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Measuring Digital Work in (German) Employee Surveys: An Overview and Proposal of Systematization

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Abstract

Innovative measurements in representative surveys are needed to draw meaningful conclusions about the prevalence of digital work and its consequences for employees' job demands and resources. Since the digitalization of work encompasses a variety of technological developments and possible implications for employment, there are many different approaches to its operationalization. Within this article, we (1) provide a scheme for classifying different approaches to measuring digital work, (2) apply this scheme to nine different representative German employee surveys that operationalize digital work, and (3) evaluate the measurement of digital work by discussing the advantages and limitations of the different approaches. We identify three approaches to measuring digital work: equipment-based, content-based, and opinion-based. Besides the advantages and disadvantages of these approaches, we discuss the state of the art in measuring digital work and whether it would make sense to create a standardized set of questions.

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1. Introduction

The digitalization of work is currently one of the most important issues in public and scientific debates. Particularly since the beginning of the COVID-19 pandemic in 2020, there has been an increase in work communication via digital means and in working from home facilitated by digital technology (e. g., messaging and videoconferencing tools) (Bolisani *et al.* 2020; Waizenegger *et al*. 2020; Kleinert *et al.* 2021). The digitalization of work includes

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more than digital communication, however; it also incorporates the implementation of different types of digital technologies in workplaces and work processes (Gray and Rumpe 2015; Hirsch-Kreinsen 2016; Govers and van Amelsvoort 2019).

Previously, researchers often operationalized the digitalization of work by collecting information on the availability of computers and internet access in the workplace, whereas more recent studies increasingly implement more differentiated and detailed evaluations of technology and equipment, including how these tools are used for specific tasks and the consequences of their use. With an increasing number of studies implementing questionnaire modules concerning digital work, the resulting measurements and data are becoming more heterogeneous. On the one hand, this can be advantageous in terms of examining such an extensive and multi-factorial concept. On the other hand, the complexity of these measurements and data also increases.

This article contributes to the disentangling and reflection of the approaches now being used to measure digital work within employee surveys. First, we briefly summarize the debate concerning the digitalization of work and its relation to job quality. Second, we propose a scheme that identifies different approaches to measuring digital work. Moreover, we apply this scheme to nine representative German studies that operationalize digital work and consider working conditions or job quality. Here, we also look at already existing results of the studies and how they relate to theoretical debates on the importance of digital work for job quality. Finally, we evaluate the approaches and discuss their advantages and limitations. Regarding the broadness of the digitalization phenomenon in particular, it is important to acquire and maintain an overview of the different types of operationalization and to place different approaches and their immanent goals within the context of current debates. In this way, we can evaluate the coverage of different aspects of digital work and consider what specific conclusions can be drawn by applying different measurements. In addition, a systematization of measurements reveals gaps in the operationalization of digital work and provides an instrument for assessing and integrating measurements within the context of research in this field.

We focus on German employee studies for two reasons: First, in Germany, the digitalization of work and its consequences for industrial sectors ("Industrie 4.0", Warhurst and Hunt 2019, 3), as well as for the labor market and the workforce ("Arbeit 4.0", Becka, Enste and Ludwig 2019, 342), is a widely discussed topic (Hirsch-Kreinsen 2016). From an international perspective, this discussion is therefore often referred to as the *German debate*, with Germany being regarded as a trailblazer (Warhurst and Hunt 2019). Increased funding for projects that concern the digitalization of work in Germany has further increased the integration of measurements in more and more employee surveys designed to provide new insights into the digital transformation of work. The strong focus on digitalization and the multitude of such surveys enables us to compare the various approaches being undertaken to operationalize digital work. Second, the specific focus on German surveys allows us to investigate the operationalization of digitalization in a homogeneous setting. Because contextual factors represent an important influence on the development of the digitalization of work and society, the industrial setting (Žwaková 2018), qualification structure (Caselli and Coleman 2001), labor market policies (Berger and Frey 2016), and country-specific discourse (Marenco and Seidl 2021) play an important role in this development and add to the already complex conceptualization of digitalization. In order to reduce this variety of

factors, we look at one specific context and limit our focus to the operationalization of digitalization within studies undertaken in Germany. However, we invite international researchers to contribute to our findings and extend the debate.

2. Theoretical Perspectives on Digital Work and Its Relation to Job Quality

According to the international literature on technological development and change, *digitalization* comprises the increasing dissemination of digital technologies as well as its impact on organizational and societal processes (Legner *et al.* 2017; Govers and van Amelsvoort 2019).

The predicted structural consequences have been thoroughly discussed, albeit in a rather *techno-determinist* sense, assuming that new technologies structure and impact work (Winner 1977; Attewell and Rule 1984; Dafoe 2015). Some authors propose a *socio-technical perspective* to digital work (Trist and Bamforth, 1951; Trist 1953; Emery [1959] 2016), implying that the technical and the social subsystems within work organizations interact with and complement each other in the execution of tasks and work processes (Govers and van Amelsvoort 2019). Hence, the systems are not determinate but are dependent on one another (Fischer and Herrmann 2011). As an example, Fischer and Herrmann (*ibid.*) mention communication systems that ease the communication between team members but also allow employees to contribute to the (further) development of such systems. This type of interaction between human action and technologies is also claimed by the *socio-material perspective* (see, e. g., Orlikowski 2000; Orlikowski and Scott 2014), which emphasizes human agency in shaping technological structures and implies that engaging employees in the use of technologies affects the way in which technology can be integrated into work processes and organizations (Orlikowski 2000). Research in this context also emphasizes the role of the organizational and structural context in the dissemination and impact of these technologies (e. g., flexibility going along with the adoption of technologies as well as the possibility to enhance skills for employees) (Hirsch-Kreinsen 2016; Arntz, Gregory and Zierahn 2019).

To understand the relationship between technologies and various aspects of job quality in particular, the techno-stress model understands the dissemination and use of digital work technologies as a stressor which leads to employees' strain (Tarafdar, Pullins and Ragu-Nathan 2015). Whereas the techno-stress model takes only the demanding aspects of digital work technologies and, thus, a downgrading of job quality into account, the integration into the already existing and widely used Job-Demands-Resources Model (J D-R Model; Bakker and Demerouti 2007; Day, Scott and Kelloway 2010; Day *et al.* 2012) allows for the classification of these technologies as a job demand but also as a job resource for employees (Day *et al.* 2012). Similar to the techno-stress model, aspects like a constant availability, ICT hassles or the possibility to monitor employees are seen as demanding factors. From a resource perspective, the support by digital technologies in an assisting way, as well as strengthening of already existing resources is of major importance and even upgrades job quality being associated with lower stress and strain (Day *et al.* 2012). Though these two concepts focus on information and communication technology, these thoughts can also be transferred to automation and algorithmic technologies. Here, digital monitoring and evaluation or digital assistance systems can on the one side be a demanding factor and im-

pact job quality in a negative way by e. g., leading to lower job performance, commitment, and external control (Posey *et al.* 2011; Jeske and Santuzzi 2015; Martin, Wellen and Grimmer 2016; Siegel, König and Lazar 2022). On the other side, they can also ease especially physically demanding working conditions or lead to more transparency in performance evaluation (Sharma and Sharma 2017; Wood *et al.* 2019; Wood 2021). Technologies and technical systems thus serve as support systems for employees' performance of repetitive or physically demanding tasks and allow for more complex decision making, which might even enhance job control for workers (Hirsch-Kreinsen 2016).

Overall, the different theoretical perspectives on digital work comprise a wide range of possible scenarios in terms of the effects on job quality. This situation opens up many reference points for empirical research and the operationalization of digital work in different studies and employee surveys.

3. Proposal of Systemization

Based on the state of research on digital work and our review of existing studies, we propose a scheme to classify different approaches for measuring digital work in employee surveys (see Figure 1). As a basis for developing a scheme, we refer to classical guidelines of survey methodology (Bhattacherjee 2012; Groves *et al.* 2009). The first step in an empirical research process is to define the subject to be measured, as based on a theory or a general goal. The underlying abstract theoretical constructs' intention is a translation into concrete terms (Bhattacherjee 2012; Groves *et al.* 2009). Thus, the *definition and theoretical concept* constitute the first level within our scheme (cf. Figure 1). The *concept of digital work*, the *study interest*, and the *study design* each play a role in designing the operationalization of digital work.

Whereas some *concepts of digital work* are quite simple and unidimensional, others are harder to grasp. The concept may include many dimensions like the use and extent of different technologies, their integration in the work organization or the relevance for employees' working conditions. The precise and concrete definition is affected by the (underlying) perspective on digital work – whether it is the focus on the diffusion of specific technologies at work, the impact on employees' daily working lives and work organization as a result of the interaction between technologies and human work, or how employees perceive the implementation of digital technologies at work. Moreover, differences regarding the dimension of work are of interest, as are their assumed consequences: specific occupations, work tasks, skills or qualification processes, work resources, or work demands. The operationalization of digital work is also connected to the *study interest*; for example, an explanation of social inequalities and polarization or capturing working conditions may lead to different approaches to this phenomenon. The study interest can also be related to different concepts of digital work. In addition to the concept of digital work and the study interest, the *study design* plays a role in shaping the operationalization of digital work. The digitalization of work unites a multitude of technologies and processes, so the implementation, type, and use of these technologies varies considerably across structural components such as jobs, branches, or the size of the company (Hirsch-Kreinsen 2016; Holler 2017; Brockhaus *et al.* 2020; Reimann, Abendroth and Diewald 2020). Moreover, the focus and structure of measuring digital work differ depending on whether the research survey is integrated

into an already existing study, how much space it takes up, or whether the study has been designed for the purpose of capturing digital work only. Thus, the operationalization of digital work is likely to depend on how one designs the study. Practically, these matters are often interrelated. For instance, if digital work is surveyed as only one part/module of a comprehensive study, the operationalization of digital work must be adapted to the (already existing) study interest and sample. Thus, the concept of digitalization depends on both these factors. Conversely, the study interest and sample may also be linked and designed according to the concept of digital work.

At the second level, questionnaires are designed that reflect the underlying definition or concept of digital work by translating them into indicators or items and verbalizing variables (Bhattacherjee 2012; Groves *et al.* 2009 on the *operationalization* of surveys or survey modules shown in Figure 1 in this article).

The many different types of operationalization reflect differences in the theoretical conceptualization of digital work but also different foci on specific aspects of digitalization as well as survey-specific populations (such as different cohorts or employees). First, understanding technology as structure in the rather technic-centered perspective, one type of operationalization focuses on the dissemination of specific digital technologies at work. We summarize these approaches under the term *work equipment-based approach.* Second, the *work content-based approach* aims to measure the work content or functioning technologies that are used (e. g., automation processes or digital communication), since technologies can be used for different purposes in line with the concept of socio-technical systems. Third, we distinguish *opinion-based approaches*, which ask directly about the *perceived* "impact" of the digitalization of work often without referring to a specific technology. Even though this operationalization does not allow for causal inferences with regard to the implications of digitalization for the employees' work situation, opinion-based approaches are particularly useful in describing the perceptions and attitudes of different employee groups or, in a longitudinal perspective, perceptual changes. Theoretically, this approach is also more technically centered and can be located, for example, in techno-stress approaches (Tarafdar, Pullins and Ragu-Nathan 2015).

Finally, most surveys also allow researchers to examine the various *impacts of digitalization*, that is, *how* job quality, work-life balance, or health relates to the use of digital work equipment, to digital work content, or to opinions about the implications of the digitalization of work. Such impacts may include transformations in the way work is organized within establishments, as well as changes on the occupational or the employee level (Govers and van Amelsvoort 2019). In terms of *impact*, we distinguish between an individual *assessment* of the impact of digital work and an empirical analysis of the *consequences* of digital work without an individual assessment. *Assessment* includes particular questions about how individuals perceive working with specific digital work equipment or how they evaluate digital work content. The direct connection between specific equipment or content and the employee's assessment distinguishes this strategy from the opinion-based measurement of digitalization, which asks for the employee's perceived general consequences of digital work. In contrast to the other two clearly distinct categories, opinion-based assessments are not always clear-cut. *Consequences* offer the potential to analyze the impact of digital work equipment or digital work content on, for instance, working conditions, educational attainment, health, or different aspects of job quality, which are independently included in most

surveys but do not rely on the respondents' subjective evaluations of digital work. Although the occupational, organizational, and national contexts are not displayed in Figure 1, we acknowledge that these factors shape the diffusion of specific technologies for work equipment and work content, as well as the opinions about digital work and their impact. Our purpose is to develop a scheme for classifying the existing measurements of digital work. When these measurements are used to answer specific research questions about digital work, such influences need to be considered.

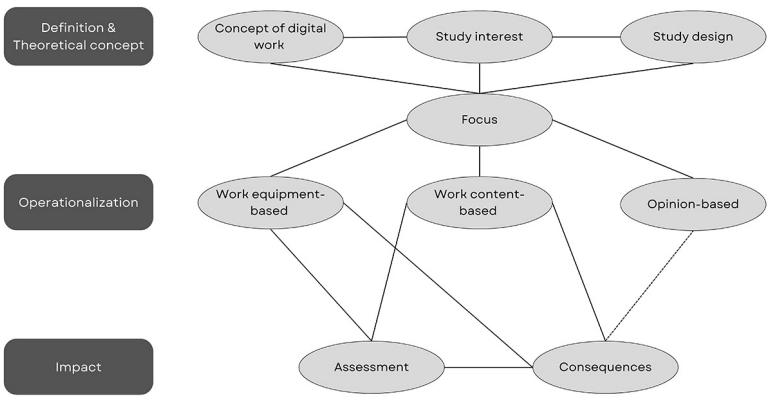

Figure 1. Scheme of Measuring Digital Work

4. Measurements of Digital Work in German Studies

4.1 Selection of Studies

We review large studies conducted in Germany in order to identify the different instruments used to measure digital work. We select studies to be analyzed based on the following criteria: (1) they have to focus on aspects of digitalization at the workplace specifically, not only on the private or general use of a certain technology; (2) they have to include working conditions, aspects of job quality, or workplace characteristics as part of their surveys; (3) they have to provide information about the general survey design and/or the specific questionnaires covering digitalization; and (4) the sampled respondents have to cover a large part of the working population and to be representative of the respective population.

Overall, nine surveys meet these criteria (see Table 1). Six out of the nine studies are employee surveys [BAuA-AZB, DiWaBe, DGB-Index "Gute Arbeit", LEEP-B3, LPP, Bertelsmann Stiftung study "Stand der digitalen Transformation in Deutschland"]. The other studies have different target groups: they focus on households [SOEP] or on specific birth

cohorts [NEPS, lidA], but questions about digital work are received by working respondents only.[1]

Most of the studies have, up to now, included the comprehensive measurement of digitalization only once (the exceptions being LPP and NEPS). DiWaBe and LEEP-B3 also include retrospective questions on different aspects of digitalization.[2] For detailed descriptions of all the studies considered, see Table 1.

4.2 Implementation Within the Studies

4.2.1 Definition and Theoretical Concept: Concept of Digital Work, Study Interest, and Study Design

Except for NEPS, which clearly refers to the digitalization of work in terms of socio-technical systems (Friedrich *et al.* 2022), the studies do not refer to a theoretical concept of digital work for their operationalization. Consequently, we can only reflect on the theoretical concept by including questionnaires and published research. In most of the studies, the questionnaire has a specific focus, particularly in relation to the study interest (see Table 1). Based on the study interest, as well as the operationalization of digitalization, it can be inferred that all studies understand the implementation of technology as part of the work environment and in its interaction with employees' work tasks and conditions. This line of inquiry indicates an understanding of digital work as a theoretical concept of socio-technical systems. However, there are some gradations in their understanding of technology as a determinant of employees' working conditions.

Some surveys, DiWaBe, lidA, BAuA-AZB and Bertelsmann Stiftung study, look at the digitalization of work by focusing on the implementation of specific technologies or the digitalization in general affecting employees rather than their integration in the work process (see Table 2 in the Appendix). The first two surveys focus on the economic, social, work organizational, and health-related consequences of digital technologies in the workplace and concentrate on the implementation and diffusion of specific technologies. The BAuA-AZB and the DGB-Index focus primarily on working conditions and the quality of work and look specifically at employees' perception of digital work in terms of their work demands and resources. The Bertelsmann Stiftung study is interested specifically in employees' perspectives on the digital transformation at their workplace and on working conditions, with a focus on capturing their perceptions about the status and implementation of digital work in their companies. The DGB-Index, LEEP-B3, NEPS, LPP take an interactive perspective by looking at the integration of digital work technologies into work processes (see Table 3 in Appendix). The LEEP-B3, which has a special interest in employment relationships and organizational inequality regimes, asks primarily about the application of digital work technologies in the work process and about the interactions with digital technologies among different groups of employees, as well as the consequences of their use when it comes to job demands and resources. In the NEPS, the emphasis is on technology as part of work tasks and changes in tasks and work, which reflects the study's interest in the

[1] For some studies, an English translation of the questionnaire was available. The other questionnaires were translated by the authors (BAuA-AZB, Bertelsmann Stiftung study, DiWaBe, DGB-Index, lidA, SOEP).

[2] We, however, did not include this as a criterion.

Table 1. Overview of the Surveys Reviewed]

Survey	**BAuA-AZB**	**Bertelsmann Stiftung study**	**DGB-Index**	**DiWaBe**	**LEEP-B3**	**lidA**	**LPP**	**NEPS**	**SOEP**
Responsibility	BAuA	Bertelsmann Stiftung, Kantar	DGB	ZEW, IAB, BAuA, BIBB	Bielefeld University (cooperation with IAB)	Bergische University Wuppertal	BMAS, IAB	IAB, WZB	DIW
Survey type	Panel	Cross-sectional	Cross-sectional (repeatedly)	Cross-sectional	Panel	Cohort study, panel	Panel	Cohort study, panel	Panel
Survey date (digitalization measured)	2019	2019	2016	2019	2018/19	2018	2014/15, 2018/19	2019/20, 2020/21, 2021/22 (in field)	2019
Study interest	Long-term consequences of the changing working environment and a continuous reporting about working hours; focus on the design of working hours, conditions and health	State of digitalization within establishments from the employees' perspective; perception of the digital transformation in daily work and at the workplace	Investigation of the quality of work from the employees' perspective; in 2016, focus on digitalization	Social, work organizational, and health-related consequences of digital technologies at the workplace	Organizational inequalities and interdependencies between work and private life; data from employers and employees about the workplace context, working conditions, and private life of employees	Long-term effects of work on health and employment participation of elder workers	Examination of personnel management, individual job quality, and corporate success	Investigation of the development of competencies and education for different cohorts over the life span	Household survey for innovative research projects; module about digitalization in 2019
Sample	Working population at least 15 years old and working at least 10 hours per week	German employees	Employees	Employees (sample based on IAB-ZEW Arbeitswelt 4.0 sample)	Employees born after 1960 within large establishments (> 500 employees)	Employee cohorts born in 1958 or 1965	Employees within establishments with at least 50 employees	Adults born between 1944 and 1986 (Study cohort 6) and born in 1995/1996 (Study cohort 4)	Households

Table 1 *(Continued)*

Survey	BAuA-AZB	Bertelsmann Stiftung study	DGB-Index	DiWaBe	LEEP-B3	lidA	LPP	NEPS	SOEP
Sample size	2019: ≈ 9,400 respondents	≈ 2,100 employees	≈ 10,000 employees	≈ 8,300 employees	≈ 6,300 employees	≈ 3,600 employees	2014/15: ≈ 7,300 employees 2018/19: ≈ 6,500 employees	2019/20: ≈ 5,100 adults in SC 6 and ≈ 3,300 in SC 4; 2020/21: ≈ 4,700 in SC 6	≈ 2,900 households
Reference for general information	Häring et al. 2020	Grzymek and Wintermann 2020	DGB 2016; Holler 2017	Arntz et al. 2020	Marx et al. 2020	Wuppertal University 2018; Steinwede, Ruiz Marcos and Kleudgen 2020	Broszeit, Grunau and Wolter 2016; Ruf et al. 2020b	NEPS 2021; Friedrich et al. 2021	Zweck and Glemser 2020
Reference for questionnaire/data	Häring et al. 2020; Pattloch et al. 2021; BAuA Arbeitszeitbefragung (2019)	zukunft der arbeit 2020	DGB 2016; Holler 2017	Arntz et al. 2020	Marx et al. 2020; Reimann, Abendroth and Diewald 2020	Borle et al. 2021	Ruf et al. 2020a	NEPS 2021	SOEP-IS Group 2021; SOEP Innovation Sample (SOEP-IS) 2020
Examples for publications	Tisch et al. 2021; Kersten and Junghanns 2022; Meyer and Backhaus 2022	Grzymek and Wintermann 2020	DGB 2016	Meyer et al. 2021; Meyer and Hünefeld 2021; Tisch et al. 2021	Gensler and Abendroth 2021; Marx, Reimann and Ribbat 2021; Marx, Abendroth and Meyer 2022	Borle et al. 2021	Arnold et al. 2016	Friedrich et al. 2021; Kleinert et al. 2021; Friedrich et al. 2022;	Giering et al. 2021; Giering and Kirchner 2021

Note: BAuA-AZB = Bundesanstalt für Arbeitsschutz und Arbeitsmedizin – Arbeitszeitbefragung (working time survey); DGB-Index "Gute Arbeit" = Deutscher Gewerkschaftsbund Work Quality Survey; DiWaBe = Digitalisierung und Wandel der Beschäftigung; *LEEP-B3 = Linked Employer–Employee Panel Survey;* lidA = leben in der Arbeit Cohort Study; LPP = Linked Personnel Panel; NEPS = National Education Panel Study; SOEP = Socio-Economic Panel.

development of competencies and education. A similar focus on work tasks and processes can be found in the LPP. Though the SOEP integrates measurements from all types of approaches equally, the module in the innovation sample focuses on the application of and interaction with technology at work.

Moreover, many of the studies include questions regarding the impact of digital technologies in an opinion-based way, which rather indicates a determining impact of digitalization on employees' work and personal lives. The use of such type of questions can be found in the BAuA-AZB, DGB-Index, LEEP-B3, the survey from the Bertelsmann Stiftung, lidA and NEPS (see Table 4 in the Appendix).

Regarding study design, the studies we have chosen tend to cover the whole labor market structure and thus are not sensitive to specific industries/sectors or jobs. Moreover, they prove suitable for most of their respondents because they incorporate a variety or quite broad measurements of work technologies or applications in work processes.

4.2.2 Operationalization: Work Equipment-Based, Work Content-Based, and Opinion-Based Approaches

Although differences in the emphases of these studies are noticeable, there is no such clear dividing line in the approaches they take. All the studies implement more than one approach for the operationalization of digital work. The following section illustrates these approaches with examples of items from the individual questionnaires themselves. Moreover, we present empirical results based on the surveys that have already been published and link them to the approaches.

The *work equipment-based approach* focuses on the use of specific technologies at work. Following this approach, a direct link between the use of a certain technology and its impact on such factors as job demands and resources, job quality, and health of employees can be analyzed. Thus, digitalization is measured by the prevalence and use of new technologies and of digital work equipment and machinery in the workplace. Most studies differentiate between (types of) information and communications technology (ICT) and production technology, such as machinery, tools, or robots. The equipment-based approach is most prominent in the DiWaBe study, which first distinguishes three main categories of technology (ICT, machines, and vehicles):

> "We would like to know which equipment you work with. Therefore, I mention three groups at first. Please tell me how often you use these on a typical workday. Also, how often do you use equipment for information and communication?"

These items are followed by more detailed questions (single answer categories) about the particular technology used, for example:

> "You told us that you use information and communication equipment at work. Does this include the following computerized tools: 1: desktop PC, 2: laptop, 3: smartphone, 4: tablet 5: POS systems 6: [something] else (open category)?"

This concept is similarly used for the other two main categories (i. e. machines and vehicles). Furthermore, the frequency with which an employee uses 4.0 technologies is surveyed for seven specific technologies (e. g., artificial intelligence, augmented reality, and big data). The lidA, LEEP-B3, and SOEP surveys also include a differentiated query, although in LEEP-B3 it is for robots only.

Most of the studies group different technologies without asking for each specific tool separately. The LPP asks:

> "In the following, we will deal with the work on machines and in plants. Do you work with tools, equipment, and machines? Please think of hand tools as well as measuring and diagnostic devices or robots. This is not referring to vehicles, means of transport, and office communication."

Similar broad measures are implemented in the BAuA-AZB, NEPS, and DGB-Index, whereas an even broader approach is implemented in the Bertelsmann Stiftung survey, which asks respondents to choose the appropriate category:

> "When thinking about your professional activity, do you perform your work mostly 'with people,' 'at the office,' 'with technical work equipment or tools,' or 'with intelligent tools or machines'?"

Overall, nearly all studies integrate the use of ICT-related work equipment, as well as machinery, devices, or tools. Particularly the use of computers, laptops, smartphones, and tablets is surveyed in most of the studies – often summarized in a single question. Moreover, in most of the surveys the use of ICT includes a mix of work equipment and applications (e. g., asking about laptops and mails in one question), thus making a clear distinction difficult. Regarding machinery and devices, more than half the studies ask about the use of robots. Questions about production machines, data glasses, or diagnostic devices are posed in at least three studies (for detailed information, see Table 2 in the Appendix). However, it has to be mentioned that especially in the studies that ask quite broadly about technologies (e. g., networked technologies), a clear distinction between technologies is difficult, but so is comparisons between studies.

Already published analyses based on the surveys find that ICT are widely used by employees (Arnold *et al.* 2016; DGB 2016; Borle *et al.* 2021; Friedrich *et al.* 2021; Marx, Reimann and Ribbat 2021; Tisch *et al.* 2021). The amount of use, however, vary between the studies. A clear distinction between technologies based on the DiWaBe shows noticeable differences between the different technologies. Whereas 53 % of the respondents primarily use a Desktop-PC, only 19 % use laptops (Tisch *et al.* 2021). Adding to this, this distinction is also important for examining the impact of digital work technologies (Giering and Kirchner 2021; Meyer and Hünefeld 2021). Meyer and Hünefeld (2021) find a positive connection to work intensity for the work-related use of smartphones or tablets but not for working with a laptop. Results from Giering *et al.* (2021) and Giering and Kirchner (2021) show that AI systems incorporated in work technologies have already found their way into the daily working world.

The *work content-based approach* considers the functions of technologies and processes when digital technology is used. Here, the focus is on changes in the organization of work, work tasks, and the application of technologies (e. g., automation or new tasks related to the prevalence of digital technology, such as virtual communication). The work content-based approach is incorporated especially in the DGB-Index, LEEP-B3, LPP, NEPS, and SOEP surveys. Two different sub-approaches can be distinguished: process-oriented and task-oriented approaches: A *process-oriented approach* is integrated within the DGB-Index, LEEP-B3, and SOEP surveys as follows:

> "Information or data about my operations are automatically stored e. g. via an app, machines or a computer program." (in LEEP-B3),

or

"Which forms of digitalization play a role for your work: 'electronic communication (e. g., via mail, smartphone, social networks)' or 'software-based work processes (e. g., route-, production-, or schedule planning')?" (in the DGB-Index).

Work content can be surveyed in a *task-oriented* manner as found in LPP, NEPS, and SOEP. Here, specific work tasks using technologies are elicited, including questions such as the following:

"Now we are interested in what you do in your job as '…' exactly. Do you use the internet or intranet to search for information?" or "Do you create or edit digital files in your job?" (in NEPS),

or

"How often do you carry out the following activities as part of your work? (Two possible replies are "A: Collect or prepare data with spreadsheet programs, such as Excel" or "D: Administration of databases") (in LPP).

The majority of studies includes questions about electronic communication at work (via mail, platforms, or apps). Common questions ask for the use of information technology in different forms, use of the internet, work involving texts and files, online meetings, and whether employees get automated work instructions or instructions about their work process. In particular, LEEP-B3, LPP, NEPS, and SOEP collect detailed information about technologies as part of an employee's work content. (For an overview, see Table 3 in the Appendix.)

Surveys which focus on the work content show that digital communication is part of the work of many employees (DGB 2016; Marx, Reimann and Ribbat 2021). As can be seen within the LEEP-B3 data, 52 % managers and 39 % employees communicate via mail on a daily basis. This share is much lower for the communication via digital platforms and apps. Results from the DGB-Index and LEEP-B3 show a relatively high amount of interference of digital technologies with work processes via digital support or control systems. As the DGB-Index reports, support by electronic devices and software-controlled processes are part of the work of about 50 % of the respondents (DGB 2016). Rather similar results can also be found in the LEEP-B3 data. On average 37 % of the employees receive algorithmic directions (Gensler and Abendroth 2021) and 40 % of employees state that their data are automatically stored (Marx, Abendroth and Meyer 2022).

While both, the work equipment-based and the work content-based approaches, focus on the pervasion of work by technologies, *opinion-based approaches* attempt to directly survey employees' perceptions of technology-induced changes in the labor market structure, work organization, or working conditions, such as techno-overload, techno-insecurity, or techno-complexity. Most studies integrate at least one opinion-based item (BAuA-AZB, Bertelsmann Stiftung study, DGB-Index, LEEP-B3, LPP, and NEPS). An example that appears in the LPP survey is

"How likely do you think it is that due to technological development your work will be taken over by machines in the next ten years?"

In the DGB-Index, this is covered by the item

"Because of the digitalization the amount of work to be handled rather 1) increased or (2) decreased."

The Bertelsmann Stiftung study asks whether the respondent agree or disagree with the following statement:

"Digitalization eases my reconciliation of work and private life."

However, opinion-based items often have a rather suggestive character, such as this one from the BAuA-AZB survey:

"The occupational use of modern communication technologies – internet, mail, smartphone […] – often goes along with information overload. How often do you struggle to deal with the amount of information?"

The topics most frequently covered within this approach are the perceived impact of digitalization on job strain and further training, followed by questions about changes in the work situation, the loss of the importance of competencies, the impact on the employee's work–life balance, the feeling of external control, and the fear of job loss. The DGB-Index and the BAuA-AZB in particular integrate many opinion-based questions. Though most studies use this approach (6 out of 9), they typically use only one or two questions of this type. (For an overview, see Table 4 in the Appendix.)

When asked about their opinion on the digitalization of work, employees have both positive and negative associations in respect to working conditions. In the DGB-Index more than 50 % report a higher amount of work due to digitalization (DGB 2016). Nevertheless, 27 % perceive more autonomy at work and for 21 % digitalization goes hand in hand with a greater reconciliation of work and family (DGB 2016). Results from the study by Bertelsmann show that even 50 % of the respondents approve this relationship, and 61 % state that digitalization leads to more positive than negative changes in their working lives (Grzymek and Wintermann 2020). This relatively balanced ratio of positive and negative associations with digital work technologies is also found in the results of the BAuA-AZB. Here, 22 % of the employees perceive new technologies as facilitating work, whereas the same amount of people feels more strain (Meyer and Backhaus 2022).

4.2.3 Impact: Assessment and Consequences of Digitalization

Most of the studies allow for the exploration of the impact of digital work based on employees' self-assessment, establishing statistical relationships about its consequences (e. g., with regard to educational attainment, income, well-being or health, or work resources and demands).

We find examples on the assessments that are linked to equipment-based or content-based measurements of digital work in LEEP-B3, LPP, and NEPS. In LEEP-B3, the use of technologies in everyday work, such as communication via mail or apps or getting automated work instructions, is queried at the outset. If the respondents state that their work involves these types of technologies, their assessment of this specific content-based measurement is then queried. For instance, if respondents used ICT-like communication through mail or apps, or in-house or external information systems regularly, they are asked to address the following items on a 5-point Likert scale:

"By using digital information and communication technology, I am more flexible in terms of work place and time."

"The use of digital information and communication technology makes communication more efficient."

"By using digital information and communication technology, I have to be constantly available."

"The use of digital information and communication technology will replace personal interaction."

"When using digital information and communication technology, I feel overwhelmed by the amount of information and communication."

Results based on this assessment show that employees perceive constant availability and overload due to digital communication, but also more efficiency in their communication, as well as flexibility in working time and place (Marx, Reimann and Ribbat 2021). Moreover, the use of digital monitoring in the sense of the automatic storage of data about employees' work steps goes along with a feeling of constant surveillance and the use of this data for performance evaluation, but also with the perception of more efficiency in work design (Marx, Abendroth and Meyer 2022).

In LPP, the question about which technology had changed the way of working and work content the most within the last 2 years is followed by a question such as

"Now think about this technological change. Does the application or use of this new technology require skills and competencies that you did not possess before?"

This technological change goes along with the perception of e. g., the need for further training (78 % of employees), multi-tasking (65 %) and higher autonomy (32 %; Arnold *et al.* 2016).

Digitalization – regardless of whether it is measured by an equipment-based or a content-based approach – is embedded in comprehensive employment relationships and can be linked to general indicators of job demands and resources, work or private life conditions, and employment chances. In contrast to the opinion-based approach or the assessment of specific technologies, these other topics and potential outcomes are surveyed independently and thus rely less on employees' direct assessment of the extent to which digital work is related to the respective outcome. Since most of the digitalization modules are part of larger surveys that query these topics independently from the digitalization of work, it is possible to calculate a statistical relationship between digital work and these outcomes. This applies to nearly all the studies we examine (BAuA-AZB, DiWaBe, DGB-Index, LEEP-B3, lidA, LPP, NEPS, and SOEP). The BAuA-AZB shows that the prevalence of health problems is positively connected to information overload due to digital technologies (Kersten and Junghanns 2022). The DiWaBe survey indicates that the use of digital technologies is related to higher work intensity, but also to more autonomy and less physical strain (Meyer *et al.* 2021; Meyer and Hünefeld 2021). Results based on the lidA study reveal a negative association between the extensive use of ICT and mental health as well as work ability (Borle *et al*. 2021). First publications based on the LEEP-B3 data show that digital work instructions and automatic data storage go along with less job autonomy (Gensler and Abendroth 2021; Marx, Abendroth and Meyer 2022). The NEPS places a special focus on qualification and further training. Based on this data, the use and perception of digital technologies is found to be connected to higher rates of further training (Friedrich *et al.* 2021). Further research on differences in the use and impact of digitalized work according to employee and employment characteristics reveals that the extent of the use of digital work technologies varies tremendously according to gender, qualification and occupation of the respondents, as well as industry sectors (Arnold *et al.* 2016; DGB 2016; Reimann, Abendroth and Diewald 2020; Borle *et al.* 2021; Friedrich *et al.* 2021; Gensler and Abendroth 2021; Giering and Kirchner 2021; Tisch *et al.* 2021). At first glance, the findings indicate no notable dif-

ferences between sectors when all of the technologies used at work were combined (Reimann, Abendroth and Diewald 2020). However, distinguishing different types of digital work technologies reveals important differences: ICT are mainly used by high-skilled employees in higher positions working in business-related, financial or information service sectors (Arnold *et al.* 2016; DGB 2016; Friedrich *et al.* 2021; Tisch *et al.* 2021). Otherwise, networked digital technologies and algorithmically controlled work processes, and the use of machines or tools are mainly prevalent in the production sector and in jobs performed by manual or low-skilled workers (Arnold *et al.* 2016; DGB 2016; Friedrich *et al.* 2021; Gensler and Abendroth 2021; Tisch *et al.* 2021; Marx, Abendroth and Meyer 2022). However, it is not only the extent and type of use, which differs according to employment characteristics. The relationship with employees' working conditions and well-being is also uneven. Results based on the DGB-Index show that digital work is related to higher levels of autonomy and a better work-life balance only for employees working under favorable conditions (DGB 2016). In the LPP, respondents with a lower qualification report of less physical strain, but also less demands for skills and competencies and a higher fear of job loss (Arnold *et al.* 2016). Similar tendencies could be found in the NEPS data (Friedrich *et al.* 2021).

5. Discussion and Further Research

Different theoretical concepts suggest increasing and new work demands in digital working environments supported by first empirical studies (e. g., Arnold *et al.* 2016; Borle *et al.* 2021; Friedrich *et al.* 2021; Gensler and Abendroth 2021; Meyer *et al.* 2021; Meyer and Hünefeld 2021; Kersten and Junghanns 2022; Marx, Abendroth and Meyer 2022). The *digitalization* phenomenon, however, includes a variety of technologies and processes such as ICT and automation technologies in all kinds of industries and work organizations. Thus, the definition of digitalization is challenging when it comes to measuring it. For this reason, it is important to get an overview of the state of art in measuring digital work, especially because of its increasing implementation in employee surveys. In Germany, research concerning the digitalization of work has been strongly encouraged and funded within recent years, leading to a variety of approaches to operationalize digital work in large (employee) surveys. In this article, we bring together theoretical considerations and representative German studies that integrate questions about the digitalization of work. Doing so, we aim to present an overview of the existing approaches and develop a theoretical scheme for classifying different approaches to measuring digital work.

Reflecting different theoretical and conceptual considerations, we identify three different approaches to measure digital work: *work equipment–based, work content–based, and opinion-based.* Within the nine German employee studies considered, all of these approaches are implemented to some degree, although they differ with regard to their focus on specific approaches. Each of these approaches can be advantageous for measuring various aspects of digitalization.

Looking specifically at the implementation and *use of work equipment* helps to gain detailed knowledge about the dissemination of digital technologies in different sectors and occupations. Moreover, it depicts the state of technological development, showing which technologies are practically implemented and widespread within firms and the workforce, and not limited to theoretical discussions. Indeed, research results based on the surveys in-

troduced show that ICT are already widespread whereas the use of algorithmics or artificial intelligence are more prevalent for a selective group of workers (Arnold *et al.* 2016; DGB 2016; Borle *et al.* 2021; Friedrich *et al.* 2021; Giering and Kirchner 2021; Marx, Reimann and Ribbat 2021; Tisch *et al.* 2021). However, asking about specific technologies or work equipment may also risk obtaining relatively group-specific results; for example, robots are probably more widespread within production facilities than among administrative occupations. In addition, asking about specific technologies may lead to erroneous answers, since one cannot assume that all employees know the exact technology they are working with or the precise terminology that is used for that technology (Giering *et al.* 2021).

The measurement of digital work by means of a *work content-based approach* allows for considering the application of technology in work processes and tasks. This type of operationalization can improve our understanding of the work tasks performed with or supported by digital technologies as well as the extent to which they are part of everyday working life and processes. For example, the results based on the NEPS considered in this paper show that ICT are used for different purposes, ranging from work-related communication, searching for information or for collecting and preparing data (Friedrich *et al.* 2021). In addition, changes in work tasks and content can be monitored in the long term. Work content-based approaches might also be easier to investigate because they are supposed to capture how work tasks and content are permeated by digital technologies and do not require questions about specific technologies such as algorithms or artificial intelligence, which are difficult for employees to identify. A good example for this is included in the SOEP Innovation Sample as Giering *et al.* (2021) show that asking for a specific technology can be biased. By comparing responses to a direct question on the use of AI and indirect questions about tasks integrating AI, they find that employees might not be aware that this technology is part of their work. The broad query of work content, however, can also be a disadvantage when it comes to certain research questions, since it is not associated with a specific technology and may therefore mask differences in terms of technology's impact, leading to an "aggregation bias" and the mutual cancellation of its effects or a "cover up." Moreover, only pre-assumed relationships can be considered, and an exploration of possible new impacts is difficult.

Whereas the two above-mentioned approaches to operationalize digital work focus on the implementation and use of technology, the *opinion-based approach* aims to depict the employees' subjectively perceived impact of digitalization. Thus, employees' perception can be used to capture sentiment regarding this topic. However, this approach is highly subjective and represents an opinion rather than an actual association. The results from the opinion-based approach point to various concerns being prevalent like a higher amount of work or strain but also positive aspects like work relief or more work-life balance due to the digitalization (DGB 2016; Meyer and Backhaus 2022).

Overall, our proposed distinction between work equipment-based, work content-based, and opinion-based approaches is not entirely selective. Small differences in the wording may have led to questions being classified in a different category. This issue also seems to reflect the complexity and ambiguity of the subject of digitalization. However, this can also be a major strength of surveys, which combine several approaches since it is possible to compare different measurements of digitalized work.

Most of the studies integrate questions about digital work in their existing surveys which sets the study interest but also restricts a wide-ranging integration of questions simply because of time and space restrictions for surveys.

Nevertheless, our systematization of existing approaches to measure digital work shows that there is not (yet) one ideal way with all three approaches having strengths and weaknesses. However, the question arises whether it would be useful to create a more uniform set of questions to measure digitalization. On the one hand, standardization allows for comparability, which would be particularly fruitful at the beginning of this development to avoid a complete defibration of operationalization and to make the results more accessible to other researchers. In addition, it could also be interesting to take a closer look at statistical metrics provided by standardized measurements to facilitate meta-analyses regarding the digitalization of work. Such meta-analyses can be used to maintain credible results in social science research (Tong and Guo 2019). On the other hand, the use of standardized measurement risks failure to apprehend rapid technological developments. Thus, the questions should be quickly adaptable and capture technological developments and processes rather than specific technologies, such as mail or specific communication software or apps, which could become outdated within a few years (an example being the BlackBerry smartphone). Such coarse measurements could in turn disadvantage the collection of specific and detailed information. As already evident in existing research, it is not sufficient to understand and capture the digitalization of work as an over-reaching phenomenon that affects heterogeneous groups of employees in the same way. Rather, digitalization seems to be stratified according to categories such as occupations, qualifications, and industry sectors (Autor, Levy and Murnane 2003; Hirsch-Kreinsen 2016). Thus, standardization of questions should be implemented on this level or at least be applicable and adaptable to these differences to avoid missing important information for specific groups. Moreover, these considerations do not yet consider country-specific differences in the development of digital work (see, e. g., Berger and Frey 2016; Žwaková 2018), which may also be challenging when it comes to standardizing survey instruments.

Additional measurements that consider the different designs of or collaborations with the same technology (e. g., the interactivity or adaptivity of robots or algorithmic work control) might also be required. Comparisons and linkages with qualitative or process-generated data on digital work might help to further evaluate and improve existing measurements in large-scale surveys.

Finally, with an increasing number of theories and approaches trying to explain potential developments in the labor market and in working conditions because of new technologies, it is increasingly important to integrate theory-based operationalization to test and advance the theoretical considerations. The comparison of the study results shows the importance of integrating digital work within employee surveys, since it is no fringe phenomenon in today's working world but already widespread. Thus, it is part of the working environments affecting employees' work and family lives, as well as their health. Further research to measure the impact of digital work on employment to examine the consequences for job quality can be realized by integrating this topic within panel surveys to measure the trends over time.

Limitations of this Study

Although our proposed scheme for classifying different measurement approaches should help to structure the debate on digitalization, certain limitations must be acknowledged. We intentionally decided to focus on German studies that involve large sample sizes and are representative of specific groups of employees. In doing so, we aim to increase the comparability of different approaches for measuring digital work because these studies provide a relatively homogeneous setting in which the different operationalizations are implemented. However, owing to these selection criteria, we omit studies of rather technically focused disciplines, smaller case studies that focused on a specific phenomenon, and international studies that involve other contextual factors. This also applies to the study subject and the study design, as well as to differences in the factors or foci at each level of the theoretical scheme. None of the studies specifically defines a concept of digital work, but the operationalization is often interrelated with the study interest. The study designs are similar, since we focus on representative employee studies that mostly cover a large part of the labor force,[3] which might also explain why these studies cover a wide range of technologies and applications of both ICT and automation. Thus, including more heterogeneous study designs and foci might enrich our scheme, since the foci and bases of operationalization might be expanded or even more distinct. Thus, further research is needed to compare studies that are conducted in a more heterogeneous and/or international setting and further expose what is missing within the scheme or research in general.

Conclusion

The operationalization of digital work has increasingly found its way from smaller case studies to larger employee surveys. As the digitalization of work encompasses a wide range of technologies, work processes and developments in the labor market and employment relationships, there are no established and standardized ways to measure digital work (yet). Our work provides an overview over approaches of operationalization and the advantages and limitations they imply. We offer a systemization and reflection of ways to measure digital work within employee surveys and apply it to nine German employee surveys. The result of our work can help researchers working with data on digital work to assess and frame their research results, but it also helps to further develop existing surveys.

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[3] Such similarity applied to the survey mode as well. The ability to survey detailed technological processes also depends on the survey mode and the feasibility of implementing a complex questions structure. It is easy to apply various filters within computer-assisted surveys because the respondents receive only applicable questions, whereas paper-and-pencil questionnaires or half-standardized interviews may be somewhat overwhelming. All studies used standardized, mainly computer-assisted methods, which explains why we did not find big differences in the complexity of the questionnaires.

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Appendix

Table 2. Work Equipment Surveyed Within the Studies]

Work Equipment	Studies
ICT	
AI	DiWaBe, SOEP
Big Data	DiWaBe
Blockchain-based data	DiWaBe
Checkout systems	DiWaBe, SOEP
Computer (single item)	DiWabe, lidA, SOEP
Internet of Things	DiWaBe
Internet of Services	DiWaBe
ICT (laptop, smartphone, tablet, computer) combined in one question	BAuA-AZB, DGB-Index, LPP, NEPS

Table 2 *(Continued)*

Work Equipment	Studies
ICT	
Laptop (single item)	DiWaBe, lidA, SOEP
Self-controlled or self-learning computer systems (combined in one question)	NEPS, SOEP
Smartphone (single item)	DiWaBe, lidA, SOEP
Tablet (single item)	DiWaBe, lidA, SOEP
Virtual or Augmented Reality	DiWaBe
Machinery, devices, tools	
Computer-based vehicles and transportation (e. g., cars, bus)	DiWaBe
Dataglasses	lidA
Diagnostic devices	DiWaBe, LPP, SOEP
Intelligent equipment or machinery	Bertelsmann
Mobile devices and tools	DiWaBe, LPP
Production- or process-technologies; automation technologies	BAuA-AZB, NEPS
(Stationary or mobile) robots	DGB-Index, DiWaBe, LEEP-B3, LPP, SOEP
Scanner	SOEP
Stationary production machines and devices	BAuA-AZB, DiWaBe, LEEP-B3
Supporting electronic devices (e. g., data glasses, diagnostic devices, scanner) combined in one question	DGB-Index
Technical equipment	Bertelsmann
3D-print	DiWaBe
Example: "You told us that you use information and communication equipment at work. Does this include the following computerized tools: 1: desktop PC, 2: laptop, 3: smartphone, 4: tablet 5: POS systems 6: [something] else (open category)?" (DiWaBe; Arntz et al., 2020)	

Table 3. Work Content Surveyed Within the Studies]

Work Content	Studies
Administration of data bases	LPP
Automatic feedback	SOEP
Automatic data storage	LEEP-B3, SOEP
Automatic work instructions, instructed work process	DGB-Index, DiWaBe, LEEP-B3, SOEP
Collect or prepare data with spreadsheet programs	LPP
Collecting information online	LPP, NEPS
Communication via mail (single question)	LEEP-B3, lidA, LPP

Table 3 *(Continued)*

Work Content	Studies
Communication via digital communication platforms or apps (single question)	LEEP-B3, LPP
Communication with costumers	SOEP
Communication with supervisors or colleagues	SOEP
Consulting, user support and training in IT	LPP
Control of processes or machines	LEEP-B3, SOEP
Creation of websites	NEPS
Crowdwork	SOEP; LEEP-B3 (employer survey)
Data analysis/science	LPP
Developing new processes	SOEP
Edit graphics	SOEP
Electronic communication combined in one question (e. g., via mail, digital/online platforms, apps)	BAuA-AZB, DGB-Index, SOEP
Exchange of files	NEPS
Give advice to others	SOEP
IT administration	LPP
Maintaining websites	NEPS
Mathematical calculations	SOEP
Programming	LPP, NEPS, SOEP
Support by electronic devices	DGB-Index
Use of computer programs, software	BAuA-AZB, LPP, SOEP
Use of information technology	LEEP-B3, NEPS, SOEP
Use of internet or websites	BAuA-AZB, DGB-Index, lidA
Use of social media, microblogging	lidA, LPP
Use of software	SOEP
Video calls	LPP
Working with automated digital systems	NEPS, SOEP
Writing or reading messages	LPP
Write or edit texts and files	LPP, NEPS, SOEP
Examples: "Information or data about my operations are automatically stored e.g. via an app, machines or a computer program." (LEEP-B3; Marx et al., 2020) "How often do you carry out the following activities as part of your work? (Two possible replies are "A: Collect or prepare data with spreadsheet programs, such as Excel" or "D: Administration of databases") (LPP; Ruf et al., 2020a)	

Table 4. Opinions About the Impact of Digitalization Surveyed Within the Studies]

Outcome	Studies
Change/Restructure of work	BAuA-AZB, LEEP-B3
Relief	BAuA-AZB
Further training and/or competence needed	BAuA-AZB, LEEP-B3, NEPS
Strain	BAuA-AZB, DGB-Index, lidA
Less competence needed/loss of importance of competence	BAuA-AZB, LEEP-B3
Information overload	BAuA-AZB, NEPS
Work-life balance	Bertelsmann Stiftung survey, DGB-Index
Rather positive than negative	Bertelsmann Stiftung survey
Workload	DGB-Index, lidA
Multi-tasking	DGB-Index
Autonomy	DGB-Index
Working from home	DGB-Index
External control	DGB-Index, NEPS
Loss of control	DGB-Index
Job loss (risk)	LEEP-B3, NEPS, DiWaBe
Change of labor market chances	NEPS
Examples: "Because of the digitalization the amount of work to be handled rather 1) increased or (2) decreased." (DGB-Index; DGB, 2016) "The occupational use of modern communication technologies – internet, mail, smartphone […] - often goes along with information overload. How often do you struggle to deal with the amount of information?" (BAuA-AZB; Pattloch et al., 2021)	