# Changing work through digitalisation –

# Further training, multitasking and the human digital twin

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## I Synopsis



## Paper 1



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## List of abbreviations

| | |
|---|---|
| AMT | Advanced manufacturing technologies |
| BIBB | Federal Institute for Vocational Education and Training |
| BMAS | Federal Ministry of Labour and Social Affairs |
| GWS | Institute of Economic Structures Research |
| HDT | Human digital twin |
| HR | Human resources |
| IAB | Institute for Employment Research of the Federal Employment Agency |
| ICT | Information and communication technology |
| QCA | Qualitative comparative analysis |
| SBTC | Skill-biased technological change |
| TBA | Task-based approach |

# List of papers

**Paper 1:**

Hellweg, Talea; Weißphal, Markus (2023). All becoming jacks of all trades? Multitasking as a result of outsourcing and digitalisation

**Paper 2:**

Schneider, Martin; Hellweg, Talea; Menzefricke, Jörn Steffen (2022). Identification of Human and Organizational Key Design Factors for Digital Maturity – A Fuzzy-Set Qualitative Comparative Analysis[1]

**Paper 3:**

Hellweg, Talea (2023). Do employees with specific skill profiles receive more employer-funded training during technological change? - Evidence from employer-employee data

**Paper 4:**

Hellweg, Talea; Schneider, Martin (2022). Which Types of Workers are Adversely Affected by Digital Transformation? Insights from the Task-based Approach[2]

**Paper 5:**

Pilz, Sarah *; Hellweg, Talea *; Harteis, Christian; Rückert, Ulrich; Schneider, Martin (2022) Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives[3]

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[1] Published in: Schneider, M., Hellweg, T. and Menzefricke, J. S. (2022). 'Identification of Human and Organizational Key Design Factors for Digital Maturity - A Fuzzy-Set Qualitative Comparative Analysis'. Proceedings of the Design Society, 2: 791-800.

[2] Published in: Hellweg, T., & Schneider, M. (2023). Which Types of Workers Are Adversely Affected by Digital Transformation? Insights from the Task-Based Approach. In The Digital Twin of Humans: An Interdisciplinary Concept of Digital Working Environments in Industry 4.0 (pp. 231-248). Cham: Springer International Publishing.

[3] Published in: Pilz, S., Hellweg, T., Harteis, C., Rückert, U., & Schneider, M. (2023). Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives. In The Digital Twin of Humans: An Interdisciplinary Concept of Digital Working Environments in Industry 4.0 (pp. 11-35). Cham: Springer International Publishing.

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# I Synopsis

# 1 Introduction

Digital transformation encompasses the change of economy and society through the development and implementation of new technologies. There is widespread consensus among both academics and practitioners that this change will involve the emergence of entirely new work tasks and occupations, as well as the disappearance of others. The goal of a comprehensive digital transformation of industry is also referred to as "Industry 4.0". In order to successfully master this transformation, training and further education programs are crucial. Failing to adapt the education and training system may result in negative consequences for the economy and societyt, as findings from a joint research project by leading German research institutes (BMAS, BIBB, IAB, GWS) indicate (Zika et al., 2019).

> *"The future labour market will be characterized by occupational fit problems. At the same time, there will be upheavals in the labour market. For example, by 2035, 3.3 million new jobs will be created that did not exist in 2018 and, at the same time, around 4 million jobs will be lost compared to today. [...] If these occupational fit problems are not remedied in time by appropriate supply-side and/or demand-side measures, the national economy could suffer annual average production losses of around 100 billion euros in the future. […] One way to remedy the occupational fit problems would be "optimal" further training or "optimal" distribution of the labour force."*[4] *(Zika et al., 2019, p. 8)*

The study identifies occupational fit problems as a major expected negative consequence of the digital transformation, because a rapid change in labour demand is to be expected (Zika et al., 2019). Pertaining to this dissertation more particularly, the study highlights the education and training system as a crucial factor to counteract these negative consequences of digital transformation. Consequently, negative effects, such as a decline in productivity in companies as well as unemployment and lower wages for workers, may be mitigated by improving the education and training system. This risk reduction is brought about in particular by the fact that targeted training can help workers affected by automation to adapt to the new work

[4] Translated from German.

requirements (OECD, 2019a, 2021). Only if employees can quickly adapt to the new requirements, can the firms‘ need for workers be met.

Although the literature agrees that digitalisation will eliminate jobs and that training will become even more important (Arntz et al., 2019; Goldin & Katz, 2008; OECD, 2019a, 2021), there is still a lack of studies that examine at the individual level which employees face particular risks due to digitalisation, whether they receive training, and whether training investment is also in the interest of companies. The literature that has already addressed these important questions has mostly used occupational-level data, making it difficult to draw conclusions about the receipt of training and to examine different risk factors for employees in depth.

Therefore, this dissertation attempts to contribute to understanding the relationship between digitalisation, employee risk factors and training needs by using mostly individual-level data. In particular, the following questions are addressed: *How are work demands changing due to digitalisation? How relevant is training for a successful digitalisation process? Who needs training? Who is being trained? And how can training needs be identified at an early stage?* In doing so, this research aims to create important practical implications for competence management, training systems and HR policies, as well as for political decision-makers to improve the education and training system during digitalisation.

The importance of education and training for digital transformation becomes even clearer by considering the developments of the preceding industrial revolutions. Since the first industrial revolution in the early 1800s, history bore witness to dramatic changes in the labour market. Just as today, technological inventions that emerged during the industrial revolutions led on the one hand to the disappearance of professions or entire industries, but on the other hand also to the creation of new professions (Xu et al., 2018). An important factor in the success of the industrial revolutions is considered to be the level of human capital, so it is assumed that one reason for the success of the British industrial revolution was the high level of human capital in the British labour market (Kelly et al., 2014). Likewise, the education system is considered a driver of rapid U.S. economic growth in the 20th century (Goldin & Katz, 2008).

The consequences of a lack of further education also become even more apparent when the developments of the previous industrial revolutions are considered. Past experience has shown that education and training were not only aimed at developing technical skills, but also had socialising effects such as preventing resistance and improving work discipline (Mitch, 2018). In the absence of appropriate support through retraining and continuing education, fierce

protests and resistance were the results (Mitch, 2018). These protests were usually carried out by workers whose activities changed greatly or were even replaced entirely in the course of the transformation processes, but who did not receive sufficient support, such as hand weavers in the first industrial revolution.

The extent to which today's industrial revolution will also negatively affect individual employee groups is still unclear. However, it is crucial to be aware of potential negative effects at an early stage to be able to counteract them. Early research on the fourth industrial revolution predicted drastic developments, such as the elimination of a whole range of occupations and work tasks, which would have a major impact on a variety of occupational groups and society as a whole (Frey & Osborne, 2013). However, new research raises hopes that this digital transformation will take a different course with less negative consequences, as it differs from the previous industrial revolutions in key aspects: Change is occurring at a slower pace than expected, and it is already foreseeable that the loss of jobs can be offset by the creation of new jobs to a large extent (Autor, 2015; Balsmeier & Woerter, 2019). One reason for this is that the new technologies often do not completely replace work tasks, but rather complement them (Arntz et al., 2019; Autor, 2015). There is also a greater body of knowledge from early research that provides foundational theories to understand today's developments early and mitigate negative consequences.

Another innovation of this time that will potentially exert both positive and negative consequences for employees is the fact that new technologies enable the collection, storage and analysis of large amounts of data. On the one hand, data use can reduce the negative impact of digital transformation on employees if, for example, researchers use detailed labour market data to examine potential risks to employees and ways to address them. This kind of research is particularly important to reduce potential systematic disadvantages for employees and to help companies successfully manage digital transformation. Therefore, this dissertation attempts to contribute to this area of research. On the other hand, data can also be misused and thus cause harm to private individuals. This possibility of data misuse and also the quantification culture itself must be debated in society when data are collected and evaluated (Mau, 2017). The quantification of a wide variety of factors can lead to a shift in society's goals and values, which are increasingly focused on data, ratings and scores (Mau, 2017). Careful consideration must also be given to where and when it makes sense to make data available and when the risks of

data misuse outweigh the benefits (Hess & Ostrom, 2003). This issue is also addressed in the research of this dissertation by discussing the use of human digital twins.

Given the challenges of digital transformation and considering the lessons learned from historical industrial revolutions, the need for further research becomes clear. This dissertation is therefore dedicated to this topic area in five research articles. These articles provide insights into changing work tasks, success factors for companies and risk factors for employees in the course of digital transformation. They also discuss mechanisms that could reduce negative consequences by improving training and job allocation, for example through the use of digital twins. The main contents of each paper are briefly summarized below.

1. Research paper 1 examines the change in work tasks due to digitalisation and outsourcing, in particular whether the amount of different work tasks employees have to perform will increase.
2. Research paper 2 investigates which combination of HR and organizational factors, especially comprehensive training programs, are crucial for the successful digital transformation of companies.
3. Research paper 3 examines whether specific skill profiles could become a risk factor in the digitalisation process, focusing on the receipt of employer-funded training.
4. Research paper 4 provides an overview of the literature on the task-based approach to identifying risk factors for employees in the digitalisation process. In addition, research paper four looks at the extent to which human digital twins can serve as a possible solution to reduce the negative consequences of digitalisation for employees.
5. Research paper 5 discusses the opportunities and risks of human digital twins from an interdisciplinary perspective.

In the next sections of the synopsis, the following aspects are described in more detail: the research project in which the research papers were developed and the theoretical foundations on which the papers are based (Section 2), the content of the individual papers and how they are related (Section 3), as well as a contextualization of the research findings in an overarching context (Section 4). In addition, the appendix provides an overview of scientific presentations and publications.

# 2 Theoretical framework

The fourth industrial revolution is a holistic change in the world of work, so it is not sufficient to conduct studies only from the perspective of a single discipline. Instead, there is increasing emphasis on the importance of working in an interdisciplinary manner. The research project "NRW Forschungskolleg - Design of flexible working environments - human-centered use of Cyber-Physical Systems in industry 4.0", in the context of which this dissertation was written, aimed to facilitate precisely such interdisciplinary perspectives. For this purpose, doctoral students and professors from Paderborn University and Bielefeld University from a wide range of disciplines were brought together. The papers of this dissertation were developed within this network and include two interdisciplinary projects (Papers 3 and 5). These were developed in collaboration with researchers from business administration, mechanical engineering, computer science and educational science. In addition, three intradisciplinary projects were developed (Papers 1, 2 and 4), which were intensively discussed in the consortium with researchers from different disciplines (business administration, mechanical engineering, computer science, educational science, mathematics, sociology and psychology).

In line with this interdisciplinary framework, different theories are used as the basis for the various research papers of this dissertation. The main theories are briefly presented below, along with a short description of how the research papers contribute to each theory. The presentation of theories is divided into two sections. Section 2.1 describes the key research theories used for studying digital transformation in the different papers. These include the task-based approach (and the related skill weights approach and multitasking), as well as the human digital twin. Section 2.2 outlines the basic research orientation of all five papers, namely the socioeconomics of personnel and the sociotechnical systems approach. Figure 1 provides an overview of the different theories and in which papers they have been taken into account and applied.

## 2.1 Task-based approach

Various research theories in economics attempt to examine the changes in the world of work resulting from digitalisation. The research in this dissertation primarily focuses on the most recent approach, the **task-based approach** in labour economics (Autor et al., 2003) (Papers 1, 3, and 4). The approach examines the change in work tasks caused by digitalisation and is an

extension of the skills-biased technological change approach (SBTC)[5]. While the SBTC approach examined changes at the educational levels and assumed that digitalisation will lead to a shift in labour demand towards highly skilled workers (Autor et al., 1998; Berman et al., 1998), the task-based approach looks at changes in workers' individual work tasks. To empirically investigate these changes in work tasks, researchers use detailed microdata (Autor, 2015; Autor et al., 2003; Goos et al., 2014).

Existing research on the task-based approach has so far focused primarily on changes in single-task types, such as the elimination of routine tasks (Acemoglu & Restrepo, 2018; Autor et al., 2003; Goos et al., 2014; Vries et al., 2020) and the increasing importance of interactive tasks such as teamwork (Deming, 2017). Changes in the composition of task profiles as holistic constructs have received little attention. The papers in this dissertation (1, 3, 4) attempt to fill this gap by looking at two measures that focus on the composition of individual task profiles. These include two constructs: multitasking and the specificity of task profiles, which both relate to the task-based approach.

Multitasking includes the number of different work tasks performed by employees (Snower & Görlich, 2013). This job characteristic is particularly relevant because it can influence workload and job satisfaction (Fahr, 2011; Hackman et al., 1975; Zaniboni et al., 2013). Paper 1 takes a closer look at this construct.

The specificity of task profiles is based on the **skill weights approach** (Lazear, 2009) and measures the rarity of a task combination in the labour market (Backes-Gellner & Mure, 2005; Geel & Backes-Gellner, 2011). A high degree of task specificity is negatively related to mobility and thus to the adaptability of workers in the labour market (Eggenberger et al., 2015, 2018; Geel et al., 2011), characteristics that are particularly important in the course of the digital transformation to remain employable (Bechichi et al., 2019). Research papers 3 and 4 therefore

[5] The skill-biased technological change (SBTC) approach is one of the first and best-known approaches. It assumes that digitalisation will primarily lead to a shift in labour demand toward highly skilled employees, as it will be these employees who will benefit from the introduction of ICT and other new technologies. Employees with a lower level of education are more likely to be substituted by them

look at this worker characteristic in more detail, contributing to the research of the skill-weights and task-based approach.

The research papers examine the possible effects of the two employee characteristics – multitasking and task specificity – in the digitalisation process. They thus contribute to the literature strand of the task-based approach by highlighting the importance of previously less considered employee characteristics. A particular focus is on the effect of both factors on the receipt of further training.

## 2.2 Human Digital Twin

To tap the expertise of different disciplines, the construct of the **Human Digital Twin (HDT)** was chosen as a common reference point in the "NRW Forschungskolleg". Human digital twins comprise digitally stored data about a person and are used in various disciplines, as they are considered one of the important next technological trends (Panetta, 2021).

The construct of human digital twins is not only well-suited as a basis for interdisciplinary cooperation due to its broad relevance for different disciplines, but also fits the topics addressed in this dissertation. Papers 4 and 5 discuss, among other aspects, whether human digital twins could play a potentially important role in the context of occupational fit problems and training needs caused by digital transformation. Especially Paper 4 highlights two applications in which human digital twins could be used to reduce risks for workers. The first application is the use of digital career platforms to improve labour market allocation (Madia, 2011). As employees and employers provide significant information on digital career platforms, and access to this information is regardless of location, they can simplify matching and increase mobility. Secondly, competence management systems and thus also competence twins of employees are discussed, to identify training needs and to develop training concepts (Lindgren et al., 2004) (Paper 4 and 5). In addition, Paper 5 discusses the opportunities and risks of human digital twins in an interdisciplinary context, as both positive and negative consequences of its use are possible.

## 2.3 Socioeconomics of personnel and sociotechnical systems approach

In addition to the theories presented above, two important research perspectives underlie the research in this dissertation, which create a common theoretical understanding and research goal: the approach of **socioeconomics of personnel** and the **sociotechnical systems approach**.

Both approaches promote that social aspects are of great importance and need to be considered in research. Their detailed assumptions and the reason why they are used as a basis of this dissertation are presented below.

The approach of **socioeconomics of personnel** serves as a common orientation for research and teaching at the Chair of Personnel Economics at Paderborn University, where this dissertation was written. The socioeconomics of personnel is an application of the socioeconomic approach (Etzioni, 2003) to personnel economics (Backes-Gellner et al., 2008). The socioeconomic approach considers not only economics as such but in addition social science theories, and it therefore differs from the neoclassical approach (Hedtke, 2015). The approach of socioeconomics of personnel, essentially, incorporates the three factors "personnel economics", "social norms" and "societal concerns" into research (see mission statement of the Socioeconomics of Personnel (SEPE) Papers, Schneider, 2021).

The aim of research on socioeconomics of personnel, and thus of the research chair, is to strengthen the long-term well-being of employees and employers (Schneider, 2021). This aim differs from the mainstream of the management literature, which often focuses on short-term profit maximization. This long-term perspective is particularly relevant in the context of digitalisation research, since changes take place over a long period of time and entail long-term consequences. A short-term way of thinking would therefore not be expedient.

In addition, the consideration of manifold influencing factors, in particular social, technical and institutional aspects is of great importance for the socioeconomics of personnel approach. This appeal of a multi-layered perspective is met in this dissertation by the interdisciplinary nature of the research.

Moreover, the socioeconomics of personnel understands people as self-interested (economic), but at the same time cooperative (social). Accordingly, social insights are of value independently of pure economic optimization. Uncovering and communicating systematic disadvantages and inequalities through digitalisation is thus relevant for institutions and members of society not only when economic benefits accrue, but also when social benefits are generated.

In line with these assumptions, this thesis tries to uncover potential negative effects of digitalisation that may disrupt the well-being of employees and employers and investigates how these disruptive factors can be mitigated. Social aspects such as systematic disadvantages for employee groups and inequalities receive particular attention in this dissertation.

Another approach that closely resembles the assumptions of the socioeconomic approach is the **sociotechnical systems approach**. The sociotechnical systems approach is often used in digitalisation research and states that processes consist of both technical and social components embedded in an organizational framework (Hirsch-Kreinsen, 2014; Trist & Bamforth, 1951; Ulich, 2013). Accordingly, the approach assumes that the introduction of new technologies can only be successful if, in addition to the technical innovation itself, organizational and human elements are also taken into account (Hobscheidt et al., 2020). Therefore, the sociotechnical systems approach is very similar to the approach of socioeconomics of personnel as it also states that the social and institutional framework is of great importance. In contrast to the socioeconomic approach, it combines social components with technical aspects rather than economic aspects.

In order to take a comprehensive look at the changes brought about by digital transformation, it is important to consider both approaches. If we look at the content and objectives of the individual research papers, the application of the two research theories becomes even clearer.

Research paper 1 examines the extent to which digitalisation could change the number of work tasks for employees and the possible advantages and disadvantages of these changes. In addition, there is a focus on differential effects for high-skilled and low-skilled employees. Therefore, the research findings are intended to reveal disadvantages and inequalities and thus strengthen the long-term well-being of employees.

Research paper 2 focuses primarily on the sociotechnical systems approach, as it examines the influence of various HR factors and organizational factors on a successful digital transformation. Moreover, the aim is to prevent disadvantages arising from a failure of the transformation and thus strengthen the long-term well-being of employees and employers.

Research papers 3 and 4 investigate which employee characteristics can lead to disadvantages in times of digital transformation and, in particular, to lower receipt of further training. Therefore, the objective is to be able to reduce possible risks for employees at an early stage and to counteract an increase in inequality, which is in line with the previously stated theories.

Research papers 4 and 5 examine the advantages and disadvantages of using human digital twins for individuals and society. It also considers the conception of human beings as self-interested (economic) as well as cooperative (social). The aim is to help ensure that human

digital twins are not used unthinkingly, but rather in a way that primarily creates benefits for society and not disadvantages.

Overall, it can thus be seen that an important motivation of the research papers in this dissertation is to reduce potential social disadvantages caused by digital transformation and the use of new technologies.

**Overview**

Figure 1 graphically illustrates the interrelationship of the different theories with the individual research papers. The dissertation consists of five research papers. All five are based on the approach of Socioeconomic of Personnel. Research papers 1, 3, and 4 are additionally based on the task-based approach, as they all examine how digitalisation is changing work tasks. Papers 3 and 4 also contribute to the skill weights approach by studying the specificity of task profiles. Research paper 2 focuses primarily on the sociotechnical systems approach, as it examines the influence of various HR factors and organizational factors on the successful digital transformation of companies. Paper 4 and Paper 5 examine the advantages and disadvantages of using human digital twins for individuals and society and thus contributes to the literature on human digital twin.

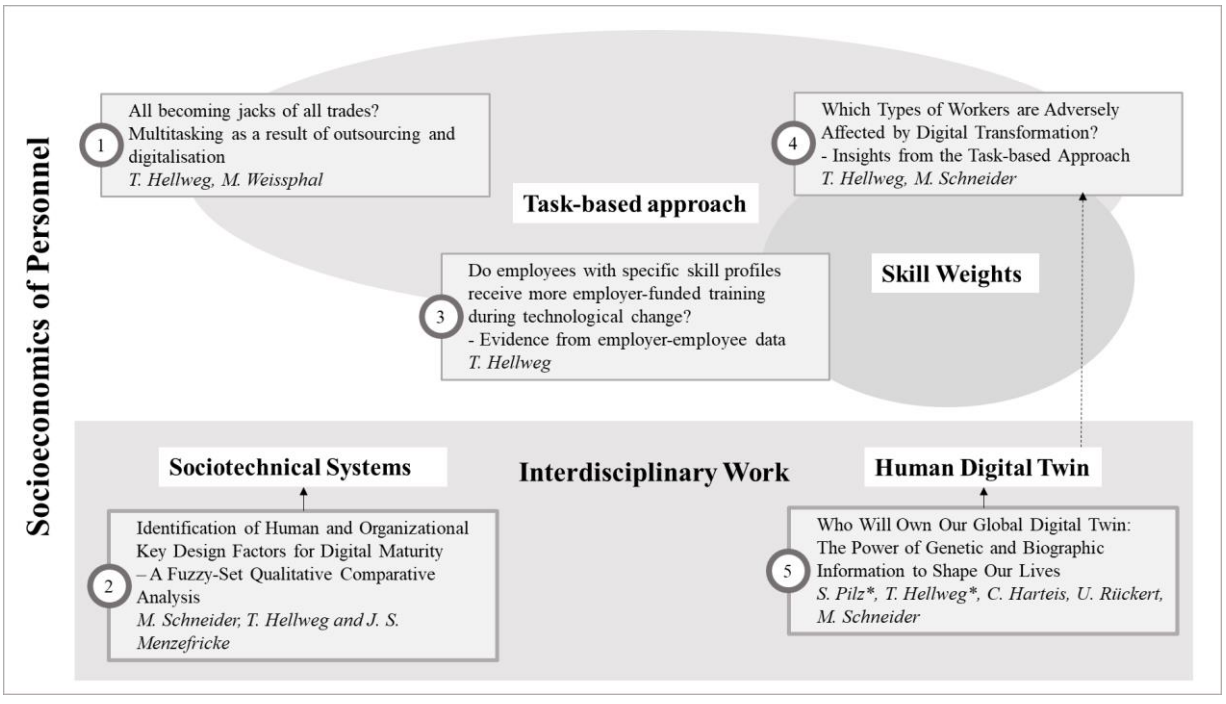


**Figure 1 Illustration of the theoretical framework**

# 3 Contextual order and content of the research papers

In this section, the five research papers of this dissertation are briefly presented and placed in a logical sequential order. To make the content of the papers and the interrelationships between the papers more comprehensible, the text is supplemented by grey boxes, in which a short explanation about the content, procedure and results of the respective paper is given. If the individual full papers have already been read, these boxes provide no additional information and can be skipped. Moreover, a brief overview of the sequence, content and core theories of the five papers is shown in Table 1.

**Table 1 Overview of the research papers**

| | Paper | Content | Theory |
|---|---|---|---|
| 1 | All becoming jacks of all trades? Multitasking as a result of outsourcing and digitalisation<br>*Talea Hellweg, Markus Weißphal* | **Changing work tasks (multitasking)** | Task-based approach |
| 2 | Identification of Human and Organizational Key Design Factors for Digital Maturity – A Fuzzy-Set Qualitative Comparative Analysis<br>*Martin Schneider, Talea Hellweg and Jörn Steffen Menzefricke* | **Success factors for digital transformation** | Sociotechnical systems |
| 3 | Do employees with specific skill profiles receive more employer-funded training during technological change? - Evidence from employer-employee data<br>*Talea Hellweg* | **Risk factors for employees. Who needs and who receives further training?** | Task-based approach<br>Skill-weights approach |
| 4 | Which Types of Workers are Adversely Affected by Digital Transformation? Insights from the Task-based Approach<br>*Talea Hellweg, Martin Schneider* | | Task-based approach<br>Skill-weights approach<br>Human digital twin |
| 5 | Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives<br>*Sarah Pilz, Talea Hellweg, Christian Harteis, Ulrich Rückert, Martin Schneider* | **Opportunities and risks of human digital twins** | Human digital twin |

The previous section has shown that the research papers share a common goal, namely to identify possible consequences of digital transformation for employees and employers and thus find ways to counteract negative effects and risks at an early stage. To contribute to this goal, research Paper 1 looks at the change in work tasks due to digitalisation. How digitalisation will change work tasks is fundamental to deriving possible consequences for employees as they can have a direct impact on workload and job satisfaction as well as job demand. In addition,

employees need sufficient time to adapt to new work tasks in order to prevent negative consequences such as work overload, wage loss or even unemployment. Only if employees and employers are aware of the changes at an early stage, they can achieve the adaptation in time. The first research paper in this dissertation addresses this question by examining the change in the number of work tasks (multitasking).

Summary Paper 1:

All becoming jacks of all trades? Multitasking as a result of outsourcing and digitalisation
*Talea Hellweg, Markus Weißphal*

One work characteristic that can impact the workload or job satisfaction is the number of work tasks to be performed, also referred to as multitasking or task variety (Fahr 2011; Hackman et al. 1975; Zaniboni et al. 2013). As a result of this relevance, multitasking has already been considered in the existing literature on digital transformation. Early researchers predicted an increase in multitasking due to digitalisation based on theoretical considerations (Boucekkine and Crifo 2008; Lindbeck and Snower 2000). However, it is still unclear how multitasking will change due to digitalisation for different groups of employees.

In addition to multitasking, another phenomenon is relevant to current labour market changes and could theoretically have an impact on the degree of multitasking: the outsourcing of activities (Cortes and Salvatori 2019; Ochsenfeld 2018). This phenomenon is closely related to digitalisation, as new technologies enable outsourcing. To ascertain a picture of how multitasking will change in the future, it is therefore important to consider both factors.

In this research paper, panel regressions are used to investigate how the introduction of new technologies, as well as being affected by outsourcing, changes the number of tasks performed in everyday work. For this purpose, the dataset WeLL from the IAB is used, which contains detailed information on different work tasks at the individual level. Since concrete work tasks are considered as the unit of analysis at the microdata level, the research paper is related to the task-based approach (Autor et al., 2003).

The results show that both outsourcing and digitalisation statistically increase the number of work tasks on average. Contrary to what is assumed by the existing theoretical literature, these changes are particularly evident for low-skilled employees. A possible positive influence of multitasking on employability was also shown. At the same time, however, the data also reveal that the increase in work tasks is accompanied by additional training only for high-skilled employees. This lack of training in the face of an increase in work tasks could mean an increase in workload for low-skilled employees.

Overall, the findings suggest that a broad range of skills is becoming increasingly important to remain employable in the labour market. This is particularly relevant for scheduling the training and continuing education of employees and contributes to the literature on the task-based approach.

The results of the first research paper show that an increase in multitasking is to be expected as a result of digitalisation (and other factors), which means that the need for further training of employees is likely to increase.

Building on this, the second research paper examines the relevance of training and other HR and organizational factors for the successful digital transformation of companies. Whether or not a comprehensive training program is a key success factor for companies is not only important in guiding companies through the process of transformation, but it can also influence whether or not companies are willing to finance the necessary training measures for employees. Literature and practice have already identified a large number of success factors for digital transformation, which also include a comprehensive training program (Hobscheidt et al., 2020; Kane, 2019). But, against the background of a limited financial budget, companies cannot invest equally in each of the known success factors; instead, a focus must be placed on core success factors. However, it is often still unclear which of the many organizational or HR success factors are decisive for the different types of companies (Buer et al., 2021; Pöppelbuß & Röglinger, 2011). This problem is investigated in the second research paper in the context of interdisciplinary cooperation between the chair of personnel economics and systems engineering by identifying different success paths to digital maturity. The results show that comprehensive training programs and employee participation are key factors for success.

Summary Paper 2:

Identification of Human and Organizational Key Design Factors for Digital Maturity – A Fuzzy-Set Qualitative Comparative Analysis
*Martin Schneider, Talea Hellweg and Jörn Steffen Menzefricke*

Digital transformation represents a major challenge for companies. Existing literature recommends a whole range of factors that companies should optimize in order to master this challenge and achieve a high level of digital maturity (Hobscheidt et al., 2020). Accordingly, a maximalist approach in line with the sociotechnical system approach is recommended. Although a holistic view is important, such recommendations represent an unrealistic goal for many companies and thus an excessive challenge. Recent literature also argues that different paths to digital maturity are possible and criticizes prevailing digital maturity models that are based on maximalist assumptions (Eller et al. 2020; Horváth and Szabó 2019; Pöppelbuß and Röglinger 2011).

This research paper addresses this issue and assumes that not all factors are relevant to the same extent for different types of companies (Park et al. 2020). For this purpose, the fs/QCA method is used to identify various success paths that can contribute to a high level of digital maturity of the product or production. The analysis is based on data from a digital maturity model that was developed as part of the INLUMIA project (Instruments for Improving the Performance of Companies through Industry 4.0). Companies have used this model as part of an online tool to record and evaluate various company factors from the areas of technology, people and organization.

The success paths identified in this research paper can be used to provide more targeted recommendations for action for different types of companies. The results also show that the fs/QCA method is suitable for identifying success paths in the context of digital transformation. Key success

factors that were found in most of the success paths are a combination of a high degree of employee participation and comprehensive training programs. The importance of further training for a successful digital transformation is therefore confirmed in the context of this study.

Thus, the results of papers 1 and 2 have once again demonstrated that further training is an important factor for successful digital transformation from the perspective of both employees and employers. However, existing literature and additional results of paper 1 indicate that not all employees receive training to the same extent. In particular, low-skilled workers are affected by insufficient training retention (Bilger et al., 2018; Mohr et al., 2016; OECD, 2019b). Therefore, workers who systematically receive less training must be supported to reduce an increase in inequality. In this regard, knowledge about employee characteristics that lead to low receipt of further training is of particular importance. Research papers 3 and 4, therefore, address possible risk factors for workers that may negatively affect the receipt of training. The focus of research paper 3 is on a worker characteristic that has received less attention so far, namely the specificity of task profiles. Accordingly, in contrast to the existing literature, the focus is not on a single type of work task or demographic characteristics, but on the composition of the task profile. Results not only show that task specificity can reduce the recipe of employer-financed further training but also that it correlates with other risk factors, such as the number of routine tasks and a low level of qualification.

Summary Paper 3:

Do employees with specific skill profiles receive more employer-funded training during technological change? - Evidence from employer-employee data
*Talea Hellweg*

While the existing literature on the task-based approach primarily considers individual work activities such as the performance of routine tasks (Acemoglu & Restrepo, 2018; Autor et al., 2003; Goos et al., 2014), less attention is paid to holistic dimensions, such as task composition. Therefore, this research paper investigates the specificity of task profiles. More precisely, it examines how the specificity of the task profile affects the receipt of employer-sponsored training for employees affected by digital transformation in the workplace. Task specificity is to be understood according to the skill weights approach (Lazear, 2009), which classifies task profiles as specific if the composition of a task profile is very different from the composition of task profiles in the overall labour market. To investigate task specificity, the german panel dataset WeLL (Further Training as a Part of Lifelong Learning) from the IAB was used. Moreover, a new method for calculating task specificity was developed, which uses the Mahalanobis distance to determine the distance between different task profiles.

The results of within-between panel analyses indicate that employees with more specific task profiles receive less training on average when they are affected by digitalisation than employees with more general profiles. In line with David Marsden's theory of employment systems (Marsden, 1999), this is explained by a shift in bargaining power.

In addition, descriptive studies show that the specificity of task profiles correlates with other risk factors, such as the number of routine tasks and a low skill level. Overall, the results highlight the importance of considering the specificity of task profiles as a risk factor.

Based on the findings of research paper 3, which highlighted the relevance of specific task profiles for obtaining further training, research paper 4 relates the relevance of specific task profiles to other risk factors from the existing literature on the task-based approach, in particular the execution of routine tasks. It also discusses mechanisms that could reduce negative consequences for employees based on technologies that use human digital twins.

Summary Paper 4:

Which Types of Workers are Adversely Affected by Digital Transformation?
Insights from the Task-based Approach
*Talea Hellweg, Martin Schneider*

How digitalisation will change work tasks is an important question of our time. The central research approach dealing with this question is the task-based approach (Autor et al. 2003). In this paper, the literature on this approach is presented with a special focus on two workplace characteristics: the number of routine tasks and the specificity of task profiles. While the number of routine tasks has been frequently examined in research, less attention has been paid to the specificity of task profiles, which is based on the skill-weighs approach (Lazear 2009). In the paper, a risk matrix is developed that illustrates how the two characteristics can act as risk factors for employees in times of digital transformation and how they are related.

Employees are accordingly particularly at risk of wage or job loss because of digitalisation if they have both characteristics at the same time: perform many routine tasks that can be automated in the future (Acemoglu and Restrepo 2018; Autor et al. 2003; Goos et al. 2014), and have very specific work tasks that limit their mobility and adaptability on the labour market (Eggenberger et al. 2018; Lazear 2009). In addition, it is pointed out that employees with both characteristics often also have a lower level of qualification and, contrary to their increased need, receive less training on average. Various risk factors consequently correlate.

In order to explore ways of reducing the risks of these employees, the research paper discusses the concept of human digital twins in two forms of application in personnel management. The first is the use of online career platforms (Madia, 2011) and the second is the use of competency management systems (Lindgren et al., 2004). In both cases, human digital twins of employees are used to improve matching and identify training needs.

The findings on risk factors and the use of human digital twin presented in the paper can be used by employees, employers and policymakers to mitigate the negative consequences of digitalisation for certain groups of employees.

Research paper 4 touches on the topic of human digital twins by explaining possible applications in the HR field. This illustrates the importance of human digital twins. However, they have many more applications in different areas of life, which can have both positive and negative consequences. In the existing literature on human digital twins, they are usually only examined from the perspective of a single discipline. A detailed interdisciplinary consideration will therefore be given in research paper 5. For this purpose, researchers from the fields of computer science, educational sciences and business administration and economics worked together. A particular focus of the research paper is the classification of data into genetic and biographical, the consideration of the free will, and the use of human digital twins as a common pool resource.

Summary Paper 5:

Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives
*Sarah Pilz, Talea Hellweg, Christian Harteis, Ulrich Rückert, Martin Schneider*

New technologies enable new possibilities, one of which is the creation of human digital twins (HDT). HDTs are digital representations of people and contain all the data that can be stored about a person. This data is collected by different stakeholders and used for different purposes. Due to the diversity of human digital twins, they have so far been viewed only from the perspective of single disciplines. Therefore, it is difficult to comprehensively assess the opportunities and risks of the use of HDTs. This research paper addresses this question by looking at the types of data, areas of application, opportunities, and risks of HDTs from an interdisciplinary perspective.

In addition, the paper provides a more general understanding of HDTs, as existing definitions are mostly contextual and depend on the particular application and field. As part of this, it is shown that the data stored in the HDT can be divided into two broad areas: genetic data and biographical data. Moreover, it is emphasized that the free will cannot be stored within the framework of the HDT.

The interdisciplinary consideration of the HDT provides important impulses on how the HDT can be used successfully in the future. It is discussed that the HDT only develops its full potential by combining many digital twins from different sources and using them as a common pool resource (Hess & Ostrom, 2003). Only if people give their consent to this kind of usage can the data be fully exploited. In this respect, people should have the possibility to effectively give or deny access to their personal data, and know which items of information are stored by whom. Only in this way can persons serve as a control authority who can withdraw their consent in the event of inappropriate or harmful use of the data.

The paper also provides recommendations for research. It highlights that analysing disparate data in HDTs is an enormous challenge that the private sector is currently more engaged with than the research community. It is therefore important to strengthen public-private partnerships in research,

since the data are mainly in private hands. Research must also increasingly be conducted in interdisciplinary teams to comprehensively evaluate the diverse data to create cross-disciplinary models.

The appendix provides more information on each research paper (Table A1-A5), including the division of responsibilities between the authors, conferences at which the papers were presented, as well as journal submissions and publication status. As can be seen from the tables, the chosen or intended forms of publication differ. Therefore, the papers vary in form, style and content. It should be particularly emphasized that paper 3 was published in the machine engineering research field. Papers 4 and 5 will appear as part of a Springer anthology aimed at a broad audience, which is why emphasis was placed on reduced complexity and ease of understanding.

# 4 Conclusion

The research findings of the five papers of this dissertation reinforce that a comprehensive education and training concept is and will be of central importance to master digital transformation in the future. Moreover, they provide insights that could help improve the education and training system. In this regard, the results highlight three aspects in particular: first, the importance of broad-based skills profiles; second, the need for better support for low-skilled workers in the continuing education and training system; and third, the opportunity to use human digital twins to improve the continuing education and training system. These aspects are important for employees, employers and policymakers alike.

The development of broad-based skills profiles is considered particularly important, as the research findings indicate that the number of work tasks to be performed will increase as a result of digitalisation and outsourcing. Moreover, specific skill profiles are identified as a potential risk factor for employees in the digitalisation process because they can not only restrict employees in their flexibility on the labour market but can also reduce the receipt of employer-funded training in the digitalisation process. The development of broad-based skills profiles can not only be encouraged by employers and policymakers, but it can also be initiated by workers themselves. Therefore, all three stakeholders must be aware of this impending need. In order to meet this future need at an early stage, adapting vocational education curricula as a policy measure could be particularly effective.

The research results also highlight that the group of low-skilled workers in particular must receive more attention in the education and training system. This group of employees is especially affected by automation and at the same time faces a spectrum of risk factors that limit adaptability, such as specific skill profiles and few training opportunities (Paper 3 and 4). In addition to the low level of training opportunities (Bilger et al., 2018; Mohr et al., 2016; OECD, 2019b), these employees have a lower willingness to participate in training (Backes-Gellner et al., 2007). However, digital transformation will be most successful, especially against the backdrop of skills shortages and demographic change, if all employee groups are included in the education and training process. Therefore, it is not only important for low-skilled workers themselves to receive more training, but it is also important for employers and policymakers to help increase the availability of training and the willingness to participate for low-skilled workers.

Research papers 4 and 5 discuss the use of human digital twins as mechanisms to contribute to this transformation by improving matching as well as identifying training needs. In particular, two applications of human digital twins are highlighted: competence management systems and online career platforms. They can support especially employees with an increased risk of automation, an increased need for further training, and low flexibility. They can also help companies to build sustainable personnel management and improve long-term employee retention. Therefore, these technical solutions can support employees as well as employers to reduce occupational fit problems. Nonetheless, they need to be reflected critically due to the use of sensitive personal data.

Despite these findings, which provide implications for policy and practice, some questions remain unanswered and thus should be investigated in future research. First, the analysis in this dissertation is limited to selected risk factors, but it can be assumed that further risk factors will develop in the course of digital transformation, for example, due to the elimination of complex tasks by AI applications (Agrawal et al., 2019; Lane & Saint-Martin, 2021; Nordhaus, 2021). Therefore, an ongoing investigation of risk factors and negatively affected employee groups is important. In this regard, it should be investigated especially which risk factors frequently occur simultaneously. Data on the individual level should be used more often for this purpose. In addition, the studies in this dissertation do not examine occupational groups individually, which could provide further important insights.

Second, measures to reduce the risks for employees should be identified, especially those that can increase low-skilled employees' retention and their willingness to participate in further training. Some research papers on this topic already exist, which for example suggest, that financial incentives and clear communication of benefits could improve participation rates (Backes-Gellner et al., 2007; Kyndt et al., 2011). Moreover, research shows that low-skilled employees with a higher degree of autonomy are more likely to participate in training (Kyndt et al., 2011). Further similar research is needed to better understand these crucial mechanisms.

Third, the scope of this dissertation only allows for a partial consideration of the broad concept of human digital twins, whose possibilities are constantly evolving. This implies a need for more detailed and ongoing research in this area, as this is the only way to adequately discuss and weigh the advantages and disadvantages of using human digital twins.

To sum up, this dissertation is dedicated to the digital transformation, especially in the context of work. Both academia and the media public forecast a wide variety of future scenarios resulting from this transformation; ranging from a utopian symbiosis of people and machines (Brynjolfsson & McAfee, 2014) to the obsolescence of human labour (Nordhaus, 2021). However, a differentiated look at today's digital transformation in the world of work shows one thing above all: new technologies do not change the world of work with a bang, but gradually. This dissertation aims to highlight that these gradual changes leave room for research that can help empower both workers and companies. In the context of this dissertation, this goal is pursued through the investigation of further education and training needs, to enable an early adaptation to the new work requirements.

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# Appendix

**Table A 1 Authorship and publications of Paper 1**

| | | |
|---|---|---|
| Hellweg, Talea; Weißphal, Markus (2023) All becoming jacks of all trades? Multitasking as a result of outsourcing and digitalisation | | |
| Research question: How are work tasks changing as a result of digitalisation and outsourcing? Is the number of tasks to be performed by employees increasing or decreasing and what are the possible consequences for employees? | | |
| Content | | Responsible person(s) |
| • Development of the research question | | Hellweg, Weißphal |
| • Literature research and creation of the literature overview | | Weißphal |
| • Data preparation and data analysis | | Hellweg |
| • Interpretation and discussion of results | | Hellweg, Weißphal |
| • Writing of the article | | Hellweg, Weißphal |
| Presentations at scientific conferences | | Speaker |
| 28 – 30 September 2022 | Herbstworkshop der Wissenschaftlichen Kommission Personal 2022– Berlin | Hellweg, Weißphal |
| 9 – 11 July 2022 | Society for the Advancement of Socio-Economics (SASE) – Amsterdam Netherlands | Hellweg, Weißphal |
| Journal Submissions | | Status |
| • Industrial Relations | | Reviewed and rejected |

**Table A 2 Authorship and publications of Paper 2**

| Schneider, Martin; Hellweg, Talea; Jörn S., Menzefricke (2022) Identification of Human and Organizational Key Design Factors for Digital Maturity – A Fuzzy-Set Qualitative Comparative Analysis | |
|---|---|
| Research question:<br>What are the success factors for different types of companies to achieve a high level of digital maturity? | |
| Content | Responsible person(s) |
| • Development of the research question | Schneider, Hellweg, Menzefricke |
| • Literature research and creation of the literature overview | Schneider, Hellweg, Menzefricke |
| • Data preparation | Hellweg, Menzefricke |
| • Data analysis | Schneider |
| • Interpretation and discussion of results | Schneider, Hellweg, Menzefricke |
| • Writing of the article | Schneider, Hellweg, Menzefricke |
| Presentations at scientific conferences | Speaker |
| 9 – 11 July 2022 Society for the Advancement of Socio-Economics (SASE) – Amsterdam, Netherlands | Schneider |
| 23 – 26 May 2022 17th INTERNATIONAL DESIGN CONFERENCE 2022– Croatia (online) | Menzefricke, Hellweg |
| Journal Submissions | Status |
| Schneider, M., Hellweg, T., & Menzefricke, J. S. (2022). Identification of Human and Organizational Key Design Factors for Digital Maturity–A Fuzzy-Set Qualitative Comparative Analysis. Proceedings of the Design Society, 2, 791-800. | Published (26 May 2022) |

**Table A 3 Authorship and publications of Paper 3**

| Hellweg, Talea (2023) Do employees with specific skill profiles receive more employer-funded training during technological change? Evidence from employer-employee data | | |
|---|---|---|
| Research question:<br>Do task-specific skill profiles represent a risk factor in times of digital transformation? Do they reduce the receipt of employer-funded training? | | |
| Content | | Responsible person(s) |
| • Sole authorship | | Hellweg |
| Presentations at scientific conferences | | Speaker |
| 26 – 27 June 2023 | David Marsden conference, London School of Economics and Political Science, London | Hellweg |
| 16 – 18 March 2022 | COPE 2022 - 25th Colloquium on Personnel Economics, Aarhus University, Denmark | Hellweg |
| 18 November 2021 | Faculty Research Workshop, Paderborn University, Germany | Hellweg |
| 21 – 24 June 2021 | 19th ILERA World Congress, Lund, Sweden (online) | Hellweg |
| 17 – 18 September 2020 | Herbstworkshop der Wissenschaftlichen Kommission Personal, Düsseldorf, Germany | Hellweg |
| 18 – 21 July 2020 | Society for the Advancement of Socio-Economics (SASE), Amsterdam (online) | Hellweg |
| Journal Submissions | | Status |
| • Labour economics | | Reviewed and rejected |

**Table A 4 Authorship and publications of Paper 4**

| Hellweg, Talea; Schneider, Martin (2022) Which Types of Workers are Adversely Affected by Digital Transformation? Insights from the Task-based Approach | |
|---|---|
| Research question:<br><br>What are key risk factors for employees and how are they related? Could human digital twins be used to reduce negative consequences for employees? | |
| Content | Responsible person(s) |
| • Development of the research question | Hellweg, Schneider |
| • Literature research and creation of the literature overview | Hellweg, Schneider |
| • Creation of the theoretical framework | Hellweg, Schneider |
| • Interpretation and discussion of results | Hellweg, Schneider |
| • Writing of the article | Hellweg, Schneider |
| Presentations at scientific conferences | Speaker |
| 20 – 22 September 2022 — Data Society. Chancen – Innovationen – Verantwortung, Paderborn University | Hellweg |
| Journal Submissions | Status |
| Hellweg, T., & Schneider, M. (2023). Which Types of Workers Are Adversely Affected by Digital Transformation? Insights from the Task-Based Approach. In The Digital Twin of Humans: An Interdisciplinary Concept of Digital Working Environments in Industry 4.0 (pp. 231-248). Cham: Springer International Publishing. | Published (17 May 2023) |

**Table A 5 Authorship and publications of Paper 5**

| Pilz, Sarah; Hellweg, Talea; Harteis, Christian; Rückert, Ulrich; Schneider; Martin (2022) Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives | |
|---|---|
| Research question:<br>What are human digital twins? What data do they comprise and what are possible opportunities and risks of their use? | |
| Content | Responsible person(s) |
| • Development of the research question | Pilz, Hellweg, Schneider, Rückert |
| • Literature research and creation of the literature overview | Pilz, Hellweg, Schneider, Harteis |
| • Creation of the theoretical framework | Pilz, Hellweg, Schneider, Rückert, Harteis |
| • Interpretation and discussion of results | Pilz, Hellweg, Schneider, Rückert, Harteis |
| • Writing of the article | Pilz, Hellweg, Schneider, Rückert, Harteis |
| Presentations at scientific conferences | Speaker |
| - | |
| Journal Submissions | Status |
| Pilz, S., Hellweg, T., Harteis, C., Rückert, U., & Schneider, M. (2023). Who Will Own Our Global Digital Twin: The Power of Genetic and Biographic Information to Shape Our Lives. In The Digital Twin of Humans: An Interdisciplinary Concept of Digital Working Environments in Industry 4.0 (pp. 11-35). Cham: Springer International Publishing. | Published (17 May 2023) |