). It is possible that these figures represent different motivations. It could be that older people consider emotions to be private and none of employers' business. In the case of younger employees, it could be that they attach greater importance to emotions than to their bodies or movements.

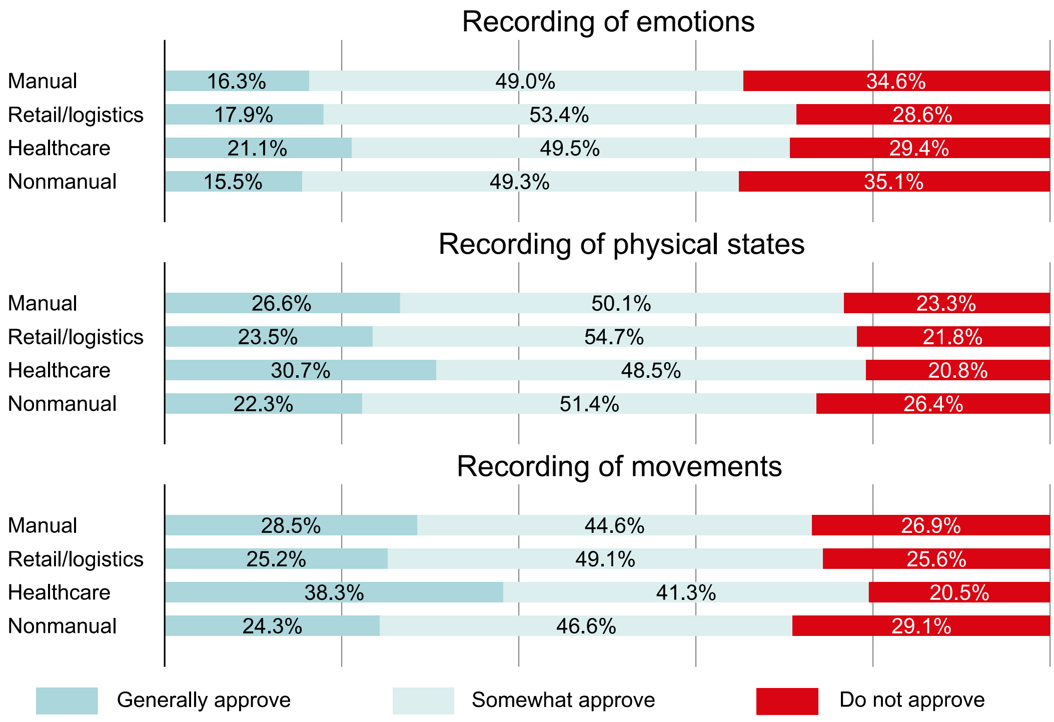
Figure 6.2d: Attitudes towards the recording of individual data at the workplace—differences by age



Source: Authors.

Figure 6.2e shows general attitudes toward the collection of different types of data by wearables in the workplace. Surprisingly, employees in healthcare are the most open-minded when it comes to the recording of movements: 38.3% say that this is conceivable in principle, and only 20.5% reject it in principle. Comparatively high acceptance values are also found in health/nursing for the recording of physical states (for 30.7% of respondents, this is conceivable in principle). The strongest rejection of data recording can be found in the nonmanual and manual occupations—in the case of the former, 35.1% are fundamentally opposed to recording emotions, in the case of the latter, 34.6%.

Figure 6.2e: Attitudes towards the recording of individual data at the workplace—differences by occupational groups



Source: Authors.

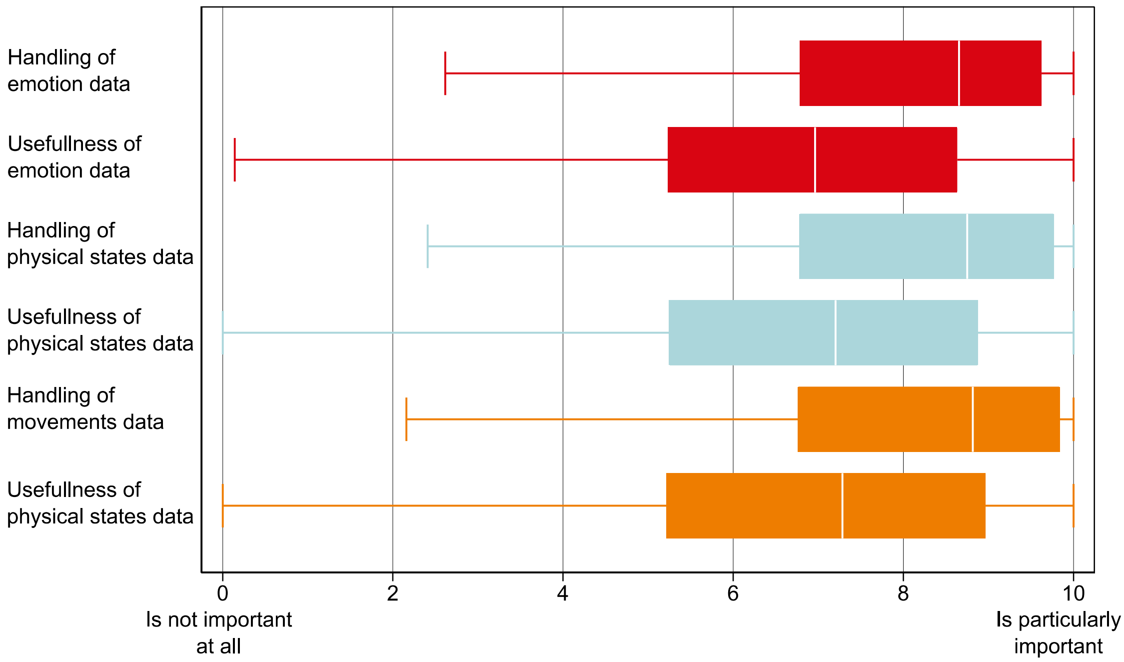
In general, respondents reject the recording of body signals less than the recording of emotions, although the two cannot always be factually separated. For example, heart rate variability could also indicate emotional stress and be evaluated in this respect. Above all, the first step of our analysis shows that the majority of employees have neither a fundamentally positive nor negative attitude towards the use of wearables to record individual data at the workplace. Their acceptance of the use of wearables is dependent on the conditions under which this use occurs.

6.3 Conditions for recording individual data—data handling and benefits for work

We formed three composite indices summarizing the importance of various conditions for acceptance of data recording with regard to emotions, physical states, and movements. This allowed us to assess the overall attitude of our respondents to wearables. Here again, the value 0 stands for low demands on privacy ("does not matter to me") and the value 10 for high demands on privacy ("is particularly important to me").

The following boxplots show the position and dispersion of the results. The box shows where 50% of all responses lie, and the white line is the median. The thin lines symbolize the location of the outer 25% of each response. With a normal distribution, a boxplot in our example would look completely symmetrical and the median would be in the middle (i.e., at 5). In our case, all distributions are strongly shifted to the right, which means that data protection and advantages for work processes are very important to the respondents.

Figure 6.3a: Employees views on the importance of specific conditions (regarding data handling and benefits for work) for the acceptance of the recording of individual data at the workplace



Source: Authors.

We illustrate our interpretation of the boxplots using the first two as examples. The first boxplot represents how important a particular approach to the handling of data is in terms of creating acceptance of the recording of emotions ("Emotions data"). The mean value is 7.94, the median 8.55. Apparently the criterion is very important, with 50% of the respondents giving values between 6.58 and 9.61.

The second boxplot shows how important the respondents consider benefits for their own work as conditions for the acceptance of the recording of emotions ("Emotion benefits"). The mean value is 6.65 and the median 6.90. Apparently the criterion is important, but significantly less than data handling. 50% of respondents give values between 5.13 and 8.60.

Fig. 6.3a leads to three major conclusions (see also Table 9.4 in the Appendix):

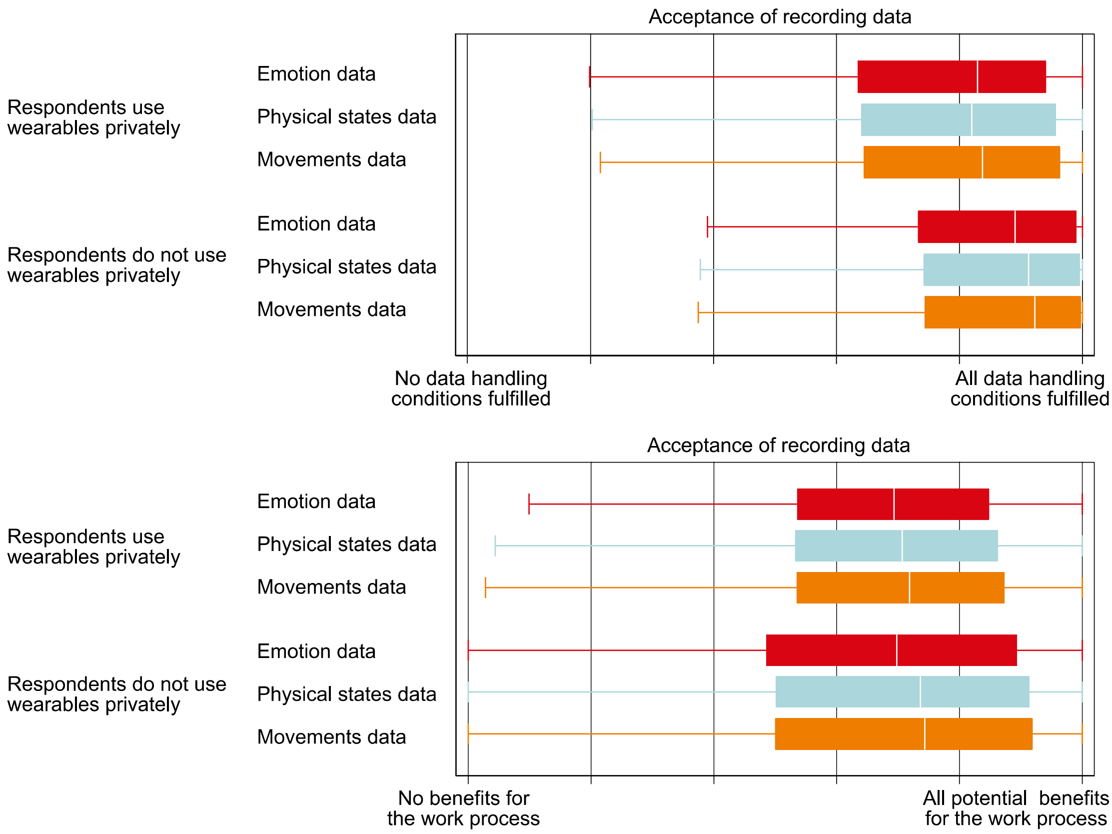
- First, for all three types of data (related to emotions, body states, movements), employees have high demands for the handling of data and benefits at work. The lowest mean value of 6.65 (SD 2.560; N=990) is found for the question of how important it is to create clear benefits for the work process as a condition for accepting the recording of emotions. The highest mean, with 7.97 (SD 2.269; N=999) shows the importance of good handling of data as a condition for accepting the recording of movement data.
- Second, for our respondents to accept the recording of all types of data, it is more important to show clear benefits of the wearables' use for the work process than to demonstrate good handling of the data. The mean values for the index related to handling

data range between 7.94 for emotion data (SD 2.154; N=946) and 7.97 for movement data. Those for the index related to benefits for work range between 6.65 for emotion data and 6.81 for movement data (SD 2.685; N=992).

- Third, different types of data create different priorities. Our respondents do not make any distinction between emotion data, body state data, and movement data regarding the importance of how the data is to be handled. The mean values of the composite indices are similarly high, with a maximum mean difference of 0.029. By contrast, there are differences between the types of data regarding how important it is to show clear benefits of data recording for the work process. In the case of emotion data, the respondents' requirement to show clear benefits for the work process are higher than for other types of data.

Employees are essentially willing to accept the use of wearables under certain conditions. However, they make very fine distinctions between the different types of data when they consider the handling of data and benefits for the work process.

Figure 6.3b: Conditions (regarding data handling and benefits for work) for the acceptance of the recording of individual data at the workplace—differences between employees with and without private use of wearables



Source: Authors.

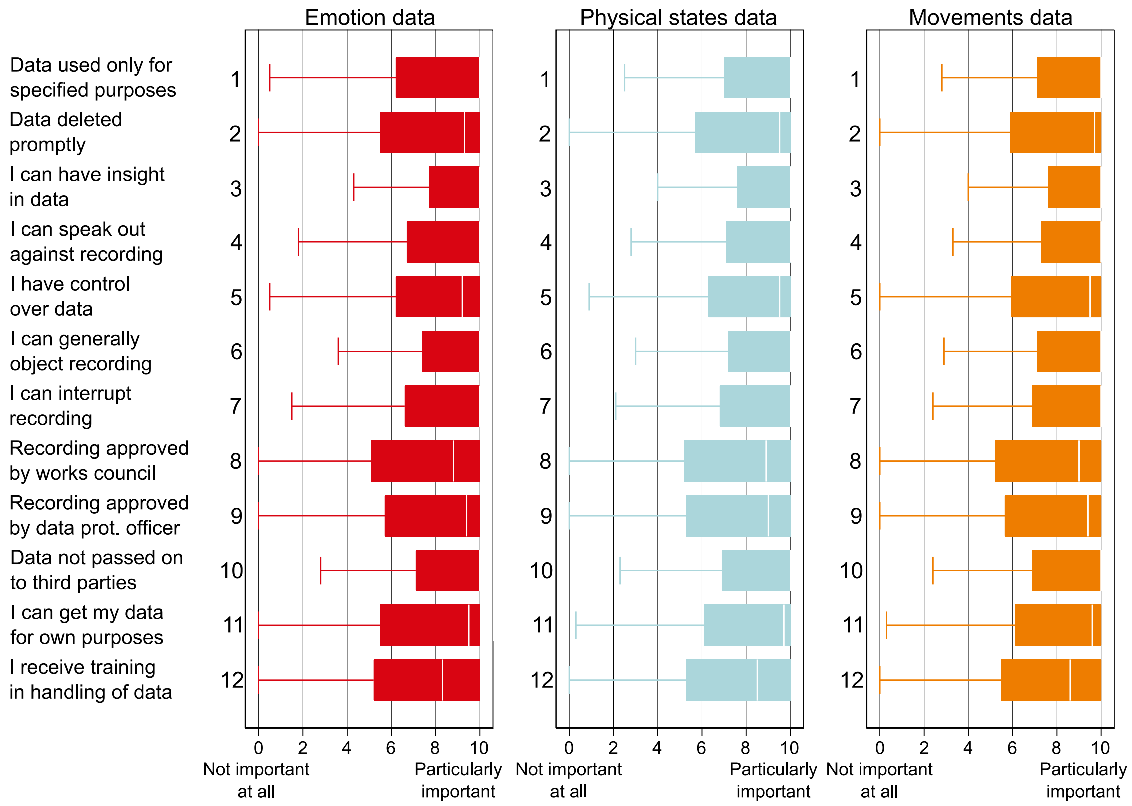
Regarding private usage experience, gender and professional background make a difference (see also Table 9.4 in the appendix for the data in detail). Figure 6.3b shows that for those who already use wearables privately, a clear benefit of wearables for the work process is even more important than specific rules for handling the data when it comes to accepting the recording of emotion, body state, and movement data. Respondents without any experience of the private use of wearables, by contrast, have very high demands regarding the handling of the data, while the benefits of wearables for the work process are slightly less important to them.

6.4 Handling data: Influence, transparency, and control

Twelve questions make up the scale for handling data from wearables in the workplace. As always, 10 means "is particularly important to me" and 0 "does not matter to me." The high values of the aggregate index formed from adding all the individual items shows that the handling of data collected by wearables is very important to employees (see Fig. 6.4 and also the table in Annex 9.4). A closer look at the responses shows which factors are more or less important. The lowest mean value of 7.33 (SD 3.025; N=998) comes in response to the question, "I receive extensive training in handling data" (question 12.12) with regard to recorded emotions; the mean values for the same question with regard to data on physical states and movements are slightly higher. The highest mean value of 8.47 is associated with the question, "I have the possibility to generally object to recording data" (question 12.6) with regard to emotion data (SD 2.534; N=1,008). The mean value for this general possibility to reject recording is only slightly lower for body and movement data. Particularly high mean values are also elicited by the question, "I get insight into the data" (mean 8.43, SD 2.559; N= 1,019 in the case of body data).

The low mean values for the inclusion of the works council (question 12.8) are surprising: The mean value is 7.36 both for the recording of movement data (SD 3.211; N=1,016) and data on body states (SD 3.231; N=1,009), and 7.37 for emotion data (SD 3.152; N=986). Although the scores for inclusion of data protection officers (question 12.9) are higher than for the works council, they are also among the somewhat lower scores in the overall scale which generally trends upward. The survey does not provide information on whether works councils and data protection officers are present at the workplaces. Given that this is not the case in many SMEs, these findings may partly reflect the fact that many employees do not have experience with these roles.

Figure 6.4: Employees' views on the importance of specific data handling conditions for the acceptance of the recording of individual data at the workplace



Source: Authors.

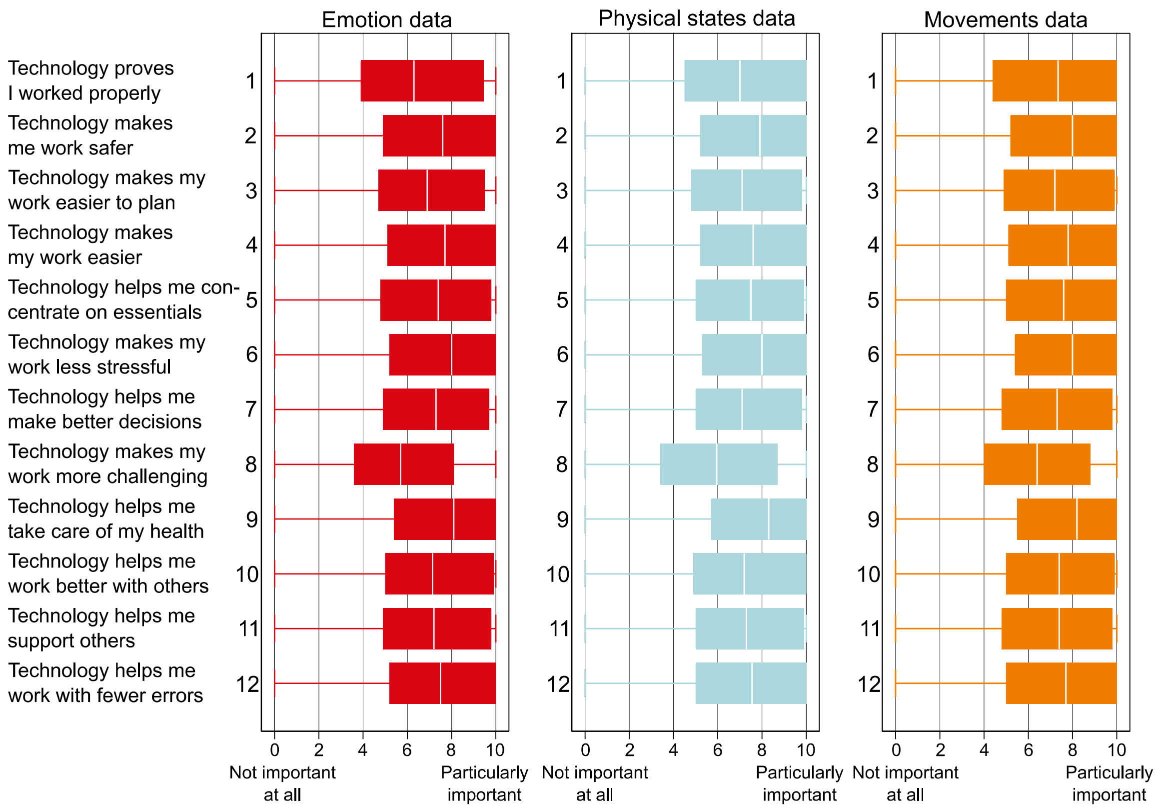
When it comes to the use of data that has already been collected, it is particularly important to the respondents that data is not passed on to third parties (question 12.10). Here, all mean values are above 8, the highest being achieved for emotions, with 8.28 (SD 2.733; N=1,007). The question "Data is not used for any other purpose" (question 12.1) reaches means above 8. This is slightly more important in the case of emotion data (MW 8.03; SD 2.881; N=1,001) than for body data (MW 8.26; SD 2.686; N=1,020) and movement data (MW 8.26; SD 2.693; N=1,014). Timely deletion of data (question 12.2) reaches lower values.

The responses to several questions illustrate the high interest of respondents in actively dealing with the data themselves. The questions on objecting to recordings in individual cases (question 12.4) and on the possibility of interrupting the recording (question 12.7) consistently achieve mean values above 8 for all types of data (emotion, body, movement). Questions on the possibility of adapting data already collected (question 12.5) or using it for one's own purposes (question 12.11) elicit mean values in the upper midfield.

6.5 Benefits of data collection: work, health, and support

Our next topic is the importance of different kinds of benefits wearables represent for the work process. We did not ask whether employees would like to use wearables for the goals or effects we asked about. Instead, we asked what types of advantages would be important for the respondents if they were to accept the usage of wearables in the workplace. Overall, all values are quite high, although somewhat lower than for data handling. Most importantly, the mean scores are again quite close, ranging from 6.03 (question 14.1 (wearables provide evidence of working properly) as condition for using wearables to record emotion data) to 7.45 (question 14.9 (wearables help to pay more attention to health) as a condition for using wearables to record body states data). Fig. 6.5 and Appendix 9.4 provide an overview of the findings.

Figure 6.5: Employees' views on the importance of specific benefits for work for the acceptance of the recording of individual data at the workplace



Source: Authors.

Our respondents are least interested in wearables making work more challenging, though the median is still relatively high. They are a little more interested in wearables making work easier. We can interpret this as a confirmation of the findings from our qualitative studies (see Chapter 5): Wearables at the workplace should neither complicate nor deskill work. In general, the potential benefit for the respondent's own health and safety is rated highest.

6.6 Conclusions: High awareness, clear expectations

The first general finding of the analysis is that employees are ready to accept wearables at the workplace for the recording of emotion, body condition, and movement data under certain circumstances (cf. Chapter 6.2). Women were somewhat more open to this usage of technology than men, but in general no strong differences by gender, age, or profession could be identified.

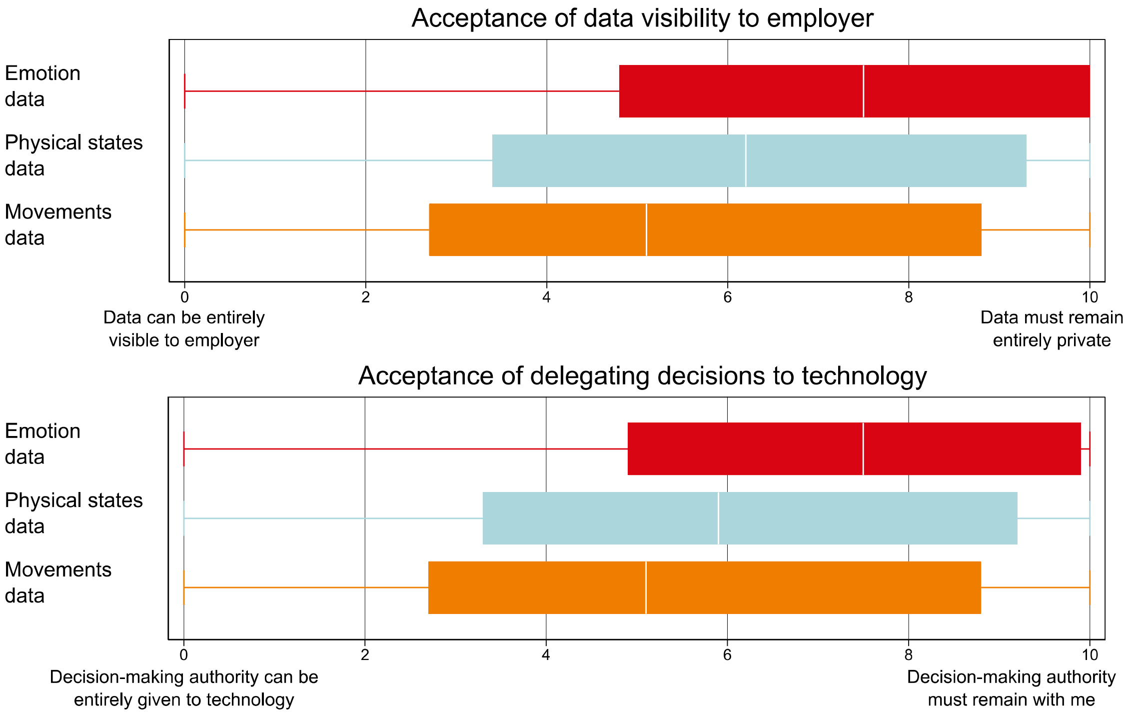
The major conditions for accepting the usage of wearables are related to the handling of the data and the benefits for the work process (see Section 6.3). Employees demand specific data handling conditions, in particular the explicit consent to record and use the data. In addition, employees demand positive benefits for their own work. Although the majority of respondents generally expressed a willingness to compromise (cf. Section 6.2), the hurdles are very high across the board: All the mean values for handling data are just under 8 in each case, i.e., it is very important to the employees. The mean values for the benefits at work index are somewhat lower, but with medians well above 6 and above, they are also high.

At first glance, it may seem surprising that employees have slightly higher requirements for the recording of (apparently less private or intimate) movements than to the recording of emotions and physical states. However, the measurement of movements is more directly associated with an assessment of performance, since the speed of action, especially in the context of work tasks involving physical activity, can be directly linked to the results achieved (be it packages packed, products produced, or patients fed). The use of emotions and bodily states to draw conclusions about performance at a deeper and more general level is yet to be realized in reality.

The handling of data is particularly important to the respondents, and the most important aspect is the possibility to influence the usage of data and object to its recording. Training and the involvement of works councils or data protection officers are less important. In addition, respondents clearly want work to become easier not more demanding. Above all, they want support regarding health, safety, and stress prevention.

It can be assumed that our questions were hypothetical for most of our respondents, as only a minority could have had experience with the technology. In this respect, these results should not be overestimated. We expected that our respondents began the survey with relatively little understanding of wearables but developed a more structured understanding while answering our questions. For this reason, we included a question about the degree to which employers should be able to see the data, and how far decisions based on this data could be delegated to technology.

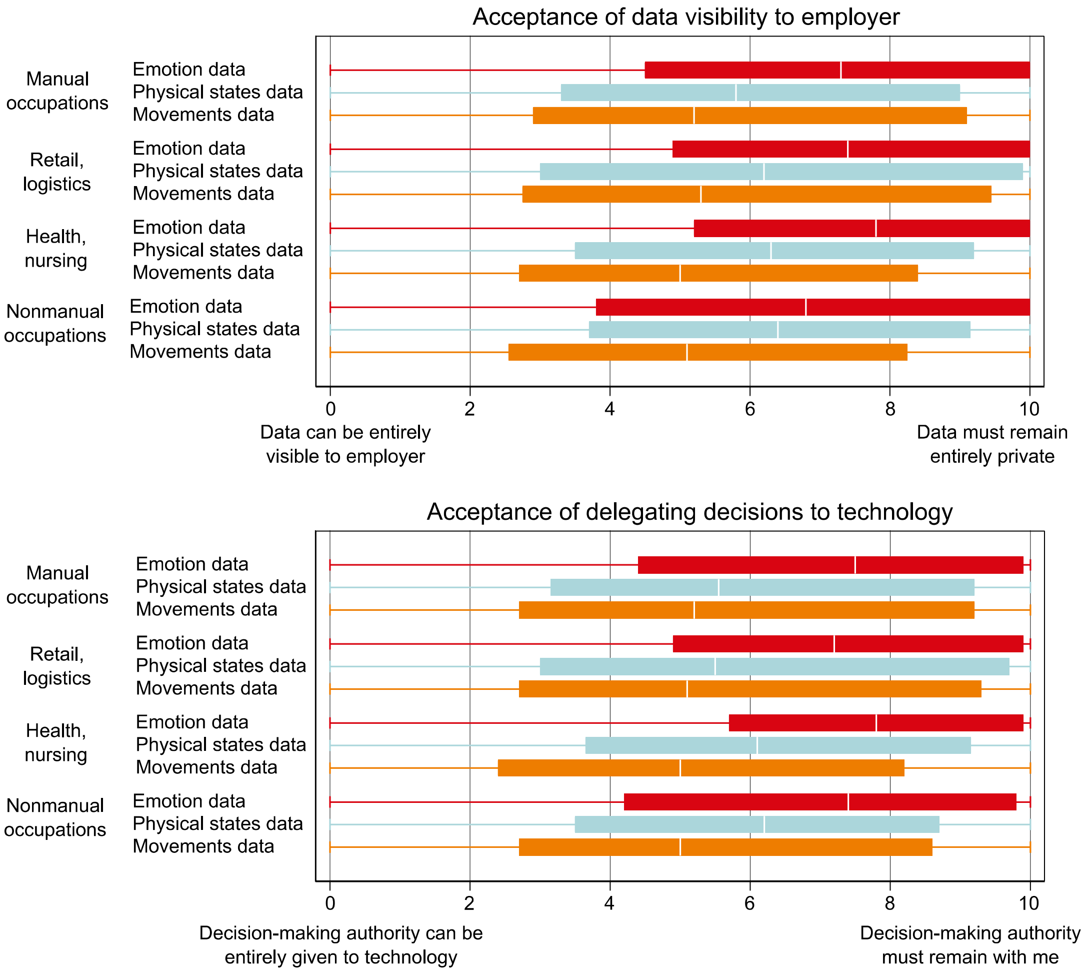
Figure 6.6a: Acceptance of data visibility to employer (top) and decision-making authority of technology (bottom) by different types of data



Source: Authors.

The respondents tend to require that decisions on who is allowed to see the data remain their prerogative. They are also skeptical about giving the technology decision-making powers based on data. At the same time, however, the values are more scattered; opinions on these questions seem to be polarized. Respondents are most open about giving the employer access to movements data. The lowest mean values are found here: 5.5 for data visibility to the employer (SD 3.351; N=1,038) and 5.4 for the decision-making authority of technology (SD 3.350; N=1,038). Concerns continue to be greatest for emotion data, with mean values of 6.9 in each case (see the table in the Appendix for details of all data). When comparing by occupational group, the greatest caution about emotion data is evident in the nursing/health field, both for data visibility to employer (MW 7.1; SD 2.889; N=300) and even more for decision delegation to technology (MW 7.2; SD 2.826; N=300).

Figure 6.6b: Acceptance of data visibility to employer (top) and decision-making authority of technology (bottom) by different types of data and occupational groups



Source: Authors.

Overall, our analysis shows that a considerable majority of employees agree with the idea that their movements, physical states, and emotions would be recorded by technologies such as wearables. However, it is very important to them that they have control over their own data, especially when it comes to recording emotions. It is also very important to employees that the use of the technology has a recognizable benefit for their own work. The implementation of wearables in the workplace requires participatory introduction processes. Only in these processes is it clear which data is collected for which purpose and when, how, and whether this can be influenced by employees. Only participatory introduction processes can identify the specific requirements regarding data handling and the potential benefits for the work of employees.

7 Conclusions

Martin Krzywdzinski, Sabine Pfeiffer

Wearables are entering the world of work much more slowly than was predicted when the Industry 4.0 discourse emerged around 2012, but they have increasingly penetrated private life and are becoming more and more a symbol of technological progress in the world of work. In this context, sociological research has looked primarily at their role as a means of surveillance and the intrusion of algorithmic management into the micro-world of social processes in the workplace. As a result, it is believed, there is pressure to improve performance and increased competition through transparent individual data. This positioning of the research has been reinforced by focusing primarily on individual practices of self-optimization (Duttweiler et al. 2016; Lupton 2013).

Our study takes a different perspective. We consider wearables as a technology whose use is negotiated (and needs to be negotiated) in a highly regulated arena of the workplace. This technology is fitted into existing production systems, especially lean production. In this way, wearables symbolize and reinforce management strategies geared toward increasing efficiency. At the same time, wearables have to be implemented and used by employees who have specific expectations and rights regarding the implementation of new technologies (at least in the context of German co-determination). In addition, data collection via wearables and the recording of body-related data is an issue governed by the General Data Protection Regulation and, in particular, employee data protection. To understand how wearables are used in the workplace, the specific regulatory environment in which this takes place cannot be neglected.

Our analysis shows how production systems and the workplace negotiation arena shape the way wearables are used. Management strategies center on increasing efficiency through standardization and flexibilization, though this does not require micro-analysis of the data generated by wearables. Rather, we find that management and works councils often agree to exclude the possibility of collecting individual data and using it for individual behavior and performance management. Works councils in Germany must consent to the implementation of technologies such as wearables, and this is only possible if management agrees to rules fixed in plant-level collective agreements. This demonstrates the value of co-determination for the future of digitalization and the need to develop it further.

We discussed in detail the impact of the introduction of wearables on work content, skills, and work quality in chapter 5. There is a second important factor besides co-determination that influences the impact of wearables on work: the specific forms of performance regulation in workplaces. Our case studies show that it is not only technical design that determines these impacts. Rather, human-centered approaches to digital assistance systems and wearables require that workers also be given thinking, planning, and decision-making time, enabling them to actively use these systems as support. By contrast, where performance targets squeeze out every second of work and where working conditions are shaped by management-by-stress, there is no room for human-centered approaches to technology design and implementation.

One notable finding of our study, however, is the relatively high acceptance of wearable technologies by employees. Workers often accept the implementation and usage of wearables, even in cases when the technology reinforces standardization of work processes. Employees in these processes often work under very strong time pressure and want to avoid errors that would create additional stress. Stress levels are reduced by assistance systems that use wearables to guide employees closely through the processes and take decisions from them. However, they should not be considered a human-centered technology design. We propose that the term human-centered technology be reserved for designs which empower workers.

The question of acceptance of wearables and its conditions was also the focus of our quantitative study (see Chapter 6). Given that this technology was only at an early stage, it was not possible to conduct a quantitative survey with employees who already work with wearables. We decided to conduct a survey among employees regardless of whether they have experience with wearables or not, and to ask them under which conditions they would agree to work with technologies measuring movements, physical states, or even emotions at work. Since such technologies are still not commonly used in the workplace, these are admittedly hypothetical questions for most of our respondents and the answers should therefore be interpreted with caution. In real life, some respondents may decide differently. Despite this limitation, the survey reveals interesting findings that invite further research.

The acceptance of technical measurement of movements, physical states, and emotions in the work process proves to be surprisingly high. Only a quarter to a third of the employees surveyed had fundamental reservations, a surprisingly low figure given the intrusive nature of these technologies. It is less surprising that those employees who already use wearables privately are more likely to accept their use in the workplace. However, this general acceptance is accompanied by very clear conditions. Employees are willing to have their movements, physical states, and emotions measured if they retain control over the data and use, and if this has a clear benefit for the work process, especially in terms of relieving and facilitating the work. These findings are a clear signal to management that the introduction of new technologies should be accompanied by a participatory process, in which the demands and conditions can be negotiated and shaped.

These high and nuanced standards for the use of wearables are confirmed by the case study-based analysis. Works councils ensure clear rules for data protection and rule out the possibility of using data from wearables for behavioral and performance monitoring. Our interviewees also reported that wearables can reduce workload if their design and usage are well negotiated.

Our study thus provides its own answer to the question of the acceptance of these new technologies. In the discussion over wearables and self-optimization, reference is often made to the "gentle coercion" (Duttweiler/Passoth 2016: 19) exerted by institutions such as health insurance companies on the one hand, and discourses about self-optimization on the other. Without negating these phenomena, we find a different situation in workplaces characterized by collective bargaining over the implementation and usage of technologies. Data protection rules and the clear benefits of the new technology for the work process play a central role.

However, wearables also represent digital technologies whose fundamental technical design places new and extended demands on workplace actors. A major problem, and research gap, concerns the implementation and usage of these technologies in companies without employee representation (in the form of a works council or trade union). Management in these companies can go much further in using wearables as surveillance technologies. Regulatory action is urgently needed to ensure that rules for data protection are followed in all companies.

8 Appendix: Case Studies

Martin Krzywdzinski, Christine Gerber, Maren Evers

8.1 Case studies in logistics

8.1.1 FoodLog

FoodLog is a family-run company in the food industry with a total of 240 employees. Of these, approximately one third each work (a) in administration, sales, and field service, (b) in production and (c) in logistics. Logistics is an area which, in addition to order picking, loading of goods, and empty containers, also primarily involves the company's own fleet of trucks with drivers.

Various types of beverages are produced. Automated filling equipment is used in production. In logistics, the company switched from a purely paper-based warehouse management system to a Microsoft Excel solution in the 1990s. For picking, however, it continued with paper lists printed out from the Excel system and then processed by the pickers. In 2005, a switch was made to a professional Warehouse Management System (WMS), accompanied by the use of a digital assistance system, including wearables in order picking.

The introduction of the assistance system was primarily due to a change in regulation. On Jan. 1, 2005, EU Regulation 178/2002 on food traceability came into effect, requiring documentation of every step in the production and processing of food. At FoodLog, the introduction of the WMS was part of a fundamental digitalization to accurately document the complete chain from production to delivery of beverages for each batch.

The focus of our case study was on picking. A pick-by-voice system is used here (as in loading with forklifts). Workers wear small devices with headphones and a microphone, allowing them to talk to the system and hear instructions. In terms of ergonomics, the system is unproblematic. Not least because of the voice interaction with the system, employees gave it a name ("Rosi") shortly after its introduction. Should the voice recognition and output fail, employees carry devices with them on which they receive information via a display.

The use of the digital assistance system has significantly changed the work content in order picking. Previously, order pickers received paper lists of what was to be loaded into the trucks. As well as picking and loading the listed beverage crates, order pickers had to plan and calculate exactly how the pallets were to be put together and the order in which they were to be loaded so that the planned load would fit in the truck. This took experience and skills.

> "There was a loading list for each truck [...]. There you had to calculate well, be able to find a good balance: 'in which order do I pick the goods so that they fit on the truck'? Otherwise you get delays in loading and this only creates stress." (IV17)

With the introduction of the digital assistance system, Rosi took over the planning. The system plans the entire load, the optimal arrangement of the pallets, and the order in which the beverage crates are picked up and loaded onto the pallets. The order pickers are told exactly which steps to take (which crate to pick up, where to load). Independent planning is no longer necessary.

In terms of work content, the introduction of the digital assistance system appears to lead to a reduction in requirements and a loss of job content. In principle, the skill requirements have remained the same: semi-skilled workers are employed, and the works council is even trying to reclassify the pickers as skilled workers, as they now have to handle computers. However, the work content has in fact decreased. Whereas before the employees had to plan the picking process themselves, now they only follow the instructions of the system. Against this background, it is remarkable that both the interviewed works council and the interviewed order picker emphasized employees' positive perception of the digital assistance system. Both argued that mistakes would be made during the previous process of independent planning by the workers, leading to problems during loading. Since the trucks had to leave on time, picking errors created a lot of stress during loading. In the new system, errors rarely occur. As a result, the loss of responsibility for planning the process is perceived by workers primarily as a reduction in stress and thus an increase in the quality of work.

> "If you want to talk about positive stress - not here. No, [working with paper lists] was a burden, that was a tremendous burden. We were loading, if I remember right, about 400 customers a day. That was stress, that was really stress." (IV17)

The new system also allows for close control of the work. Since only the next step to be performed is ever announced, it is not possible for workers to change the order of the work steps and follow their own plan. In addition, each step is closely controlled; workers must scan markings on their location and on the beverage crates:

> "She [Rosi] says, 'you go there now and take 12 crates, you go to the block in the warehouse or compartment 12-10.' And when you're there now in 12-10, you have to confirm a control number, it's so jumbled that the human brain can't remember the numbers. It is specially designed that way. And once you have mentioned this control number, then it knows you are there and then it says, 'now take ten boxes' as an example. That means she's permanently checking someone, what they're doing. [...] In loading the forklift drivers, she [also] checks [...]. She says, 'you go to warehouse 1, row 12-10'. Now the forklift driver goes there, then he has a laser gun that can scan 12 meters and then he has to scan the sign on the block. Then Rosi knows, okay, he is now in front of the block. Then he

takes the pallets and then he scans each pallet individually and… Rosi knows, does he have the right pallets or not." (IV17)

In terms of monitoring the work process, the digital assistance system creates considerable opportunities for management. It can precisely record the sequence of work steps and the time required for each step, and has the potential to reconstruct how quickly employees work, as well as when and for how long they take breaks.

A conflict developed between management and the works council over the control options associated with the digital assistance system. Management began the rollout without consulting the works council. The works council itself was hardly prepared to deal with such a complex technical system. One dedicated works council member immersed himself in the issues associated with the introduction of the system and mobilized within the works council and the workforce. By pointing out the potential impact on control and monitoring, the works council was eventually able to rally the workforce and threaten conflict. Due to the high level of organization (90%) and strong support for the works council among the workforce, pressure was finally generated (employees refused to work with the system), and management concluded an agreement with the works council in 2006. It was stipulated that the data from the digital assistance system could not be used for individual performance monitoring and "must not have any consequences under labor law". It was also stipulated that employees could pause the system at any time and that these pause times would not be recorded.

The works council emphasizes that since the conclusion of the company agreement, there have been no attempts to use the system's data for individual performance monitoring. A very cooperative culture and relationship between management and the works council has developed, not least following a change in management. The works council commented:

> "They do, I'll say for sure, they see the data. But we've never had a case where they say 'he's too slow, I don't want him here.' And that was important to me because we all do get older at some point." (IV17)

Finally, rationalization effects were also achieved with the digital assistance system. The error rate in order picking was reduced from about 10% to virtually 0%. This also enabled a significant acceleration of the picking process. Before the introduction of the digital assistance system, 4 people worked in two shifts in the order picking team, and additional people were added flexibly when a large order had to be processed quickly. Since the introduction, there are now 2 pickers per shift. In absolute terms, therefore, the reduction in employment was minimal, especially since the people affected were not laid off but transferred. In relative terms, however, the reduction in employment was 50%.

8.1.2 CarLog1

CarLog1 is a global automotive manufacturer with well over 100,000 employees worldwide. The case study took place at one of the company's engine plants, which employs over 2,000 people, producing engines and engine components. The case study focused on the intralogistics unit at the plant, which employs a total of 45 workers (three shifts, 15 workers per shift).

The digitalization of intralogistics began at the plant in the late 1990s, when the previously paper-based control system was converted to a digital logistics management system, available as a module in the SAP system. The digital system monitors and documents the flow of materials from call-off from the production line, through staging in the warehouse, to delivery to the line. As part of the implementation of the SAP system, the material racks in production were equipped with radio modules. When there is only material for 2.5 hours of production remaining on the production line, a call-off of parts from the warehouse is automatically initiated. The entire journey from staging in the warehouse to delivery to the line normally takes 2 hours, so there is a 30-minute buffer.

Order picking had not been completely digitalized by the end of the 1990s. Parts call-offs from production were printed out on site. Employees fetched and loaded the required parts according to the paper list, documenting the processing in each case by scanning the barcode of the fetched parts with a scanner and entering the number of parts taken out into the scanner. It was not until 2005 that the scanners were connected directly to the IT system via a narrowband connection (from 2007 via Wi-Fi), so that the paper list was no longer required. The pickers received the call-offs directly on the scanner and worked through the orders.

In 2015, testing began on a new assistance system linked to data glasses, a 'pick-by-vision' system. The central motivation here was the difficulties in handling the scanners. Weighing over 1kg, it is cumbersome for employees to repeatedly pick up the scanner, position it, and enter the number of parts picked up. Scanners or parts boxes frequently fell down. The central goal was to enable hands-free work, reducing the number of defects caused by dropped parts or scanners. Another goal was to gain experience with the new data glasses technology and test its maturity.

The pick-by-vision system works as follows: Employees wear data glasses and are fed the numbers and the number of parts to be picked up, step by step. They take the corresponding parts from the shelf and load them, before acknowledging the completed step by voice input into the microphone. The glasses are also equipped with a camera, originally intended to automatically scan the number of the picked-up parts by camera, but the camera did not yet prove to be powerful enough to recognize the often-small labels on the parts. Pickup is acknowledged by reciting a control number, present at each rack section to ensure that workers are actually picking up parts at the correct location. If there is an unloading order, the workers are fed the stations in production that they have to supply. These must be acknowledged in the same way.

At CarLog1, the use of data glasses and the associated assistance system barely changed the work content. Semi-skilled workers are employed. The work process in order picking has long been highly streamlined, and all the work steps of the order pickers are specified and controlled by the IT system. One manager comments:

> "This is because our processes were already very good. We made virtually no mistakes even before we introduced the data glasses. It's no different now. [...] I can't make a process

> better yet with the data glasses. What I can achieve is, first, that the employees have their hands free, second, that the speed increases.” (IV20)

An important issue in the implementation of the pick-by-vision system was the ergonomics of the data glasses, which were tested as part of a pilot project. A risk assessment was carried out in consultation with the works council and employees were also surveyed. Since the data glasses are not quite as light as normal glasses, they are mounted on a headset or attached to a baseball cap. Employees rated the wearing comfort, vision quality, operation, scanning, and speech recognition as good to very good. In tests, the field of vision proved to be sufficient to ensure occupational safety. However, the data glasses can only be worn by employees who do not require glasses as a visual aid, as there are no versions with different lens strengths. A restriction on use also arises from the fact that Wi-Fi coverage of the plant is not uniform. In some places where there are delays in the connection, employees still prefer hand-held scanners.

Overall, however, the introduction of the data glasses was very positively received by the employees as it greatly facilitated the picking process. A logistics worker emphasized that the work process becomes calmer and easier with the data glasses because workers can see the information and confirm the pick without having to use their hands:

> “I can work much more calmly with the glasses and have simply more time. With the scanner, I sometimes lost time; had to walk twice to put the scanner down and pick it up again.” (IV20)

He continued by saying that the workers in picking have to keep a certain time during the call-off. They have half an hour for the picking process and usually have to load about 60-70 parts and get them ready for transport to the production hall. Working with the handheld scanner was cumbersome and seconds were always lost during handling, which could add up to several minutes per call-off:

> “With scanners, it's really mental pressure to see if I can make the round.” (IV20)

Management confirmed that the use of data glasses made the picking process calmer and faster . However, this streamlining is not used to save employment; the effects are simply too small. The rhythm of the call-offs is dictated by the pace of production, and it makes no sense to deliver the parts faster. However, the works council was initially quite apprehensive about this issue. To counteract these fears, at the time of the investigation management denied any interest in such “squeezing out seconds”.

Another important point of discussions between the managements and the works council was the question of data recording. The picking software records exactly when, where, and which parts were loaded, as well as where and when the parts were delivered. This theoretically enables the creation of performance profiles of employees. It should be noted that this possibility existed long before the introduction of digital scanners. However, the use of the data glasses exacerbates the data protection issue, as it is now also possible to record through the microphone and camera, as well as to approximately localize the location of employees via the data glasses’ connection to the Wi-Fi network. These possibilities led to major reservations in the works council about the introduction of the data glasses.

Following negotiations between management and the works council, a company agreement was signed, including the following elements:

- The use of data collected via the data glasses for individual performance and behavior control was excluded. Camera and microphone recordings would not be stored.
- As part of a pilot project, a risk assessment had to be carried out. The use of data glasses would only be continued if both management and the works council agree that it is unproblematic in terms of ergonomics and occupational health and safety.
- The use of the data glasses was to be voluntary and employees were not to suffer any disadvantages if they did not use the data glasses.

The agreement was limited in time to a few years, leaving the works council open to the possibility of evaluating the experience after some time and adjusting the conditions for the use of data glasses.

Although the agreement can certainly be described as a success for the works council, works council members emphasized that the negotiation process was difficult. Management approached employees very early on and presented them with the idea of introducing data glasses. This idea met with great approval among employees, putting pressure on the works council to accept the trial of the technology. It was admittedly recognized relatively quickly that the introduction in intralogistics would have little impact on work content and, accordingly, on skill requirements and pay classification. However, management also proposed pilot projects in assembly, viewed more critically by the works council, as this could lead to a reduction in skill requirements and a loss in job contents. At the time of the study, however, no pilot project had yet been launched in assembly.

8.1.3 CarLog2

CarLog2 is a global automotive manufacturer with well over 100,000 employees worldwide. The case study took place at one of the company's automotive assembly plants. The focus of the case study was on intralogistics at the plant, where a pilot project on pick-by-vision had been conducted.

The pilot test took place in the logistics area of rear window assembly. This area includes 25 shelves in which different rear window variants are stored. Data glasses were used to show the employees (a) the way to the shelves and the positions of the parts to be picked up and (b) the parts to be picked up. The glasses automatically scanned the article designation so that the system automatically confirmed the pickup. The desired display was more demanding than in the case of CarLog1. Using augmented reality, the walking paths and the position of the parts to be picked up were to be displayed via the data glasses, virtually superimposed on reality.

The pilot project tested the data glasses technology. In analyzing the project, technical aspects (such as the reliability of the software, speed of the technology, and display) were examined alongside ergonomic and health aspects. To this end, five workers were involved in the pilot test and later interviewed by the OHS responsible and the company doctor about the comfort of the data glasses, the clarity of the display, the ease of use, the field of vision, and also generally about their sense of well-being when wearing the glasses.

Unlike in the CarLog1 case study, management considered the data glasses technology immature and abandoned the project. In particular, four problems emerged:

- The data glasses were found to be ergonomically unsuitable. The glasses weighed too much, and the workers complained after some time about pressure marks and headaches due to the strain. A solution like CarLog1 (data glasses with headset or baseball cap) was not tried. The battery also weighed too much according to management.
- It was not possible to combine the data glasses with other visual aids, so glasses wearers could not use them at all. The workers who tried the glasses complained of headaches and nausea from the display after a few hours of use. It seemed impossible to management to use the glasses for the entire shift.
- The data glasses were too slow, due to the data connection and the limited data processing capability of the glasses. The workers found the wait times and delays to be very inconvenient.
- The glasses proved to be unsuitable for automatically scanning the items picked up.

Limited use, as with CarLog1 (without displaying the walking paths and position of the parts and without automatically scanning the parts), was not considered. Instead, the company decided not to use pick-by-vision in real operations for the time being. However, further developments are being planned with a possibility of retesting the technology within a few years.

Employee representatives were informed (the level of organization at the site is 80%), but the implementation and analysis of the pilot project were carried out by management alone. Since the project was not pursued further, there was no further discussion between management and employee representatives on issues such as the handling of employee data and the regulation of its use.

8.1.4 CarLog3

CarLog3 is a globally operating automotive supplier with well over 50,000 employees worldwide. The case study took place at a production site for air conditioning systems, employing 570 people at the time of the study. Employment is made up of about 400 workers in direct production and maintenance, about 90-100 people with management tasks and in administrative areas, and about 80 employees in logistics (about 40 employees in goods provision and about 40 forklift drivers). The plant operates in three shifts.

The focus of the case study was on logistics. Semi-skilled workers are employed here. The work process has long been digitalized. Logistics employees drive down the assembly line in small electric trains in a regular rhythm according to the milk-run principle common in lean production concepts. In doing so, they check the stock of parts on the assembly line; if a minimum stock level is no longer available, employees scan the codes of the required parts to retrieve them from the warehouse later. At the same time, logistics workers unload parts requested during the previous Milk Run. After the Milk Run, employees go to the warehouse and load the parts onto their trolleys according to the codes scanned on the line. The entire cycle takes approximately 1 hour, and 7 runs are made by each employee per shift.

The subject of the case study was the introduction of smart gloves, equipped with miniature scanners and connected to the SAP system via Wi-Fi. Smart gloves were intended to improve the ergonomics of the work process and reduce disruptions. The smart gloves were introduced in 2016 and replaced a pick-by-voice system. In the pick-by-voice system, the codes of the required parts were recorded by employees via voice input during the milk run. The system also gave employees the stations to be approached for parts delivery via voice output; they were also informed in the warehouse via voice output of the parts to be picked up (as in the FoodLog case study). The system was replaced because workers complained about the headphones, as well as headaches from their use. Instead of the pick-by-voice system, handheld scanners were later purchased, but they were too heavy and cumbersome and kept falling off and getting damaged (as in the CarLog1 case study). This system was also replaced, as it was unwieldy for employees and prone to failure.

The digital assistance system now works with a combination of a monitor mounted on the electric hoist, displaying all information about parts to be picked up and stations to be approached, and smart gloves, used to scan the codes of parts picked up as well as those to be retrieved from the warehouse. Before the system was introduced in the entire supply chain, two logistics employees tested the technology in a pilot project. The results were discussed by management and the works council, but no ergonomic problems were found.

The work content and work process hardly changed as a result of the introduction of the smart gloves, nor did the skill requirements. Compared to the pick-by-voice system and hand scanners, the introduction of the smart gloves was perceived by the workers as an enormous reduction in workload. A shift supervisor from logistics commented:

> "People have to lift 350-500 boxes per shift. When they had to handle the hand scanner or put it down every time to do that, it was enormously inconvenient." (IV26)

The shop steward emphasized that handling the hand scanners also always resulted in lost time, as the scanners had to be put down and picked up again. These seconds added up to substantial amounts over the entire shift. The smart gloves eliminated these hand movements and slightly reduced work intensity.

Potentially, the new system does offer opportunities for greater monitoring of employees. The Wi-Fi connection could at least roughly determine the employee's location. Scanning could be used to generate individualized data on the pace of work. However, such monitoring is precluded by existing agreements between the works council and management. An agreement at the level of the entire CarLog3 Group stipulates that all systems that raise data protection issues be submitted to the central works council for review and approval. The works council at the investigation site stresses that this is important because locally it does not have the capacity to deal with such issues on its own. The introduction of the smart gloves was accordingly reviewed by the General Works Council. The company has undertaken not to store any employee-related data via the system (such as position data or individual performance data). The Works Council emphasizes that relations between management and the Works Council are cooperative, noting:

> "We've already discussed in the GBR, can we be 100% sure that there's no behavioral control there, for example, with the gloves? And of course we can't. But we have to rely on what the company tells us. And we don't really have any reason to question that in general." (IV25)

Rationalization effects were not achieved with the introduction of smart gloves. The number of milk runs and the number of parts to be provided result from the assembly call-offs. The use of smart gloves certainly saves a few seconds in each loading operation, slightly reducing time pressure. However, these small time gains are not enough to change staffing requirements for the milk runs. The works council comments on the performance management issue as follows:

> "After all, the pressure comes from the assembly line. People have to deliver parts to the line or it stops and there's trouble. That puts enough pressure." (IV25)

8.1.5 CarLog4

CarLog4's parent company is a global logistics company with over 20,000 employees worldwide. CarLog4 is a logistics site located directly at an automotive plant responsible for JIT (just in time) delivery of a variety of components (molded headliners, center consoles, handles, wiring harnesses, exterior mirrors, seats, and exhaust systems) to the plant. About 400 employees work at CarLog4 in three shifts.

The work process in logistics at CarLog4 has long been controlled digitally via the car manufacturer's JIT logistics management system. Parts call-offs with details of the parts required, delivery locations, and delivery times are transmitted to CarLog4 via the system. The JIT system is linked to the picking systems in use at CarLog4. Two different picking systems are used. For larger parts, the employees use tugger trains. They use parts lists previously printed out from the JIT system, as well as small scanners attached to the belt which confirm that the parts have been picked up by scanning the barcode. Smaller parts are controlled with a pick-by-light system: a light appears on those boxes from which the employees have to remove parts, and removal is confirmed by pressing a button. The confirmation by scanner or button is used by the system to provide an overview of material flows and feedback to the car manufacturer that the parts are on their way.

The case study focused on the use of wearables in an area where larger parts are picked, and where previously three employees per shift (i.e., nine in total) worked with paper lists and hand scanners. One of the company's key goals was to speed up the picking process. At the same time, according to the works council, it was a prestige project with which the company wanted to demonstrate its technological capabilities.

The use of data glasses was initially planned for picking in another area, but employees there rejected the data glasses. The employees in the area which finally agreed to do the test were equipped with data glasses connected to the JIT system. The glasses displayed information about the parts to be picked up as well as the location of these parts. Originally, the video camera of the data glasses was intended to be used directly as a scanner for the confirmation about the recording of the parts. However, the quality of the camera was not sufficient, so handheld scanners attached to the strap were used.

The data glasses were used for two years. However, employees complained of headaches throughout the entire period, and that the glasses were too heavy and the display too small. In addition, people who wore glasses could not use the data glasses because there were no lenses adapted for them. Over a period of two years, the data glasses and their batteries repeatedly broke down, causing extra costs.

When the data glasses were introduced, no risk assessment was carried out and the introduction was not coordinated with the works council. There are few union members at CarLog4 and the works council has little influence. It was only after complaints from employees had accumulated over a period of two years that management was convinced by the works council that the use of data glasses would not bring any benefits. Instead, the system was changed to a combination of tablets and RFID wristbands. Employees now move around the warehouse with their carts, on which a tablet is mounted. Based on the retrievals in the JIT system, the tablet shows which items are to be taken from which boxes and in what numbers, and in which baskets in the cart they need to be placed. When the employees load the parts, the RFID chip automatically registers the pickup and transmits the corresponding data to the system.

The use of wearables (data glasses, RFID wristbands) did not change the work content. According to the works council, the intensity of work has also hardly changed, as this is primarily determined by the speed of call-offs from the automotive plant and the staffing levels in the logistics warehouse. The use of the RFID wristband has made work a little quieter, as there is no longer any need to scan barcodes during the picking process. In addition, the use of the tablet and RFID wristband made it easier to train new employees:

> "With the list, there were always mistakes; it took time for people to get good at it. Now the learning phase is shorter and mistakes hardly ever occur." (IV27)

The company has used the corresponding effects directly for rationalization. Instead of three employees, there are now two employees working in the affected area, plus a floater who is assigned to two areas (in other words, 2.5 employees). This corresponds to a rationalization effect of 17 %.

However, according to the works council, the basic problem with work intensity derives from the company repeatedly calculating with too few personnel, putting great pressure on employees:

> "We are, after all, dependent on the [car manufacturer]. They determine the quantities and call-off times. If they want to build 3,000 units, we can't say that we'll only deliver 2,800 so that the people don't have too much work. [...] [In some areas] it's already sporty, people have to run." (IV27)

Both the data glasses and RFID wristbands could be used for performance monitoring, especially since there is not yet a works agreement on this (though the works council is striving for one). In the works council's view, however, using the data for individual performance monitoring would involve a great deal of effort, as the data is not linked to individuals, but to the car manufacturer's retrievals. Of course, supervisors could try to merge the call-off data with information about who worked where on each shift. However, given the pressure to perform that already exists, the Works Council does not believe that management would benefit from additionally monitoring individual performance in this way.

8.1.6 RetailLog

RetailLog is a global retail group with over 200,000 employees worldwide. The site is a large warehouse that supplies the group's sales locations and has about 2,000 employees. About 600 employees work in administrative functions, the remaining 1,400 are industrial employees. Work is carried out in three shifts.

The work process in logistics has long been guided by digital systems. Employees drive through the warehouse on tugger trains equipped with a computer. This displays the exact list of goods to be picked up and their locations. They confirm the pickup by entering control numbers indicated at the location. They also scan the barcodes of the goods with a scanner.

Although the system precisely specifies the sequence of steps for processing the order, employees can deviate from this and plan their own work steps. The works council argues that the wide variety of goods sizes and shapes means that the system's recommendations do not always make sense. He explains:

> "It's intended that the system already tells you all this. [...] They say you have to go to aisle 208, compartment 72, and then to 310, compartment 58, and that you can logically build the pallet like that and don't have to repack it again. That is wishful thinking. Of course, that doesn't work in practice the way you would like it to. Not one hundred %. But if you do it more often... The goods don't change. And after two or three days, you've got it down and you know that aisle 318 is the pulp aisle. Aisle 312 is the aisle for the extra-long items. And then the picker is already looking himself, okay, I have to go there. [...] That means, for example, that I can't pack extra-wide and extra-long goods on one pallet, because then I would have so much loss that the loader can't load it properly. So far, no system is as intelligent as man." (IV28)

The focus of the case study was on the introduction of smart gloves in the picking process. These are special gloves on which a lightweight scanner is mounted, connected to the picking system via Wi-Fi. The smart gloves have replaced the large handheld scanners previously used. The company's goals were to try out the technology and further increase the efficiency of the picking process.

A pilot project was first developed for the rollout, in which the works council was closely involved. All steps were discussed and implemented jointly by management and the works council. In the pilot project, 24 employees used the smart gloves for one month, and care was taken to include employees from every hall and every shift, and also of different ages. Works council members also tried out the smart gloves in practice for one day each. After four weeks, all participants in the pilot project were asked about the results.

The use was evaluated very positively overall, but a need for improvement of the ergonomics was identified. Special gloves were introduced for use in summer and winter. The scanners were also optimized, as they repeatedly caused errors in the initial period. Once these technical problems had been solved, the use of smart gloves was extended to all picking workers.

The work content has not changed as a result of using the smart gloves, but the picking process has become faster and smoother because there is no longer any need to handle the handheld scanners. The company estimates that scanning time has been reduced by 50 %. The works council confirms the perception:

> "It probably only increases [productivity] by a few seconds, but if you extrapolate that..." (IV28)

What is important: the introduction of wearables was not linked to an increase in targets. Targets are defined for an entire department at a time, and it is common for them to increase regularly. Time measurements are repeatedly taken in the logistics areas and projects are carried out to increase productivity. The works council emphasizes, however, that the development of the performance targets is kept within a framework that can be easily managed by the employees:

> "Each department has its own key figures [...] and is also told the key figure from the previous day, whether they have managed it or not, how much was open, how much was handed over. And it then also gets the key figures for the day, which it should achieve [...]. Then it's like everybody goes about their work. And yes, nobody gets their head torn off if they talk to someone for two minutes. And as a rule, these are [...] feasible figures that you can actually manage in eight hours [...]." (IV28)

The works council was concerned about the potential for performance control and monitoring of employees via wearables, as the smart gloves are connected to the IT system via Wi-Fi and could theoretically also be used to collect data on employees. However, the works council emphasizes that when the smart gloves were introduced, it was agreed with management that no personal data would be collected and that no functions such as GPS would be installed. A separate works agreement was not concluded for the smart gloves because, in the view of the Works Council, the existing works agreements covered such cases and excluded the collection of personal data and technical performance monitoring. The works council emphasizes that the plant is well organized in terms of trade unions (the level of organization used to be 80 %, but has fallen somewhat recently), the works council is taken seriously by management, and relations with management are cooperative:

> "And in our company this is not just words but real life. Even if it were possible to collect this data, if it were technically feasible... There is also technical data that you can't fend off, where you say, okay, this has to be collected, there is nothing you can do about it. Even then, in our company this data will never be used against you. That's always the case in every company agreement." (IV28)

8.1.7 ElectroLog

ElectroLog is a global industrial group with over 200,000 employees worldwide. The site is an electronics plant that manufactures electronic assemblies and programmable logic controllers (PLCs). More than 1,000 employees work in three shifts at the plant.

The case study focused on a pilot project using data glasses in the setup of SMD (surface-mounted devices) systems. The workers insert the appropriate rolls of components for SMD assembly into the systems and connect them to the old roll using adhesive tape. The required parts are displayed on the screen at the system. The workers then retrieve the reels from the warehouse, where they confirm acceptance by hand scanner, as well as insertion into the system. This process takes place hundreds of times per shift, and the employees "run around like busy little bees," as the head of production planning points out. Under this time pressure, mistakes kept happening, disrupting the production flow.

For this reason, ElectroLog undertook a pilot test of data glasses. The original goal was to output the information about the required reels and components on the data glasses and scan the barcodes of the reels and components, automatically confirming their pickup and later their insertion into the placement system. For this purpose, software was developed that connects the data glasses to the equipment via Wi-Fi, and imports the corresponding information onto the data glasses. However, the glasses proved to be too heavy for use throughout the shift. The cameras on the glasses were also not accurate enough to reliably perform the scanning. The idea of using data glasses was discarded. Instead, the software was used to provide information to employees via smartwatch. Scanning will continue to be done with a small handheld scanner. In addition, when items are picked up in the warehouse, an RFID chip in the smartwatch will automatically ensure that the pickup is registered in the system. A corresponding pilot project was being coordinated between management and the works council at the time of the investigation.

In the pilot project, a workshop was held with the employees at the beginning to record their expectations of the technology, and their experiences were evaluated at the end. With regard to wearables, the ergonomics issue proved to be central: the data glasses technology was not yet classified as ergonomically mature enough. In contrast, the learning effects of integrating wearables into local IT were highlighted as positive by production planning. The field was considered to be very dynamic, and management emphasized that industrial companies urgently need to build up competencies in this area.

Since this was a pilot project whose implementation in normal production was not yet on the agenda, there had not yet been any discussions with the works council about a possible agreement on this topic. The works council was informed about the project and was kept up to date on the results.

8.2 Case studies in manufacturing

8.2.1 ChemMain

ChemMain is a company with approximately 3,000 employees. The company's focus is to manage manufacturing sites in the chemical and pharmaceutical industries as a service provider. About half of the company's workforce consists of salaried employees and engineers, and the other half of skilled workers in production and indirect functions. The company hardly employs any semi-skilled workers without vocational training.

The case study took place at a production site operated by ChemMain; the focus was on the maintenance of the production facilities and buildings. Maintenance at the chemical plants is confronted with the challenge of looking after very large areas with a large number of different equipment. Maintenance tasks are controlled via a ticket system. The so-called dispatchers organize the maintenance, from regular routine maintenance tasks to the elimination of malfunctions. They assign the tickets (orders) to the maintenance staff who take care of the maintenance or troubleshooting. These are well-trained skilled workers, and the dispatchers are also recruited from the ranks of the maintenance staff and have very good knowledge of the process. However, the company is increasingly confronted with labor shortages. Accordingly, the central motives for digitalization lie first in making the maintenance process more efficient to enable maintenance staff to look after a larger number of equipment. Second, an assistance system will support younger maintenance staff with less experience in their tasks.

The digitalization of the maintenance process began in the early 2000s, when assets were recorded and barcoded so that they could be entered into the SAP system and ticketing could be recorded electronically. Based on this system, a mobile application for maintenance had been developed a few years before our study, using smartphones. For special applications, the smartphone connects to data glasses. The application is used for message processing and maintenance support. Maintenance workers get the order on the smartphone, confirming all process steps. Previously, they had to process the order in paper form—they received it printed on paper and had to perform all documentation steps on paper. In terms of support, a number of functions were implemented: the app provides information via GPS about the location of the fault and also any spare parts or materials that may be required (additional information about the location of the fault can also be entered directly into the app by the maintenance staff). The app can directly read measured values from the machine, which can be saved with the machine data. If necessary, construction plans and stored information about the machine can be retrieved via the app. If necessary, an expert or supervisor can be called in directly. In the event of a malfunction, the smartphone can be connected directly to a pair of data glasses. Information about the malfunction can be displayed (e.g., exact name and location of the malfunction); an image can also be forwarded directly to a connected expert via the camera of the data glasses.

The use of the digital assistance system has not yet changed work content in maintenance, particularly with regard to skill requirements for maintenance staff. According to the works council, the technical expertise of the maintenance staff is still needed and the application has supporting functions, also with regard to occupational safety. In many processes, specialist training is necessary precisely because of the specific safety requirements and legal stipulations. At the same time, a generational change is taking place in the company and many experienced maintenance staff will soon be retiring. The aim is therefore to provide as much support as possible in the maintenance process through the application.

> "We have a large number of processes where troubleshooting is associated with significant health hazards. We often have a kind of dead man's button there. If someone doesn't check in every three minutes, then an alarm goes off. And we have the problem that a lot of experienced people will be leaving us in the near future and that we won't be able to recruit qualified young people. So we desperately need support systems like this to at least somewhat compensate for the loss of experience." (IV33)

In the long term, there are plans to set up a kind of knowledge database and objectify at least part of the knowledge of the maintenance staff. However, the works council emphasizes that this will not mean a reduction in the qualification requirements in maintenance:

> "We will try to avoid having an electrical helper as a maintenance man. [...] I have to have people pulling cables. They'll know they're pulling cables, and they'll get paid like cable pullers. And I can't let them, no matter how many data glasses I put on them, on the machines, because the wrong button pressed at the wrong time has fatal costs and consequences." (IV31)

The assistance system certainly enables closer control of the work. Through the app, from the technical side, the exact processing times of the orders are now stored directly in the system and can be analyzed. However, such digital systems as the maintenance app are regulated jointly by management and the works council. There is a basic works agreement stating that all data collected may only be used for purposes clearly defined in advance. When the app was introduced, IT and the works council discussed in detail: what data is generated, for what purposes is it needed, how long must it be stored? In the process, it was agreed that data would not be used for performance and behavior monitoring. For additional technical security, employees only log in with a pseudonym, and the link between the pseudonym and the real name can only be resolved by a joint decision by HR and the works council. So even though individual performance monitoring would be technically feasible, company rules preclude it.

The transparency of work processes in maintenance, which has increased with the maintenance app, could theoretically be used to raise performance norms and intensify work. However, the works council considers such a scenario unrealistic for several reasons. First, the works council can prevent such developments. The level of unionization in the company is very high and the relationship between management and the works council is very cooperative. So when there are conflicts, it is easy for workers to mobilize the works council and articulate their concerns to management.

Second, the works council argues that given the current situation, the high level of transparency is rather positive for the workers. For some time, the company has had difficulty recruiting enough skilled workers for maintenance (and other functions), and maintenance staff were rather overworked at the time of the study. With the transparency and data provided by the app, the works council can now accurately document workload and staffing needs. This is an advantage because documenting time delays and problems in processing orders "is the only language that operations managers understand".

Accordingly, there has been no reduction in employment as a result of using the digital assistance system. Rather, the company and the works council hope that the efficiencies created by the use of digital assistance systems will help to offset the aging of the workforce and the departures of experienced workers that will occur in the near future.

8.2.2 ElectroSup

ElectroSup is a company with about 5,000 employees worldwide. The company focuses on the production of electrical components, sensors and electronics. The company has its headquarters and a number of production sites in Germany, but also has a global presence. The expansion of its global presence has also meant a significant relocation of production from Germany to Eastern Europe and Asia.

The case study took place at the company's German headquarters (about 500 employees) and focused on the application of data glasses (in this case the HoloLens) for remote support. The idea for this application came from the central role the company's German sites play in supporting production worldwide: they are responsible for the acceptance of new production lines worldwide and for providing support in the event of particularly difficult problems that cannot be solved locally. For a long time, this central support function of the German sites meant considerable personnel and travel costs, as the company's production experts had to travel a lot internationally, and travel also tied up a lot of working time. The goal of using wearables was to reduce the need for travel and make the remote support process more efficient.

The Microsoft HoloLens is used in remote support. HoloLens is a special pair of data glasses that not only allows information to be superimposed on the wearer's field of vision, but also provides a programming environment that can be used to superimpose interactive 3D projections on the real environment. The projections thus blend into the real environment, while the motion sensors and camera register the movements of the person. In this way, virtual objects can be selected and moved by hand movements or manipulated in other ways.

ElectroSup's maintenance employees can wear HoloLens when inspecting equipment or performing maintenance work in a manufacturing plant. Information is displayed on their data glasses, and their camera image is transmitted via the Internet to an employee at headquarters, who thus sees everything that they see. The remote support employee can control the graphic display on the computer that the employees on site see on the data goggles and display markers and can also provide support via voice connection. They can confirm the settings and processes and provide support during maintenance activities.

In principle, the use of HoloLens does not change the work content and work processes in the maintenance and commissioning unit, except that it reduces the need for experts to travel. At the time of the study, mainly skilled workers and engineers at German sites were using HoloLens technology to provide remote support for other sites worldwide. However, the same technology is also used by the company for training (see Chapter 5.3) and a pool of experts is gradually being built up at other sites to provide remote support.

Ergonomic problems are not reported with regard to HoloLens use, not least because the data glasses are used for specific assignments lasting 1-2 hours but are not worn for an entire shift.

The introduction of HoloLens was discussed with the works council and the framework conditions were clarified in advance. The works council supported the introduction of HoloLens, not least because it can also mean a strengthening of the competencies of the German sites. From the works council's point of view, it was important to analyze the ergonomic conditions of using the data glasses in detail, achieved through test trials in the company. Since the HoloLens is relatively heavy, it is attached to a helmet.

No personal data is collected and stored when the data glasses are used, a key concern of the works council. Cybersecurity is an important issue, also to protect plant data and customer data. The company is investing heavily in this area. The works council does not fear deskilling for the maintenance staff. In the future, HoloLens could be used to support semi-skilled workers with maintenance tasks via remote support. In view of the lack of vocational training in many countries and the shortage of skilled workers, it is also in the interest of the company to be able to support employees with a lower level of skills in maintenance work.

8.2.3 ElectroMan

ElectroMan is a global industrial corporation with over 200,000 employees worldwide. The site is an electronics plant that manufactures electronic assemblies and programmable logic controllers (PLCs). More than 1,000 employees work in three shifts at the plant.

The case study took place in the production area of the electronics plant. Production consists of fully automated lines for volume products and some semi-automated lines for small batches. On the latter, placement takes place automatically, but assembly is manual.

The case study focused on a pilot project in the final stages of implementing a digital assistance system running on smartwatches on a semi-automated line. This line consists of six stations. Each time there is a change in production, the line has to be retooled. The line is controlled by two skilled workers per shift who take care of material feeding, setup, reprogramming up to maintenance tasks.

As part of the project, ElectroMan developed an assistance system for machine operation. In addition to the developers, six production employees participated in the project, testing various models of the system over the course of nine months. The smartwatch is connected directly to the line's machine network and the machines' controls. It reads the status of the machines and can thus issue error messages in the event of malfunctions, information on the status of order processing (and warnings when 90 % of the order has been processed and the machine will soon need to be retooled). Employees can confirm that they are taking over the task in the event of error messages or messages about retooling or material replenishment. All of this information was previously displayed via light signals at the stations, requiring employees to be near the stations. The use of smartwatches enables the deployment of staff in a much more flexible way. Employees can now take on tasks that require them to be away from the machines. The company also wanted to test the possible uses of smartwatches in machine operation.

The use of the digital assistance system has not changed the work content in machine operation, and the qualification requirements remain the same. The project was consulted with the works council, which paid attention to a number of points:

> "We discussed, how should we regulate the project? We then decided, we'll just try it out. We had confidence that everything would be transparent and that we would be told everything. Now that the project is coming to an end, we will establish some key points. We have to ensure the hygiene conditions, so make it clear that the watches are permanently assigned to workers and not rotated. We need to make sure that people can turn off the smartwatches during the breaks and not be interrupted. We need to make sure that there is no analysis of the data for performance monitoring, so that, for example, the data is deleted on a daily basis. We'd also like to have the ability to include cellphones in case some employees don't want to wear a watch." (IV41)

A separate operating system has been developed for the smartwatches used, disabling some functionalities (such as sensors for body temperature). Management and the works council agree that systems such as smartwatches should not be used to monitor workers. There is a general works agreement in the company that regulates the use of such systems. Once the pilot project is formally completed and the system is adopted for normal use, an agreement will be negotiated specifically for this system.

With regard to personnel deployment, the digital assistance system has a clear impact. At the moment, two skilled workers per shift are deployed on the semi-automated line that was the focus of the study. If the employees work with the smartwatches as standard, they can potentially also be deployed for other tasks if they are not currently needed on the line, informed about the situation on the line at all times via the smartwatch. Once all employees in production are equipped with the smartwatches, they can be deployed more flexibly, and waiting times on the lines can be reduced and working time utilized more efficiently. From the perspective of the workforce, this may result in work intensification.

Managers emphasized that at the time of the study there were no plans to change the work organization and staffing levels for the production lines. They argued that there are rationalization targets of 8-10% in the company every year and that the use of smartwatches would simply help to achieve them. So far, such rationalization targets have been absorbed by growth in production volume, and management expected the same in the future. The works council noted:

> “We discuss this in the works council: will people be more broadly deployable? Will jobs be cut? Is there that risk? Our plant management promises that this will not happen. They want to use the time gains for people to work on new ideas, on improvements. We will see. In the past, we would have made an agreement at the beginning and regulated everything. Now we do it iteratively. We run projects and go with it. Everything is simply developing too fast for us to do it any other way. We’re counting on building mutual trust.” (IV41)

In the discussion over the project, the works council emphasized that digitization makes it necessary to change the work of the works council. Digitalization leads to new challenges in terms of work design and also data protection, but at the same time it is necessary for the long-term competitiveness of the sites. It therefore makes no sense for the works council to want to stop digitalization. However, to be able to help shape the digitalization projects, a new way of working is needed. The works council argues:

> “We have a general agreement on these topics in the company, but in fact it is not very well known. It is too long and complicated. We had to question our own work. We have our agreement, we have our Works Constitution Act, but it’s often not practical. We have discussed how we need to change our work to find more workable ways. In the past, we dealt with everything in committees. We got information from management, discussed it internally and then announced our position. Now we work in such a way that we help shape projects, participate." (IV39)

In view of the many digitalization projects running in the company, the works council lacks the expertise to be able to assess everything right at the start of the projects, especially since many projects also test technologies without a clear picture of the possibilities and risks. The works council therefore does not try to regulate projects right at the beginning but has agreed with management that it will participate in the projects as a project participant and learn about the subject matter and develop its position in the course of the projects. The challenge for the works council is to mobilize sufficient manpower for this approach in view of the large number of projects.

8.2.4 SteelSafe

SteelSafe is a company in the steel industry with over 20,000 employees worldwide. The focus of the investigation was a steel mill with about 5,000 employees. Our investigation related to a pilot project for the use of wearables for occupational safety. The company hoped to demonstrate its innovative capability in the area of digitalization, and further increase the level of occupational safety.

The project aimed to equip employees in production and maintenance with wearables that record important key data (position, temperature, etc.) and can also inform and warn employees about hazards. The wearables were to be used in production and maintenance, with skilled workers in maintenance and both skilled and semi-skilled workers in production.

The pilot project focused on data glasses. It very quickly became clear that the solutions available on the market did not meet the technical requirements in a steel mill in terms of robustness and ergonomics, and technical performance with regard to batteries, field of vision, and display quality. To this end, the company, in collaboration with a university, began developing its own data glasses that could demonstrate the appropriate sensor technology and industrial suitability. However, development was put on hold after the creation of a first prototype because the costs of the project proved to be too high. The maturity of the technology had been overestimated and the required development effort underestimated.

The initial ideas for using wearables were discussed by the project team with employees in production, and there was positive feedback. The works council was informed about the project from the beginning. Due to its focus on occupational safety, the application relied on individually recording position and other potential factors such as temperature. This touches on key issues of data protection, creating a danger of monitoring employees. The company's management emphasized that it regulates such issues in mutual agreement with the works council and that a regulation compliant with data protection standards would also have been found for the wearables in occupational safety. However, since the project was not pursued further after the prototype phase, there were no further discussions or negotiations on this. The company continues to monitor developments in the area of wearables, and potential usage scenarios.

8.3 Case studies in training

8.3.1 AutoTrain

AutoTrain is a global company in the automation industry with over 20,000 employees worldwide. The case study took place at a production site in Germany, where about 3,000 employees manufacture drives for production plants. This includes about 200 employees in administrative and service functions, about 600 in logistics, and over 1,000 employees each in machining and assembly. Almost all of the employees in mechanical processing are skilled workers; in assembly, employment is mixed with people with and without relevant vocational training.

The case study focused on a pilot project for the use of data glasses in induction training in the assembly area. At each station in assembly, 5-7 parts are assembled, with the cycle varying between 1 and 2 minutes depending on the product and workload (leaving 5-20 seconds per part for assembly). During vacations and vacation periods, students and temporary workers are employed on the line in large numbers. This regularly results in a high need for training so that employees are able to work on the assembly line in the short cycle time.

The pilot project was designed to test whether the HoloLens could be used to shorten and facilitate the familiarization process. For this purpose, a HoloLens from Microsoft was used, with which a three-dimensional virtual representation can be superimposed on the employees' field of vision. The HoloLens simulates the entire assembly process. The employee stands at a training workstation and the program displays the parts to be assembled. The worker clicks on the required parts and on the place where they are to be assembled. The application provides information about this via audio.

In the pilot project, training was simulated for a single workstation where the usual induction takes two hours. This familiarization normally takes place directly on the line, with the cycle time slowed down for this purpose. In the pilot test with 10 students, a learning time of 40 minutes was achieved with the HoloLens plus 10 minutes directly on the line, a significant reduction of the required time. Other advantages of the HoloLens are that information about the process and hand movements is also provided directly during the teach-in through audio output.

For the pilot project, a special agreement was reached between the works council and management that participation was voluntary and that the project would be limited to training in assembly, meaning any expansion of the project would require the approval of the works council. The works council was also involved in the evaluation of the project with the test persons, which was very positive. The display was judged to be very good, and the ergonomics of the glasses were also adequate. However, the works council emphasized that the glasses are heavy and therefore cannot be worn for much longer than the 40 minutes required for the training.

It should be noted that the test subjects needed the same support from trainers with the HoloLens as in the normal training process on the line. According to the assessment of those responsible for the project and the works council, this will remain the case even if augmented or virtual reality technologies are used. The work content of the trainers may change, but the need for human trainers will not decrease. However, shortening the overall duration of the learning process will reduce the time required for instructors.

Despite the positive results in terms of optimizing the learning process, the project was not continued because the development of a three-dimensional assembly simulation is still very complex and expensive. In the examined case, development by an in-house team took two months and cost several thousand euros in total, far too expensive and complex to use the system in practice for the large number of assembly workstations and the frequency of process changes. However, the company is monitoring market developments and is on the lookout for simpler solutions that can be implemented at low cost.

8.3.2 ElectroTrain1

ElectroTrain1 is a globally operating industrial group with over 200,000 employees worldwide. The site under study is an electronics plant that manufactures electronic assemblies and programmable logic controllers (PLCs). Over 1,000 employees work at the plant.

The case study focused on the use of data glasses for learning processes in the assembly of small batches of electronic assemblies. Many temporary and seasonal workers are employed in this area, and fluctuation is very high. A test was conducted to determine whether the HoloLens could be used to shorten and facilitate the training process. The training run was rehearsed with 16 employees, who received both traditional instruction and instruction with HoloLens. The latter was conducted according to the following principle: first, the employees received a brief introduction to the product and the HoloLens, after which they were introduced to the workstation. A trainer explained the work steps, which were also displayed on the HoloLens. The employees then practiced assembly independently with the HoloLens.

Three workstations were programmed in the test. The effort required was considered reasonable. One computer scientist required one month to program the training for the three workstations. Product data had to be converted into 3D representations, workstations had to be measured, and the menus, texts, and displays of the HoloLens had to be programmed in.

The test subjects were able to evaluate the training. The display quality and the use of the program scored well, but the wearing comfort of the HoloLens was criticized. The data glasses are heavy and cannot be worn for much longer than 30–40 minutes without discomfort.

The works council was involved in the project and its evaluation. Data protection issues did not arise because no data was collected on the employees. Both management and the works council emphasized that no savings can be made with regard to human instructors. The test persons with the HoloLens needed the same support from instructors as in the traditional learning process. The company's hope is that after an initial phase, employees will also be able to practice independently with HoloLens, reducing the need for instructors to guide their learning. This would bring savings.

Despite the results, the project was not continued because the ergonomics of the HoloLens were not yet considered sufficient and the benefits of the investment were not clear.

8.3.3 TransportTrain

TransportTrain is a globally operating company in the transport industry with over 200,000 employees worldwide. The case study took place at the corporate headquarters, in a unit of the IT department that conducts research on digital applications for training and skill development.

A number of applications using data glasses are used in the group. In maintenance, data glasses are used for certain systems in trains (e.g., braking systems) to guide skilled workers in testing and troubleshooting the systems. However, the case study focused on applications in initial vocational education. Here, the company relies on virtual reality applications with data glasses that create a completely virtual world. Such applications do away with real training objects altogether, making savings much easier to achieve.

The interest in training with VR data glasses arose when a new generation of trains was introduced recently and put into service step by step. At the beginning, the number of new trains was limited. Thousands of employees had to be trained on the new trains during a one-year trial operation, in addition to the commercial operation of the trains. To facilitate this, some applications in the operation of the trains (e.g., operation of the automatic lifts during boarding, coupling of the trains) were programmed and trained with the VR glasses. A single training VR application such as coupling requires about 1-2 months of development time. Given the bottlenecks of training on real trains, this effort was worthwhile. After this experience, other applications were developed, the most complex being learning simulations for dispatchers:

> "They are responsible for a station or section of track. [...] A large part of the infrastructure is relatively old. That is, almost 30% of signaling boxes are still operated mechanically. [...] They are operated from a signal box by a dispatcher who is a bit of a lone wolf, i.e. these systems also communicate with the neighboring stations, a kind of advance notification is made, sometimes electronically or by telephone, that a train is coming, and then he can basically determine on the basis of a timetable and local map, ok, the train may now enter this track." (IV30)

The strength of VR glasses is that they enable entire simulations. The developers emphasize that even these simulations do not make the instructor redundant. Rather, the instructor continues to take on a central role and is given new opportunities, controlling the simulation of the interlocking.

> "We now have a fully functional mechanical interlocking in simulation in VR, where a user has data glasses on and can fully operate all the controls. The trainer takes the role of the neighboring station. He has a tablet application and can simulate rail operations and send trains and can continue to simulate incidents. So for instance that a control element doesn't work, the visibility conditions are bad, or for example, a foggy situation. Or a cable pull breaks, such issues can be simulated." (IV30)

The virtual signaling boxes significantly increase the company's training capacity. In view of the demographic upheaval already being felt by the company, this is proving to be a major advantage. Many dispatchers will be retiring in the years after our study, and training capacity will have to be increased. The cost of developing such a simulation is still relatively high—developing the simulation for a particular type of interlocking takes a year of development time by a team of developers—but it is considered worthwhile given the training needs.

The use of VR glasses and simulations was discussed by management with the works council at an early stage, but was seen by the works council as relatively uncritical. The simulations do not collect any data on the employees and processes, and questions of behavioral and performance monitoring do not arise. For the works council, the ergonomics of the data glasses was important. They are still relatively heavy, which limits the time of use.

8.3.4 CarTrain

CarTrain is a global automotive company with over 200,000 employees worldwide. The case study took place in an engine plant that employs about 5,000 people. The focus was on the use of data glasses for learning processes in the plant's training center.

The training center is responsible for basic training related to the company's production system, i.e. it deals with topics such as standardized work, shop floor management, and TPM (Total Productive Maintenance). These are combined with area-specific introductions to the respective work process (e.g., engine assembly). The aim is always to teach and practice standard processes.

The training center at the engine plant undertook a pilot project for all CarTrain engine plants on the use of data glasses for training processes. This involved the use of AR data glasses, worn by employees during training and display information and instructions for all work steps.

In the traditional learning process, employees work with so-called standard worksheets on which the work steps are presented (1) as a picture, (2) as a precise description of the individual activities (gripping, screwing, etc.), and (3) as a brief description of the particularly important aspects and potential problems.

All this information has now been translated into a digital format displayed on data glasses. In the learning process, workers perform all the steps on the assembly bench in the training center. As they do so, they wear the data glasses, and the information associated with each work step is displayed on the glasses. Since they can look through the glasses, the real and virtual images overlap.

The project was coordinated with the works council, the main stipulation being that participation is voluntary and that any use other than in the scenario presented requires new consent from the works council. At the time of the study, the works council rejected the use of data glasses as assistance systems in assembly and insisted that they only be used in the learning process. Since no data about employees and processes is recorded, but only a training program is played back via the glasses, questions of data protection and behavior and performance monitoring did not arise.

In the pilot project, 40 employees went through the traditional form of training. Their results were compared with those of 40 employees who did the training wearing data glasses. Employee feedback was very positive: the display on the glasses, the field of vision, the ease of use, and the wearing comfort were described as good or very good.

Interestingly, however, a more differentiated picture emerged when the learning effects were examined. For this purpose, a test was conducted immediately after the training and another three weeks after the training. This showed that the employees who went through the training process without data glasses performed better in almost all test questions on the positioning and assembly sequence of components. It seems that the use of the data glasses influences the employees to follow the instructions of the glasses without really learning and internalizing the work steps.

The pilot project showed that the learning process with the use of the glasses took just as long and also required just as much supervision by a trainer as in the case without glasses. There were no savings in time or effort. In light of these results, the training center manager summed up his impressions:

> "I am therefore rather skeptical. I don't think that data glasses will be the panacea now." (IV31)

In addition to the use of AR data glasses in the learning processes, VR glasses were also tested. For this purpose, HTC Vive glasses were used. The company developed an introduction to the structure of an electric motor and a hybrid motor running on the data glasses. The program provides a 3D representation of the motor, which can be viewed from all sides and also disassembled into its components. There is also a test module where the assembly and positioning of the components are simulated and thus tested. The company's goal is to create a library of such training courses.

In the engine plant under study, this virtual training is used as one element of a more comprehensive training concept on electric motors. First, there is a classroom introduction to the structure and operation of the electric motor. Second, small and simple electric motors are presented at assembly tables and assembled by the participants themselves. Third, there is a virtual introduction to the motor built in the factory. Fourth, participants disassemble and reassemble a real motor.

This training concept was evaluated with a survey of the participants, although there were no comparison groups with and without virtual training. Interestingly, evaluations of the usefulness of the VR data glasses were very diverse. While some of the participants found this module very useful, others rated it rather poorly. In comparison, the disassembly and assembly of the real engine scored uniformly very well.

Despite these mixed results, the use of AR and VR data glasses in qualification is being pushed by the company. However, the technical maturity of the devices in terms of performance and robustness is still perceived as relatively limited. A lack of standards is said to be a problem. In addition, there are problems with integrating the devices into the company IT systems because these devices attempt to connect to their manufacturers' networks (for example, in the case of Microsoft HoloLens), which is a data protection problem for industrial customers and highly undesirable.

8.3.5 ElectroTrain2 case study

ElectroTrain2 is a company with about 5,000 employees worldwide. The company focuses on the production of electrical components, sensors and electronics. The company has its headquarters and a number of production sites in Germany, but also has a global presence.

The company is experimenting with wearable technologies and trying out different usage scenarios. The use of wearables in training quickly emerged as a potential application. Using data glasses, training units can be imparted individually and also directly at the point of use (in the real working environment). This saves time and can also be more conducive to learning than classroom training.

In a first step, the acceptance and evaluation of such technologies by employees was tested with a trial application developed by an external company. In consultation with the works council, an information point was set up where sample training sessions for machines ran on Microsoft HoloLens and could be tried out by employees during breaks or before or after their shift. Employee feedback was collected and proved to be very positive.

However, it became clear that developing such training requires substantial investment as there are no standard programs that can be used to develop VR training for an industrial context. The company's goal is to empower its various production sites to develop such training themselves according to their needs. Therefore, a team of five developers has been assembled to create a kind of development environment for VR training.

The goal is to provide an environment in which templates are available for various machines, workstations, and process flows. The sites can now use these templates, adapt them, and combine them with a text, image, and video display to create a training session on VR glasses. One example is tool changes on machines. Such training could interactively guide employees step by step through a tool change and test their knowledge in simulations.

The development of such an environment is challenging. The first problem is the lack of suitable data. Although there is a great deal of design data about the machines and workstations, it is in formats that are not suitable for VR glasses and must first be converted. There are now software aids available for this, but there is still considerable effort involved. In addition, it is a challenge to develop templates, representations, and linguistic designations that can be used by different locations worldwide. Finally, usability is a major challenge because, on the one hand, the application should enable production supervisors and specialists to develop training courses even without special programming knowledge, and on the other hand, good manageability by the employees to be trained must be ensured. At the time of the case study, the application was under development.

9 Appendix: Quantitative online survey

Sabine Pfeiffer

9.1 Questionnaire

9.1.1 Filter questions for target group

1. Do you work mainly in an office? y/n

2. Do you perceive your work as physically demanding? y/n

9.1.2 Sociodemographic and general information

3. In which year were you born? [open statement]

4. To which gender do you classify yourself? m/f/d

5. What is your current main occupation? [Please state the exact job title (e.g. not "mechanic" but "car mechanic"). This does not refer to the occupation you learned in the past, but to the occupation you have today.

6. In which federal state is the company where you are working?
Selection 16 Federal States/ Abroad/ n.a.

7. How long have you been working in your current occupation?
Less than 5 / 5-10 years / 11-20 years / 21-30 years / More than 30 years

8. Approximately how many employees, including yourself, are employed at your company site?
1 to under 5 / 5 to under 10 / 10 to under 20 / 20 to under 50 / 50 to under 100 / 100 to under 200 / 200 to under 250 / 250 to under 500 / 500 to under 1,000 / 1,000 to under 2,000 / 2,000 and more

9.1.3 Wearables in the workplace—basic principles

New technologies make it possible for body-related data to be permanently collected in the workplace and used for various purposes. For example:

- To record emotions, e.g., are you in a good mood or are you annoyed? (this can be recorded via the voice, for example).
- To record physical conditions, e.g., how efficient or strained are you? (this can be captured via vital signs such as heart rate frequency with a sensor on the body or via a video recording).
- To detect movements, e.g., to warn of danger (if you reach in at the wrong moment), to protect against overload (if you move the wrong way, e.g. if you lift heavy things), to optimize processes (e.g. to assist with more complex movement sequences or to shorten walking distances).

A wide variety of technologies can be used for this purpose: Your phone's voice recording, your computer's camera, or data recording devices you wear directly on your body such as smart glasses, a sensor band on your pulse, a smart work glove, or even motion sensors in your work clothes.

9. Regardless of your specific work situation or the technology used: what is your general opinion on recording your emotions at work: am I fundamentally against it / would I accept it under certain conditions / can I imagine it in principle?

10. Regardless of your concrete work situation or the technology used: what is your general opinion on the recording of your physical states at the workplace: am I fundamentally against it / would I accept it under certain conditions / can I imagine it in principle

11. Regardless of your specific work situation or the technology used: what is your general opinion on the recording of your movements at the workplace: am I fundamentally opposed to it / would I accept it under certain conditions / can I imagine it in principle

9.1.4 Wearables in the workplace—handling data

12. Now we would like to ask under which conditions you could imagine a recording of your body-related data at your workplace (even though there may not yet be an application for your current work).

Using the slider, rank each statement between 0% (doesn't matter to me) and 100% (is especially important to me).

In order to agree to a recording of my emotions during my work, the following conditions for handling the data would be particularly important to me:

12.1 The data will not be used for any other purpose within the company.
12.2 The data will be deleted promptly.
12.3 I have insight into the data.
12.4 I can speak out against the recording of individual data.
12.5 I have control over the data and can adjust it if necessary, for example to correct errors.
12.6 I can generally object to the recording.
12.7 I can interrupt the recording at any time.
12.8 Deployment and introduction are monitored and approved by the works council.
12.9 Deployment and introduction will be monitored and approved by the data protection officer.
12.10 The data will not be passed on to third parties (e.g. a health insurance company).
12.11 I can get my data for my own purposes.
12.12 I receive extensive training in the handling of the data.

13. To agree to a recording of my physical conditions during my work, the following conditions for handling the data would be particularly important for me: [repeat the same 12 questions about data].

14. To agree to a recording of my movements during my work, the following conditions for handling the data would be particularly important for me: [repetition of the same 12 questions about data].

15. Regardless of your specific work situation or the technology used, how private do you think this data should be, or how much access should the employer/company or your supervisor also have to the data?

Using the slider, rank each statement between 0% (must remain entirely with me) and 100% (may become entirely visible).

Capture of emotions / Capture of physical state / Capture of movement

9.1.5 Wearables in the workplace—benefits at work

16. In order to agree to a recording of my emotions during my work, the following conditions would be particularly important to me for handling and use at work:

Using the slider, rank each statement between 0% (does not matter to me) and 100% (is especially important to me).

16.1 The use of technology enables me to prove that I have worked properly.
16.2 The use of technology makes my work safer because it warns of dangers or hazards.
16.3 The use of technology is designed to make my work easier to plan.
16.4 The use of technology is designed to make my work easier.
16.5 The use of technology is designed in such a way that I can better concentrate on the essentials.
16.6 The technology use is designed to make my work less stressful.
16.7 The technology use is designed so that I can make better decisions.
16.8 The technology use is designed to make my work more challenging.
16.9 The technology use is designed to help me take better care of my own health.
16.10 The technology assignment is designed to help me work better with others.
16.11 The use of technology is designed in such a way that I can better support others when working together.
16.12 The technology use is designed to help me do my job better and with fewer errors.

17. To agree to a recording of my physical states during my work, the following conditions would be particularly important for me to handle and use in my work: [repeat the same 12 questions about data].

18. To agree to a recording of my movements during my work, the following conditions for handling and use in work would be particularly important for me: [repetition of the same 12 questions on data].

19. Regardless of your specific work situation or the technology you use, how much would you want to delegate decisions you need to make in your job to technology?
Using the slider, rank each statement between 0% (decision-making authority must remain entirely with me) and 100% (decision-making authority may remain entirely with technology).
Regarding the recorded emotions / the physical condition / the movements

20. Wearables also exist in the private sphere, such as fitness wristbands, smartwatches, or digital glasses to optimize one's running pace, count one's steps, or otherwise optimize oneself. How often do you use wearables in your private life? very often / often / rarely / never

Table 9.1: Own sample and ETB Microcensus in comparison

	Own sample		ETB Micro-census	Diff.	Own sample			ETB Microcensus		Diff.	
	N	*%*			*Men*	*Women*	*Other*	*Men*	*Women*	*Men*	*Women*
Total					59.4%	40.44%	0.2%	54.5%	45.5%	4.8%	-5.0%
Occupational classification											
0 Armed Forces	3	0.3%	0.5%	-0,2%	100%	0%	0%	77.8%	22.2%	22.2%	-22.2%
1 Agricultural, forestry and horticulture	17	1.6%	2.2%	-0,6%	52.9%	47.1%	0%	75.4%	24.6%	-22.5%	22.5%
2 Production of raw materials, goods, manufacturing	251	24.0%	20.5%	3,5%	82.9%	16.7%	0.4%	81.7%	18.3%	1.2%	-1.6%
3 Construction, architecture, technical building	90	8.6%	5.9%	2,7%	93.3%	6.7%	0%	92.0%	8.0%	1.3%	-1.3%
4 Natural sciences, geography, informatics	29	2.8%	5.2%	-2.4%	58.6%	41.4%	0%	76.7%	21.2%	-18.1%	20.1%
5 Traffic, logistics, safety and security	127	12.1%	12.6%	-0.5%	78.0%	22.0%	0%	71.1%	28.9%	6.9%	-6.9%
6 Commercial services, trade, hospitality	107	10.2%	9.9%	0.3%	47.7%	52.3%	0%	38.4%	61.6%	9.3%	-9.3%
7 Business organization, accounting, law	101	9.7%	18.1%	-8.4%	55.4%	43.6%	1.0%	35.0%	65.0%	20.4%	-21,4%
8 Healthcare, social sector, education	303	29.0%	21.1%	7.9%	27.7%	72.3%	0%	25.1%	74.9%	2.6%	-2.6%
9 Nontechnical sciences, culture	18	1.7%	3.9%	-2.2%	55.6%	44.4%	0%	46.6%	53.4%	9,0%	-9,0%
Occupational groups											
Manual	361	34.5%	29.2%	5.3%	84.2%	15.5%	0.3%	83.2%	16.8%	1.0%	-1.3%
Retail, logistics	234	22.4%	22.5%	-0.1%	64.1%	35.9%	0%	56.7%	43.3%	7.4%	-7.4%
Health, nursing	303	29.0%	21.1%	7.9%	27.7%	72.3%	0%	25.1%	74.9%	2.6%	-2.6%
Nonmanual	148	14.1%	27.2%	-13.1%	56.1%	43.3%	0.7%	44.7%	55.3%	11.4%	-12.1%

State	*N*	*%*	ETB Micro-census	Diff.
Schleswig-Holstein	29	2.8%	3.4%	-0.6%
Hamburg	40	3.8%	2.4%	1.4%
Niedersachsen	91	8.7%	9.4%	-0.7%
Bremen	8	0.8%	0.8%	-0.0%
Nordrhein-Westfalen	195	18.6%	20.5%	-1.9%
Hessen	61	5.8%	7.5%	-1.6%
Rheinland-Pfalz	40	3.8%	4.8%	-1.0%
Baden-Württemberg	109	10.4%	13.8%	-3.4%
Bayern	156	14.9%	16.7%	-1.8%
Saarland	7	0.7%	1.1%	-0.4%
Berlin	71	6.8%	4.5%	2.3%
Brandenburg	39	3.7%	3.1%	0.6%
Mecklenburg-Vorpommern	20	1.9%	1.9%	0%
Sachsen	101	9.7%	4.9%	4.7%
Sachsen-Anhalt	34	3.2%	2.6%	0.6%
Thüringen	37	3.5%	2.6%	0.9%
No data	8	0.8%	–	–

Job tenure	Own sample		ETB Micro-census	Diff.
	N	*%*		
Less than 5 years	186	17.8%	40.8%	-23.0%
5 to 10 years	241	23.0%	25.6%	-2.6%
11 to 20 years	246	23.5%	20.0%	3.5%
21 to 30 years	201	19.2%	9.9%	9.3%
More than 30years	172	16.4%	3.7%	12.7%

Table 9.2: Attitudes to wearables in the workplace

	… Recording of emotion data				… Recording of physical states				… Recording of movements data			
	Generally approve	*Somewhat approve*	*Do not approve*	*N*	*Generally approve*	*Somewhat approve*	*Do not approve*	*N*	*Generally approve*	*Somewhat approve*	*Do not approve*	*N*
Total	18.0%	50.2%	31.8%	1046	26.5%	50.9%	22.7%	1046	30.0%	44.9%	25.0%	1046
Gender												
Men	17.2%	47.8%	34.9%	621	23.8%	51.2%	25.0%	621	25.1%	45.7%	29.1%	621
Women	18.7%	53.9%	27.4%	423	30.3%	50.4%	19.4%	423	36.9%	44.0%	19.1%	423
				1044				1044				1044
Age												
Below 30	17.2%	51.6%	31.1%	122	32.8%	51.6%	15.6%	122	36.9%	41.0%	22.1%	122
30 to 49	19.4%	53.9%	26.7%	469	26.2%	52.7%	21.1%	469	31.3%	45.2%	23.5%	469
50 and older	16.7%	45.9%	37.4%	455	25.1%	48.8%	26.2%	455	26.8%	45.7%	27.5%	455
				1046				1046				1046
Occupational groups												
Manual	16.3%	49.0%	34.6%	361	26.6%	50.1%	23.3%	361	28.5%	44.6%	26.9%	361
Retail, logistics	17.9%	53.4%	28.6%	234	23.5%	54.7%	21.8%	234	25.2%	49.1%	25.6%	234
Health, nursing	21.1%	49.5%	29.4%	303	30.7%	48.5%	20.8%	303	38.3%	41.3%	20.5%	303
Nonmanual	15.5%	49.3%	35.1%	148	22.3%	51.4%	26.4%	148	24.3%	46.6%	29.1%	148
				1046				1046				1046
Private use of wearables												
Yes	21.4%	54.7%	23.9%	561	30.7%	52.4%	16.9%	561	35.5%	45.8%	18.7%	561
No	14.0%	44.8%	41.1%	484	21.5%	49.2%	29.3%	484	23.6%	44.0%	32.4%	484
				1045				1045				1045

Table 9.3: Conditions for the use of wearables

		... Recording of emotions				... Recording of physical states				... Recording of movements			
		Median	*Mean*	*SD*	*N*	*Median*	*Mean*	*SD*	*N*	*Median*	*Mean*	*SD*	*N*
Aggregate indices													
Index "Data Handling"		8.65	7.94	2.154	946	8.75	7.69	2.218	1004	8.82	7.97	2.269	999
Index "Benefits for work"		6.96	6.65	2.560	990	7.20	6.77	2.649	996	7.28	6.81	2.685	993
	General attitudes												
Generally approve	Data handling	7.73	7.54	2.081	171	8.11	7.57	2.271	269	8.36	7.74	2.280	306
	Benefits for work	7.31	7.02	2.320	186	7.30	7.07	2.432	270	7.77	7.14	2.553	309
Somewhat approve	Data handling	8.42	7.84	2.057	491	8.77	8.07	1.981	526	8.73	7.95	2.092	461
	Benefits for work	7.13	7.87	2.228	514	7.38	7.03	2.270	522	7.15	6.98	2.233	460
Do not approve	Data handling	9.18	8.35	2.298	284	9.21	8.17	2.629	209	9.48	8.28	2.550	232
	Benefits for work	6.53	6.04	3.101	290	6.20	5.69	3.447	204	6.78	6.01	3.456	224
	Private use of wearables												
Data handlingn	Yes	8.29	7.76	2.033	503	8.20	7.75	2.120	541	8.38	7.76	2.191	540
	No	8.90	8.16	2.237	442	9.13	8.21	2.305	463	9.23	8.21	2.338	459
Benefits for work	Yes	6.93	6.80	2.203	534	7.07	6.84	2.305	536	7.19	6.90	2.316	536
	No	6.98	6.48	2.914	456	7.36	6.68	3.002	460	7.43	6.70	3.060	457
	Gender												
Data handling	Men	8.49	7.80	2.211	563	8.57	7.83	2.260	592	8.72	7.86	2.291	589
	Women	8.76	8.13	2.056	381	8.92	8.15	2.148	410	8.95	8.12	2.235	408
Benefits for work	Men	6.87	6.55	2.568	587	6.99	6.62	2.674	588	7.10	6.68	2.685	587
	Women	7.13	6.80	2.544	401	7.46	6.97	2.603	406	7.61	7.00	2.680	404
	Occupational groups												
Data handling	Manual	8.41	7.83	2.182	328	8.58	7.83	2.282	340	8.54	7.83	2.319	339
	Retail, logistics	8.48	7.82	2.239	210	8.77	7.89	2.248	225	8.84	7.90	2.315	221
	Health, nursing	8.73	8.11	2.046	277	8.84	8.14	2.083	296	9.03	8.16	2.153	297
	Nonmanual	8.78	8.04	2.160	131	8.88	7.99	2.287	143	8.84	7.99	2.309	142
Benefits for work	Manual	7.00	6.62	2.644	337	7.20	6.71	2.733	338	7.10	6.68	2.685	587
	Retail, logistics	7.10	6.65	2.569	220	7.25	6.74	2.633	221	7.13	6.76	2.663	217
	Health, nursing	6.93	6.72	2.496	293	7.35	6.88	2.618	295	7.43	6.97	2.653	295
	Nonmanual	6.80	6.59	2.492	140	7.11	6.69	2.554	142	7.13	6.61	2.581	141
Conditions: Data handling													
1 Data not be used for other purposes		10.00	8.03	2.881	1001	10.00	8.26	2.686	1020	10.00	8.26	2.693	1014
2 Data deleted promptly		9.30	7.71	2.931	1003	9.50	7.78	2.929	1017	9.70	7.80	3.006	1014
3 I have insight into the data		10.00	8.40	2.642	1006	10.00	8.43	2.559	1019	10.00	8.42	2.567	1011
4 I can speak out against recording		10.00	8.19	2.671	1006	10.00	8.26	2.634	1019	10.00	8.33	2.611	1012
5 I have control over the data		9.20	7.79	2.820	999	9.50	7.86	2.866	1017	9.50	7.81	2.905	1012
6 I can generally object to the recording		10.00	8.47	2.534	1008	10.00	8.39	2.564	1019	10.00	8.36	2.585	1013
7 I can interrupt the recording		10.00	8.11	2.760	1006	10.00	8.11	2.750	1017	10.00	8.19	2.651	1008
8 Recording monitored by works council		8.80	7.37	3.152	986	8.90	7.36	3.211	1016	9.00	7.36	3.231	1009
9 Recording monitored by data protection officer		9.40	7.71	2.944	996	9.00	7.50	3.115	1015	9.40	7.62	3.086	1008
10 No passing on of data to third parties		10.00	8.28	2.733	1007	10.00	8.16	2.778	1017	10.00	8.17	2.705	1009
11 I can get my data for own purposes		9.50	7.69	2.964	996	9.70	7.88	2.900	1013	9.60	7.88	2.856	1009
12 I receive training in data handling		8.30	7.33	3.025	998	8.50	7.39	3.035	1012	8.60	7.47	2.992	1005
Conditions: Benefits for work													
1 Technology proves that I work properly		6.30	6.03	3.371	1000	7.00	6.43	3.321	1005	7.35	6.56	3.281	1000
2 Technology makes my work safer		7.60	6.85	3.116	1003	7.90	7.13	3.016	1010	8.00	7.16	3.052	1006
3 Technology makes my work easier to plan		6.90	6.41	3.174	999	7.10	6.60	3.150	1007	7.20	6.68	3.124	1002
4 Technology makes my work easier		7.70	6.88	3.135	1005	7.60	6.96	3.030	1010	7.80	6.99	3.034	1007
5 Technology helps me concentrate on the essentials		7.40	6.69	3.096	999	7.50	6.76	3.108	1008	7.60	6.84	3.104	1001
6 Technology makes my work less stressful		8.00	7.14	2.995	1003	8.00	7.21	2.942	1009	8.00	7.20	2.999	1007
7 Technology helps me make better decisions		7.30	6.66	3.066	1001	7.10	6.67	3.077	1006	7.30	6.63	3.127	1003
8 Technology makes my work more challenging		5.70	5.61	3.152	995	5.95	5.78	3.269	1002	6.40	6.02	3.255	999
9 Technology helps me take better care of my health		8.10	7.32	2.928	1003	8.30	7.45	2.868	1007	8.20	7.33	2.964	1006

10 Technology helps me work better with others	7.15	6.68	3.077	998	7.20	6.68	3.092	1006	7.40	6.69	3.117	1001
11 Technology helps me supporting others when working together	7.20	6.65	3.063	997	7.30	6.70	3.088	1004	7.40	6.68	3.113	1003
12 Technology helps me work with fewer errors	7.50	6.94	3.030	999	7.55	6.83	3.107	1006	7.70	6.89	3.083	1000

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