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Influence of Digitalization on the Tasks of Employees with Disabilities in Germany (1979–2006) †

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Abstract: The deployment of technology in the workplace is increasingly replacing routine tasks and creating more non-routine tasks. In this article, we investigate the influence of computer technology on tasks carried out by employees with disabilities compared to employees without disabilities. We assume significant differences between both groups and stronger substitutive and complementary effects of computer technology in the case of a higher degree of disability. We use four waves of the German BIBB-IAB (BIBB: Federal Institute for Vocational Education and Training- IAB: Institute of Employment Research) and BIBB-BauA (BIBB: Federal Institute for Vocational Education and Training- BauA: German Federal Institute for Occupational Safety and Health Employment surveys (1976–2006) to investigate the development of tasks and the influence of computer technology carried out by employees with disabilities compared to employees without disabilities. The results show a development of tasks carried out by employees with disabilities that is very similar to that of employees without disabilities. In line with the assumptions of the task-based approach, we find that computer technology in the workplace has a complementary effect on routine tasks and a substitutive effect on non-routine tasks carried out by employees with disabilities. Against our theoretical assumptions, we find no systematic differences in the effects of computer technology on the tasks of employees with and without a disability. Moreover, we do not find systematic differences with regard to the degree of disability.

Keywords: digitalization; disability; labor market inclusion; labor market participation; routinization; tasks

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1. Introduction

Numerous changes to disability policies have been made in Germany over recent years, with the aim of improving the participation (including in working life) of people with disabilities, such as the introduction of Volume Nine of the Social Security Code (SGB IX) and implementation of the United Nation Convention on the Rights of Persons with Disabilities (UN-CRPD). Nevertheless, persons with a disability are less likely to work in the primary labor market. Their employment rate is lower, and it is also more probable that they will work on a part-time basis and receive a lower hourly wage. They are also more frequently found to be working below their qualification level [1]. In addition, disabled people also face considerable problems in finding a job [2] and tend to be affected by unemployment more frequently and for longer periods [3]. Even highly qualified disabled persons find that there are considerable barriers to labor market inclusion [4,5].

Today's world of work is characterized by numerous structural changes. The deployment of technology in the workplace is increasingly replacing simple tasks and creating newer and more complex requirements for the qualification of workers. There is an ever growing demand for the effective development of cognitive characteristics such as analytical abilities, a strong capacity for conceptual and abstract thought, systematically acquired specialist knowledge, and soft skills including a sense of responsibility, inner discipline, and autonomy [6]. The introduction of Industry 4.0[1], which denotes interactive networking between production and the digital realm, will entail further serious structural changes in trade and industry and in the world of work [7]. It remains to be seen whether the fourth industrial revolution will offer employment opportunities to persons previously viewed as being at a disadvantage in the labor market and if it will be of benefit to highly qualified workers.

A number of studies have investigated whether, and to what extent, technology opens up new task fields in which persons with a disability could have better access to. Vanderheiden [8] arrives at the conclusion that technology is becoming more complicated and more difficult to operate because the complexity of applications is growing. The process of digitalization is leading to greater intricacy of work processes. This is associated with an increase in skill requirements and a reduction in, or outsourcing of, simple tasks and, thus, also leads to poorer labor market opportunities for persons with disabilities [9]. Technological development requires the disabled to meet new conditions on an ongoing basis and to use new tools in a competent manner, something which is only possible to a limited extent depending on the nature of the disability [9].

Investigations conducted by Revermann and Gerlinger [10,11] reveal effects of technology that are fundamentally positive. They show that modern technologies and simple operating systems have made it easier for persons with a disability to function in the workplace and have increased efficiency, particularly in the case of those with physical disabilities. New forms of work (e.g., home office) have also helped people suffering from chronic diseases to structure their workplace and working time in a flexible way. The Internet also offers a route towards participation in the labor market for persons whose mobility is restricted because of their disability [10,11]. Apt et al. [12] come to the conclusion that the flexibilization and virtualization of work may produce effects such as an increasing labor market participation by people with disabilities. A report by the National Council on Disability [13] ascertains that various technological developments (e.g., communicability of work assignments and results via the Internet) improve employment opportunities for the disabled. Digitalization has meant a removal of financial and physical barriers for those with limited motor and sensory functions and restricted mobility in particular. The result has been an improvement in this regard in the general conditions governing the world of work [13]. Nevertheless, these developments have also produced new forms of stigmatization because they have created specific requirements for specific technical applications [13,14]. The outcome is that persons with certain forms of disability are being excluded from the exercising of some tasks. According to a study carried out by the United Nations Educational, Scientific and Cultural Organization (UNESCO) [15], technological achievements such as computers, the Internet, apps, and the mobile telephone are facilitating access to lifelong learning and to the labor market for persons with disabilities because it is easier for them to avail themselves of the contents.

Deployment of technology in the workplace is fundamentally associated with benefits for disabled persons (above all for those with a physical disability) because burdensome tasks are increasingly being performed by machines and robots [16,17]. In respect of functional restrictions relating to mobility, sight, and hearing in particular, assistive technologies are in place that are able to facilitate the execution of tasks by compensating for the disability [11,18–20].

These are, however, only effective if they are sufficiently accessible, if they are compatible via an interface with the devices and programs used, and if they are supplemented by further measures

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1 In Industry 4.0, production is interlinked with modern information and communication technology. The driving force behind this development is the rapidly increasing digitalisation of the economy and of society as a whole. This fourth industrial revolution will be determined by the deployment of so-called "smart factories".

aimed at supporting persons with a disability (e.g., reduced work and time pressure, and optimum processes) [9]. Around 30 percent of severely disabled persons in the working age population are affected by such disabilities [11].

Compensation via the deployment of technology is not possible in the case of persons with a mental or psychological disability [21]. On this basis, technology in the workplace primarily appears to represent an improvement in participation in working life for highly qualified workers with a physical disability [9,11,22,23].

Taking this as a starting point, the aim of the following analysis is to investigate the influence of increasing digitalization in the workplace on the tasks carried out by employees with an officially recognized disability in Germany. In order to evaluate the impact of technological changes on jobs, we use the framework of Autor, Levy, and Murnane [24] that introduces the so-called "task-based approach". Whereas computers substitute for workers' skills in performing routine tasks, they are complementary in performing non-routine tasks, such as problem solving. Consequently, a "new division of labor" [25] between workers and machines creates new jobs, while existing jobs might disappear over time. Following this approach, Goos/Manning [26] provide evidence of a polarization of jobs in the UK, where the medium-skill jobs are most strongly affected by computerization. Frey and Osborne [27] confirm these findings for the US and at the same time predict 47 percent of jobs being at risk of computerization. In Germany, literature on tasks reflects the employees' [28–32] as well as the employers' perspectives [33]. A comprehensive analysis by Helmrich et al. [34] indicates an upgrading of qualifications rather than a job market polarization. The main aim of this paper is to investigate the influence of the digitalization in the job participation of employees with a recognized disability. Following the theoretical framework we showed above, we analyze the following hypotheses:

1. Computer technology in the workplace substitutes for employees with disabilities in performing routine and manual tasks.
2. Computer technology in the workplace complements employees with disabilities in performing non-routine tasks.

The paper is organized in four sections. The next section describes the data set, the variables, and the derivation of the multivariate models. Section 3 investigates the influence of computer technology on tasks carried out by employees with and without disabilities. Section 4 presents the discussion of the results.

2. Data and Methods

2.1. Data

The subsequent analyses were based on a synopsis of employment surveys made by Hartmann [35]. The surveys were extended, via inclusion of the 2006 survey, and were used in the investigations of Rohrbach-Schmidt and Tiemann [36].[2] Only data from the years 1979, 1986, 1999, and 2006 could be taken into account because they contained information relating to the presence of an officially recognized disability [37].[3] The synopsis of the BIBB-IAB and BIBB-BauA[4] employment surveys constituted an accumulation of selected variables (including task items, information on qualification structure, work contents, and socio-demographic characteristics) from the cross-sections

[2] For the statistical analysis the programme Stata was used. The computer code used is available and can be requested by the author.

[3] The data used is publicly available via the Research Data Centre of the Federal institute of vocational education and training Germany (BIBB): 1979: doi:10.7803/501.79.1.8.10, 1986: doi:10.7803/501.85.1.8.10, 1999: doi:10.7803/501.98.1.8.10, 2006: doi:10.7803/501.06.1.8.11. [38].

[4] BIBB: Bundesinstitut für Berufsbildung/federal institute for vocational education and training; IAB: Institut für Arbeit und Beschäftigung/Institute of Employment Research; BauA: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin/German Federal Institute for Occupational Safety and Health

between 1979 and 2006 [39]. Because the target population was not uniform throughout the investigation, and due to the fact that the sampling design changed over the different waves[5], the synopsis was restricted to employees with German nationality living in western Germany. The data also did not include self-employed persons and workers in agricultural occupations and the agricultural sector. Employees younger than 18 and older than 65 were excluded from the dataset.[6]

The operationalization of dependent and explanatory variables used in the investigation are explained below. The dependent variables represented the individual task categories, which provided a metric to measure the respective task focus as a proportion of all tasks. Since the task items contained in the employment surveys were not recorded in reference to the categories of "routine" and "non-routine" used in the task-based approach, and due to the fact that not all task variables were collected in a standardized way in the individual surveys, the challenge was to form task categories that encompassed similar contents. The alignment undertaken here was based on Rohrbach-Schmidt and Tiemann [36] and Antonzcyk [40], whereby three categories were differentiated (routine, non-routine, and manual non-routine tasks) (see Table 1).

Table 1. Alignment of task items of the 2006 Employment Surveys (ES) to the categories of the task-based approach.

	Description	ES 1979	ES 1986	ES 1999	ES 2006
Routine task (Manual and cognitive routine)	Monitoring				
	Producing				
	Storing			N/A	
	Measuring		N/A		
	Written work			N/A	
	Calculating			N/A	N/A
Non-routine task (Analytical and interactive non-routine)	Investigating			N/A	
	Organizing				
	Researching	N/A	N/A	N/A	
	Computer			N/A	
	Applying laws			N/A	N/A
	Training				
	Advising				
	Procuring				
	Managing			N/A	N/A
	Negotiating		N/A		N/A
Manual non-routine task	Repairing				
	Catering			N/A	
	Caring				
	Securing			N/A	
	Cleaning			N/A	

Source: Based on Rohrbach-Schmidt & Tiemann [36] and Antonzcyk [40]. N/A = not applicable.

Pooling of the items took place based on the method of Antonzcyk et al. [40], in which the whole of the spectrum of tasks performed by the employees was taken into account. The relevant formula is:

$$I_{ijt} = \frac{\sum_i Tjt}{\sum_{j=1}^{3} Tjt} \times 100, \quad (1)$$

whereby

$$t = 1979, 1986, 1999 \text{ and } 2006, \quad (2)$$

5 In longitudinal studies several cross sections (waves) are analyzed.

6 For further details about the participants please see Table A1 (Appendix A).

and

$$j = \begin{cases} 1 = \text{Routine task} \\ 2 = \text{Non} - \text{routine task} \\ 3 = \text{Manual non} - \text{routine task} \end{cases} . \quad (3)$$

In the formula, I_{ijt} gives the proportion of tasks of i in the category j measured against all tasks. Antonzcyk et al. [40] interpreted the values as the proportions of working times that employees spent executing tasks in category j. In the case of every person, these individual measurement values added up to one (or 100 percent).

Table A2 (Appendix A) shows a summary of all variables used in the analyses, of the relevant questions in the surveys, and of the operationalization.

2.2. Methods

The descriptive part of the article chronicles the development of computer use by the employees with no disability, with a slight disability, and with a severe disability over the course of time. The complementarity and subsidiarity hypotheses were then investigated on the basis of bivariate and multivariate regression analyses. Linear regression was used to model the functional relationship between a metrically measured variable ("individual task category") and the independent variables.

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k + u_i. \quad (4)$$

The OLS method (Ordinary least squares) was deployed to calculate a straight line in which all points had the smallest possible distance. In this way, the sum of the squared residuals is minimized as follows:

$$\sum e_i^2 = \min(y_i - \overline{y}_i), \quad (5)$$

as long as

$$b = \frac{cov(x,y)}{var(x)}, \quad (6)$$

and

$$a = \overline{y} - b^*\overline{x}. \quad (7)$$

The estimated slope coefficients b state by how many units the dependent variable changes if the independent variable increases by one unit (keeping all other variables constant) [41].

In order to find out whether the differences between the employees with and without a disability identified in the multivariate models were caused by differing structures in the composition of the groups, a further model that contained a dummy variable for the degree of disability alongside the stated covariates was estimated for the employees as a whole.

3. Results

The empirical results are presented below. We begin with a description of the development of computer use by the employees with no disability, with a slight disability, and with a severe disability over the course of time. The complementarity and subsidiarity hypotheses are then investigated on the basis of bivariate and multivariate regression analyses. Our results confirmed both hypothesis, both in the case of the employees with an officially recognized disability and the employees without an officially recognized disability: a substitutive effect of computer technology in the workplace could be identified for routine tasks, and a complementary effect could be ascertained in respect to non-routine tasks. Against our theoretical assumptions, we found no systematic differences in the effects of computer technology on the tasks of employees with and without a disability.

3.1. Descriptive Results

The task-based approach assumed a dissemination of computer technology in the workplace from the 1970s onwards. Increasing distributions of computers amongst users can be identified for employees both with and without a disability. The proportion of the employees without a disability using a computer as their main work tool increased from 6.1 percent (1979) to 56.2 percent (2006). In the case of the employees with a slight disability, the rise was from 6.8 percent (1979) to 51.8 percent (2006). The corresponding proportion of the employees with a severe disability went up from 7.9 percent (1979) to 58.2 percent (2006).

In order to obtain a differentiated picture of the dissemination of technology in the workplace, we looked at the use of computers as a main work tool in correlation with highest qualification level and degree of disability (see Table 2). In the case of the employees both with and without a disability, the proportion of computer use had risen significantly in all qualification groups over the course of time. Moreover, we saw that a higher qualification was associated with greater computer use. Over the course of time, a comparison between the groups did not provide any clear pattern with regard to computer use by the employees with and without a disability. The reason for this may be that the results were not capable of reliable interpretation because sample sizes for the employees with a slight and severe disability were frequently too low.

Table 3 shows the developments of the task structure between 1979 and 2006, differentiated by existence of a disability and by qualification level. In line with the theoretical predictions, an increase in non-routine tasks and manual non-routine tasks was revealed over the course of time, in the case of the employees both with and without a disability. In accordance with the assumptions formulated, mean values for non-routine tasks increased as qualification levels rose over the course of time for the employees with and without a disability. In the area of routine tasks, these mean values fell. Mean values in the area of manual non-routine tasks increased over the course of time for the employees both with and without a disability, and mean values also increased in the case of low and intermediate level of qualification. Virtually no change was recorded for highly qualified workers.

At almost all qualification levels, mean values for the employees with a slight and severe disability in the field of routine tasks were higher than those for the employees without a disability (exceptions in which the mean values were higher for the employees without a disability were: degree of disability (DOD) = 0 and a low level of qualification in 1986 = 57.27; DOD = 0 and an intermediate level of qualification in 2006 = 34.22; and DOD = 0 and a high level of qualification in 1986 = 24.06).

In the area of manual, non-routine tasks, virtually no differences were shown with regard to the mean values of the employees with and without a disability across all three qualification levels.

Over the course of time, the mean values of the employees with a severe disability in the area of non-routine tasks were lower than those of the employees without a disability at all qualification levels (an exception in which the mean values of the employees with a severe disability were higher than those of the employees without a disability was: DOD $\geq$ 50 and a low level of qualification in 1986 = 18.12). This development may not only be technology-related, but it may also be healthcare-related due to mismatches in fitting the job role pre- and post-disability, or the lack of training, or depression, etc.[7]

[7] Further influencing extrinsic factors (which cannot be analysed with the given data) may be that the computer technology at non-routine task work may not be effective; however, to make it to work every day from home and stay independent, perhaps individuals use a lot of computer technology. These factors will also play into depression, mood, and work culture.

Table 2. Development of computer use by degree of disability (DOD), 1979–2006 (absolute terms and in percent).

Qualification	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	N	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	N	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	N	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	N
		1979				**1986**				**1999**				**2006**		
Low	5.13	*8.03*	*7.99*	373	5.09		*7.57*	98	26.55	*20.71*	*30.08*	595	32.38	*23.39*	*27.55*	342
Medium	5.94	*8.03*	*7.38*	818	7.27	*5.59*	*6.16*	409	38.47	35.29	33.22	3539	43.34	40.55	44.48	3436
High	7.71	*10.45*		156	9.72		*6.26*	113	55.25	59.05	58.64	1697	73.31	61.51	78.75	2063
N	1274	43	30	1347	606	*6*	*6*	620	5572	127	133	5831	5499	168	176	5841

Source: BIBB-IAB/BIBB-BAuA employment surveys 1978, 1986, 1999, and 2006, N = 86,155, weighted. Italics: N < 30 (the assumption is that these results are not reliable). Own calculations.

Table 3. Development of task structure by qualification level and degree of disability (DOD), 1979–2006 (mean values).

	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50	DOD = 0	20 $\geq$ DOD > 50	DOD $\geq$ 50
		1979			**1986**			**1999**			**2006**	
						Low level qualification						
Routine task	68.15	71.52	72.71	57.27	60.49	50.37	41.50	59.21	55.11	36.04	47.83	44.48
Non-routine task	13.26	12.56	5.77	17.85	18.12	20.31	47.43	32.32	34.22	37.08	24.52	28.54
Manual non-routine	18.58	15.90	21.51	24.87	21.37	29.31	11.06	8.45	10.66	26.87	27.64	26.97
						Medium Qualification						
Routine task	65.74	69.24	71.15	49.53	52.90	54.86	31.01	37.66	32.25	34.22	37.84	31.26
Non-routine task	20.24	17.30	12.39	28.13	31.42	24.22	52.93	47.39	51.78	45.36	40.15	48.06
Manual non-routine task	14.01	13.45	16.45	22.33	15.66	20.91	16.06	14.94	15.95	20.41	21.99	20.66
						High qualification						
Routine task	33.86	41.54	*36.80*	24.06	*22.12*	*16.82*	16.54	24.35	18.57	18.63	25.09	20.55
Non-routine task	58.10	50.47	*58.70*	69.01	*25.14*	*78.77*	76.98	68.96	76.39	73.91	64.61	71.46
Manual non-routine task	8.04	7.98	*4.49*	6.46	*6.68*	*5.03*	6.46	6.68	5.03	7.45	10.29	7.98

Source: BIBB-IAB/BIBB-BAuA Employment surveys 1978, 1986, 1999 and 2006, N = 103,072, weighted. Italics: N < 30 (the assumption is that these results are not reliable). Own calculations.

Over the course of the years and qualification levels analyzed in this investigation, the mean values of the employees with a slight disability were also, in most cases, lower than those of the employees with a disability (exceptions in which the mean values of the employees with a slight disability were higher than those of the employees without a disability were: DOD < 50 and a low level of qualification in 1986 = 18.12; and DOD < 50 and an intermediate level of qualification in 1986 = 31.42). In overall terms, it was revealed that the differences between the employees with a severe disability and the employees without a disability were greater than those between the employees with a slight disability and the employees without a disability.

The descriptive investigations showed that the trend towards higher qualification led to an increase in force for non-routine tasks and in computer use in the workplace with respect to the employees with and without a disability. This was accompanied by a decrease in routine tasks, and this decline was more marked for the employees without a disability than for the employees with a disability (especially with a severe disability). In overall terms, these results were in accordance with the theoretical assumptions. Multivariate analyses were undertaken in the following section in order to find out whether systematic differences not based on chance were produced between the groups in the study. The hypotheses formulated at the outset were tested within the scope of the investigated models.

3.2. Multivariate Results

In the following section, the complementary and subsidiary hypotheses are investigated for the employees on the basis of bivariate and multivariate regression analyses and differentiated by degree of disability. In order to ascertain whether significant differences for tasks were produced between the employees with and without a disability, two further regression models were estimated for each task focus. Alongside the covariates investigated above, these also contained a dummy variable for the degree of disability and an interaction term between the degree of disability and computer use. Within this process, both gross and net models were estimated. Table 4 indicates the influences of computerization and disability on individual task focus.

With regard to the influence of degree of disability on non-routine tasks, significant differences were produced in the gross and net models. The employees with both a slight and a severe disability were significantly less likely to perform non-routine tasks than the labor force without a disability. In the area of routine tasks, significantly higher influences in the gross and net models were produced only for the employees with a slight disability. No significant differences between the employees with and without a disability were revealed in respect to non-routine tasks. This result showed that employees with a severe disability were currently performing more tasks that will be less demanded for in the labor market in the near future. Thus, people with severe disabilities who do not have the skills that are demanded by the labor market present a risk group for exclusion from the labor market if no matching activities are offered (e.g., retraining, further education, etc.).

The interaction terms between degree of disability and computer use did not produce any significant differences with respect to all tasks focused on, either in respect to the employees with a slight disability or the employees with a severe disability, as compared to the employees without a disability.

These results, thus, provided empirical evidence for the assumption that increasing computerization had a substitutive effect on the exercising of manual routine tasks and a complementary effect on the performance of non-routine tasks in the case of the employees with and without a disability. No empirically significant differences were produced between the groups.

Table 4. Linear regressions—influence of computerization and disability on task focus, 1979–2006 (gross and net effect).

	Routine Tasks M1	Routine Tasks M2	Non-Routine Tasks M1	Non-Routine Tasks M2	Manual Non-Routine Tasks M1	Manual Non-Routine Tasks M2
DOD (reference DOD = 0)						
20 ≥ DOD < 50 (1 = yes)	4.29	3.85	−3.32	−3.29	−0.97	−0.56
	(1.04) ***	(1.10) **	(1.01) **	(1.07) **	(0.81)	(0.87)
DOD ≥ 50 (1 = yes)	2.07	1.31	−3.40	−2.97	1.33	1.66
	(1.14) *	(1.19)	(1.11) **	(1.15) *	(0.89)	(0.93)
Computer (1 = yes)	−9.90	−10.51	22.66	22.14	−12.76	−11.63
	(0.38) ***	(0.41) **	(0.37) **	(0.39) **	(0.29) **	(0.32) **
Interaction computer 20 ≥ DOD < 50	−2.51	−1.99	1.72	1.91	0.79	0.09
	(2.02)	(2.13)	(1.95)	(2.06)	(1.56)	(1.67)
Interaction computer DOD ≥ 50	−0.44	0.93	1.78	1.24	−1.35	−2.17
	(2.07)	(2.24)	(2.00)	(2.17)	(1.60)	(1.76)
Qualification level (reference—low qualification)						
Medium qualification	−6.85	−8.50	7.38	8.63	−0.52	−0.13
	(0.39) ***	(0.42) **	(0.38) **	(0.40) **	(0.30)	(0.33)
High qualification	−25.06	−26.54	33.53	35.44	−8.47	−8.90
	(0.49) ***	(0.54) **	(0.47) **	(0.53) **	(0.38) **	(0.43) **
Year dummy (reference—1976)						
1986	−14.95	−13.59	8.10	6.97	6.85	6.62
	(0.41) ***	(0.42) **	(0.40) **	(0.41) **	(0.32) **	(0.33) **
1999	−30.02	−25.92	24.78	21.16	5.24	4.75
	(0.39) ***	(0.42) **	(0.38) **	(0.41) **	(0.30) **	(0.33) **
2006	−27.09	−22.52	18.24	14.05	8.85	8.47
	(0.42) ***	(0.48) **	(0.41) **	(0.46) **	(0.33) **	(0.37) **
Employment in the public sector (reference—employment in the private sector)						
Public sector		−7.86		5.48		2.37
		(0.38) **		(0.37) **		(0.30) **
Company size (reference—<20 employees)						
20-< 250 employees		11.10		−8.15		−2.95
		(0.38) **		(0.37) **		(0.30) **
>250 employees		14.27		−11.12		−3.16
		(0.46) **		(0.45) **		(0.36) **
Working time (reference—<17 h)						
Working time ≥18 h		6.10		−2.72		−3.38
		(0.83) **		(0.80) **		(0.65) **
Gender (1 = female)		−6.44		9.12		−2.68
		(0.32) **		(0.31) **		(0.25) **
Age (reference—40–55 years)						
Age < 25 years		5.13		−5.45		0.32
		(0.54) **		(0.53) **		(0.43)
Age 25–40 years		1.08		−1.16		0.08
		(0.33) **		(0.32) **		(0.26)
Age > 56 years		−1.43		2.50		−1.07
		(0.53) **		(0.51) **		(0.42) **
Constant	72.34	60.43	12.06	18.32	15.60	21.25
	(0.38) ***	(0.98) **	(0.36) **	(0.95) **	(0.29) **	(0.77) **
R^2	0.26	0.28	0.34	0.36	0.06	0.06
N	55,529	48,827	55,529	48,827	55,529	48,827

Source: BIBB-IAB/BIBB-BAuA Employment surveys 1978, 1986, 1999 and 2006, * $p < 0.1$, ** $p < 0.05$ *** $p < 0.01$. ß coefficients are presented. Dependent variables—task categories. Own calculations.

4. Discussion

A significant shift in the labor market, characterized by an increasing deployment of computer technology in the workplace, has been taking place over recent decades. The consequence of this is that human work is being replaced by technology in the area of simple routine tasks. The routinization hypothesis formulated in the task-based approach [24] assumes that routine tasks will be subject to a lesser degree of demand in the wake of technology, whereas the need for complex non-routine tasks will rise. In order to find out where persons with an officially recognized disability are located within the context of these developments, the present article undertook an investigation into the influence of technology on the development of tasks carried out by employees with an officially recognized disability compared to employees without a disability. The analyses were conducted using the BIBB-IAB/BIBB-BAuA employment surveys from 1979 to 2006.

We analyzed the hypotheses that (1) computer technology in the workplace substitutes for employees with disabilities in performing routine and manual tasks, and (2) that computer technology in the workplace complements employees with disabilities in performing non-routine tasks. Our results confirmed both hypothesis, both in the case of the employees with an officially recognized disability and the employees without an officially recognized disability: a substitutive effect of computer technology in the workplace could be identified for routine tasks, and a complementary effect could be ascertained with respect to non-routine tasks. Against our theoretical assumptions, we found no systematic differences in the effects of computer technology on the tasks of employees with and without disability. This means that the analyses carried out did not provide any indications that the growing deployment of technological tools in the workplace was enabling the employees with a disability to exercise the more complex tasks, for which there is an increasing demand.

One major shortcoming of the analyses is that the information on computer use does not permit any specific statements to be made regarding deployment in combination with technological aids, which compensates for disability. Because this aspect is of crucial importance within the scope of investigating the influence of technology on employees with a disability in the workplace, it should form a subject for further analysis. Moreover, the employment surveys do not contain information on employers taking the initiative to train employees post-disability to be able to do non-routine computer tasks. It is also possible that some of the non-routine tasks have been prohibited by medical or healthcare professionals post-disability. Computer technology, the employer, or implementation practices themselves may not be the limiting factors in this regard, there may be other external factors, which we are not able to control for in this data.

Another point is that the analyses are based on data only available until the year 2006. No current data of the BIBB-BAuA survey with information on disability are available.[8] Many studies confirm that there has been an explosion of digital use at workplaces since 2006. However, these studies still show the same tendencies in the decline of routine tasks [16] and complimentary and substitution effects of computer technology at the workplace [30,31].

How do these results tie in with the poorer labor participation conditions of persons with a disability as opposed to those without a disability, as outlined in the relevant literature (e.g., [21,42–44])? The first thing that should be pointed out is that the analyses in this paper constitute a selection. The investigation focuses on the employees with a core working time of at least ten hours per week. This means that the only persons who are investigated are already integrated into the labor market in the sense that they are in regular employment. This is not the case for a large proportion of persons with a disability [42].

Because many people acquire and gain recognition of their disability during the course of working life [45], the assumption must be made that many of those affected are already participating in the labor

8 The next wave of the BIBB-BAuA employment survey with information on disability was conducted 2018 and will be available via the BIBB-Research Data Centre (https://www.bibb.de/en/53.php).

market at the time when a disability occurs. An employer may perceive an incentive in continuing to employ a member of staff who is fully inducted into the company and has now been officially recognized as disabled because the mandatory quota can be fulfilled in an efficient way [21,46–48]. Thus, the results may indicate that only the employees with a disability that is integrated into the labor market (which is by no means all employees with a disability) do not exhibit any differences to the employees without a disability, with respect to the aspects investigated.

A further limitation to the present work is that the BIBB-IAB and BIBB-BauA employment surveys do not map a comprehensive picture of the heterogeneous composition of persons with a disability. The assumption may be made that the employment surveys systematically excluded certain groups of persons with a disability. Employees at workshops for persons with disabilities are not, for example, included in the data investigated. It is not clear whether those employed at integrative companies are recorded in the employment surveys.

Because the group of employees with an official disability exhibits extraordinarily individualized characteristics, which in some cases may be associated with considerable differences regarding opportunities for participation in the labor market, categorization on the basis of officially recognized degrees of disability also has its drawbacks. Differentiation in accordance with the type of disability and resultant restrictions would permit differentiated statements and conclusions. Due to an absence of data, the group of disabled persons accorded equal status had to be omitted from the analyses entirely.

In order to be able to conduct detailed analyses, larger surveys of persons with a disability, which contain information on the nature of the disability and the time of its occurrence, should therefore be carried out in the future. It would also be desirable for future socio-scientific data surveys to map the characteristics of disability in accordance with the International Classification of Functioning, Disability, and Health (ICF), which takes account of social and psychological barriers to participation alongside physical barriers.

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Appendix A

Table A1. Descriptive statistics of sociodemographic variables by degree of disability.

		1979	1986	1999	2006
DOD = 0		95.50%	95.80%	95.0%	92.80%
DOD < 50		2.60%	2.30%	2.60%	4.00%
DOD ≥ 50		1.90%	1.80%	2.40%	3.20%
DOD = 0	male	75.60%	72.20%	72.50%	68.50%
DOD = 0	female	24.40%	27.80%	27.50%	31.50%
DOD < 50	male	82.60%	75.50%	68.00%	59.00%
DOD < 50	female	17.40%	24.50%	32.00%	41.00%
DOD ≥ 50	male	60.80%	62.30%	59.30%	55.80%
DOD ≥ 50	female	39.20%	37.70%	40.70%	44.20%
DOD = 0	15–25 years	3.60%	0.30%	-	0.70%
DOD = 0	25–45 years	24.90%	14.70%	25.50%	31.00%
DOD = 0	45–65 years	71.50%	84.90%	74.50%	68.30%
DOD < 50	15–25 years	1.70%	3.90%	-	0.70%%
DOD < 50	25–45 years	25.10%	25.80%	25.80%	27.70%
DOD < 50	45–65 years	73.20%	70.30%	74.20%	71.60%
DOD ≥ 50	15–25 years	16.60%	10.10%	-	6.20%
DOD ≥ 50	25–45 years	52.30%	47.30%	46.70%	54.20%
DOD ≥ 50	45–65 years	31.10%	42.70%	53.30%	39.60%
DOD = 0	Low qualification	34.10%	19.50%	17.10%	11.70%
DOD = 0	Middle qualification	47.40%	55.10%	54.10%	67.00%
DOD = 0	Technical college	12.40%	16.40%	14.70%	7.90%

Table A1. *Cont.*

		1979	1986	1999	2006
DOD = 0	High qualification	6.00%	8.90%	14.10%	13.40%
DOD < 50	Low qualification	31.50%	21.00%	16.00%	12.50%
DOD < 50	Middle qualification	53.50%	56.30%	54.00%	65.60%
DOD < 50	Technical college	9.90%	17.50%	12.90%	5.90%
DOD < 50	High qualification	5.10%	5.20%	17.10%	16.00%
DOD ≥ 50	Low qualification	28.10%	19.70%	14.50%	8.80%
DOD ≥ 50	Middle qualification	52.70%	54.10%	55.60%	61.60%
DOD ≥ 50	Technical college	11.40%	14.50%	11.90%	6.80%
DOD ≥ 50	High qualification	7.80%	11.70%	18.00%	22.80%

Source: BIBB-IAB/BIBB-BAuA Employment surveys 1978, 1986, 1999, and 2006, N = 86,155, weighted. Own calculations.

Table A2. Summary of all variables taken into account.

Variable	Question in the Employment Surveys	Operationalization
Tasks	- Training, teaching, etc. - Advising, informing, etc. - Measuring, testing, etc. (not in 1986, 1992) - Monitoring, monitoring and controlling machines, etc. - Repairing, maintaining, etc. - Procuring—purchasing, sourcing, etc. - Negotiating—conducting negotiations, lobbying (only in 1979, 1999) - Advertising—promoting, Public Relations (PR), etc. - Investigating—collecting information, researching, evaluating (only 2006, 1998) - Organizing—organizing, planning, etc. - Researching—developing, researching, constructing, etc. (not in 1999) - Researching—developing, researching (not in 2006) - Constructing—constructing, designing, etc. (not in 1999, 2006) - Producing—producing, manufacturing of goods, etc. - Catering—catering, serving, providing accommodation (2006, preparing food not in 1999) - Caring—caring, looking after people, etc. - Managing—leading/instructing staff, recruiting (not in 2006, 1999) - Storing—transporting, storing, dispatching, etc. (not in 1999) - Securing—securing, protecting, guarding, etc. (not in 1999) - Computer—working with computers, IT activities, etc. (not in 1999) - Cleaning—cleaning, removing waste, recycling, etc. (not in 1999) - Written work—written work, correspondence, working with forms (not in 2006, 1999) - Calculating—calculating, charging, posting (not in 2006, 1999) - Applying laws—applying laws/regulations, interpreting/certifying (not in 1999, 2006)	- Routine task - Non-routine task - Manual non-routine task
Degree of disability[9]	F1514: Do you have an officially recognized disability? (Yes/no) F1515: What is the recognized degree of disability? (Less than 50 percent/or 50 percent and more[10])	- DOD = 0—no disability - 20 ≥ DOD < 50—slight disability - DOD ≥ 50—severe disability
Main tool in the workplace	Mechb—degree of technology (main work tool) (Simple work device, tool/powered hand tools/simple machines/semi-automated machines, plants/computers, program-controlled tools)	- Computer use yes/no

Table A2. *Cont.*

Variable	Question in the Employment Surveys	Operationalization
1979, 1986, 1999, 2006		- Dummy survey year 1979 (yes/no) - Dummy survey year 1986 (yes/no) - Dummy survey year 1999 (yes/no) - Dummy survey year 2006 (yes/no)
Highest qualification level[11]	Nvausbr—highest vocational qualification (no full qualification/apprenticeship, full-time vocational school/trade and technical school (master craftsman, technician, certified senior clerk and similar)/university of applied sciences/university)	- Low qualification level—no formal vocational skills - Intermediate qualification level—vocational education and training or completion of vocational school - High qualification level—degree from a university or university of applied sciences
Economic sector	Q087—economic sector (industry/craft trades/commerce/public sector/agriculture/other economic sector	- Employment in the public sector/ - Employment in the private sector
Working time	Q008—weekly working time in main employment	- <17 working hours per week - $\geq$18 working hours per week
Company size[12]	Q089—company size (1 to 4 employees/5 to 9 employees/10 to 49 employees/50 to 99 employees/100 to 499 employees/500 to 999 employees/1000 employees and above)	- Companies not subject to a mandatory requirement to employ disabled persons (<20 employees) - Medium-sized companies with a mandatory requirement to employ disabled persons (20 $\leq$ 250 employees) - Large companies with a mandatory requirement to employ disabled persons (>250 employees)
Age	Age	- <25 years - 25 to 40 years - 40 to 55 years - >56 years
Gender	Q002—gender of target person	- Male - Female

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[9] Although the systematic exclusion of some disability groups in the employment surveys (presumably employees with a mental, psychological, and hearing disability) means that it is possible to assume that most of the employees recorded have a chronic or physical disability, it is not possible to arrive at the direct conclusion that a majority of such persons uses a technical tool in the workplace. Because the composition of respondents with a disability cannot be precisely determined, assumptions regarding the effect of computer influence on the task structure remain speculative at this point.

[10] The items are listed here in the same way as they are contained in the questionnaire. The author is aware that it is incorrect to state degrees of disability in percent.

[11] This qualification level is not taken into account because of low sample sizes for employees with a disability that are in possession of a master craftsman, technician, certified senior clerk qualification, etc.

[12] As is the case with other regulations under employment law, the rate of employment of disabled persons varies in accordance with the size of the company. The degree of fulfilment of the mandatory requirement to employ disabled persons rises in line with company size. Whereas companies with up to 40 staff achieved an employment rate of 2.9 percent in 2013, the corresponding figure for companies offering between 250 and 500 jobs was 4.3 percent. Companies with 500 to 1,000 employees reached a rate of 4.7 percent, and the rate for major corporations with a total of 1 million jobs was 6.3 percent (BA 2015).

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