Work Design in Times of Digitalization: Challenges of Advanced Technologies at Work With Job and Task Rotation as Potential Remedies

by

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Summary

Current and future digital technologies, which are characterized by a great degree of interoperability, real-time capability, and modularity, have the potential to greatly impact workplaces and processes. The reason is that these technologies are more strongly interwoven with everyday work processes than previous technologies. Hence, they become an increasingly important research topic in the field of work design. To design motivating, challenging, and meaningful work, it is necessary to investigate how digital technologies might affect employees and their work as well as explore potential solutions to the challenges posed by digitalization. In three studies, the present work examines to what extent digitalization is associated with competency requirements and employee reactions, whether job rotation and task rotation could be effective in facilitating competency development and enhancing monotonous jobs, and how the effects of task rotation can be explained theoretically.

In a field study (Study 1) with $N = 127$ employees from 19 companies, we investigated the relationships between the digitalization level of a division (i.e., the extent to which the utilized technologies had certain characteristics, such as real-time information), the competencies required in that division, and several employee reactions (e.g., work engagement). By comparing two occupations that differed regarding their extent of cognitive versus manual tasks, we were able to examine whether digitalization had occupation-specific effects. Regression analyses revealed an indirect effect of the digitalization level via competency requirements on most employee reactions, moderated by the occupational context. In the occupation with mainly nonroutine cognitive tasks, a great digitalization level was associated with a greater degree of competency requirements. In the occupation with mainly nonroutine manual tasks, a great digitalization level was associated with a smaller degree of competency requirements. As a result, jobs with a high level of digitalization can either require more training due to greater competency requirements or necessitate an

enhancement of jobs that have become undemanding and possibly monotonous due to lower competency requirements.

To address both cases, we meta-analytically investigated job rotation and task rotation as possible remedies in Study 2. The three-level meta-analysis on 56 studies (N = 284,086) revealed positive relationships between rotation and certain attitudinal (e.g., job satisfaction) and development-related (e.g., career success) outcomes, as well as outcomes concerning psychological health (e.g., less stress and burnout) and organizational performance (e.g., productivity). Relationships between rotation and physical health (e.g., fewer musculoskeletal complaints) were only positive when compared to high-intensity work. Task rotation was more strongly related to attitudes than job rotation, job rotation had stronger relationships with learning and development, psychological health, and organizational performance. A notable shortcoming of most included primary studies was that they had a correlational design and therefore did not allow causal inferences.

In Study 3, we combined the technology-supported work context of Study 1 with the knowledge about task rotation of Study 2 and experimentally investigated effects and explanatory mechanisms of task rotation as a technology feature. The study consisted of two consecutive experimental vignette studies (N_1 = 135, N_2 = 159), in which we described a work scenario where a digital assistance system either specified when to rotate between tasks or only supported work steps. Regression analyses confirmed the expected effects of task rotation on positive anticipated employee reactions (e.g., job satisfaction and positive affect). Additionally, we found evidence that these effects could be explained by the perceived work characteristics task variety, skill variety, and task identity, combined with the anticipated satisfaction of the need for competence. Contrary to our expectations, there were no individual differences in the effects of task and skill variety on employee reactions due to the participants' openness to experience.

In sum, the present work advances our understanding of digitalization as well as job and task rotation and suggests that the combination of digitalization and rotation is a worthwhile approach to design current and future workplaces. Corresponding theoretical (e.g., explanations for job and task rotation effects) and practical implications (e.g., a recommendation on how to anticipate work design changes when implementing technologies) are discussed and directions for future work design research pointed out.

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Introduction

Work design has been an essential research topic of industrial and organizational (I/O) psychology for more than one hundred years (for a historical overview see Parker et al., 2017). As the world of work has been changing during that time, so have the key topics of work design. The present work combines the classic work design approaches job and task rotation with one of the most prominent current drivers of work design: digital technologies.

Digital technologies (e.g., digital assistance systems, collaborative robots) describe technologies that can collect and process information about their environment via sensors, are interconnected, modular, and thus react in real time to certain situations, problems, and individual customer requests (Hermann et al., 2015). Researchers are convinced that these technologies not only provide new opportunities for psychological work design but also require it (e.g., Cascio & Montealegre, 2016; Parker & Grote, 2020). It is, however, not yet clear how current technologies and different technology features might affect employees and their work. Research on previous technologies found ambiguous results. For instance, the use of information and communication technologies (i.e., tablets, computers) was in some cases associated with less burnout and anxiety (Salanova et al., 2013; Ter Hoeven et al., 2016), but in other cases with more perceived stress (Eijckelhof et al., 2014; Goldfinch et al., 2011).

The claims for psychological work design in the context of digital technologies are based on the central tenet of sociotechnical systems design and sociomateriality. Both approaches state that the design of technical systems (e.g., machines, tools) and social systems (employees) should be conducted in harmony with each other to ensure usage of the system, well-being, and positive employee attitudes (Clegg, 2000; Orlikowski, 2007; Trist et al., 1977). Yet, in practice, the design of digital technologies is usually primarily aimed at ensuring productivity, workplace safety, or the reduction of human errors (Djuric et al., 2016; Hold et al., 2017), and rarely considers psychological criteria of work design. Therefore, there are two possible extreme scenarios that might result: a deskilling or an upskilling of jobs

(Autor et al., 2003) that can be associated with impaired or improved employee well-being, attitudes, and behavior (van den Broeck et al., 2016). A deskilling might happen when the technology provides so much assistance that the employee no longer needs the competencies that were necessary to perform the job without assistance. Such simple and undemanding jobs could then result, for example, in decreased job satisfaction and performance (Humphrey et al., 2007). An upskilling might be possible when the technology enables the employee to perform more advanced tasks because the simpler tasks are performed by the technology. As a result, employees might feel overwhelmed with their new responsibilities. While some researchers claim that the deskilling or upskilling effect of technologies on jobs is deterministic (e.g., Frey & Osborne, 2017), I/O psychologists, such as Parker and Grote (2020), would argue that work design provides the tools to counteract possible negative effects.

We propose job and task rotation as methods to mitigate possible negative effects of deskilling on the one hand, and to address increased competency requirements on the other. Job rotation refers to a lateral transfer of employees within an organization without a change in salary or hierarchy (Campion et al., 1994) and most commonly describes a change between different functions, departments, or units (e.g., Le Meunier-Fitzhugh & Massey, 2019). Task rotation also includes a move between work tasks, but on a smaller scale. More specifically, it refers to the alternation between tasks within a job that can require different skills and responsibilities but is not associated with a change to a different function or department (e.g., Jones & James, 2018). A distinction to job enlargement—a work design method where new tasks are added to an existing job—is that in the case of job and task rotation, each employee is responsible for one single job or task at any given time (Cosgel & Miceli, 1998). As a result of job or task rotation, the job offers more diverse tasks, possibly requires a greater range of competencies, and in some cases the job adds up to a complete cycle of a work process. All of these attributes contribute to a healthy and motivating workplace that also stimulates learning

and development (Hackman & Oldham, 1976; Morgeson & Humphrey, 2006; Parker, 2017). Consequently, organizations anticipate four main benefits by adopting job or task rotation: First, their employees should become more satisfied and motivated due to a reduction of monotony, second, the employees learn more due to a greater variety of stimulating work environments, third, the staff is healthier due to reduced muscle fatigue and repetitiveness, and fourth, the organizational performance increases due to greater labor flexibility and more organizational learning. Although theoretical considerations imply positive effects of rotation, existing research is ambiguous. As an example, there is evidence for a positive ($r = 0.44$; Muramatsu et al., 1982) as well as a negative significant relationship ($r = –0.17$; Mohsan et al., 2012) between rotation and employee motivation.

Job and task rotation are not only ways to address effects of digitalization, but they can also be more easily implemented by the means that digitalization offers. One prominent example of digital technologies are digital assistance systems, for example, augmented reality glasses or workspace-integrated displays that provide instructions on how to perform each step of a task (Wang et al., 2016; Yang & Plewe, 2016). Thus, digital assistance systems provide situation-sensitive guidance for the employee, for example, step-by-step instructions or advice on special cases (Reinhart & Patron, 2003). As a consequence, these systems are especially suitable to consider the implementation of rotation because jobs with rotation require employees to quickly adjust to a new work task.

Despite the existing research in the fields of sociotechnical systems, digital technologies, and job and task rotation, there are still four important questions left unanswered. First, although the interplay between the technical and the social system are a central idea of sociotechnical systems theory, there are no theoretical explanations as to how and why the technical and the social system are related. Knowledge about the underlying mechanisms could help explain why previous research found ambiguous effects of technologies on employees (Eijckelhof et al., 2014; Ter Hoeven et al., 2016).

Second, in the past, there were two contradicting perspectives regarding the development of competency requirements due to the introduction of technologies: skill-biased (e.g., Berman et al., 1998) and routine-biased technological change (Autor et al., 2003). The former assumes a general upskilling trend due to technologies, the latter postulates that there is an increase in high-skilled and low-skilled jobs, and a decrease in middle-skilled jobs. It is not yet clear which perspective holds true for the current digitalization of work. Being able to anticipate such changes in jobs can help to create appropriate human resources and work design measures.

Third, before being able to confidently propose rotation as a means against possible negative effects of digitalization, it is necessary to know whether it really has positive effects, as could be assumed based on theoretical considerations. This is not entirely clear because there is some evidence that found no or even negative relationships between rotation and motivation, health, employee development, or organizational performance (e.g., Bouville & Alis, 2014; Kapellusch et al., 2017; Kim et al., 2016; Mohsan et al., 2012). In order to provide clarity, a statistical integration of all existing empirical studies on job and task rotation is indicated. This can also answer the question whether there are any conditions that might increase or decrease rotation effects, such as the design of the rotation or the societal culture of the countries where the primary studies were conducted.

Fourth, even when all the existing research on rotation is integrated, the result allows only a rather generalized answer about its effects because existing studies have not addressed certain questions. First of all, to be certain that rotation is uniquely associated with beneficial outcomes, experimental research is needed. Additionally, job or task rotation have not yet been investigated as a technology feature, such that the technology plans the rotations. There might be differences, for instance, because the technology could increase the feeling of being monitored, or because the technology might plan the rotations based on criteria different from those that a supervisor would use. Furthermore, previous studies have made theoretical

assumptions on why rotation is effective but possible underlying mechanisms have not yet been investigated empirically. Lastly, based on person-job fit theory (Edwards, 1991), it is possible that a job with rotation may fit some individuals better than others because it provides certain characteristics. Yet to date, there is no research on individual differences that might increase or decrease the effects of rotation-specific work characteristics on employees' attitudes, behavior, and well-being.

By addressing these open questions, the present work contributes to theorizing on the sociotechnical systems approach and job and task rotation and provides valuable implications for researchers and practitioners. In three studies, we investigated the effects of digitalized workplaces on employees (Study 1 and Study 3), whether rotation really has unique beneficial effects and can therefore mitigate possible negative effects of digitalization (Study 2 and Study 3), and the underlying mechanisms and boundary conditions of rotation (Study 2 and Study 3).

Theoretical Background

Work Design

Work design describes the "content and organization of one's work tasks, activities, relationships, and responsibilities" (Parker, 2014, p. 662). In earlier years, theories and methods of psychological work design had the primary aim to counteract the monotony and skill degradation that had resulted from Taylor's scientific management (Taylor, 1911). Scientific management had the goal to maximize efficiency by fragmenting jobs into single tasks so that each worker was proficient at a very specific task. While this resulted in increased wages, it also led to greater absenteeism and turnover because the jobs were repetitive and did not allow for any initiative on the part of the workers (Hoxie, 1920). Thus, approaches from I/O psychology introduced greater variety and significance into the jobs. As an example, Trist and Bamforth (1951) found that the introduction of a new technology and new organization of work in a coal mine had resulted in performance losses because the new

organization required each employee to perform just one task, which was too rigid for the unpredictability of coal mining. An introduction of autonomous teams, that means teams that could divide the work tasks among themselves independently, resulted in greater workplace safety, lower costs, and increased productivity (Trist et al., 1977). These and related studies were the basis for sociotechnical systems design. This approach emphasizes the importance of considering technical, social, and organizational aspects when designing a new system, for example, a new technology, management practice, or work process (Baxter & Sommerville, 2011).

Another alternative to mechanistic work design (what scientific management has later been called; Campion, 1988) is the job characteristics model by Hackman and Oldham (1976), which Parker et al. (2017) called "by far the most influential model of work design" (p. 407). The job characteristics model claims that there are five work characteristics that determine how motivating a job is: skill variety, task identity, task significance, autonomy, and feedback. That means, a job should require a diverse set of competencies, allow the employee to perform an entire task from start to finish, have an impact on other people, allow control over decisions and methods, and provide information on how effective the employee is working (Hackman & Oldham, 1976). Later on, the job characteristics model was extended by Morgeson and Humphrey (2006). They grouped their 21 work characteristics into task (e.g., task variety), knowledge (e.g., job complexity), social (e.g., social support), and context characteristics (e.g., physical demands). Meta-analytic evidence could show that these work characteristics were positively related to a variety of employee reactions, for example, job satisfaction, subjective performance, internal work motivation, and organizational commitment as well as negatively associated with burnout and exhaustion (Fried & Ferris, 1987; Humphrey et al., 2007).

Digitalization of the Workplace

When contemplating work design, there is also the question of external influences. The following sections therefore go into more detail about digitalization, a major current driver of work design, before introducing job and task rotation as promising work design approaches in times of digitalization. During Taylor's time, work was dominated by mass production and assembly lines. Later on, in the 1970s and 1980s, companies increasingly adopted information and communication technologies. For the past five to ten years, the implemented technologies have become even more sophisticated and affected an increasing number of workplaces. Scholars and practitioners agree that these new forms of technology deserve special attention because they have the potential to entirely change the way people work (Cantoni & Mangia, 2019; Cascio & Montealegre, 2016; Parker & Grote, 2020).

The reason for drastic changes in the work context is that more tasks are being automated so that employees work more closely with technologies (Brynjolfsson et al., 2018). This development is facilitated by ubiquitous computing, which describes the interconnectedness of all systems, objects, individuals, and the physical environment, for example, with the help of sensors (Cascio & Montealegre, 2016). This produces massive amounts of real-time data ("big data") that employees can access to accomplish work tasks, and that technologies can draw on for machine learning purposes. Machine learning means that algorithms inside technologies learn and thus improve through experience (e.g., Bishop, 2006), which enables them to act more autonomously. As a result, more tasks previously performed by employees are taken over by technologies (Parker & Grote, 2020). Hence, humans and digital machines or robots working alongside each other and being dependent on each other is becoming a reality for an increasing number of employees (Ötting & Maier, 2018; Parker & Grote, 2020).

Research on previous technologies has shown that the adoption of a technology has an impact on the employees that work with it. As an example, several studies found positive

relationships between the extent of technology use (investigated technologies were computers, tablets, or smartphones) and job satisfaction, performance, and work engagement as well as less burnout and anxiety (Eggert & Serdaroglu, 2011; Román et al., 2018; Salanova et al., 2013; Ter Hoeven et al., 2016). Yet, there is also evidence for negative effects of technology on employees: Eijckelhof et al. (2014) and Goldfinch et al. (2011) found that the extent of computer use was positively associated with perceived stress. Taken together, these studies show that technologies do not generally have a positive or a negative effect on employees.

One reason for why there are differences in how technologies affect employees is the job content, as could be shown by Korunka et al. (1995). They investigated how the introduction of a new technology affected different jobs in a longitudinal study. The examined technology implementations were either a change from drawing board to computer aided drawing or from manual to electronic data processing. The authors clustered the jobs that they analyzed into computer aided drawing, clerical work, relatively monotonous work (e.g., cashier work), and extremely monotonous work (e.g., keeping note of book loans), and stated that the former two could be regarded as higher ranked jobs compared to the latter two. They found that employees in the highest-ranked cluster (computer aided drawing) reported a significant increase in job satisfaction after the technology introduction, whereas employees in the lowest-ranked cluster (extremely monotonous work) reported a decrease. Such a job content-related perspective on technology effects has also been adopted in a more recent, much-noticed study by Frey and Osborne (2017). The authors analyzed the tasks of more than 700 occupations and derived predictions on how susceptible these occupations were to being replaced by computers. According to their estimations, about 47% of U.S. employments are at risk of becoming automated in the near future. Despite its popularity, it should be considered that an important criticism of the study is that it is unrealistic that entire jobs will be replaced by technologies. Rather, there will be certain tasks that are more efficient to be accomplished

by technologies, and others that will still remain with human employees (Brynjolfsson et al., 2018).

Effects of Digitalization on Competency Requirements

The theoretical basis for a focus on the job content when predicting effects of technologies on jobs—and subsequently their competency requirements—stems from the perspective of routine-biased technological change (Autor et al., 2003). This approach claims that the impact of technologies on a job is determined by the proportion of routine tasks in that job. Routine tasks are those tasks that follow explicit rules. Consequently, it is easy to program them into an algorithm for a technology. A task that does not follow explicit rules because it involves the application of new knowledge or problem-solving techniques, is a nonroutine task. Besides this distinction between routine and nonroutine tasks, routine-biased technological change further differentiates between manual and cognitive tasks. Autor et al. (2003) assumed that technologies are most likely to replace routine cognitive and routine manual tasks, such as calculation or order picking. These usually require low to medium skills. Nonroutine cognitive tasks, such as diagnosing problems, usually require more sophisticated skills and are expected to be complemented by technologies. Lastly, the authors claimed that there is only limited potential for technologies to substitute or complement nonroutine manual tasks, such as unpacking differently shaped items. Such tasks typically require only low skills.

Following from this argumentation, technologies should cause a "polarization" of jobs, which means that there should be an increase in high-skilled and low-skilled jobs and a decline in middle-skilled jobs. Evidence for these assumptions could be observed, for example, on the British and the U.S. labor market and was attributed to the massive decline in the price of computing power in the 1990s (Autor et al., 2006; Goos & Manning, 2007).

An alternative to routine-biased technological change is described in the hypothesis of a skill-biased technological change (e.g., Berman et al., 1998). This perspective does not

differentiate between job contents but claims that the introduction of technologies causes a general shift toward more high-skilled and fewer low-skilled jobs (Bresnahan et al., 2002). The argumentation is that the operation and maintenance of technologies as well as the analysis of technology output require greater skills, and that those tasks that had been performed by less-skilled employees would become automated (Bresnahan et al., 2002; Fernandez, 2001). As there have also been studies supporting this hypothesis in the past (e.g., Bresnahan et al., 2002; Gale et al., 2002; Kim, 2002), it is uncertain whether the current digitalization can best be described by routine-biased or skill-biased technological change. Arguments in favor of a routine-biased technological change are that it is more nuanced and was also the basis for Frey and Osborne's (2017) study on the computerization of U.S. jobs. If the current digitalization can indeed best be described with routine-biased technological change, and therefore leads to a decline of medium skills, the result should be twofold: on the one hand simplified, perhaps monotonous jobs, and on the other hand jobs that require greater knowledge, skills, and abilities and thus require employee development.

Competency Requirements and Employee Reactions

Assuming that digitalization has an effect on the level of competency requirements, it follows from self-determination theory (Deci et al., 2017; Deci & Ryan, 2000) that it should also indirectly affect employee reactions, which means their well-being, attitudes, and behavior. Self-determination theory states that there are three basic, innate needs that every individual has and that each lead to optimal motivation and engagement when satisfied: the needs for autonomy, relatedness, and competence. In the context of competency requirements, our focus is on the need for competence. It describes the need to feel effective and gain mastery when interacting with one's environment. Furthermore, it drives individuals to engage in challenging activities that allow them to use and extend their skills and abilities (Ryan & Deci, 2002). A greater level of competency requirements should provide more opportunities to satisfy the need for competence. Previous studies found, for example, positive

relationships between satisfaction of the need for competence and skill utilization (i.e., the number of skills and abilities that are required for and developed in the job) as well as skill variety (van den Broeck et al., 2010; van den Broeck et al., 2016). A satisfied need for competence results, according to self-determination theory, in greater well-being and optimal functioning, which manifest in affective, attitudinal, and behavioral employee reactions (Deci et al., 2017). Empirical evidence supports this assumption, for example, for work engagement, job satisfaction, organizational commitment, work effort, and performance (Greguras & Diefendorff, 2009; van den Broeck et al., 2010; van den Broeck et al., 2016).

Beneficial Effects of Job and Task Rotation for Employees and Organizations

As already pointed out in the introduction, job and task rotation could be suitable methods to address the diverse effects of digitalization that arise from the potential polarization of jobs. On the one hand, rotation may be suitable to enhance low-skilled jobs because it is supposed to reduce monotony, on the other hand, rotation is regarded useful in high-skilled jobs because it is supposed to provide learning opportunities on the job. Previous research is, however, inconsistent: Some studies reported, for example greater motivation (r = .44; Muramatsu et al., 1982), more labor flexibility (r = .57; Sawhney, 2013), and reduced mental fatigue (r = –.32; Jones & James, 2018) for jobs with rotation. Others found significantly reduced motivation (r = –.17; Mohsan et al., 2012), decreased employee adaptability (r = –.41; Zhu et al., 2013), and less employee energy (r = –.09; Luger et al., 2016).

Past research on job and task rotation has been conducted in multiple disciplines. The interdisciplinary approach to work design by Campion and Thayer (Campion, 1988; Campion & Thayer, 1985) therefore provides a suitable framework for possible outcomes of these work design methods. It has also been identified as the starting point of integrative work design perspectives in Parker and colleagues' (2017) historical overview of work design research. The approach includes the disciplines of organizational psychology, human factors,

ergonomics, and industrial engineering and the corresponding work design goals, which are positive employee attitudes (e.g., job satisfaction), reliability (e.g., reduced stress), physical well-being (e.g., few health complaints), and efficiency (e.g., reduced idle time). A more recent goal of work design is learning and development, which is claimed to have been neglected in past work design research and theory (Parker, 2014, 2017). Besides this overarching approach of Campion and Thayer, each discipline provides more detailed theories and models on why job and task rotation might have beneficial effects. These will be shortly reviewed in the following.

Rotation and Employee Attitudes

Drawing on the job characteristics model (Hackman & Oldham, 1976) and its extension, the work design framework (Morgeson & Humphrey, 2006), a job with job or task rotation is associated with certain employee attitudes because of its unique combination of work characteristics. Compared to a job without rotation, jobs with rotation offer a greater variety of tasks, sometimes require more diverse skills, and are more likely to provide a holistic work experience because the employee performs tasks that might make up a complete cycle of a work process. Meta-analytic results found associations between these individual characteristics (i.e., task variety, skill variety, and task identity) and employee attitudes, such as job satisfaction, internal work motivation, job involvement, and organizational commitment (Humphrey et al., 2007).

Rotation and Learning and Development

Parker (2017) further extended the work design framework and included learning and development outcomes in her work design growth model. According to this model, certain work characteristics lead to short-term and long-term learning and development outcomes. Hence, it is conceivable that the greater levels of task and skill variety and task identity in jobs with rotation facilitate learning because employees are introduced to new knowledge domains and gain a broader perspective about organizational processes. Weststar (2009)

found that a change in work techniques and equipment as well as a change in skill level required to perform a job were related to employees increasingly seeking advice from colleagues with the intention of developing their job skills. Another reason why rotation might foster learning is that it facilitates the creation of tacit knowledge. This refers to knowledge that is acquired through experience because it cannot be explicitly verbalized (Nonaka & Takeuchi, 1995) and might be shared more often when employees have more contact to colleagues from other disciplines through the rotation (Kane et al., 2005).

Rotation and Psychological Health

The integrative model of psychologically healthy workplaces by Kelloway and Day (2005) explains why rotation could benefit the employees' psychological health. According to the model, employee well-being can be ensured when negative demands and stressors are eliminated, and organizational resources are promoted.

It is likely that rotation reduces the job stressors repetitiveness and imbalanced workload and therefore alleviates the effects of these demands on, for example, psychological distress or depression (Loukidou et al., 2009). Additionally, rotation may also provide certain resources. More specifically, Warr (1999) described variety and opportunities for skill use as potential environmental determinants of well-being. There is also empirical evidence by Sevastos et al. (1992), who found significant associations between skill variety and task identity and the well-being indicators of anxiety-contentment and depression-enthusiasm.

Rotation and Physical Health

Westgaard and Winkel (1996) explain in their model on musculoskeletal health, how environmental exposures at work, for example, in the form of repetition and monotony (Andersen et al., 2002), cause individual reactions in the body, which ultimately result in acute physiological and psychological responses, such as discomfort, pain, or muscle fatigue. The repetitiveness at some jobs without rotation stresses one particular body region continuously and does not provide enough time for the internal structures to recover (Luger et

al., 2014). Thus, task rotation with a change between tasks that stress different body regions could be a solution. However, previous narrative reviews on the effects of task rotation on physical health reported either weak positive (e.g., Luger et al., 2014; Padula et al., 2017) or inconsistent effects (e.g., Leider et al., 2015; Mathiassen, 2006). An explanation could be that the overall effect of task rotation was canceled out because only participants who previously performed a task with high work intensity experienced a relief due to the rotation, whereas participants who previously performed a task with low work intensity had a disadvantage because the rotation introduced tasks with higher work intensity (Leider et al., 2015; Luger et al., 2014).

Rotation and Organizational Performance

Resource-based theory claims that an organization's performance is to a great extent determined by its internal resources, one of them being human capital resources (Barney, 1991; Barney et al., 2011). One can assume that rotation increases human capital resources in two ways. First, as described above, rotation enables employees to become proficient in a variety of tasks, which means that they can be allocated to these tasks more flexibly. This labor flexibility helps to avoid bottlenecks, reduce idle time, and achieve a shorter lead time, which contribute to an enhanced financial performance of the organization (Beltrán-Martín et al., 2008; Bhattacharya et al., 2005). Second, rotation also facilitates organizational learning, which means that individual knowledge is shared and thus becomes organizational knowledge (Maier et al., 2001). This knowledge sharing is more likely to happen in rotation jobs. Hauptman and Hirji (1999) and Xie et al. (2003) found, for example, that job rotation was associated with more communication between functions and more involvement in cross-functional activities. As stated above, this can facilitate the sharing of tacit knowledge (Kane et al., 2005).

Underlying Mechanisms of Task Rotation Effects

As stated above, the job characteristics model (Hackman & Oldham, 1976) and its extension, the work design framework (Morgeson & Humphrey, 2006), provide a theoretical explanation for why rotation is associated with positive employee attitudes. The proposed underlying mechanisms of perceived task variety, skill variety, and task identity should be especially relevant in the case of task rotation. Compared to job rotation, task rotation implies a more frequent change between activities so that one can assume that the perception of variety is stronger and that a job appears more holistic because the employee might work on each step of the work process during a relatively short time frame.

The job characteristics model claims that the relationships between skill variety and task identity and several employee reactions is mediated by experienced meaningfulness, which refers to the degree to which an employee feels that their job is important and has value (Hackman & Oldham, 1976). This assumption has not been extensively supported by empirical research. More recently, Gagné and Panaccio (2014) therefore suggested an alternative mediating mechanism, which stems from self-determination theory: the satisfaction of the basic human needs. With regard to task rotation, it is conceivable that the satisfaction of the need for competence serves as a mediator. The need for competence is satisfied by environments that provide opportunities to engage in challenging activities and that facilitate learning and development. According to Gagné and Panaccio (2014), task variety, skill variety, and task identity create such an environment: Task identity may cause an increased feeling of mastery of one's environment, and task and skill variety likely facilitate the development of a broader skill set. In conclusion, the effect of task rotation on employees might be explained by the work design characteristics task variety, skill variety, and task identity, together with the satisfaction of the need for competence.

Individual Differences in Task Rotation Effects

Previous studies in the field of work design already found that employees' personalities and other individual differences affected the effects of several work design practices. As an example, Berdicchia et al. (2016) found that the positive association between job enlargement and job crafting (an employee-initiated approach to changing tasks or interactions at work; Wrzesniewski & Dutton, 2001) was affected by the employees' self-competence. For employees with low self-competence, the association was significantly stronger than for employees with high self-competence. In a study on high-performance work systems, such as flexible job assignments, Zhang et al. (2019) found that the relationship between these types of work design and, for example, task performance was moderated by the employees' proactive personality. Consequently, one might assume that the effect of task rotation-related work characteristics on potential employee reactions could also depend on the employee's personality.

The theoretical explanation for such differential effects is provided by person-job fit theory (Edwards, 1991; Kristof-Brown et al., 2005). The theory proposes that when there is a match between an individual's characteristics and those of their job, the employee shows more positive job attitudes and behavior, such as job satisfaction and performance (Edwards & Shipp, 2007). One form of person-job fit is needs-supplies fit, which refers to the compatibility between an individual's needs or preferences (e.g., the need to be part of a group) and the characteristics of a job (e.g., a great degree of teamwork; Kristof, 1996).

The supplies provided by a job with task rotation are, as derived above, task variety, skill variety, and task identity. A personality factor that matches especially the supplies task variety and skill variety is the Big Five factor openness to experience (McCrae, 1993) because individuals high on this factor are characterized by an aversion to routines, a preference for variety and novelty, a need for change, and an open mind. A job with task rotation might be a

match for open individuals because it offers a wide range of work activities that are not necessarily familiar in advance.

Aims and Outline of the Present Work

The aim of the present work is to advance theoretical and practical knowledge in the fields of digitalization and job and task rotation. Both shape the way work is designed and might affect employees, jobs, and organizations. The focus in Study 1 is on digitalization and its relationship with competency requirements and employee reactions in two occupations. The study sheds light on a central tenet of sociotechnical systems theory because it provides an explanation why the technical and the social systems in an organization are related. Furthermore, the study answers the question, whether the current digitalization rather leads to a skill-biased or a routine-biased technological change. With the knowledge that digitalization might result either in simple and monotonous jobs or in jobs that require more advanced competencies, Study 2 serves the purpose to investigate job and task rotation and their capability of addressing these challenges. More specifically, the study is a meta-analytic integration of relationships between rotation and employee attitudes, learning and development, psychological health, physical health, and organizational performance. The results show how effective job and task rotation actually are and clear up conceptual confusion of the methods job rotation and task rotation. Lastly, Study 3 combines task rotation and digitalization. It therefore answers the question whether task rotation could be an effective technology feature in creating meaningful and motivating technology-supported workplaces. The focus was on task rotation because digital assistance systems can unfold their full potential when supporting frequent job changes. The systems can give instructions for work steps and communicate the time for a rotation, which might be more helpful when employees often have to switch between tasks and need to remember how to perform the necessary work steps. Additionally, we investigated possible theoretically-derived mediators

and a moderator so that the study sheds light on the underlying mechanisms of task rotation effects as well as potential individual differences.

Study 1 – Not Everyone Benefits from Technological Advancements: Associations with Competency Requirements and Employee Reactions in Two Occupations

The aim of Study 1 was to investigate the relationship between digitalization in the workplace, competency requirements, and employee reactions. By doing that, our goal was to derive knowledge about the mechanisms that underlie the relationship between technical and social systems from the sociotechnical systems approach (Clegg, 2000; Trist & Bamforth, 1951). Participants in the study were 127 employees from 19 German small and medium-sized companies. We compared employees from production divisions (82 employees from 11 companies) with employees from warehouse logistics divisions (45 employees from eight companies). We had chosen these occupations because they allowed us to test the hypothesis of routine-biased technological change. We assumed that both occupations contained routine tasks, but that production jobs additionally required more nonroutine cognitive tasks, and jobs in warehouse logistics divisions had a greater focus on nonroutine manual tasks. Thus, assuming that the hypothesis of a routine-biased technological change applied to the current digitalization, a great degree of digitalization should have different effects on these occupations.

The data were collected with three methods. A workplace observation and a structured interview with the respective supervisor, both conducted by a work psychologist, were used to determine the division's digitalization level. The interview guideline was newly developed for this study, based on digitalization principles identified in a literature review by Hermann et al. (2015), and had good inter-rater reliability ICC(1,1) = .76, $F(43,44) = 7.37$, CI [.60, .86], $p < .001$. The third method of data collection was questionnaires, which were used to assess the competency requirements and employee reactions, namely work engagement, job satisfaction, organizational commitment, and work effort. These were distributed among the employees.

The questionnaires to assess the competency requirements were based on job descriptions by the German Federal Employment Agency (https://www.berufenet.arbeitsagentur.de), the Fleishman Job Analysis Survey (Fleishman & Reilly, 1992; German version by Kleinmann et al., 2010), and expert judgements. For the employee reactions, we used items from established questionnaires (e.g., Oldenburg Burnout Inventory to assess work engagement; Demerouti et al., 2010; Reis et al., 2015).

A regression analysis showed that the relationship between a division's digitalization level and competency requirements for employees was moderated by the occupational context (regression weight of the interaction: $b = 0.29$, 95% CI [0.13, 0.44], occupational context was effect-coded with production = 1 and warehouse logistics = –1), specifically there was a positive relationship in production divisions and a negative relationship in warehouse logistics divisions. Furthermore, we found for both occupations significant positive correlations between competency requirements and all outcomes ($r = .18$–$.27$) except job satisfaction (which was positive but nonsignificant, $r = .12$). As a last step, we investigated a model that included digitalization level, competency requirements, occupational context, and employee reactions using regression analyses. The results confirmed our assumption that the digitalization level of a division had an indirect effect on employee reactions, mediated by competency requirements, which was moderated by the occupational context for all outcomes, except job satisfaction.

The study contributes to sociotechnical systems theory by offering an explanation why technologies affect employees: A great degree of technology use (here: digitalization level) is associated with greater competency requirements, which in turn may affect employees' well-being, attitudes, and behavior. Additionally, the study was able to show that the effects of a technology differ depending on the extent of cognitive compared to manual nonroutine tasks in a job. Lastly, the instrument that was developed to assess the digitalization level in this

study brings the benefit that it is based on general digitalization principles so that its use is not restricted to specific jobs.

Study 2 – More Hype Than Substance? A Meta-Analysis on Job and Task Rotation

Results from Study 1 showed that the digitalization of the workplace was associated with either a decrease or an increase in competency requirements, and we proposed that job and task rotation could be suitable work design methods for both cases. Hence, the aim of Study 2 was to investigate whether rotation in fact has beneficial effects. Although this might be expected based on theoretical considerations and suggestions in practitioner literature, there are also some empirical studies that found negative effects. The focus was on relationships between job and task rotation and several attitudinal, learning and development, psychological health, physical health, and organizational performance outcomes. In addition, we investigated the concrete design of the rotation (i.e., job rotation vs. task rotation) and the collectivism values of the primary studies' culture as potential moderators. We meta-analytically integrated research on these relationships using a three-level meta-analysis on 56 studies with 253 effect sizes and 284,086 participants. A three-level meta-analysis has the advantage that it accounts for dependencies of effect sizes and therefore allows the inclusion of multiple effect sizes from the same primary study (Cheung, 2015; Van den Noortgate et al., 2013).

The meta-analytic results showed that rotation was significantly associated with job satisfaction (r = .27, 95% CI [.17, .37]), organizational commitment (r = .16, CI [.03, .29]), career success (r = .31, CI [.11, .51]), labor flexibility (r = .32, CI [.10, .55]), general psychological health (r = .20, CI [.05, .36]), stress/burnout (r = −.13, CI [–.24, –.02]), individual performance (r = .13, CI [.02, .24]), and productivity (r = .13, CI [.03, .24]). These correlations exceeded in magnitude between 27–75 % of effect sizes reported in the human resources and organizational behavior literatures (Paterson et al., 2016). As previous narrative reviews of the relationship between rotation and physical health had reported weak positive or

inconsistent results, we had not assumed a general positive or negative relationship. Instead, we expected that the relationship would be moderated by the work intensity of the reference group. We indeed found that when the reference group performed high-intensity work, job rotation was beneficial because there were negative relationships between rotation and musculoskeletal complaints ($r = -.38$, CI [–.63, –.13]) and physical workload ($r = -.32$, CI [–.56, –.08]). When the reference group performed low-intensity work, these relationships were positive, but smaller and nonsignificant.

Moderated meta-analyses that compared job rotation and task rotation revealed that job rotation had stronger relationships with employee development, psychological health, and organizational performance outcomes, whereas task rotation yielded stronger relationships with attitudinal outcomes. However, none of these differences were statistically significant. Further analyses showed that the relationship between task rotation and employee attitudes was significantly stronger in societies with greater collectivism values. Contrary to our expectations, the relationship between job rotation and employee attitudes was not significantly stronger in societies with greater individualism values. Lastly, the correlations between rotation and organizational performance as well as physical health were only significant for subjective outcome measures.

The meta-analysis advances job rotation and task rotation research in that it showed that many expectations toward their effects cannot be empirically supported. As most studies did not provide any details on the rotation (e.g., frequency of rotations, similarity of tasks within a rotation), it is possible that the design of the rotation weakened some of the relationships (e.g., due to too frequent task changes or very similar tasks). The results further indicate that the methods job rotation and task rotation differ in their impact on employees. This knowledge is extremely relevant for the interpretation of such studies and for a more coherent use of terminology in the future, as some previous studies used the terms *job rotation* and *task rotation* interchangeably.

Study 3 – New Work Situations Call for Familiar Work Design Methods: Effects and Mediating Mechanisms of Task Rotation in a Technology-Supported Workplace

Although the meta-analysis in Study 2 found mostly small relationships between rotation and beneficial outcomes, there were two reasons to further investigate rotation. First, only very few existing studies are experimental. Yet, the controlled setting of experiments allows more valid conclusions and might therefore provide other results than cross-sectional and correlational studies. Second, the digitalization of workplaces introduces a new work context, which might alter rotation effects, because technologies like digital assistance systems support employees in their changing work tasks. Consequently, the aim of Study 3 was to investigate whether task rotation could be an effective technology feature of digital assistance systems, of which individuals expect that it could affect their attitudes, behavior, and well-being. Additionally, we investigated underlying mechanisms and boundary conditions. The focus in this study was on task rotation because, as stated above, digital assistance systems probably are more helpful in these jobs than in jobs with job rotation. We expected that the three work characteristics task variety, skill variety, and task identity functioned as parallel mediators, and the satisfaction of the need for competence as a serial mediator. Furthermore, we examined whether individuals with greater openness to experience benefitted more from the perceived task variety and skill variety provided by task rotation. To address these questions, we conducted two consecutive experimental vignette studies. The first study investigated the main effects of task rotation on anticipated employee attitudes (job satisfaction, intrinsic work motivation), behavior (subjective performance), and well-being (positive and negative affect) as well as the mediators in a hypothetical technology-supported workplace. The second study served the purpose of replicating the first study, and thus substantiating its findings, and additionally investigating the moderator openness to experience. Both studies had a between-subjects design. The vignette described a workplace where the employee worked with a digital assistance system that illustrated work steps and

either determined a rotation between four tasks (experimental condition) or indicated an appropriate time for a morning or lunch break (control condition). The participants (N_1 = 135, N_2 = 159 employees from various occupations) were asked to imagine working at the respective workplace and responding to the subsequent questions from this perspective. These questions first covered the expected mediators and then the anticipated outcomes. Participants in the replication study also answered questions regarding their openness to experience before they saw the vignette.

Regression analyses showed that task rotation had a significant, positive main effect on anticipated job satisfaction (b = 0.61 in Study 1, b = 0.49 in Study 2) and positive affect (b = 0.30 in Study 1, b = 0.25 in Study 2) in both studies, as well as on anticipated intrinsic motivation (b = 0.79 in Study 1) and performance (b = 0.73 in Study 2) in one of the studies. Furthermore, there were significant indirect effects of task rotation, mediated by the parallel mediators perceived task variety, skill variety, and task identity, and the serial mediator expected satisfaction of the need for competence, on anticipated job satisfaction, performance, and positive affect in both studies, as well as on anticipated intrinsic motivation in one of the studies. A comparison of the indirect effects showed that most significant effects involved skill variety or task identity, partly together with the satisfaction of the need for competence. Lastly, the moderation analyses revealed that there was no significant interaction effect between task and skill variety and the participants' openness to experience when predicting the anticipated employee reactions. The incremental variance explained by the interaction term was only small (ΔR^2 between .002 and .01).

The studies make substantial contributions to the existing knowledge about task rotation and technology design. The results provide support for our assumption that task rotation could be an adequate method in the context of digitalized workplaces because we found consistent effects of task rotation as a technology feature on job satisfaction and positive affect. Additionally, the investigation of mediating mechanisms provides a theoretical

basis for task rotation that was so far approached only from a mostly practical perspective. The fact that we could not find a moderating effect of the participants' openness to experience could be due to too little variance in openness to experience to detect an effect, which is also in line with McCrae and Costa's (1997) statement that most people are intermediate in openness.

General Discussion

The aims of the present work were to investigate effects of digitalization as well as job and task rotation and determine whether the adoption of rotation could be an appropriate method to enhance digitalized jobs. These aims were addressed in three studies using a variety of research methods.

In Study 1, which was a field study, we found that the digitalization level of a division was associated with the competencies required from employees, which were in turn related to employee reactions, such as work engagement or organizational commitment. An essential insight gained from Study 1 was that the direction of the association between digitalization level and competency requirements depended on the extent of cognitive versus manual nonroutine tasks. More specifically, we found that in production jobs, which include mainly nonroutine cognitive tasks, a great digitalization level was positively associated with competency requirements. In warehouse logistics jobs, which include mainly nonroutine manual tasks, a great digitalization level was negatively associated with competency requirements. These results support the hypothesis of routine-biased technological change (Autor et al., 2003) and indicate that digitalization does not have universal effects on employees. Instead, employees either require more advanced competencies, or their jobs become less demanding, which can negatively affect their organizational commitment, work engagement, and work effort. The development of competencies as well as the handling of a job that has become unfulfilling, are challenges that might be addressed with the help of work design.

To investigate whether the classic work design methods job rotation and task rotation could be adequate means to address these challenges, we conducted a meta-analysis on job rotation and task rotation in Study 2. The results indicated that rotation was indeed positively associated with beneficial outcomes, such as greater job satisfaction and organizational commitment, more labor flexibility, less stress and burnout, and increased productivity. Many expected effects were, however, small and nonsignificant. Additional analyses revealed that job rotation and task rotation, although sometimes used interchangeably, need to be distinguished because the correlations with their outcomes differed in strength. Task rotation was more strongly associated with employee attitudes, whereas job rotation had stronger relationships with learning and development, psychological health, and organizational performance outcomes. It is important to note that the vast majority of primary studies included in the meta-analysis were correlational studies and therefore do not allow causal inferences.

To fill this methodological research gap—and to address further theoretical and practical open questions on task rotation—we conducted a vignette-based experiment in Study 3. In the experiment, we described a workplace in which a digital assistance system supported the worker in conducting their work tasks. In the rotation condition, the assistance system also indicated when it was time to rotate among work tasks. In the control condition, participants imagined performing one task throughout the whole workday. The results showed that task rotation had significant effects on several anticipated employee reactions (e.g., job satisfaction). In addition, we found that perceived task variety, skill variety, task identity, and the expected satisfaction of the need for competence explained these effects, and that there were no differences in effects due to the participants' openness to experience. The fact that the most prominent mediators were skill variety and task identity could explain why the average effects in the meta-analysis in Study 2 were mostly small: Maybe the rotations in the investigated primary studies only provided task variety, which is the most obvious

characteristic of rotation, and did not consider the use of diverse skills or the creation of a holistic job.

Theoretical Implications

A first theoretical implication, which results from all three studies, is the importance of context-sensitive research. Context refers to situational or environmental opportunities or constraints that can either affect work design features or interact with these features as well as with individual variables to affect outcomes (Johns, 2006, 2018; Morgeson et al., 2010). In his much-cited essay, Johns (2006) depicted that research in organizational behavior lacked a consideration of the context in which a study was conducted. He argued that context could cause study-to-study variations, and that its consideration is therefore necessary to correctly interpret study findings and to derive more fitting applications of research. All studies support this notion: Study 1 showed that relationships between digitalization and employees were not universal but depended on the extent of cognitive and manual nonroutine work tasks, the meta-analysis in Study 2 provided evidence that the relationship between task rotation and employee attitudes differed due to the individualism/collectivism value of a society, and Study 3 actively addressed a new work context to investigate whether evidence from previous studies could also be expected in this context of a technology-supported workplace. In sum, the consideration of context allowed a more detailed insight into the studied topics, which will also be acknowledged in the following theoretical and practical implications. The next section will focus first on the implications in the field of digitalization and subsequently on those in the field of work design.

On the topic of digitalization, the present work has three theoretical implications. First, by comparing two occupations with differing foci of work tasks (nonroutine cognitive or nonroutine manual) in Study 1, we were able to show that the current digitalization is a routine-biased technological change (Autor et al., 2003). Consequently, researchers who investigate relevant competencies for future workplaces should be aware that there can be

great differences between jobs that include mainly nonroutine cognitive tasks and jobs with mainly nonroutine manual tasks. A good example is provided by Oberländer et al. (2020), who conducted a review on digital competencies and restricted their analyses and recommendations to white collar workers. A universal shift toward greater competency requirements across occupations, as assumed by the hypothesis of skill-biased technological change, could not be supported by our results because there was no main effect of digitalization on competency requirements.

Second, we advance sociotechnical systems theory (Davis et al., 2014; Trist & Bamforth, 1951) by providing an explanation as to why the technical system in an organization affects the social system: Study 1 showed that the relationship between a division's digitalization level (the technical system) and several employee reactions (the social system) could be explained by the degree of competency requirements in the respective division. Knowing about this underlying mechanism, combined with the knowledge about routine-biased technological change, might help interpreting contradictory results from previous studies regarding the effects of technologies on employee reactions like stress (e.g., Eijckelhof et al., 2014; Ter Hoeven et al., 2016). Furthermore, we had derived our assumption by combining theories from two disciplines: the hypothesis of a routine-biased technological change from economics (Autor et al., 2003) and self-determination theory from psychology (Deci & Ryan, 2000). The confirmation of our assumption, and the fact that digitalized technologies are believed to have a more extensive impact on an organization than previous technologies (Legner et al., 2017; Parker & Grote, 2020), illustrate that research on digitalization should be an interdisciplinary endeavor.

Third, in order to be able to investigate digitalization, we developed an instrument, which consists of an interview guideline, and was complemented with a workplace observation. Up to this point, there was no method to assess a division's digitalization level. Our instrument had good interrater reliability and the questions are universal enough that the

instrument can be used in a variety of industries. With the help of the instrument, researchers can now investigate other correlates of digitalization. As an example, it might be interesting to compare workplaces with varying digitalization levels in terms of their work characteristics, such as autonomy or task feedback.

Besides digitalization, the present work also has important theoretical implications regarding job and task rotation. The meta-analysis in Study 2 was a first step toward identifying theoretical explanations for job rotation and task rotation effects. In previous empirical studies on job or task rotation, researchers had rarely derived their assumptions from specific theories but had used previous evidence as a justification for their hypotheses. Based on our comparison of job rotation and task rotation, the meta-analytic results give first indications on this knowledge gap, which are explained in the following.

Based on the job characteristics model (Hackman & Oldham, 1976) and the work design framework (Morgeson & Humphrey, 2006, 2008), we had assumed that rotation would be beneficial for employee attitudes because the job offered certain work characteristics, such as task variety and skill variety. These characteristics are probably more pronounced in the case of task rotation because it involves more frequent changes between different tasks than job rotation. The fact that the results indeed showed stronger correlations between task rotation and attitudes, can be interpreted as a first indicator that the job characteristics model provides an appropriate theoretical basis for the relationship between rotation and attitudes. We had further investigated these relationships in the experiment in Study 3 and the results provide additional support. Furthermore, we found evidence for the serial mediator satisfaction of the need for competence, which shows that self-determination theory could offer appropriate alternatives or additions to the mediators of the original job characteristics model. These had been criticized because there was only limited empirical evidence that they mediated the relationships between work characteristics and outcomes (Gagné & Panaccio, 2014).

Drawing on the work design growth model (Parker, 2017), we had expected that rotation facilitated learning and development because it resulted in more diverse work environments that could stimulate diverse perspectives. As job rotation usually involves rotations to other departments, the change in work environments should be more noticeable than in task rotation. Hence, we had assumed that a stronger association between job rotation and learning than between task rotation and learning would be an indicator that the work design growth model is an appropriate explanation for the relationship between rotation and learning. The results of Study 2 supported this assumption.

The integrative model of psychologically healthy workplaces of Kelloway and Day (2005) was our basis to assume that rotation could improve psychological health because it reduced stressors and demands and promoted organizational resources. Our expectation was that task rotation would provide more resources, such as variety and opportunity for skill use, and be better at reducing demands, such as an imbalanced workload, than job rotation. We found, however, that job rotation had a stronger association with psychological health. A reason could be that task rotation results in some cases in an interrupted workflow and is therefore perceived as more stressful. There is empirical evidence that workflow interruptions are related with psychological stress reactions (Fletcher et al., 2018).

With regard to physical health, the theoretical model by Westgaard and Winkel (1996) implied that task rotation should have stronger effects than job rotation because the more frequent rotations provided more opportunities for muscle recovery. There was only one primary study about the relationship between job rotation and physical health so that this assumption could not be tested. If there are more studies on this relationship in the future, it would be sensible to conduct the analysis because there could also be alternative explanations. One possibility is that rotation only affects physical health because it enhances psychological health, which then reduces stress-induced physical complaints. Several reviews found relationships between psychosocial work factors, such as stress, and physical complaints (e.g.,

Bongers et al., 2002; Linton, 2000). Yet, the fact that there are almost exclusively studies on the relationship between task rotation and physical health might also be an indication that task rotation simply is more appropriate to maintain or improve physical health.

Lastly, based on resource-based theory (Barney, 1991; Barney et al., 2011), we had expected that the association between rotation and organizational performance was due to the fact that rotation facilitated workforce flexibility and organizational learning. Again, this should be more pronounced in the case of job rotation. As the results of Study 2 supported this assumption, they are a first indication that the resource-based theory provides a suitable explanation for the relationship between rotation and organizational performance.

Practical Implications

Overall, the present work emphasizes the tight interconnection of the technical and the social system in an organization. Managers and system developers planning to implement a technology should therefore assess its influence on employees, workplaces, and work processes early during the development of a technology. The results of Study 1 give a first indication of how digitalization can affect competency requirements and subsequently employee reactions. As the study was restricted to production and warehouse logistics divisions, and there might also be other contextual influences in an organization, it is advisable to conduct an organization-specific analysis. Using an approach described by Schlicher et al. (in press), leaders can develop future scenarios for digitalized workplaces. These workplaces can then be assessed with the instrument presented in Study 1 and the required competencies and anticipated employee reactions can be determined with an employee survey. The advantage of such a scenario-based approach is that potential effects of a technology can be estimated before its implementation, as has been shown in Study 3.

With respect to the relationship between digitalization and competency requirements, the results of Study 1 revealed two possible extremes: A greater digitalization level was either associated with greater competency requirements so that employees might require training or

learning on the job, or with lower competency requirements so that the job might run the risk of becoming undemanding and monotonous. The results of Study 2 suggest that rotation could be an adequate means in both cases. To be more specific, managers aiming to facilitate learning and competency development can implement job rotation because employees likely gain a better understanding of work processes and develop more diverse perspectives from rotating between departments or work units. Managers aiming to enhance jobs that have become undemanding and monotonous can adopt task rotation because it increases the variety of activities performed in a job. The results from Study 3 give further guidance on the concrete design of task rotation: The comparison of the investigated mediators revealed that the tasks within a rotation cycle should require a diverse set of competencies and ideally make up a complete work process, and not just a great variety of tasks.

Lastly, although the adoption of job rotation and task rotation was significantly associated with a variety of positive outcomes in the meta-analysis, organizations should adjust their expectations regarding the magnitude of the effect. Most correlations were only small, and regarding physical health and organizational performance, the correlations were only significant for subjective (and not objective) outcome measures. Thus, until further experimental studies on job and task rotation have confirmed a beneficial causal effect that can be anticipated from the results in Study 3, it might be wise to combine rotation with other methods, of which the effectiveness is clearer. As an example, to improve the employees' physical health, one could introduce active rest breaks (i.e., work breaks where employees perform cognitively demanding activities). Studies have shown that these can enhance recovery from physically demanding tasks (Aleksandrov & Knyazeva, 2017; Mathiassen et al., 2014).

Strengths and Limitations

There are several strengths that characterize the present work, but also certain limitations that need to be addressed.

A major strength is the combination of job and task rotation and technology. These have not yet been combined in research and, due to the novelty of assistive technologies, probably also not in practice. There is, however, great potential in their combination. As digital assistance systems can give detailed instructions on the work tasks, organizations can reduce training efforts for these workplaces so that job and task rotation become quite affordable work design methods. Additionally, a study by Della Torre and Solari (2011) found that companies that invested in advanced technologies plus high-performance work practices, such as job and task rotation, had greater labor productivity and economic performance, compared to companies that invested in either technologies or work practices. Lastly, the use of digital assistance systems and other advanced technologies will become reality in an increasing number of workplaces (Parker & Grote, 2020). To be prepared, it is therefore advisable to investigate the concrete design features of these technologies in the workplace early in advance.

A further strength is that the investigation of digitalized workplaces is now easier because researchers can use the instrument that was developed for Study 1. The basis for the instrument was a literature review by Hermann et al. (2015), but their summarized design principles of digitalization have also been addressed by other key articles on the digitalization of work (e.g., Cascio & Montealegre, 2016; Parker & Grote, 2020). The instrument thus allows a generalized assessment of digitalization and is not restricted to specific industries.

As a last point, the methodological strengths of the present work should be noted. Study 1 combined survey data with workplace observations and structured interviews. This methodological diversity reduced common method bias (Podsakoff et al., 2003) and made the rating of the digitalization level more reliable because it was based on a combination of interview and observation. The investigation of task rotation was also approached with two methods, each compensating for the potential weakness of the other: The meta-analysis (Study 2) offered a broad picture of potential outcomes of rotation but included mostly studies

with a correlative design, the experiment in Study 3 allowed causal inferences but examined fewer outcomes, which were also hypothetical, and had a smaller sample than the meta-analysis.

Apart from these strengths, there are also some limitations. First, the digitalization level in the examined divisions in Study 1 was on average rather low. Reasons might have been that participants were solely from small and medium-sized companies, which likely have fewer resources for advanced technologies, and that the study was conducted in 2016. At that time, the debate about digitalization (or the buzzword "industry 4.0") was still quite new in Germany (e.g., acatech, 2016). As a consequence, the results cannot be generalized to companies with greater digitalization levels. Future studies should address this population because it is possible that here, even nonroutine cognitive tasks are replaced by technologies to a certain degree, which would lead to different results. This is conceivable because technologies are evolving from a mere rule-based approach, which was the basis of Autor and colleagues' (2003) hypothesis of routine-biased technological change, to a pattern-based, machine learning approach. Machine learning means that technologies are trained with existing datasets so that they become capable of detecting patterns and developing solutions in new data (e.g., Bishop, 2006).

Second, the results from the meta-analysis (Study 2) strongly depended on the primary studies on which the analysis was based. There was a relatively small number of studies for some of the analyses so that these results cannot be easily generalized. It should, however, be noted that the alternatives to meta-analysis (e.g., vote counting or narrative reviews) are even less accurate because they include subjective and sometimes untransparent decisions. In contrast to that, meta-analyses provide a quantification of the average effect so that they are already informative when they include only two studies (Valentine et al., 2010). Another aspect related to the primary studies is that the reported information in these studies determined which moderator analyses could be conducted. For instance, it would have been

interesting to compare rotations that varied with regard to the perceived similarity of tasks or jobs. It is conceivable that a greater similarity would result in weaker relationships between rotation and beneficial outcomes because the job provided less variety, more repetition, less diverse work environments, and might not offer enough opportunity for muscle recovery. To allow researchers of future integrative studies to investigate these and other moderators, researchers of primary studies should report more information on the design of the rotation as well as the specific tasks and jobs during a rotation.

Third, a limitation that concerns Study 1 and Study 3 is a potential common method bias (Podsakoff et al., 2003). In Study 1, we assessed the competency requirements and the employee reactions from the same source, which could theoretically result in an overestimation of their relationship. Yet, as recommended by Podsakoff et al. (2012), we implemented several strategies to reduce the common method bias. We used different scale types (Likert and Kunin) and a varying number of scale points so that each construct was assessed with different scale properties. Additionally, we chose different layouts for the questionnaire assessing the competency requirements and the questionnaire assessing employee reactions. One was in portrait orientation and the other in landscape orientation. Our aim was to create a psychological separation between the constructs so that the participants could not recall their previous answers when filling out the later questions (Podsakoff et al., 2003). Lastly, we aimed at reducing social desirability by attaching a blank envelope to the questionnaires, which the participants could seal before giving it to their supervisors. In Study 3, the vignette methodology did not allow the use of multiple sources, which would have been a remedy against common method bias. Conway and Lance (2010) argued that when a study is concerned with the perceptions of study participants, as is the case in vignette studies, self-report measures are appropriate.

Fourth, a common criticism of experimental research, and thus vignette studies, is their lack of external validity, which reduces the generalizability of results (Scandura & Williams,

2000). Thus, the results of Study 3 should only be interpreted in terms of prospective work design. However, the reasons in favor of a vignette study were that they allowed the investigation of unique effects of task rotation because they were not confounded by environmental factors that would have been present in a field study, and that the vignettes could describe a workplace scenario that did not yet exist in the field. This latter aspect is highly relevant in the current work context, which is affected by fast-changing technologies. To be able to adjust these technologies to the employees' needs, it is important to know about their effects while they are still being developed. Nevertheless, once advanced technologies have become more established in real work settings, it would be ideal to repeat Study 3 and examine whether the results can be replicated.

Directions for Future Research

Based on the results of the three studies, there are four aspects that deserve attention in future research. First, the results of Study 1 showed that in some occupations the adoption of advanced technologies is associated with lower competency requirements. In the long term, it would be interesting to examine whether the previously relevant knowledge, skills, and abilities might decay because they are no longer needed to accomplish everyday work activities. This assumption of not being able to retrieve once-learned information or competencies due to a reduced use stems from Bjork and Bjork's (1992, 2006) theory of disuse. Additionally, researchers should investigate whether a potential decay of competencies has any negative effects or whether it might be compensated by assistive technologies that provide so much situational support that employees do not need the competencies anymore.

Second, as described earlier, the combination of Study 2 and Study 3 provided a detailed picture of task rotation, its effects, and some mediating and moderating mechanisms. As a complement to the experimental investigation of task rotation, future research should also investigate job rotation in an experiment. The meta-analytic results imply that job

rotation might be especially beneficial to foster learning and development, psychological health, and organizational performance. As the primary studies on these outcomes were mainly correlative, an experiment could clarify whether job rotation really was the cause of these effects.

Third, a further direction for future research on rotation is the investigation of other moderators. One group of potential moderators are the three basic human needs from self-determination theory: the needs for competence, autonomy, and relatedness (Deci et al., 2017). The results from Study 3 already showed that the satisfaction of the need for competence mediated effects of task rotation. To examine whether it might also be a moderator, a study should compare rotation workplaces that require a diverse set of skills (and thus should satisfy the need for competence) with workplaces that require only one or two different skills (and thus do not properly satisfy the need for competence). The need for autonomy refers to the desire to act according to one's own volition. It is therefore conceivable that employees who have a say during the adoption of job or task rotation might react more positively. Meta-analytic results showed that in general, greater work autonomy was related to more positive attitudes, greater job performance, and reduced stress and burnout (Humphrey et al., 2007). Lastly, the need for relatedness describes the need to feel connected with others and as part of a group (Gilbert & Kelloway, 2014). Consequently, it is possible that a rotation between jobs or tasks with varying colleagues has more positive effects than a rotation in which the employees have only few possibilities to interact with others. A study by Hauptman and Hirji (1999) found, for example, that job rotation between different functions was associated with more cross-functional activities and interdepartmental communication.

An additional suggestion for further moderators is the investigation of other individual differences. The results of Study 3 did not support the assumption that individuals with greater openness to experience benefit more from work characteristics related to task rotation.

We had investigated this moderator because it is one of the Big Five, and therefore most basic, personality factors. It is, however, possible that other, more work-related, individual differences have an impact on the effect of task or job rotation on employee reactions. One possibility is a proactive personality, which refers to the extent to which individuals take personal initiative to influence their environment (Bateman & Crant, 1993). One might assume that more proactive employees can provide for their resources through their proactive behavior, whereas less proactive employees depend more strongly on the resources provided by their job. Thus, job and task rotation might be especially beneficial for these latter employees. This assumption is supported by a study by Zhang et al. (2019), who found that the relationship between high-performance work practices and thriving was positive for employees with low proactive personality, but nonsignificant for employees with high proactive personality.

Conclusion

The rapid development, sinking costs, and easier implementation of digitalized technologies result in an increasing number of workplaces that are affected by such technologies. In order to enable researchers to make suitable recommendations on these technology-supported workplaces, work design research needs to address these changes. The present work contributes to closing this knowledge gap. The results showed that, depending on the extent of nonroutine cognitive or manual work tasks, digitalization can be associated with either an increase or a decrease in competency requirements and subsequently enhanced or impaired employee reactions. This implies that the implementation of technologies cannot be a one-size-fits-all approach. The results further suggest that job rotation and task rotation could be a remedy for both outcomes, although with mostly small effects. As results from previous studies reported contradictory effects, this is an important conclusion. Lastly, by investigating task rotation as a technology feature of a digitally assisted workplace, the present work added this prospectively increasingly relevant work context to the research on

task rotation. The results showed that task rotation should also work in this context and additionally provided knowledge on explanatory mechanisms. These suggest that a rotation should not only include various tasks, but these should also require many different competencies and make up a complete work process. In conclusion, although the digitalization of work is only beginning to be acknowledged in work design research, the present work already contributes important knowledge on challenges associated with digitalization and offers starting points on how to address these challenges.

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Statement of Authorship

Hiermit erkläre ich, dass ich die vorliegende Dissertation „Work design in times of digitalization: Challenges of advanced technologies at work with job and task rotation as potential remedies“ weder in der gegenwärtigen noch in einer anderen Fassung einer anderen Fakultät vorgelegt habe oder hatte.

Ich versichere, dass ich die Dissertation selbstständig und ohne unerlaubte Hilfe angefertigt sowie unter ausschließlicher Verwendung der von mir angegebenen Quellen verfasst und wörtlich oder sinngemäß aus der Literatur entnommene Textstellen kenntlich gemacht habe.

Ferner bestätige ich, dass ich den federführenden Beitrag zu den unter gemeinschaftlicher Autorenschaft entstandenen Manuskripten geleistet habe.

Hamm im März 2021

Overview of Submitted and Published Work

Study 1

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Not Everyone Benefits from Technological Advancements: Associations with Competency Requirements and Employee Reactions in Two Occupations

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Declaration of interest

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Abstract

Recent technological developments allow an increasing automation and digitalization of work processes. The aim of this study was to analyze the relationship between digitalization, competency requirements, and employee reactions (work engagement, job satisfaction, organizational commitment, and work effort) in two occupational contexts. Data were collected from 127 employees within 19 German companies using a multi-methodological approach. Our results confirmed an indirect effect of digitalization level via competency requirements on most employee reactions, moderated by the occupational context. The results advance our understanding of the association between technology and employees, and thus give guidance for future interdisciplinary research in this field.

Keywords: digitalization; technology; sociotechnical system; competency requirement; employee reaction

1. Introduction

Current technological advancements allow companies to integrate a wide range of intelligent systems (e.g., collaborative robots, technological assistance systems) that can collect and process information about their environment via sensors, and thus react in real time to problems, as well as individual customer requests (Hermann et al., 2015). Implementing such technologies is necessary for a company to stay competitive (Lee et al., 2015), which means that the number of technologies at the workplace is likely to increase further. In the present study, we investigated this digitalization of the workplace and examined how it affected the employees working with the technologies. More specifically, we focused on associations with competency requirements and employee reactions, such as work engagement and job satisfaction, and compared two occupations that differed with regard to the routinization of job tasks.

According to the sociotechnical systems approach, changes in technologies affect employees and the work organization (Davis et al., 2014; Trist & Bamforth, 1951). Although principles of sociotechnical systems emphasize this interdependence of social and technical systems (e.g., Cherns, 1987; Clegg, 2000), there are no theoretical explanations as to how and why they are associated. Yet, knowledge about the underlying mechanisms could help explain contradictory effects of technologies on employees in previous studies (e.g., Morris & Venkatesh, 2010; Ter Hoeven et al., 2016). In an attempt to reify the mechanisms that underlie the sociotechnical systems approach, we combine theories from the fields of economics and psychology and introduce the sociotechnical systems model of employee reactions. In the first part of our theoretical explanations, after depicting the research field of digitalization in the workplace, we draw on the hypothesis of routine-biased technological change (Autor et al., 2003) to explain how technologies at the workplace affect competency requirements. *Competency requirements* serves as an umbrella term for knowledge, skills, abilities, and other characteristics needed to successfully perform a job. In the second part of the study, we draw on self-determination theory (Deci & Ryan, 2000) to establish that a change in competency requirements is also associated with changes in well-being, attitudes, and behavior. As Parker and Grote (2020) frame it: “if technology deskills work, it is likely to reduce motivation-related and learning-related outcomes.” As a result, we present the sociotechnical systems model of employee reactions that shows the extent to which the digitalization of the workplace affects the employees.

Our study makes several important contributions. First, by combining the hypothesis of routine-biased technological change and self-determination theory into the new sociotechnical systems model of employee reactions, we provide clarification as to how and why technologies

affect employees. This knowledge is valuable for future researchers investigating sociotechnical systems. Second, the study explains how the digitalization of the workplace is associated with a change in competency requirements, and the extent to which these changes are related to the employees' well-being, attitudes, and behavior. Knowledge about changing competency requirements is of practical value as it can be used to revise human resources management strategies, for example by attracting job applicants with specific abilities or offering training. Knowledge about positive employee reactions (e.g., work engagement) is relevant because they are associated with, for example, higher productivity (Judge et al., 2001). Third, by investigating these relationships in two occupational contexts, namely in production divisions and in warehouse logistics divisions, we were able to examine conditions for positive versus negative effects of digitalization. Morgeson et al. (2010) pointed out that the occupational context can influence the relationships between work design characteristics, such as the use of technology, and various outcomes. Thus, we respond to the need for more context-sensitive research, as demanded, for example, by Johns (2006).

2. Digitalization of the Workplace

Computer-controlled technology has gained significance in the work environment since the 1980s (Kemp & Clegg, 1987). In the beginning, there were advanced manufacturing technologies that are defined as "a variety of technologies that utilize computers to control, track, or monitor manufacturing activities, either directly or indirectly" (Boyer et al., 1996, pp. 298–299). Prominent examples are computer aided design (CAD) and manufacturing (CAM). In recent years, the technological advancements have allowed the interconnectivity of technological systems that collect data via sensors, analyze them in real time, and are able to make autonomous decisions (Cascio & Montealegre, 2016). This technological development can be seen as a continuation of the automation technologies of the 1980s, and is termed, for example, the *fourth industrial revolution* (e.g., Schwab, 2016) or *digitalization* (e.g., Ras et al., 2017). In the present study, we use the term digitalization because it describes the investigated technologies most fittingly. The unique characteristics of digitalization, as opposed to previous advanced manufacturing technologies, are that current technologies allow all physical processes to be represented in a virtual way, that they facilitate the tracking and monitoring of work processes, and that they become increasingly "intelligent," which enables them to act autonomously (Cascio & Montealegre, 2016).

In a literature review aimed at identifying the key criteria of highly digitalized organizations, Hermann et al. (2015) identified six design principles: interoperability, virtualization, real-time capability, decentralization, customizability, and modularity.

Interoperability refers to technological systems being able to communicate autonomously with each other and initiating work steps depending on each other. Virtualization describes the creation of a virtual copy of the physical world using sensors. Technological systems are then capable of monitoring statuses and processes. Real-time capability refers to the constant tracking and analysis of work steps. Decentralization describes the transition from central control to each technological system being equipped with a computer, and making their own decisions. Customizability refers to customers being able to communicate product specifications via the Internet that are passed on to the technological systems using, for example, radio-frequency-identification tags. Lastly, modularity means that technological systems can be adapted flexibly according to changed needs, for example, when product characteristics change.

Although summarized by Hermann et al. (2015), these design principles have also been addressed by various other authors. For example, in their review on technology at the workplace, Cascio and Montealegre (2016) described the virtualization of information that allowed the physical world to be directly linked to the electronic space. The goal should be that people, computers, networks, and objects are connected with each other. This could be realized with sensors. As another key aspect, they mentioned ubiquitous computing, which refers to the constant availability and processing of data and information. In a more recent article on work design in the digital world, Parker and Grote (2020) referred to artificial intelligence and machine learning as core technologies of digitalization. Their capability of self-directed learning allows a shift of decision-making from employees to technologies. Other technologies that have been used in the work context in the past few years include collaborative robots (Steil & Maier, 2017) and augmented and virtual reality (Farshid et al., 2018).

The implementation of digital technologies is supposed to enable companies to manufacture goods at a lower price as all steps in the process can be perfectly aligned. Therefore, according to Lee et al. (2015), companies need to implement such technologies in order to stay competitive. Accordingly, there is an increasing number of companies deciding to implement information and communication technologies (ICTs; United States Census Bureau, 2015), which raises the question of whether this new technological work context might have an impact on other aspects of the work environment, more specifically, the employees.

The belief that technical aspects (i.e., technologies, methods of working) and social aspects (i.e., employees, teams) of the workplace are interdependent, is a central tenet of the sociotechnical systems approach (Trist & Bamforth, 1951). Accordingly, Clegg (2000) pointed out in his sociotechnical principles that during the process of designing a technology, one should also consider how competency requirements change, and how employees will react to the

change. A central goal is to enhance performance, which includes, besides productivity, improved well-being and attitudes of employees.

3. Digitalization and Competency Requirements

In order to explain how technology use was associated with competency requirements, earlier studies tested the hypothesis of a *skill-biased technological change* (e.g., Berman et al., 1998). This hypothesis states that the introduction of ICTs causes a general shift toward more high-skilled jobs and fewer low-skilled jobs (Bresnahan et al., 2002). It is argued that a rise in competency requirements across occupations is caused by a greater need for skilled employees who operate and maintain the technology, and analyze the produced information, whereas tasks formerly performed by less-skilled employees are automated (Bresnahan et al., 2002; Fernandez, 2001). In addition, there is a change in competency requirements within jobs because employees need specific skills to operate software and equipment correctly, new job tasks are more abstract and conceptual, and the organizational structure changes and requires employees to perform more decision-making and problem-solving tasks (Kim, 2002).

Despite supportive evidence (e.g., Bresnahan et al., 2002; Gale et al., 2002; Kim, 2002), some authors have noted that there was a phenomenon that skill-biased technological change was not able to explain: Among others, Goos and Manning (2007) and Autor et al. (2006) described a “polarization” of jobs that they had found in their studies on the British and U.S. labor market, respectively. The term polarization refers to an increase in high-skilled and low-skilled jobs, and a decline in middle-skilled jobs. Therefore, Autor et al. (2003) presented a more nuanced approach to explain why competency requirements might change due to the adoption of technology. The perspective of *routine-biased technological change* asserts that the impact of technologies on jobs is dependent on the proportion of routine tasks in that job. Routine tasks are defined as tasks that could be performed by a technological system following explicit rules and algorithms. If rules cannot be determined because a task involves the application of new knowledge or problem-solving techniques, it is a nonroutine task. This distinction between routine and nonroutine tasks also constitutes the methodological base of Frey and Osborne’s (2017) much-noticed study on the computerizability of jobs. In the task model of Autor et al. (2003), the authors further distinguish between manual tasks and cognitive tasks. They assume that a technology is more likely to replace routine cognitive and routine manual tasks, which require low to medium skills, such as calculation or picking. High-skilled, nonroutine cognitive tasks, such as diagnosing problems, are expected to be complemented by technologies. According to their argumentation, there is only limited potential for technology to substitute or

complement nonroutine manual tasks, which require only low skills, such as unpacking differently shaped items.

Analyses by Autor et al. (2003) and Autor et al. (2006) found support for a routine-biased technological change. They investigated employment growth across different occupations in the timespan from 1980 to 2000. They observed a rapid employment growth in the 1990s for occupations with a high share of nonroutine cognitive tasks, a decline in employment growth for occupations with mainly routine cognitive or manual tasks, and a ceasing decline for jobs with a large share of nonroutine manual tasks. The authors identified the massive decline in the price of computing power in the 1990s as the cause of these developments. Furthermore, Spitz (2004) found evidence that technologies replaced routine manual and cognitive tasks, and complemented nonroutine cognitive tasks. In addition, Dauth et al. (2017) found initial evidence that nonroutine manual tasks might also be complemented by technology. They analyzed the impact of industrial robots on job tasks and found that workers who were exposed to robots would usually remain in their jobs, partly doing different tasks than before the robot implementation. In conclusion, although there is evidence for both, the skill-biased and the routine-biased technological change, the hypothesis of a routine-biased technological change seems more fitting, especially in the light of the polarization of jobs.

4. The Occupational Context as a Moderating Factor

In the present study, one aim was to investigate whether current technological developments would also lead to a routine-biased technological change, or if the alternative of a skill-biased technological change could be observed. To this end, the focus was on jobs in production and warehouse logistics divisions, two main blue-collar divisions in the manufacturing industry. The increasing digitalization has different effects on these occupations. A greater digitalization level in production divisions allows a greater variance of the work process, for example, more complex products, smaller batch sizes, and the achievement of higher-quality standards (Byrne et al., 2016). In the warehouse context, the effects of digitalization are mainly driven by an increasing availability of sensors and data, which interconnected systems use to autonomously control the flow of items in the warehouse (Ollesch et al., 2018; Tsai & Tang, 2012).

Tasks in the production division include, for example, the processing of raw materials, the setting up, operation, and monitoring of production facilities, and the execution of repair and maintenance work (see O*NET Standard Occupational Classification codes 51-9198.00, helpers – production workers, 17-3029.09, manufacturing production technicians, and 49-9041.00, industrial machinery mechanics; https://www.onetonline.org/). In warehouse logistics divisions,

tasks include the acceptance, control, and storage of goods, as well as the picking and dispatching of products (see O*NET Standard Occupational Classification codes 43-5071.00, shipping, receiving, and traffic clerks, and 43-5081.03, stock clerks – stockroom, warehouse, or storage yard). Both occupations require the execution of routine tasks (e.g., starting machines in production jobs and preparing shipping documents in warehouse logistics jobs). Additionally, jobs in production divisions require more nonroutine cognitive tasks (e.g., quality inspections, analyzing machine error messages and repairing machinery), and jobs in warehouse logistics divisions have a greater focus on nonroutine manual tasks (e.g., unpacking items, counting and marking stock items). If the hypothesis of a routine-biased technological change was true and technologies replaced routine tasks, a great degree of digitalization should have different effects on production jobs and warehouse logistics jobs. The resulting jobs for employees in the production context should consist of mainly nonroutine cognitive tasks that have greater competency requirements, and the resulting jobs for employees in the warehouse logistics context should consist of mainly nonroutine manual tasks that have lower competency requirements. In conclusion, we assumed that the relationship between the digitalization level of a division and the competency requirements would depend on the occupational context.

> *Hypothesis 1*: The relationship between digitalization level and competency requirements is moderated by the occupational context. There is a positive relationship in occupations with mainly nonroutine cognitive tasks and a negative relationship in occupations with mainly nonroutine manual tasks.

5. Competency Requirements and Employee Reactions

As we stated earlier, one of the goals of the sociotechnical systems approach is the improvement of employee well-being and attitudes (Clegg, 2000). In this section, we draw on self-determination theory (SDT) to explain why there could be a relationship between competency requirements and such employee reactions. SDT argues that individuals experience optimal motivation and well-being when three basic, innate needs are satisfied: the need for autonomy, relatedness, and competence (Deci et al., 2017; Deci & Ryan, 2000). The need for autonomy refers to the need to act of one's own volition and according to one's personal, integrated values. The need for relatedness describes the desire to feel connected to others, to be taken care of, and to have a sense of belongingness with other individuals. The need for competence refers to an individual's wish to feel effective when interacting with the environment. It drives individuals to engage in challenging activities that allow them to use and extend their skills and abilities (Ryan & Deci, 2002).

We believe that greater competency requirements offer more opportunities to satisfy the need for competence than lower competency requirements. van den Broeck et al. (2010) found, for example, a positive relationship between skill utilization (i.e., the amount of skills and abilities that are required for and developed in the job) and a satisfied need for competence. Additionally, a recent meta-analysis found a positive significant relationship between skill variety (i.e., the range of diverse competencies used in a job) and satisfaction of the need for competence (van den Broeck et al., 2016). SDT states that when the need for competence is satisfied, employees experience greater well-being and optimal functioning, which can be reflected in affective, attitudinal, and behavioral reactions (Deci et al., 2017). Previous studies found, for example, associations between satisfaction of the need for competence and the affective reactions work engagement and job satisfaction (e.g., van den Broeck et al., 2010), as well as the attitudes organizational commitment and lower turnover intentions (Greguras & Diefendorff, 2009; van den Broeck et al., 2016), and the behaviors work effort and performance (van den Broeck et al., 2010; van den Broeck et al., 2016). Therefore, we expected a positive relationship between competency requirements and employee reactions.

To find out how extensive these reactions were, we did not only examine the most immediate (i.e., affective) reactions, but also focused on attitudes and behavior. As affective reactions, we investigated work engagement and job satisfaction. Work engagement is characterized by great levels of energy and individuals being dedicated to their work (Demerouti et al., 2010). Job satisfaction refers to the affective state that an individual experiences when the job is appraised as facilitating the achievement of their job values (Locke, 1969). As attitudinal reaction, we investigated organizational commitment, which means that an individual identifies with the organization and aims to remain a part of this organization (Mowday & Sutton, 1993). The investigated behavioral reaction was work effort, which refers to behavior that is beneficial to the organization because it is either required by the job or voluntary (de Cooman et al., 2009).

> *Hypothesis 2*: There is a positive relationship between competency requirements and (a) work engagement, (b) job satisfaction, (c) organizational commitment, and (d) work effort.

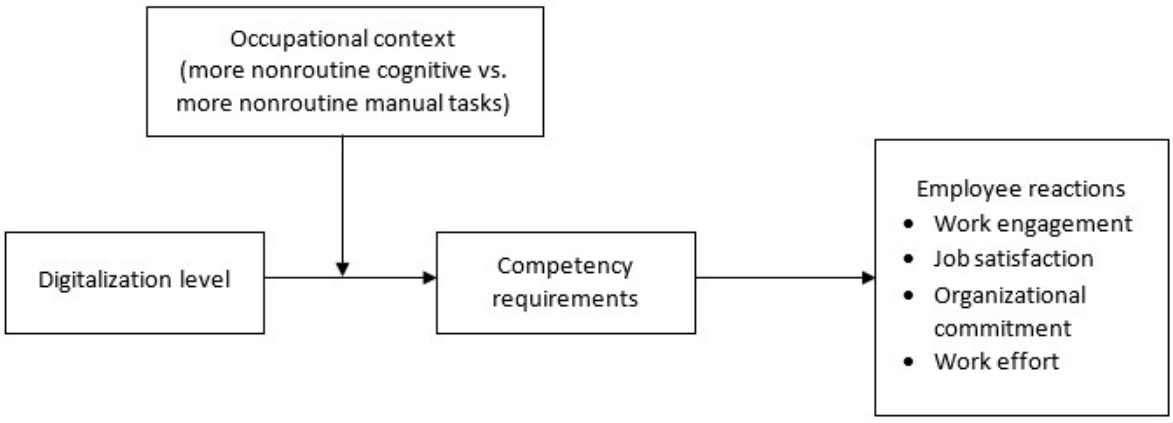
To sum up, we drew on the hypothesis of routine-biased technological change to explain how digitalization might change competency requirements, and, using theoretical considerations based on SDT, we then inferred that there would be a positive relationship between competency requirements and positive employee reactions. The combination of these arguments could explain to what extent the digitalization level of a company's division affected the employees' reactions. We assumed that there would be an indirect effect of the digitalization level on

employee reactions, which was explained by the required competencies, which in turn were dependent on the occupational context. The examination of this assumption offers a first explanation for the contradictory results in existing studies. Some studies reported a positive effect of technologies (e.g., computer-aided design, enterprise resource planning systems) on well-being outcomes, such as job satisfaction, work engagement, and lower stress (Korunka & Vitouch, 1999; Ter Hoeven et al., 2016). In contrast to that, there are also some studies that found negative effects, for example, Morris and Venkatesh (2010), who reported a decrease in job satisfaction after the introduction of an enterprise resource planning system. Another example is a study by Majchrzak and Cotton (1988), where employees had a significant decrease in organizational commitment after the change from mass production to computer-automated batch production. A conceptual model of the expected relationships of the present study is depicted in Figure 1. We assumed the following hypothesis.

> *Hypothesis 3*: There is an indirect effect of digitalization level via competency requirements on employee reactions, more specifically on (a) work engagement, (b) job satisfaction, (c) organizational commitment, and (d) work effort, which is moderated by the occupational context. Given a high digitalization level, employees from occupations with mainly nonroutine cognitive tasks have greater competency requirements and consequently more positive reactions, while employees from occupations with mainly nonroutine manual tasks have lower competency requirements and consequently less positive reactions.

Figure 1

Sociotechnical Systems Model of Employee Reactions



6. Method

6.1 Participants

The study was embedded in a project aimed at promoting small and medium-sized enterprises (SMEs). Therefore, the sample consisted of employees from companies with a maximum number of 250 employees (see European Commission, 2020). The focus on SMEs had two main advantages: First, they constitute the majority of companies in large economies, for example in the United States (99.7% with fewer than 500 employees; United States Census Bureau, 2018), as well as in the EU (99.8%; Papadopoulos et al., 2018), and in Germany (99.3%; Federal Statistical Office of Germany, 2019), and employ a large part of the working population (47.5% in the US, 66.3% in the EU, 60.8% in Germany). The results of our study are therefore highly relevant to most companies and a large amount of the working population. Second, we expected to be able to observe a wider range of digitalization levels in SMEs because we assumed that most larger companies were already high in automation and digitalization and therefore did not show enough variation (acatech, 2016; Buonanno et al., 2005; Kennedy & Hyland, 2003).

Participants were recruited by contacting various SMEs and offering a free job analysis as well as an examination of the level of digitalization in one division. Eligibility was granted when the company was an SME and when they had either a production or a warehouse logistics division. To minimize the time and effort for each company, we investigated one division per company and the contacted company representatives could decide which division should be examined. Of the 21 recruited companies, two were excluded from the analyses as they did not send back any questionnaires. The resulting 19 companies employed a mean of 139 employees (SD = 79, Min = 8, Max = 250) and were mostly in the manufacturing industry (42.11% mechanical engineering, 15.80% electronics, 10.53% metalworking, 5.26% point-of-sale logistics, furniture, logistics, chemistry, drive engineering, and food engineering, respectively).

Of the 262 distributed employee questionnaires, 132 were returned (50.38%). Two of those had to be excluded as they filled in a job title not in the scope of this study, and three were excluded as they left the majority (> 50%) of the competency requirements questionnaire blank, resulting in a final sample of N = 127 (77.17% male, 14.17% female, 8.66% missing). Eighty-two participants were from 11 companies where the production division was examined, while 45 participants were from eight companies where the warehouse logistics division was examined. The participants had a mean age of 39.29 years (SD = 12.86, Min = 17, Max = 61) and a mean tenure of 9.48 years (SD = 9.98, Min = 0.33, Max = 42.33). Most participants (57.48%) had completed basic vocational education, 11.81% had completed higher vocational education,

12.60% held a university degree, 6.30% had not (yet) completed vocational education, and 1.57% had a different vocational education (10.24% missing).

6.2 Procedure

The data were collected using three methods. A workplace observation and a structured interview, both conducted by a work psychologist, were used to determine the division's digitalization level. The observation lasted 30 minutes. Each observed employee was informed about the procedure beforehand and had given his or her consent by signing an informed consent form. The interview was carried out with the employee's direct supervisor and followed the same structure each time. Supervisors also gave their consent by signing the informed consent form. Lastly, questionnaires were used to assess the competency requirements and employee reactions. They were distributed among the employees in the examined divisions and mailed back to the authors collectively. To ensure anonymity, each questionnaire had a blank envelope enclosed that the participants could seal before they handed it to their supervisors.

6.3 Measures

6.3.1 Digitalization Level. As there was no validated instrument available that could be used to assess the digitalization level of a division, we developed a new instrument. The aim was to develop a structured interview that allowed an external assessment of a division's digitalization level using predefined criteria, irrespective of specific implemented technologies. The instrument was based on the six digitalization design principles identified in the literature review by Hermann et al. (2015): interoperability, virtualization, real-time capability, decentralization, customizability, and modularity.

For each principle, the interviewer first gives a definition and asks about the extent to which this principle is implemented in the examined division. If the interviewee does not fully understand the definition, the guidelines offer two or three optional questions that clarify the meaning of the principle. Based on the answers as well as a workplace observation, the interviewer rates each digitalization principle on a scale from 1 (*low*) to 5 (*high*), with each point on the scale having its own anchor. Additionally, each scale is described in terms of the role of the employee to facilitate the rating decision. The complete interview guidelines and rating scales can be found in the online supplementary material. In our study, the interviews, observations, and subsequent assessment of the digitalization level were conducted by the first author, a work psychologist.

To estimate the quality of the instrument, we calculated the inter-rater reliability. To this end, five work psychologists rated the digitalization level of 11 divisions that were not part of the present study. The intraclass correlation coefficient (ICC) was ICC(1,1) = .75, $F(62,63)$ =

7.15, 95% CI [.63, .84], $p < .001$, which can be interpreted as good (cf. Tannenbaum & Wesley, 1993). As the principles of customizability and modularity could not be observed in the warehouse logistics division, further analyses were conducted using only the remaining four criteria (interoperability, virtualization, real-time capability, decentralization) for both divisions. The inter-rater reliability for these four criteria was ICC(1,1) = .76, $F(43,44) = 7.37$, CI [.60, .86], $p < .001$ in the pretest. The value for the digitalization level was obtained by computing the mean of these criteria (Cronbach's alpha = .74).

6.3.2 Competency Requirements. The competency requirements in the examined divisions were assessed by self-ratings from the employees using a questionnaire. We performed the following four steps to develop one questionnaire each for production employees and warehouse logistics employees: First, we studied job descriptions for jobs in production (e.g., industrial machinery mechanic) and warehouse logistics (e.g., stock clerk) divisions using the job information website provided by the German Federal Employment Agency (https://www.berufenet.arbeitsagentur.de). Second, we extracted competency requirements and, third, reviewed them with one job expert each from both occupational groups. For both occupational groups, we added competency requirements that might gain in importance due to digitalization (ICT skills, problem-solving skills, flexibility, contextual knowledge, self-management, social skills, and creativity) that we collected doing a literature research. We omitted competency requirements that were only physical and therefore irrelevant based on our assumption of routine-biased technological change (e.g., hearing capacity, eyesight). This resulted in a list of 17 competency requirements for production employees and 14 competency requirements for warehouse logistics employees. Fourth, using again the job descriptions from step one as well as definitions from a validated job analysis instrument, the Fleishman Job Analysis Survey (Fleishman & Reilly, 1992, German version by Kleinmann et al., 2010), we built a scale with one to five items for each competency requirement. One example is "the understanding of technological procedures" as an item for the scale technical skills.

Employees rated the importance of each item for their job using a six-point scale ranging from 1 (*does not apply*) to 6 (*exceedingly important*). Scales with an internal consistency (Cronbach's alpha) below .70 were excluded from further analyses, which resulted in a set of 13 competency requirements for the production employees and 11 competency requirements for the warehouse logistics employees (see online supplementary material for included competency requirements, number of items, internal consistencies, and correlations between competency requirements and digitalization level). For our analyses, we were not interested in the specific competency requirements. Instead, we wanted to find out if the overall importance of

competency requirements was affected by an interaction between digitalization and occupation. Therefore, to obtain a single value for competency requirements, we computed the mean of the 13 and 11 competency requirements for production and warehouse logistics employees, respectively.

In order to keep the survey as short as possible and therefore increase the likelihood of complete data sets, we decided to shorten the employee reactions measures. In the case of job satisfaction, there is meta-analytical evidence that single-item assessments correlate highly with scale measures (Wanous et al., 1997). In the other cases, we chose the items with the highest loadings, which means that they represent the underlying construct best. This approach has already been adopted several times (e.g., Parker, 2003; Perko et al., 2016).

6.3.3 Work Engagement. We used four items from the Oldenburg Burnout Inventory (Demerouti et al., 2010, German version by Reis et al., 2015) to measure the participants' work engagement. The inventory consists of two subscales, *exhaustion* and *disengagement*, and we chose the two items with the highest loadings from each subscale. An example item is "I always find new and interesting aspects in my work" ($\alpha = 0.70$). Participants rated their agreement on a scale from 1 (*strongly disagree*) to 4 (*strongly agree*).

6.3.4 Job Satisfaction. We measured the overall job satisfaction with a single-item measure by Neuberger and Allerbeck (1978): "When you think of everything that is important for your work (e.g., the work itself, working conditions, colleagues, working hours), how is your overall satisfaction with your work?" Participants rated their job satisfaction on a seven-point Kunin scale (Kunin, 1955).

6.3.5 Organizational Commitment. We used the three items with the highest loadings from the Organizational Commitment Questionnaire (Mowday et al., 1979, German version by Maier & Woschée, 2002) to assess the participants' organizational commitment. An example item is "I am proud to tell others that I am part of this organization" (Cronbach's alpha = 0.89). Participants rated the items on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*).

6.3.6 Work Effort. To assess the participants' work effort, we used one item from the Work Effort Scale (de Cooman et al., 2009). We chose the item with the highest loading on the *intensity* subscale ("I put a lot of energy into the tasks that I commence") and translated it into German. Ratings could range from 1 (*strongly disagree*) to 7 (*strongly agree*).

7. Results

Table 1 displays the descriptive statistics for the main study variables. It can be noted that the mean digitalization level is smaller in the production context.

Table 1

Means, Standard Deviations, and Intercorrelations Among Study Variables as a Function of the Occupational Context

Variable	1	2	3	4	5	6	*M*	*SD*
1. Digitalization level	–	-.37*	-.29	.24	.32*	.27	2.97	0.95
2. Competency requirements	.28*	–	.22	-.07	.05	-.03	4.39	0.74
3. Work engagement	-.06	.16	–	.51***	.21	-.08	2.42	0.57
4. Job satisfaction	.11	.20	.60***	–	.53***	.13	5.18	1.05
5. Organizational commitment	.18	.39***	.40***	.52***	–	.11	3.74	0.95
6. Work effort	.17	.40***	.31**	.35**	.51***	–	6.21	0.93
M	1.66	4.39	2.72	5.09	3.53	6.11	–	–
SD	0.71	0.72	0.49	1.32	1.05	1.12	–	–

Note. Intercorrelations for the warehouse logistics area (n = 45) are presented above the diagonal, intercorrelations for the production area (n = 82) are presented below the diagonal. Means and standard deviations for the warehouse logistics area are in the vertical columns, means and standard deviations for the production area are in the horizontal rows.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

7.1 Preliminary Analyses

7.1.1 Missing Data. We conducted Little's MCAR test (Little, 1988) to investigate if the missing data in our sample were missing completely at random. The test was not significant for the production workers subsample, $\chi^2 = 892.01$ ($df = 887$; $p = .45$), the warehouse logistics workers subsample, $\chi^2 = 297.17$ ($df = 358$; $p = .99$), or the whole sample regarding outcomes, $\chi^2 = 586.47$ ($df = 639$; $p = .93$), which indicates that the data were missing completely at random. Missing data were imputed using the expectation maximization algorithm with 40 iterations (Dempster et al., 1977). All analyses were repeated using the incomplete data set and yielded comparable results.

7.1.2 Hierarchical Data. The gathered data were hierarchical with Level 1 being the employee estimates of competency requirements and employee reactions, and Level 2 being the digitalization level ratings of divisions. Therefore, we needed to consider a multilevel analysis. However, as the predictor (i.e., the digitalization level rating) was a Level 2 variable, we would only have been able to perform between-division analyses and not within-division analyses,

which would have substantially decreased the power of the analyses (N = 19 divisions, compared to N = 127 respondents). In addition, following the recommendations and using the R code by Aguinis et al. (2013), we calculated the ICC, meaning the proportion of variance in the competency requirements and outcomes accounted for by differences between divisions. The ICC can reach any value between zero and one, with values bigger than zero hinting at a Level 2 variable causing heterogeneity across divisions. According to a review of multilevel studies from the *Journal of Applied Psychology* by Mathieu et al. (2012), ICCs usually range from .15 to .30. In our study, the ICC was below this range for the mediator competency requirements and most outcomes (.00–.12), except for organizational commitment, which had an ICC of .18. To conform to the principle of parsimony, further analyses were multiple regression analyses without specifically considering the multilevel structure of the data (Aguinis et al., 2013).

7.2 Hypothesis Testing

In Hypothesis 1, we predicted that the relationship between a division's digitalization level and competency requirements for employees was moderated by the occupational context, specifically that there was a positive relationship in production divisions and a negative relationship in warehouse logistics divisions. We conducted a regression analysis using the PROCESS macro for SPSS by Hayes (2018). Digitalization was the predictor and was mean centered, the occupational context was the dichotomous moderator and was effect-coded prior to analysis (production = 1, warehouse logistics = -1), and competency requirements were the outcome variable. The results are displayed in Table 2. The interaction effect of digitalization level and occupational context in predicting competency requirements was significant, thereby providing support for Hypothesis 1, $F(3, 123) = 4.55$, $R^2 = .10$, $MSE = 0.49$, $p = .00$. Figure 2 shows a visualization of the interaction effect.

Table 2

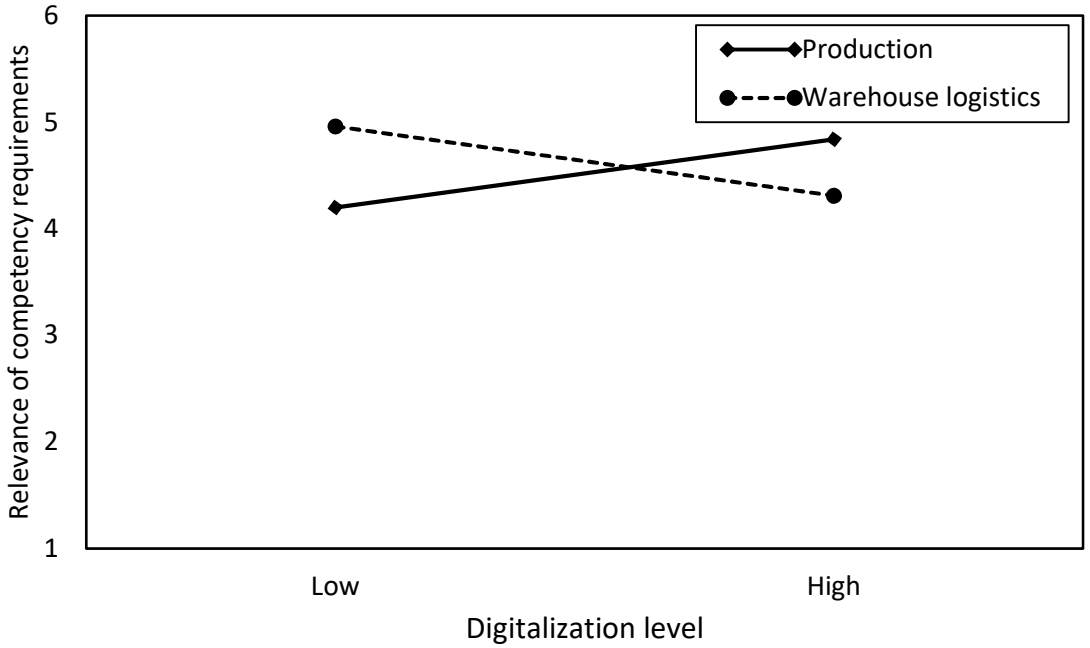
Moderated Regression Analysis Examining the Interaction Effect of Digitalization Level and Occupational Context in Predicting Competency Requirements

Predictor	*B*	*SE*	*t*	*p*	CI
Constant	4.58	0.08	54.47	< .001	[4.41, 4.75]
Digitalization level	-0.00	0.08	-0.02	.98	[-0.16, 0.15]
Occupational context	-0.06	0.08	-0.69	.49	[-0.22, 0.11]
Digitalization level x occupational context	0.29	0.08	3.69	<.001	[0.13, 0.44]
			R^2 = .10, *MSE* = 0.49 *F*(3, 123) = 4.55, *p* = .00		

Note. Occupational context is effect-coded with production = 1 and warehouse logistics = -1. *B* = unstandardized regression coefficients; *SE* = standard error of *B*; CI = 95% ordinary least squares confidence intervals; *MSE* = mean squared error.

Figure 2

Interaction of Digitalization Level and Occupational Context on Relevance of Competency Requirements



The second hypothesis stated that there was a positive relationship between competency requirements and several employee reactions. We investigated the correlations between competency requirements and work engagement, job satisfaction, organizational commitment,

and work effort for the whole sample. The results (see Table 3) showed that there was a positive significant association between competency requirements and work engagement (r = .18), organizational commitment (r = .27), and work effort (r = .26). The association between competency requirements and job satisfaction was positive, but not significant. We also calculated curvilinear regressions to examine if a very high amount of competency requirements might result in negative outcomes at a certain point. For all outcomes, the addition of the quadratic term of competency requirements did not result in significant increments in the variance explained. This indicates that the positive relationships between competency requirements and employee reactions did not reverse when competency requirements were very high. Thus, the results provide support for Hypotheses 2a, 2c, and 2d, but they do not support Hypothesis 2b.

Table 3

Means, Standard Deviations, and Intercorrelations Among Study Variables for the Whole Sample

Variable	*M*	*SD*	1	2	3	4	5
1. Digitalization level	2.12	1.02	–				
2. Competency requirements	4.39	0.73	.00				
3. Work engagement	2.61	0.54	-.29**	.18*			
4. Job satisfaction	5.12	1.23	.14	.12	.53***		
5. Organizational commitment	3.61	1.02	.24**	.27**	.29**	.52***	
6. Work effort	6.15	1.06	.19*	.26**	.16	.29**	.40***

Note. N = 127.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In our third hypothesis, we stated that the digitalization level of a division would have an indirect effect on employee reactions, mediated by competency requirements, which would be moderated by the occupational context. To test this hypothesis, we used Model 7 in the PROCESS macro, which describes a moderated mediation, where the moderator has an effect on the relationship between predictor and mediator. Digitalization was the predictor and was mean centered, the occupational context was the dichotomous moderator and was effect-coded prior to analysis (production = 1, warehouse logistics = -1), competency requirements were the

mediator, and work engagement, job satisfaction, organizational commitment, and work effort were the outcome variables. We performed separate analyses for each outcome.

To assess whether an indirect effect is dependent on a moderator, Hayes (2015) developed the index of moderated mediation, which is a quantification of the association between a moderator and an indirect effect. One can assume a moderated mediation when the confidence interval of this index does not include zero. The indices of moderated mediation in Table 4 indicate that the indirect effects of digitalization level on work engagement (0.08), organizational commitment (0.20), and work effort (0.23) through competency requirements were significantly related to the moderator occupational context. Further investigation of these three outcomes showed that the indirect effects were significantly positive for production divisions, and significantly negative for warehouse logistics divisions. In conclusion, the results provide support for Hypotheses 3a, 3c, and 3d, but do not support Hypothesis 3b.

Table 4

Conditional Indirect Effects Model Predicting Employee Reactions

	Work engagement			Job satisfaction		
Occupational context	*B*	Boot *SE*	CI	*B*	Boot *SE*	CI
Production	0.04	0.02	[0.0008, 0.09]	0.06	0.04	[-0.02, 0.15]
Warehouse logistics	-0.04	0.02	[-0.09, -0.002]	-0.06	0.04	[-0.15, 0.02]
	Index	Boot *SE*	CI	Index	Boot *SE*	CI
	0.08	0.04	[0.005, 0.16]	0.12	0.08	[-0.05, 0.29]

	Organizational commitment			Work effort		
Occupational context	*B*	Boot *SE*	CI	*B*	Boot *SE*	CI
Production	0.11	0.05	[0.02, 0.20]	0.11	0.05	[0.02, 0.23]
Warehouse logistics	-0.11	0.05	[-0.23, -0.03]	-0.11	0.05	[-0.21, -0.03]
	Index	Boot *SE*	CI	Index	Boot *SE*	CI
	0.22	0.08	[0.07, 0.39]	0.22	0.08	[0.08, 0.40]

Note. Occupational context is effect-coded with production = 1 and warehouse logistics = -1. *B* = unstandardized coefficients for indirect effect; Boot *SE* = bootstrapped standard errors; CI = 95% percentile bootstrap confidence intervals; Index = index of moderated mediation.

8. Discussion

The aim of our research was to examine how the digitalization of the workplace was associated with competency requirements and, subsequently, employee reactions. To this end, we analyzed and compared employees from two occupational contexts that differed regarding the routinization of job tasks. Both occupational contexts had jobs with routine tasks, jobs in the production context had additionally a greater focus on nonroutine cognitive tasks, and jobs in the warehouse logistics sector consisted additionally of mostly nonroutine manual tasks. In the production area, a high digitalization level was associated with greater competency requirements, which in turn were related to more work engagement, organizational commitment, and work effort. In the warehouse logistics area, a high digitalization level was associated with lower competency requirements, which in turn were related to less work engagement, organizational commitment, and work effort. We could not find evidence for a relationship between competency requirements and job satisfaction. This might have been due to the wording of the used item, which targets the overall satisfaction and consequently gives satisfaction with colleagues or with working hours as examples. It is conceivable that the competency requirements only affect one part of job satisfaction, for example, with the job tasks, which was not covered by the used item.

8.1 Theoretical Implications

The results of our study not only support the claim of the sociotechnical systems approach that the technical system (here: digital technologies) affects the social system (here: employees) but also give an explanation as to why and under what conditions this happens. This entails two implications. First, researchers investigating sociotechnical systems can better understand that a technology does not always lead to the same consequences. More specifically, we could show that the effects of a technology differed depending on the routinization of job tasks. Consequently, our study also highlights the need for context-sensitive research (Johns, 2006; Morgeson et al., 2010). Second, it emphasizes the value of interdisciplinary research. We successfully combined the hypothesis of routine-biased technological change, a perspective from the field of economics, with SDT, a theory from the field of psychology, into the sociotechnical systems model of employee reactions. Especially with regard to digitalization, it will become increasingly important to conduct interdisciplinary research because the implementation of digitalized technologies has a more extensive impact on an organization than previous technologies (Legner et al., 2017; Parker & Grote, 2020).

Additionally, our results provide support for a routine-biased technological change. Although this was also our assumption, there is also empirical evidence for a skill-biased technological change, which would have assumed that digitalization always leads to an increase in competency requirements, irrespective of the occupational context (e.g., Bresnahan et al., 2002; Kim, 2002). The fact that in our study there was no main effect of the digitalization level on competency requirements showed that in the investigated divisions, there was no skill-biased technological change.

Another important theoretical contribution of our study is the development and initial use of our instrument to assess the digitalization level. The instrument has the advantage that it can be applied to different kinds of technologies, which makes it suitable for many different industries. Its application can therefore advance the understanding of correlates of digitalization. For example, researchers could use it to investigate the relationship between digitalization level and work design characteristics to find out if technologically advanced workplaces differ from their conventional counterparts, for example, in terms of autonomy, skill variety, or task identity.

8.2 Practical Implications

Technological change processes never happen in isolation, but rather are also associated with changes in the work organization that can affect the employees (e.g., Eriksson-Zetterquist et al., 2009). In accordance with the sociotechnical systems approach, it is therefore advisable to assess the requirements and needs of the technology and of the employees before implementing the technology. That way, adverse effects of the technology can be mitigated, for example, by restructuring the work process. Universal human needs that, according to SDT, should always be satisfied in the work context are the needs for competence, relatedness, and autonomy (Deci & Ryan, 2000). SDT claims that the needs are additive so that strong satisfaction of one need can complement a lack of satisfaction in another. Thus, jobs that require fewer competencies due to a technology implementation could, for example, be redesigned in a way that they offer more opportunities to act autonomously.

As our results indicate greater competency requirements in digitalized production divisions, we suggest that a technology implementation in this occupational group should be accompanied by training for the affected workers. This is also relevant because Chung (1996) found that the employees' skills, knowledge, and attitude were critical factors in reducing the risk of failure in technology implementation. One example of a digitalized method of training is serious games. These games are played at a computer and, while being entertaining for the

user, serve the primary purpose of imparting knowledge. A review by Wouters et al. (2009) found positive effects of serious games on knowledge acquisition and cognitive skills. More recently, serious games have also been programmed for virtual reality appliances (e.g., Ferguson et al., 2020). Thus, technological advancements not only influence the work environment but also the way skills can be acquired.

Further, our results showed lower competency requirements in digitalized warehouse logistics divisions that were also associated with less positive affective, attitudinal and behavioral reactions. In order to enhance these jobs, more demanding or more diverse tasks could be added to each job. A popular work design method to accomplish this is job rotation. Job rotation refers to regular and planned alternation between different job tasks (Casad, 2012), and is positively related to job satisfaction, organizational commitment, performance, and less burnout, among other things (Hsieh & Chao, 2004; Jeon et al., 2016; Khan et al., 2014). The employees themselves can also become active by changing their job. As Hirschi (2018) pointed out, a high mobility between and within organizations, which is a core aspect of what Hall (2004) and Arthur (2014) have termed protean and boundaryless career models, will become more important for a rising number of people in the future.

Lastly, as the present study focused only on production and warehouse logistics divisions, companies planning to implement a new technology in a different division first need to assess the anticipated changes in competency requirements, and how they could affect the employees. In order to reflect on the impact of a planned technology, companies can conduct workshops where leaders develop future scenarios for the digitalized workplaces (Schlicher et al., in press). In a next step, these scenarios can be assessed with regard to the digitalization level, for example, by using the interview guidelines from the present study. Finally, the employees can use the scenario descriptions to rate the required competencies and anticipated employee reactions. Such a scenario-based approach (cf. Aguinis & Bradley, 2014) has the advantage that the impact of a technology can be estimated before it is implemented.

8.3 Limitations and Directions for Future Research

We believe that our study provides important contributions for research in the field of digitalization. However, there are also some limitations that need to be addressed. First, the digitalization level in the investigated production divisions was quite low. This indicates that our results cannot be generalized to divisions with greater digitalization levels. Future studies should therefore address this population. It is possible that in very digitalized jobs, even the nonroutine cognitive tasks are replaced by technologies to a certain degree. The course of

technological advancements, from a logic- and rule-based approach to a pattern-based approach (i.e., machine learning; Ahram, 2019), suggests the assumption that some nonroutine cognitive tasks will soon be performed by artificial intelligence.

Second, our sample consisted solely of employees from SMEs, which means that the results cannot be generalized to larger companies. Future research should analyze whether the found effects also exist in companies with more than 250 employees. It is possible that there are differences because it is easier for larger companies to move employees to completely different jobs if a technology has replaced them in their former jobs because they have the financial resources to retrain their employees. Nevertheless, as the vast majority of U.S., as well as European and German, companies is small or medium-sized and employs a large part of the working population (Federal Statistical Office of Germany, 2019; Papadopoulos et al., 2018; United States Census Bureau, 2018), the results of our study are still relevant for a large number of companies and employees.

Third, a limitation of our research is a potential common method bias because we assessed the competency requirements and employee reactions via self-report (Podsakoff et al., 2003). However, we implemented several strategies to reduce common method bias, as recommended by Podsakoff et al. (2012): First, we ensured anonymity by attaching a blank envelope to the questionnaire that the respondents could seal before they gave it to their supervisors. This was supposed to reduce social desirability. Second, we eliminated common scale properties by using different scale types (Likert and Kunin) and a different number of scale points (six points for competency requirements, between four and seven points for employee reactions). Third, we designed the questionnaire for the competency requirements and the employee reactions differently. One was in portrait orientation, one was in landscape orientation. This served the purpose to create psychological separation between the constructs, which reduces the respondent's ability to base their answers on what they recalled from previous answers (Podsakoff et al., 2003). Lastly, the potential threat of common method bias did not apply to associations with the digitalization level because this was not assessed via self-report. Instead, it was assessed by the first author, based on structured interviews and workplace observations.

Finally, we would like to point out a direction for further research for occupations with a decline in competency requirements due to digitalization, in our case the warehouse logistics jobs. It should be examined whether the previously relevant competencies might decay over time when they are not needed in the daily work. Bjork and Bjork (2006) describe this process of not being able to retrieve once-learned information or competencies as a core

assumption in their theory of disuse. However, even if employees forget some of the competencies, it is not yet clear if this also poses a problem to the company. It might be possible that, in the long run, the implemented technologies provide so much support for the employees that they can perform the work tasks without any vocational training. Likewise, it is possible that workers still need their skills in case of an emergency, for example, when the intelligent system malfunctions. This latter case is also the reason why automotive manufacturer Toyota decided to reintroduce a manual assembly line operated by human workers next to the fully automated assembly lines (Trudell et al., 2014).

8.4 Conclusion

The increasing digitalization of work processes is also accompanied by social and organizational changes. One large concern regarding organizational strategies is changes that affect employees, and our study provides occupation-specific answers: When there is much digitalization, employees in production divisions report a greater relevance of competencies and more positive employee reactions, whereas employees in warehouse logistics divisions report a lower relevance and less positive employee reactions. Companies planning to implement a new technology need to consider these occupation-specific relationships to ensure that all employees are qualified as needed, and their well-being and motivation is ensured.

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More Hype Than Substance? A Meta-Analysis on Job and Task Rotation

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Abstract

Although there exist numerous publications on job and task rotation from various disciplines, there is no consistent evidence of their effectiveness. Drawing on theories from industrial and organizational psychology, knowledge management, ergonomics, and management science, we meta-analytically investigated relationships between job/task rotation and employee attitudes, learning and development, psychological and physical health, and organizational performance. Due to a conceptual overlap and frequent confusion of terminology, we analyzed the design of the rotation (job rotation vs. task rotation) as a possible moderator. The three-level meta-analysis on 56 studies (N = 284,086) showed that rotation was significantly associated with job satisfaction (r = .27), organizational commitment (r = .16), career success (r = .31), labor flexibility (r = .32), general psychological health (r = .20), stress/burnout (r = −.13), individual performance (r = .13), and productivity (r = .13). Positive relationships between rotation and physical health could only be found when rotation was compared to high-intensity work. Task rotation yielded stronger relationships with attitudinal outcomes, job rotation with learning and development, psychological health, and organizational performance outcomes. Further moderator analyses showed that individualism decreased relationships between task rotation and attitudes, and correlations with organizational performance and physical health were stronger for subjective measures. The findings indicate that many expectations towards job and task rotation are not fully supported.

1 Introduction

Job and task rotation describe techniques where employees shift periodically and in a planned manner between a range of jobs or tasks within an organization (He et al., 2016; Jones and James, 2018). The first, rather unsystematic appearance of the term *job rotation* dates back to the 1940s and 1950s, when work design methods started to counteract the simplification, specialization, and repetitiveness that dominated the Tayloristic work design of the early twentieth century (Morris, 1956; Tucker, 1942). Since then, rotation has oftentimes been recommended in textbooks and practitioner literature in the fields of industrial and organizational (I/O) psychology (e.g., Jex and Britt, 2014), organizational behavior (e.g., Robbins and Judge, 2017), human resources management (e.g., Armstrong and Taylor, 2017), and engineering (e.g., Kutz, 2014). Despite its widespread use, a closer look at the literature reveals that the label *job rotation* is not used in a consistent way. It describes the rotation either between different jobs (Hsieh and Chao, 2004; Mohsan et al., 2012), between different tasks (Jeon et al., 2016; Weichel et al., 2010), or both (Colombo et al., 2007; Kim et al., 2016). Although job and task rotation are conceptually similar, this impreciseness in terminology could lead to false conclusions. Overall, there are more than 800 publications on job and task rotation from all over the world, and the number of articles as well as citations has been steadily growing (Posthuma et al., 2013; Web of Science, 2021). In the CRANET survey of 2014/15, more than 50% of U.S. organizations reported that they practiced job rotation (Cranet, 2017). They anticipate multiple advantages from rotation: employees with greater satisfaction and motivation due to a reduction of monotony; more skill development due to a greater variety of stimulating work environments; a healthier workforce due to a decrease in monotony and muscle fatigue; and an increase in organizational performance due to greater labor flexibility and a stronger stimulation of organizational learning. Existing studies seem to support these expectations at first glance. In jobs with rotation, they found, for example, greater motivation (r = .44; Muramatsu et al., 1982; where necessary, values are converted to correlation coefficient r for easier comparison) and labor flexibility (r = .57; Sawhney, 2013), decreased mental fatigue (r = −.32, Jones and James, 2018), a lower incidence of carpal tunnel syndrome (r = −.23; Roquelaure et al., 1997), and increased process innovation performance (r = .21; Pini and Santangelo, 2005). However, some studies also reported contradicting significant results for motivation (r = −.17; Mohsan et al., 2012), employee adaptability (r = −.41; Zhu et al., 2013), employee energy (r = −.09; Luger et al., 2016*),* incidence of upper-extremity musculoskeletal disorders (r = .07; Roquelaure et al., 2009), and innovation performance (r = −.11; Song et al., 2010). Thus, despite much interest in job and task rotation from a variety of disciplines and from researchers and practitioners alike, there are still questions left unanswered: Does rotation really provide the benefits that organizations expect? Is the interchanging use of the terms *job rotation* and *task rotation* justified, or are there differential effects for the interventions? How does the study context affect relationships between rotation and beneficial outcomes? In this manuscript, we present a meta-analytic integration of the relationships between rotation and beneficial outcomes and aim to provide answers to these questions. The participants of the included studies were either employees affected by rotation, managers reporting about rotation in their organization, or student samples in experimental settings. Our aim was to compare great levels of rotation with small levels of rotation (e.g., many job changes vs. few job changes, rotation vs. no rotation) and their relationship with a variety of outcomes (e.g., job satisfaction, career success, stress and burnout, musculoskeletal complaints, and speed of product development). We used the PRISMA reporting guidelines (see supplementary material, Supplementary Table 8, for PRISMA checklist).

This manuscript makes several contributions to the literature. First, this is the first meta-analysis and most comprehensive integration of outcomes of job and task rotation. So far, there have been only narrative reviews (e.g., Leider et al., 2015; Padula et al., 2017), and also, these are almost exclusively

focused on physical health criteria, such as musculoskeletal complaints or physical strain. Narrative reviews have the limitations that they do not consider measurement error in primary studies, and particular studies might be overweighted or underweighted such that conclusions can be misleading (Schmidt and Hunter, 2015). Moreover, the existing reviews mostly do not cover outcomes from the fields of I/O psychology and management science (e.g., employee development or performance). Second, our meta-analysis contributes to theoretical knowledge about the mechanisms of rotation. We use the interdisciplinary approach to work design of Campion and Thayer (1985) as a guide for possible outcomes of rotation, and complement it with other theories and models from multiple disciplines to explain why rotation might have beneficial effects and under which conditions these effects might increase or decrease. As potential moderating factors, we point out context-related differences regarding the societal culture, investigate differences due to the work intensity in the nonrotation condition, and show to what extent the design of the rotation has an impact on the relationship between rotation and possible beneficial effects. By doing that, we acknowledge conceptual differences between job rotation and task rotation that have been neglected by some previous studies. Third, the meta-analysis provides relevant information for practitioners. The results can give guidance to managers who need to know about the effects of rotation, as well as potential differences between job and task rotation, when considering its implementation. In conclusion, the purpose of this manuscript is to help in understanding the effects of job and task rotation, explain when and where rotation works, and make transparent those areas where we are still lacking knowledge.

2 Conceptual Overview of Job Rotation and Task Rotation

Job rotation refers to a lateral transfer of employees within an organization without a change in salary or hierarchy (Campion et al., 1994). It most commonly describes a change between different functions, departments, or units (Dinis and Fronteira, 2015; Le Meunier-Fitzhugh and Massey, 2019). Task rotation also includes a move between job tasks, but on a smaller scale. More specifically, it refers to the alternation between tasks within a job that can require different skills and responsibilities but is not associated with a change to a different function or department (Jeon et al., 2016; Jones and James, 2018). In the past, job and task rotation have not been strictly separated. Some authors defined job rotation as a change between jobs or tasks (e.g., Comper et al., 2017; Kim et al., 2016). Others used the label *job rotation* but actually measured a change of job tasks (e.g., Bao et al., 2016). Then again others used the term *task rotation* to refer to a transfer between functions (e.g., Tsai and Huang, 2020).

The fact that there are no prevailing definitions of job and task rotation could be attributed to the fact that both interventions are based on a change of work settings, and that making a distinction between tasks and jobs is often difficult. Yet, in comparison to task rotation, job rotation refers to more severe job changes. Thus, it probably requires more initial training and a longer time to adjust to the new job, and is more likely to be associated with a change in work environment, colleagues, or supervisors. Additionally, it is likely that job rotation indicates a longer time interval between rotations than task rotation. These arguments are supported by Eriksson and Ortega's (2006) employee learning hypothesis of job rotation. They argued that interfunctional job rotation could be a way to prepare employees for management positions, whereas intrafunctional rotations (i.e., task rotations) are primarily aimed at being able to reallocate employees across different tasks. They also stated that this latter rotation was only efficient when employees already had experience in the tasks and thus did not need much initial training.

Both job rotation and task rotation describe workplace interventions aimed at improving outcomes for employees and the organization. Since research on rotation stems from various disciplines, its outcomes are also multifaceted. In their historical overview of work design research, Parker et al. (2017) identified the interdisciplinary approach of Campion and Thayer (1985) as the starting point of integrative perspectives of work design. Campion and Thayer analyzed work design characteristics from the four disciplines of organizational psychology, human factors, ergonomics, and industrial engineering, and showed that the disciplines are typically aimed at different goals, namely positive employee attitudes (e.g., job satisfaction), reliability (e.g., reduced stress), physical well-being (e.g., few health complaints), and efficiency (e.g., reduced idle time), respectively. To address the multidisciplinarity of rotation research, we investigated in our meta-analysis the relationships between rotation and employee attitudes, psychological health (which Campion and Thayer subsumed under reliability), physical health, organizational performance (which is a broader concept than Campion and Thayer's efficiency), and employee learning and development. Although this last outcome was not a work design goal in Campion and Thayer's approach, more recent publications emphasize its importance in work design research and theory (Parker, 2014, 2017). In the following, we will outline in more detail the theoretical background of attitudinal, developmental, psychological and physical health-related, and organizational outcomes of rotation.

3 Rotation and Employee Attitudes

One of the most influential theories of psychological work design, the job characteristics model of Hackman and Oldham (1976), explains why rotation may result in more positive employee attitudes. The authors stated that the five job characteristics of skill variety, task identity, task significance, autonomy, and feedback affect job-related outcomes, such as motivation and satisfaction. The job characteristics model has been complemented by Morgeson, Humphrey, and colleagues (Humphrey et al., 2007; Morgeson and Humphrey, 2006). The authors added knowledge characteristics, social characteristics, and characteristics of the work context. In their meta-analysis (Humphrey et al., 2007), they found evidence for this extended model.

While there already exists cumulative knowledge on single work characteristics (meta-analyses by Fried and Ferris, 1987; Humphrey et al., 2007), there is a unique combination of characteristics that distinguishes jobs with rotation from jobs without rotation. On the one hand, it is likely that the rotation between tasks or jobs increases the perceived variety of tasks, requires a greater variety of skills, and in some cases makes a job more holistic because the tasks or jobs add up to a complete cycle of a work process. Humphrey et al. (2007) found in their meta-analysis positive relationships between these characteristics (task variety, skill variety, and task identity) and positive employee attitudes, such as job satisfaction, internal work motivation, job involvement, and organizational commitment. We assumed that a job that provides a combination of these characteristics, as we expect to be the case in jobs with rotation, is also associated with positive employee attitudes.

On the other hand, jobs with rotation might decrease the experience of autonomy regarding the scheduling of work tasks because employees might be required to follow a fixed rotation roster. In their meta-analysis, Humphrey et al. (2007) investigated the relationships between autonomy and job satisfaction (there were not enough primary studies to investigate other outcomes). They found only significant associations between job satisfaction and other types of autonomy (e.g., work methods autonomy), but not between job satisfaction and work scheduling autonomy. Hence, even a fixed rotation schedule should not affect the positive relationship between rotation and employee attitudes.

Hypothesis 1: Rotation is positively associated with the employee attitudes (a) job satisfaction, (b) work motivation, (c) job involvement, and (d) organizational commitment.

4 Rotation and Learning and Development

A more recent expansion of the job characteristics model—the work design growth model—was proposed by Parker (2017). This model states that the way work is designed also influences several short-term (e.g., a change in cognition or skills) and long-term learning and development outcomes (e.g., an increase in intellectual flexibility), which had been neglected in previous work design models. Applied to an employment with job or task rotation, it is conceivable that the greater levels of task variety and task identity enhance learning because employees are introduced to new knowledge domains and gain a broader perspective of organizational processes. This notion is supported by a study with 5,800 working participants by Weststar (2009). Here, a change in skill level required to perform a job and a change in work techniques and equipment (both core features of jobs with rotation) were significantly associated with an increase in employees seeking advice from someone knowledgeable with the intention of developing their job skills. Additionally, Antonioli and Della Torre (2016) found in their study of 118 small and medium enterprises that the adoption of job rotation was negatively associated with formal training. The authors interpreted this finding to mean that the investigated companies may adopt job rotation as a substitute for formal learning approaches.

Another explanation is that rotation facilitates the creation of tacit knowledge. Tacit knowledge refers to knowledge that is acquired through experience because it cannot be explicitly verbalized (Nonaka and Takeuchi, 1995). When employees rotate between jobs or tasks, it is more likely that they share their tacit knowledge and learn from each other because they might have more contact with colleagues from other disciplines (Kane et al., 2005). This knowledge acquisition in a variety of jobs or tasks allows employers to deploy their workers more flexibly.

Lastly, the meta-analysis by Humphrey et al. (2007) indicates that rotation might facilitate not only competence development but also career development because they found positive relationships between several rotation-specific work characteristics (i.e., task variety, skill variety, and task identity) and satisfaction with promotion. Thus, we proposed the following hypothesis.

Hypothesis 2: Rotation is positively associated with the employee development indicators (a) competence development, (b) career success, and (c) labor flexibility.

5 Rotation and Psychological Health

According to an integrative model of psychologically healthy workplaces, employee well-being can be ensured by reducing negative demands and stressors and promoting organizational resources (Kelloway & Day, 2005). Thus, the model suggests changing the objective working conditions, as opposed to addressing individual perceptions and attitudes (Hurrell, 2005).

It can be argued that rotation benefits psychological health because it reduces the job stressors repetitiveness and imbalanced workload. In a review about boredom at work, Loukidou et al. (2009) found that repetitive and monotonous jobs were associated with, for example, psychological distress, depression, and feelings of hostility. Consequently, there are many simulation studies that aim to find an algorithm for job rotation scheduling that diminishes employee boredom (e.g., Azizi et al., 2010; Bhadury and Radovilsky, 2006). Additionally, it is possible that employees' psychological health is positively affected by rotation because the workload is more balanced than in jobs with a single

activity, which improves physical health (as described in the following section). Previous studies found a high correlation between physical and psychological health (e.g., Bonzini et al., 2015).

Besides the reduction of these stressors, rotation also provides certain resources. Warr (1999) summarized ten potential environmental determinants of well-being, two of them being variety and opportunities for skill use. As described above, these are assumed to be provided by jobs with rotation. Sevastos et al. (1992) found significant associations between the well-being factors of anxiety-contentment and depression-enthusiasm and the job characteristics of skill variety and task identity. We proposed the following hypothesis.

Hypothesis 3: Rotation is (a) positively associated with general psychological health, and (b) negatively associated with stress and burnout.

6 Rotation and Physical Health

A model developed by Westgaard and Winkel (1996), based on a review of guidelines for occupational musculoskeletal load, explains why rotation can have an effect on a wide variety of health-related outcomes. The authors state that environmental exposure at work leads to individual reactions in the body, which then cause acute physiological and psychological responses, such as fatigue, change in heart rate, and (dis)comfort. Ultimately, these lead to improved or impaired musculoskeletal health. One important environmental exposure in the workplace proved to be repetitive or monotonous work (Andersen et al., 2002). Increased repetitiveness means that one particular body region is continuously stressed, and the affected internal structures have little opportunity to recover (Luger et al., 2014). As a relief, employees could either have more rest breaks or change between tasks that stress different body regions, and thus engage in task rotation (Luger et al., 2014).

Previous literature reviews on the effects of task rotation on physical health found ambiguous results. On the one hand, reviews about task rotation and shoulder fatigue (Luger et al., 2014), muscular activity variability (Rodriguez and Barrero, 2017), or work-related musculoskeletal disorders and sick leave (Padula et al., 2017) reported (weak) positive effects of task rotation on physical health. On the other hand, reviews about task rotation and musculoskeletal complaints and physical workload (Leider et al., 2015) or upper limb muscle fatigue (Santos et al., 2016) found inconsistent effects across studies. The authors discussed several explanations: First, the overall effect of rotation might have been canceled out because employees who normally performed high-intensity work benefitted from rotation, whereas employees who normally perform low-intensity work experienced a disadvantage due to the introduction of rotation (Leider et al., 2015; Luger et al., 2014). Second, it is possible that the tasks within a rotation cycle did not stress different body regions so that the expected beneficial effects could not unfold. Leider et al. (2015) described, for example, a study where the employees had to work above shoulder level and do repetitive hand movements for an extended time both before and after the introduction of rotation. Mathiassen (2006) noted that there are currently no appropriate metrics to determine the diversity of exposed body regions.

To account for the previous ambiguous results, we assumed the following hypothesis.

Hypothesis 4: The associations between rotation and physical health outcomes are moderated by the work intensity of the reference group. If the reference group performs high-intensity work, there is a (a) positive association with general physical health, and a negative association with (b) musculoskeletal complaints and (c) physical workload. If the reference group performs low-intensity

work, there is a (d) negative association with general physical health, and a positive association with (e) musculoskeletal complaints and (f) physical workload.

7 Rotation and Organizational Performance

We drew on resource-based theory to explain why job and task rotation may affect organizational performance. The theory states that the major determinant of an organization's success is its internal resources, one of them being human capital resources (e.g., experience of managers and workers; Barney, 1991; Barney et al., 2011). Ensuing from human capital resources in resource-based theory, there are two explanatory approaches for the effect of rotation on organizational performance: workforce flexibility and organizational learning.

First, workforce flexibility ensues from rotation because, as described above, rotation fosters employee development, and thus proficiency in a variety of jobs and tasks. This labor flexibility helps to avoid bottlenecks, reduce idle time, and achieve a shorter lead time. All of these contribute to an enhanced financial performance of the organization (Beltrán-Martín et al., 2008; Bhattacharya et al., 2005). Additionally, the work characteristics of task variety and task identity have also been found to be positively related to individual, subjective performance (Humphrey et al., 2007).

Second, organizations can use rotation as a method to convert individual resources (i.e., employee knowledge and skills) into organizational knowledge, a process called *organizational learning* (Basten and Haamann, 2018; Maier et al., 2001). This process reduces employee turnover and is critical to an organization's innovative capabilities, which, in turn, should translate into organizational performance (Egan et al., 2004; Jiménez-Jiménez and Sanz-Valle, 2011). One important component of organizational learning theories is the transfer of knowledge among employees (Argote, 2013; Nonaka, 1994). This knowledge sharing should be facilitated by rotation activities: Studies on cross-functional teams found that job rotation was associated with increased communication between functions, more involvement in cross-functional activities, and more congruent goals across functions (Hauptman and Hirji, 1999; Xie et al., 2003). Thus, rotation enables a tighter network within the organization (Jansen et al., 2005). These factors can contribute to faster processes, such as product development, greater productivity, and increased innovative capabilities. Thus, we proposed the following hypothesis.

Hypothesis 5: Rotation is positively associated with the organizational performance indicators (a) individual performance, (b), productivity, (c) speed of product development, (d) innovativeness, and (e) financial performance, and negatively associated with (f) turnover (intention).

8 Potential Moderators of Rotation Outcomes

As described above, previous studies have often confused task rotation with job rotation (or vice versa). Thus, it is possible that ambiguous results from primary studies can be explained by the concrete design of a rotation intervention, which is either a job rotation or a task rotation. Based on the theoretical arguments presented above, one can assume that for some outcomes, the relationships with rotation are stronger for job rotation than for task rotation and conversely for other outcomes. As regards employee attitudes, we expected stronger relationships for task rotation than for job rotation. Task rotation implies a more frequent change between activities so that the perceived task variety and skill variety, which are both associated with positive employee attitudes, should be greater (Humphrey et al., 2007). Additionally, job rotation is often associated with a change to a different workplace, which can result in a lack of social support because employees will have new colleagues. Meta-analytic results indicate that a lack of social support is associated with less positive

employee attitudes (Humphrey et al., 2007). In the case of learning and development, it is likely that employees gain a broader perspective from job rotation than from task rotation because they experience more diverse work environments. These are more likely to stimulate learning and growth (Parker, 2017). Based on our reasoning for psychological health, the relationship should be stronger for task rotation than for job rotation. As described above, task rotation is more likely to provide the resource of variety, which was found to be related to less depression and anxiety (Sevastos et al., 1992). Additionally, task rotation is potentially more suitable to reduce the stressor of an imbalanced workload, which should indirectly affect psychological health (Bonzini et al., 2015). With regard to physical health, we expected stronger relationships with task rotation than with job rotation (when compared to high-intensity work) because the recovery of specific strained body parts can be best achieved when the alternation between work activities occurs quite frequently (Mathiassen, 2006). Regarding organizational performance, we believed that job rotation would result in stronger relationships because it more often includes a change to another department. This contributes firstly to a broader picture of the organization and consequently more workforce flexibility (Parker, 2017), and secondly to organizational learning because it encourages more interdepartmental knowledge sharing (Hauptman and Hirji, 1999). We proposed the following hypothesis.

Hypothesis 6: The relationship between rotation and (a) employee attitudes, (b) learning and development, (c) psychological health, (d) physical health, and (e) organizational performance is moderated by the concrete design of the rotation (job rotation vs. task rotation).

As another potential moderator, we investigated the context of the primary studies. As Johns (2006) pointed out, it is important to always interpret study results in the light of situational factors that might affect the occurrence of behavior and the relationship between variables. We expected that the collectivism/individualism of the societal culture would have an influence on the relationship between rotation and attitudes. In individualistic cultures, people tend to view themselves as independent individuals. Employees are thus more likely to strive for individual goals and pursue individual interests. In contrast, employees from collectivistic cultures see themselves as part of a collective (e.g., their organization), are motivated by the collective's norms, and are willing to give the collective's goals a higher priority than their own (Triandis, 1995). Task rotation could be more strongly related to positive employee attitudes in collectivistic cultures because it puts an emphasis on the collective's goal by diminishing job specialization and making employees more interchangeable (Fægri et al., 2010). Employees from individualistic cultures, however, might feel that their individual contributions at work cannot be identified in the context of task rotation, which might result in less positive employee attitudes. In regard to the adoption of job rotation it is likely that it is more beneficial for employee attitudes in individualistic cultures than in collectivistic cultures. Job rotation helps employees broaden their skill set and gain a deeper understanding of business operations (Eriksson and Ortega, 2006). As this could ultimately be beneficial for their individual career advancement, the possibility of participating in job rotation might be perceived as a privilege, which results in more favorable attitudes. These individual-oriented goals are theorized to be less relevant for employees from collectivistic cultures (Triandis, 1995).

Hypothesis 7: The individualism/collectivism value of the societal culture moderates the relationship between rotation and employee attitudes, based on the concrete design of the rotation. As the societal culture becomes more individualistic, the positive relationships will (a) decrease in the case of task rotation and (b) increase in the case of job rotation.

In addition to the theoretically derived potential moderators, we also addressed a practically relevant aspect that could affect the relationships between rotation and its outcomes: We investigated whether

there were any differences depending on whether the outcome was measured subjectively or objectively. Especially from an organization's point of view, objective success indicators are highly relevant because they are believed to be the most accurate representation of the real world and therefore guide future strategic decisions (Andrews et al., 2006). Although often used interchangeably, meta-analytic studies suggest that subjective and objective organizational performance measures are only weakly correlated (e.g., Bommer et al., 1995).

Research Question: Are there any differences in the strength of the relationship between rotation and its outcomes based on whether the outcome was measured subjectively or objectively?

9 Method

The data underlying the present meta-analysis are openly available in Open Science Framework (OSF[1]).

9.1 Literature Search and Inclusion Criteria

We conducted a variety of search strategies to identify empirical studies published before February 2021. First, we conducted a search in the online databases PsycINFO, PSYNDEX, Education Source, Web of Science, EconLit, and Medline using the search term *"job rotation" OR "task rotation."* Second, we conducted a manual search of all conference programs that were available online of the Society for Industrial and Organizational Psychology (1998–2020), Academy of Management (1954–2020), European Association of Work and Organizational Psychology (2007–2019), and International Ergonomics Association (2015–2018) conferences. Third, we manually searched major journals from the fields of I/O psychology, management, health, and ergonomics, including the *Journal of Organizational Behavior*, *Journal of Applied Psychology*, *Personnel Psychology*, *Organization Science*, *Journal of Occupational Health Psychology*, *Applied Ergonomics*, *Health Psychology*, and *Work & Stress*. Fourth, we examined the reference lists from previous literature reviews on job rotation and pertinent topics (e.g., Basten and Haamann, 2018; Leider et al., 2015; Padula et al., 2017). Lastly, we conducted a manual search of the reference lists of all included articles. In an effort to obtain more grey literature, we complemented these search strategies with further approaches. More specifically, we posted a call for unpublished data in the Calls and Announcements section on the website of the Society for Industrial and Organizational Psychology[2] and via the mailing list of the German Psychological Society. As the European Association for Work and Organizational Psychology does not have a mailing list or announcements section on their website, we shared our call for unpublished data in the corresponding LinkedIn group[3]. Additionally, we contacted all authors of primary studies that we had identified thus far and asked whether they had further unpublished data that we could include.

We included all studies that reported a sample size and an effect size, or enough information to calculate it, and examined a unique sample that had not been included in this meta-analysis already. In line with past meta-analyses, we only included outcomes of job and task rotation when they were represented in at least three independent samples (cf., Berry et al., 2007; Eby et al., 2008; Kleine et al., 2019). We included experimental studies, quasi-experimental studies, and correlational studies in

[1] https://osf.io/xtrkn/

[2] https://www.siop.org/Career-Center/Calls-and-Announcements

[3] https://www.linkedin.com/groups/1999015/

all languages. In studies in a language other than English, German, or French, we retrieved the relevant information using Google Translate[4]. Due to the recommendation by Roth et al. (2018), we excluded studies that only reported regression weights and where we could not obtain zero-order correlations from the authors.

9.2 Coding Procedures

For the coding of the included studies, we compiled a manual that described the coding procedure, including all relevant coding decisions. The first author coded all studies, and another I/O psychologist familiar with the coding procedure coded a randomly selected 30% of the studies. We assessed the interrater agreement for categorical variables with Cohen's kappa, and the interrater reliability for continuous variables with intraclass coefficients (ICC 2,1) after all studies were coded. The kappa coefficients ranged from 0.76 (level of operationalization) to 1 (e.g., nationality), and the ICC from 0.99 (mean age) to 1 (e.g., sample size). Overall, these analyses showed good to very good interrater agreement and reliability. The discrepancies among the coders were then resolved by discussion between the coders, and the first author re-evaluated the coding decisions of the single-handedly coded studies based on the aspects that were discussed most frequently.

The effect size metric was the correlation coefficient Pearson's *r*. We coded either *r* directly, another effect size that could be converted to *r* (e.g., odds ratio for the incidence of low back pain), or the necessary information to calculate an effect size that could be converted to *r* (e.g., means and standard deviations). For the conversion, we used formulae by Borenstein et al. (2009). We included studies with a between-subjects design as well as those with a within-subjects design. Borenstein et al. (2009) argue that it is legitimate to combine studies with different designs as long as they aim to answer the same question. When studies used a within-subjects design, we first calculated Cohen's *d* using the formula provided by Cheung (2015), which accounts for the dependency between pre and post values by including the intercorrelation, and then converted it to *r*. When studies used two independent groups with repeated measures, we used the formula provided by Lipsey and Wilson (2001). In two cases (Comper et al., 2017; Kuijer et al., 2005), we could not obtain the intercorrelation for the within-person values, so we only coded the between-person effect size for the post values.

9.2.1 Coding of Methodological Factors and Study Characteristics

Publication status of the study was coded as a dummy variable (peer-reviewed publication vs. unpublished). For the study design, we coded whether rotation and the corresponding outcome were assessed concurrently or if the outcome was assessed after rotation. Thus, the binary variable had the two categories cross-sectional and time-lagged. Other design factors that we coded were the study setting (laboratory vs. field) and whether the study used a within- or between-subjects design. A within-subjects design meant that participants of the primary study were their own control group because they were assessed before and after the rotation intervention. A between-subjects design meant that participants with and without rotation (or with varying degrees of rotation) were compared with each other. Additionally, we coded the study rigor using an ordinal variable with the categories experiment (greatest rigor), quasi-experimental study, and correlational study (lowest rigor). As there were only few studies with an experimental or quasi-experimental design, we later combined these categories in our calculations.

[4] https://translate.google.com

9.2.2 Coding of Outcomes

For some outcomes, we decided to create synthetic construct groupings because primary studies reported very similar, conceptually overlapping constructs. We analyzed the operationalizations of each construct and logically combined semantically similar constructs. A table with all synthetic constructs and the underlying operationalizations can be found in the supplementary material (Supplementary Table 1).

9.2.3 Coding of Moderators

In terms of the concrete design of the rotation, we created a categorical variable with the groups job rotation, task rotation, and both. The coding was based on the measurement of rotation (not on the definition the primary authors provided). An example description that indicated job rotation is "any change in job title or department that did not coincide with an increase in salary" (Campion et al., 1994, p. 1525), an example that indicated task rotation is "a dichotomous question asking whether an employee's job involves rotating tasks between the employee and colleagues" (Avgoustaki, 2016, p. 663), and an example of both is "do operators rotate across jobs or tasks on the line?" (Colombo et al., 2007, p. 1045). To investigate the relationships between rotation and physical health outcomes, we coded whether the control group performed tasks with a higher work intensity or lower work intensity. For the cultural moderator, we used the dimension *individualism/collectivism* by Hofstede (2001). Every study that provided information on the country of data collection was assigned the individualism/collectivism index for this country. The values ranged from 1 to 100, with higher scores indicating greater levels of individualism. To address our research question, we also coded whether the outcome measure was a subjective (e.g., a self-rating questionnaire) or an objective (e.g., company data) measure.

9.3 Meta-Analytic Procedure

Most of our included studies reported more than one effect size. These effect sizes are usually dependent, which is why traditional meta-analytic procedures (e.g., Schmidt & Hunter, 2015) require the meta-analyst to include only a single effect size per study. Common strategies to accomplish this are, for example, calculating composites or selecting one effect size per sample. These strategies, however, result in an underestimation of heterogeneity and a loss of information (Cheung, 2014; Cheung & Chan, 2014). Hence, we decided to perform a three-level meta-analysis, which accounts for dependencies of effect sizes (Cheung, 2015a; Van den Noortgate et al., 2013).

Traditional meta-analytic procedures can be regarded as two-level models, with participants at Level 1 and studies at Level 2. That means that effect sizes vary due to two types of variance: sampling variance and between-study variance. With the use of a three-level model, it is possible to consider a third source of variance: within-study variance, which can result, for example, from the use of several measures for the same criterion, or from the measurement of various criteria in one study. The resulting three levels were participants at Level 1, effect sizes within studies at Level 2, and studies at Level 3.

We calculated the sampling variance of the effect sizes (Level 1 variance) using formulae provided by Cheung (2015a, Chapter 3) and Borenstein et al. (2009, Chapter 7). To calculate the mean effect sizes across studies (r) and the heterogeneity of effect sizes τ^2 within studies (Level 2) and between studies (Level 3), we used the metaSEM package (Version 1.2.5; Cheung, 2015b) for R (Version 4.0.1; R Core Team, 2020). The package calculates significance (p values) and 95% confidence intervals based on Wald approximations (Z).

10 Results

10.1 Study Characteristics

Our literature search yielded 803 hits (excluding duplicates). After excluding studies according to our predefined criteria, the analyses are based on a total of 56 studies, 253 effect sizes, and 284,086 participants, reported in 56 articles (see Figure 1 for a flow chart depicting reasons for article exclusions). An overview of all included studies with the investigated constructs, operationalizations, and the respective effect sizes can be found in the supplementary material (Supplementary Table 9).

– Insert Figure 1 about here –

Overall, 53 articles were peer-reviewed publications and three were unpublished studies (one working paper, one news article without peer review, and one unpublished data set). The primary studies were carried out between 1982 and 2020. We could not include any earlier articles because these were either not empirical studies or they were qualitative and thus did not report an effect size. Most studies were conducted in Europe ($k = 24$), followed by North America and Asia (both $k = 13$), mixed samples ($k = 3$), South America, Australia, and Africa (all $k = 1$). On average, the samples had a mean age of 34.73 years ($SD = 6.30$; $Min = 22$; $Max = 42$) and were 47.64% female. The majority of the samples were employees ($k = 37$), followed by managers ($k = 16$), and students ($k = 3$). Most studies had a correlational design ($k = 46$), eight studies were experiments, and two studies used a quasi-experimental design.

10.2 Relationships Between Rotation and Employee-Related and Organizational Outcomes

To test the relationships between rotation and employee-related and organizational outcomes, we computed a mixed-effects three-level meta-analysis that included the type of outcome as a covariate (see Table 1). As all outcomes were included in this analysis, we reverse-coded the effect sizes of those outcomes that indicate a negative effect: stress and burnout, musculoskeletal complaints, physical workload, and turnover (intention). Thus, positive values in these outcomes indicate a reduced level of the respective outcome. The results showed significant correlations between rotation and job satisfaction ($r = .27$, $p < .001$), organizational commitment ($r = .16$, $p = .02$), career success ($r = .31$, $p = .002$), labor flexibility ($r = .32$, $p = .004$), general psychological health ($r = .20$, $p = .01$), stress and burnout ($r = .13$, $p = .02$), individual performance ($r = .13$, $p = .02$), and productivity ($r = .13$, $p = .02$). These correlations exceed in magnitude between 27–75 % of effect sizes reported in the human resources and organizational behavior literatures (Paterson et al., 2016). Thus, the results supported our Hypotheses 1a, 1d, 2b, 2c, 3a, 3b, 5a, and 5b. They did not support our Hypotheses 1b (work motivation), 1c (job involvement), 2a (competence development), 5c (speed of product development), 5d (innovativeness), 5e (financial performance), and 5f (turnover).

Regarding the relationships between rotation and physical health, we had not assumed a general positive or negative relationship. Instead, we expected differences due to the work intensity of the reference group. Most studies did not specify which tasks were performed by the reference group, or work intensity was similar in the rotation and the non-rotation condition. Also, there was only one study that reported a comparison between rotation and high work intensity and investigated an effect of job rotation on general physical health (Han et al., 2020, $r = .17$). Thus, we could not test Hypotheses 4a and 4d. To test the other hypotheses on physical health, we investigated the subsample of rotation vs. low work intensity and the subsample of rotation vs. high work intensity (see Table 2). In line with our hypotheses, when the reference group performed high-intensity work, there were negative relationships between rotation and musculoskeletal complaints ($r = –.38$, $p =$

.003) and physical workload (r = –.32, p = .01). These results support Hypotheses 4b and 4c. When the reference group performed low-intensity work, there were positive relationships between rotation and musculoskeletal complaints (r = .16, p = .06) and physical workload (r = .20, p = .07), but they were smaller and nonsignificant. Thus, Hypotheses 4e and 4f could not be supported.

– Insert Table 1 about here –

– Insert Table 2 about here –

10.3 Differences Between Job Rotation and Task Rotation

To investigate whether the concrete design of the rotation affected the relationships between rotation and employee attitudes, learning and development, psychological health, physical health, and organizational performance, we conducted analyses for each outcome category and included the intervention (job rotation vs. task rotation) as a covariate. There was only one study with one effect size that investigated the relationship between job rotation and physical health outcomes. Therefore, we could not test Hypothesis 6d. The results for the other outcome categories are presented in Table 3. As we investigated the overall outcome categories, we again used the reverse-coded effect sizes for stress and burnout and turnover (intention). As expected, the relationship between rotation and employee attitudes was stronger in the case of task rotation (r = .10, p = .03) than in the case of job rotation (r = –.00, p = .97). The difference was, however, nonsignificant (r_{Diff} = .11, p = .23). Also as expected, the relationship between rotation and learning and development was stronger when the intervention was job rotation (r = .21, p = .10) than when it was task rotation (r = .09, p = .48). Again, the difference was nonsignificant (r_{Diff} = –.12, p = .51). Contrary to our expectations, the relationship between rotation and psychological health was stronger for job rotation (r = .20, p = .005) than for task rotation (r = .14, p = .01). This difference was also not significant (r_{Diff} = –.05, p = .54). Lastly, in line with our expectations, the relationship between rotation and organizational performance was stronger in the case of job rotation (r = .12, p = .002) than in the case of task rotation (r = .03, p = .26). This difference was also not significant (r_{Diff} = –.09, p = .07). In conclusion, the results indicated slight differences between job rotation and task rotation, which were mostly in line with our expectations. As none of these differences were statistically significant, we had to reject Hypotheses 6a–c and 6e.

– Insert Table 3 about here –

10.4 Differences Due to Societal Culture

To examine whether collectivism/individualism affected the relationship between rotation and employee attitudes, depending on the concrete design of the rotation, we created subsamples for task rotation and job rotation and added the collectivism/individualism value as a continuous covariate in both subsamples. In the task rotation subsample, with greater levels of individualism, the relationship between rotation and attitudes decreased significantly (B = –.004, p = .003). Thus, the results supported Hypothesis 7a. In the job rotation subsample, with greater levels of individualism, the relationship between rotation and attitudes increased, however not significantly (B = .00, p = .80). Thus, the results did not support Hypothesis 7b.

10.5 Differences Between Subjective and Objective Outcome Measures

To investigate whether there were differences between subjective and objective outcome measures, we conducted analyses for each outcome category and included the measurement type (subjective vs.

objective) as a covariate. The only outcome categories that contained any objective outcome measures were physical health and organizational performance. As we had found that the work intensity of the reference group affected the results, we excluded effect sizes that compared rotation to low-intensity work in this analysis. The results (see Table 4) showed that for both outcome categories, the relationship between rotation and subjective outcome measures was stronger (physical health: $r = .21$, $p < .001$; organizational performance: $r = .18$, $p < .001$) than between rotation and objective outcome measures (physical health: $r = .07$, $p = .23$; organizational performance: $r = .01$, $p = .88$). The difference was significant in both cases (physical health: $r_{Diff} = –.14$, $p < .001$; organizational performance: $r_{Diff} = –.19$, $p < .001$).

– Insert Table 4 about here –

10.6 Methodological Factors and Influential Studies

Where possible, we examined whether methodological factors of primary studies affected the relationships between rotation and the superordinate outcome categories (see supplementary material, Supplementary Tables 2–6, for detailed results). For all outcome categories, there were no significant differences between correlational and (quasi-)experimental studies, laboratory and field studies, and studies with a within- and between-subjects design. The comparison of cross-sectional with time-lagged studies showed significant differences for learning and development outcomes ($r_{Diff} = .43$, $p = .01$) and for physical health outcomes ($r_{Diff} = –.20$, $p = .05$). The relationship between rotation and learning and development was stronger in cross-sectional studies, the relationship between rotation and physical health was stronger in time-lagged studies.

To determine whether single studies with very large sample sizes might have skewed the results of the meta-analysis, we conducted a sensitivity analysis. More specifically, we computed the relationships between rotation and the outcomes without the studies of Avgoustaki (2016; $n = 29{,}537$), Bouville and Alis (2014; $n = 24{,}486$), Kampkötter et al. (2016; $n_1 = 90{,}321$; $n_2 = 91{,}987$), and Ollo-Lopez et al. ($n = 12{,}056$). The results showed that the exclusion of these studies affected the effect sizes only marginally (Supplementary Table 7).

11 Discussion

Ambiguous results from previous studies required a quantitative integration to assess an average relationship between job and task rotation and the beneficial outcomes that organizations expect and textbooks assert. Based on theories and models from multiple disciplines, we had assumed that rotation was positively associated with various employee attitudes, learning and development outcomes, psychological health, and organizational performance. The results supported our assumptions regarding the positive relationships between rotation and job satisfaction, organizational commitment, career success, labor flexibility, general psychological health, individual performance, productivity, and less stress and burnout. We could, however, not find significant evidence for positive relationships between rotation and work motivation, job involvement, competence development, speed of product development, innovativeness, financial performance, and reduced turnover (intention).

Regarding the relationships between rotation and physical health outcomes, we had expected positive relationships between rotation and physical health when the reference group performed high-intensity work, and negative relationships when the reference group performed low-intensity work. The results indeed showed that rotation was associated with reduced musculoskeletal complaints and physical workload when compared to high-intensity work. When compared to low-intensity work, there were

positive, yet nonsignificant, relationships with musculoskeletal complaints and physical workload. There were not enough studies to investigate the associations between rotation and general physical health.

A comparison of job and task rotation revealed that, as expected, task rotation resulted in stronger correlations with attitudes, whereas job rotation had stronger correlations with learning and development and organizational performance. Contrary to our expectations, job rotation was also more strongly correlated with psychological health outcomes. In each case, the difference between job rotation and task rotation was not significant, although the absolute values of the correlation coefficients differed greatly in most cases. For example, when compared to averaged effect sizes in the human resources and organizational behavior literatures (Paterson et al., 2016), the association between job rotation and learning and development exceeds in magnitude 50% of effect sizes, whereas the association between task rotation and learning and development exceeds only about 17%. There were not enough primary studies on relationships between job rotation and physical health so that we could not test our assumptions for this outcome category.

Lastly, as expected, we found that as the societal culture of the primary studies becomes more individualistic, the relationship between task rotation and employee attitudes decreases. We had also assumed the opposite for job rotation but could not find evidence for this assumption. We had thought that job rotation could be more beneficial for individual-oriented goals, such as career advancement, and therefore result in more favorable attitudes. However, it is possible that these individual-oriented goals are only relevant in the more distant future so that they do not affect more direct attitudinal responses.

The results of our exploratory research question showed that there were significant differences between subjectively and objectively measured outcomes. The association between rotation and physical health and organizational performance—the only outcome categories with enough objectively measured outcomes—was stronger when the outcomes were measured subjectively.

11.1 Theoretical Implications

We aimed to explain the expected relationships between rotation and employee attitudes, learning and development, psychological and physical health, and organizational performance with the help of theories and models from the respective disciplines. Based on the results of the comparison of job rotation and task rotation, we could draw initial conclusions on the appropriateness of our theoretical arguments for the investigated outcomes.

Based on the job characteristics model (Hackman and Oldham, 1976), we had assumed that a positive association between rotation and employee attitudes could be explained by the fact that jobs with rotation usually provide certain work characteristics (e.g., task variety). These should be more prominent in task rotation than in job rotation because task rotation usually happens more frequently. Also, job rotation should be more likely to reduce the work characteristic of social support, as it usually involves a change to a different workplace. Hence, we assumed that if the association between attitudes and task rotation was stronger than between attitudes and job rotation, this would be a first indicator that the job characteristics model provided an appropriate explanation of the relationship between rotation and attitudes. The results supported this assumption.

In regard to learning and development, we drew on the work design growth model (Parker, 2017) and expected rotation to be beneficial because it broadened the employees' skills and perspectives. We believed that job rotation provided more diverse work environments than task rotation and thus more

diverse perspectives that could stimulate learning and growth. The comparison of job and task rotation showed that there was indeed a stronger correlation between learning and job rotation. This finding can be regarded as a first confirmation that the work design growth model is an appropriate explanation for the relationship between rotation and learning and development.

Based on the integrative model of psychologically healthy workplaces of Kelloway and Day (2005), we had assumed that rotation improved psychological health because it reduces negative demands and stressors and promotes organizational resources. We had expected that task rotation would be more suitable than job rotation to provide resources, such as variety and opportunity for skill use, and reduce demands, such as an imbalanced workload. The results, however, indicated slightly stronger relationships between job rotation and psychological health. One explanation could be that in some cases, task rotation could be perceived as stressful because the workflow is interrupted. Fletcher et al. (2018) found, for instance, a positive relationship between workflow interruptions and psychological stress reactions.

Drawing on a model by Westgaard and Winkel (1996), we had expected a beneficial effect of rotation on physical health because rotation between activities that stress different body regions provides opportunities to recover. However, previous literature reviews (e.g. Leider et al., 2015; Padula et al., 2017) had found only weak or ambiguous relationships between rotation and physical health. Our results provide an explanation for these results: There is only a beneficial health effect of rotation when it is compared to high-intensity work. Thus, the model by Westgaard and Winkel (1996) is a fitting explanation for the relationship between rotation and physical health, as long as the rotation introduces more light-intensity work.

Lastly, based on resource-based theory (Barney, 1991; Barney et al., 2011), we expected rotation to be associated with organizational performance because it promotes workforce flexibility and organizational learning. Analogously to our expectations regarding learning and development, we believed that job rotation would yield stronger effects than task rotation. The results supported this assumption and therefore give a first indication that the resource-based theory provides a suitable explanation for the relationship between rotation and organizational performance.

11.2 Practical Implications

The prevailing view of job and task rotation is that they provide a variety of advantages for organizations and employees. More than half of U.S. organizations practice job rotation (Cranet, 2017) and many textbooks recommend rotation as a work design technique. The results from this meta-analysis give reason to reconsider the unrestricted recommendation of rotation. First, although the relationships between rotation and its outcomes were positive on average, many correlations were nonsignificant and small. Thus, organizations planning to implement rotation should be aware that the intervention might not improve the targeted outcomes very much. On the basis of the existing primary studies, organizations can only expect great associations between rotation and job satisfaction, career success, labor flexibility, and general psychological health.

Second, depending on the desired outcome, organizations should also bear in mind that the concrete design of the rotation can potentially influence the relationship between rotation and its outcomes. More specifically, the results of our meta-analysis indicate that task rotation seems to be more suitable than job rotation when the desired outcomes are improved employee attitudes. Job rotation, however, should be preferred when the goal is an increase in employee learning and development, improved psychological health, or an increase in organizational performance. In addition,

practitioners should carefully analyze future primary studies to determine whether they report on job or task rotation so that they can draw correct conclusions from these studies.

Third, with regard to physical health and organizational performance, organizations should be aware that subjectively measured outcomes were more strongly related to rotation. This is critical because the actual, objectively measurable benefit is highly relevant for these outcomes. It is probably a waste of resources to adopt a work design method that only improves the perceived innovativeness, individual performance, or physical workload. In comparison to that, the perceived stress or satisfaction in a workplace are measures where the subjective assessment might provide appropriate information.

11.3 Limitations and Directions for Future Research

We believe that our meta-analysis provides important insights into the effects of job and task rotation. However, there are also some limitations. To begin with, the relatively small number of studies for some of the analyses prevents us from drawing wide generalizations. However, compared with alternative techniques of study aggregation (e.g., vote counting or narrative reviews), which are usually dependent on subjective and sometimes untransparent decisions, the meta-analytic integration of studies provides the advantage of a quantification of the average effect. Valentine et al. (2010) therefore came to the conclusion that a meta-analysis already provides added value when it is based on as few as two studies. Furthermore, by using a three-level meta-analysis, we included as much information as possible from each primary study.

A further limitation is that we could include only a relatively small number of unpublished primary studies. This is problematic because the results from the included studies might differ from the results of the overall research that has potentially been done on the effects of job and task rotation. The reason for a possible difference lies in publication bias, which describes the tendency that significant results and results that support the authors' hypotheses are more likely to be published (Rothstein et al., 2005). Thus, the averaged effect sizes reported in this meta-analysis might have been lower if we would have been able to include more unpublished data. On the other hand, a meta-meta-analysis of 83 meta-analyses published in *Psychological Bulletin* has found only weak evidence for publication bias and an overestimation of effect sizes in psychological meta-analyses (van Aert et al., 2019).

Additionally, most included primary studies had a cross-sectional, correlational design. This could be regarded as a limitation because these studies do not allow for conclusions to be drawn about causality. To find out more about the direction of the effect and to rule out alternative explanations, we recommend that further research with (quasi-) experimental designs be carried out.

Another limitation was that our moderator analyses were limited by the information provided in the primary studies. This meant that there were some moderators that we could not investigate. For instance, we were interested in whether the perceived similarity of tasks or jobs would moderate the relationships between rotation and beneficial outcomes. We believed that a greater similarity would weaken the relationships because it would result in less variety, provide less diverse stimuli from the work environment, could be perceived as more repetitive, and might not leave enough opportunity for muscle recovery.

Another group of moderators that might further explain heterogeneity can be derived from self-determination theory (Deci et al., 2017). The theory claims that every individual has basic human needs (i.e., the needs for autonomy, competence, and relatedness), which, when satisfied, result in internal motivation and consequently lead to psychological well-being and enhanced performance

(Deci et al., 2017). The design of job and task rotation might satisfy these needs in some cases more than in others. One could, for instance, assume that having a say during the implementation of rotation strengthens its relationship with employee-related outcomes because this would satisfy the need for autonomy. In general, greater work autonomy is associated with more positive attitudes, greater job performance, and reduced stress and burnout (Humphrey et al., 2007). In order for job and task rotation to satisfy the need for competence, it might be necessary for the rotation to involve activities that require a diverse set of skills. Lastly, it might be possible that the rotation between workstations with varying colleagues is more beneficial than a rotation with limited potential for interaction because the latter alternative does not satisfy the need for relatedness. Studies that investigated job rotation between different functions in an organization found, for example, that the rotation was associated with more interdepartmental communication and cross-functional activities (Hauptman and Hirji, 1999).

11.4 Conclusion

Job and task rotation have been a research topic in several disciplines for many years. This meta-analysis is the first to provide a quantitative estimate of the relationships between these work design methods and their expected outcomes, point to moderating factors, and clarify the differences between job rotation and task rotation. Our results showed that rotation was generally positively related to a variety of outcomes. However, many relationships were only small and nonsignificant. Positive relationships between rotation and physical health could only be found when rotation was compared to high-intensity work. A comparison of job and task rotation revealed that task rotation yielded stronger relationships with attitudinal outcomes, whereas job rotation had stronger relationships with development, psychological health, and organizational performance outcomes. Individualism led to weaker relationships between task rotation and attitudes, and relationships between rotation and physical health as well as organizational performance were stronger for subjective outcome measures. In conclusion, this meta-analysis enriches our understanding of job and task rotation because we showed that these two methods should not be confused, and that many expectations towards rotation cannot yet be empirically supported.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

LM and GM contributed to conception and design of the meta-analysis. LM conducted the literature search, coding of studies, and performed statistical analyses. LM wrote the manuscript. LM and GM contributed to manuscript revision, read, and approved the submitted version.

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Data Availability Statement

The datasets generated for this study can be found in Open Science Framework: https://osf.io/xtrkn/.

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Figure 1. Flow Chart With Reasons for Article Exclusions

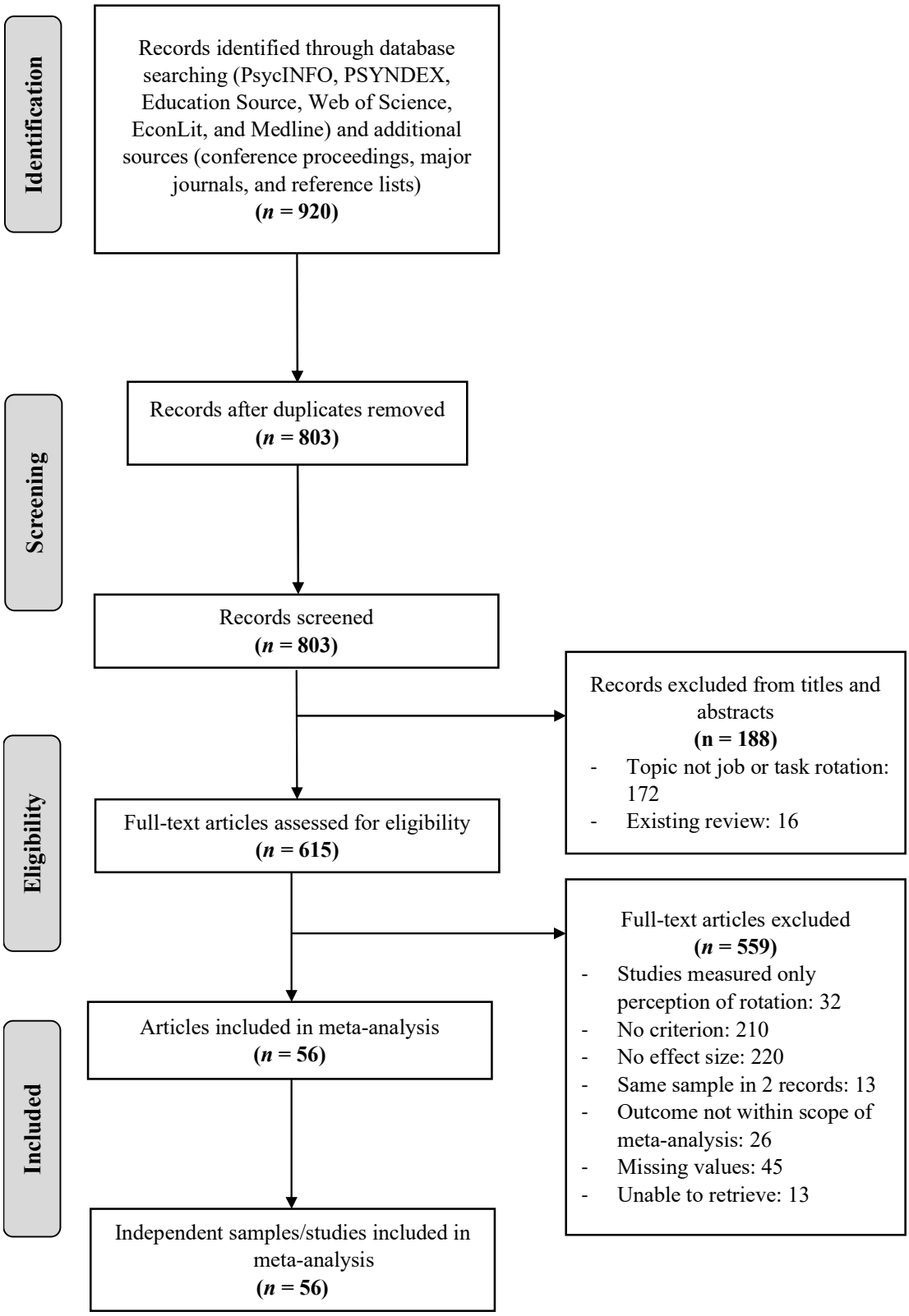

Table 1. Relationships Between Job and Task Rotation and Outcomes

Outcomes	*k*	n_{es}	Estimate	*SE*	CI 95% LL	CI 95% UL	*Z*	*p*	R^2
Attitudes									
Job satisfaction	8	21	.27	.05	.17	.37	5.39	< .001	
Work motivation	6	6	.12	.08	–.04	.28	1.44	.15	
Job involvement	6	6	.10	.08	–.05	.26	1.28	.20	
Organizational commitment	7	8	.16	.07	.03	.29	2.36	.02	
Learning & development									
Competence development	4	7	.13	.08	–.02	.30	1.63	.10	
Career success	3	5	.31	.10	.11	.51	3.07	.002	
Labor flexibility	3	4	.32	.11	.10	.55	2.85	.004	
Psychological health									
General psychological health	5	7	.20	.08	.05	.36	2.55	.01	
Stress and burnout[a]	10	17	.13	.06	.02	.24	2.35	.02	
Physical health									
General physical health	6	8	.12	.07	–.02	.26	1.63	.10	
Musculoskeletal complaints[a]	12	72	.08	.04	–.00	.17	1.91	.06	
Physical workload[a]	6	27	.13	.07	–.00	.26	1.95	.05	
Organizational performance									
Individual performance	10	18	.13	.06	.02	.24	2.31	.02	
Productivity	3	24	.13	.06	.03	.24	2.41	.02	
Speed of product development	3	3	.17	.13	–.09	.42	1.30	.19	
Innovativeness	5	8	.12	.09	–.06	.30	1.58	.11	
Financial performance	6	7	.13	.08	–.03	.30	1.58	.11	
Turnover (intention)[a]	5	5	.12	.09	–.06	.29	1.28	.20	
$\tau^2_{(Level\ 2)}$			.02	.00	.02	.03	7.39	< .001	.16
$\tau^2_{(Level\ 3)}$			.03	.01	.01	.04	3.42	< .001	.00

Note. *k* = number of independent samples; n_{es} = number of effect sizes; CI = confidence interval; LL = lower level; UL = upper level; Z = Wald approximation; R^2 = estimated heterogeneity at Level 2 and Level 3 that is explained by the outcomes; $\tau^2_{(Level\ 2)}$ = heterogeneity of effect sizes within studies; $\tau^2_{(Level\ 3)}$ = heterogeneity of effect sizes between studies.

[a]Reverse-coded; high values indicate low levels of stress and burnout, musculoskeletal complaints, physical workload, or turnover (intention)

Table 2. Relationships Between Job and Task Rotation and Physical Health Outcomes Subdivided According to Work Intensity of Reference Group

Subsample: rotation vs. low work intensity									
					CI 95%				
Outcomes	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Musculoskeletal complaints	3	10	.16	.09	–.01	.33	1.86	.06	
Physical workload	3	6	.20	.11	–.01	.41	1.84	.07	
$\tau^2_{(Level\ 2)}$			.03	.02	–.01	.07	1.35	.18	.02
$\tau^2_{(Level\ 3)}$			.00	.02	–.05	.05	0	1.00	.00
Subsample: rotation vs. high work intensity									
					CI 95%				
Outcomes	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Musculoskeletal complaints	3	10	–.38	.13	–.63	–.13	–3.01	.003	
Physical workload	3	6	–.32	.12	–.56	–.08	–2.57	.01	
$\tau^2_{(Level\ 2)}$			.02	.01	–.00	.05	1.74	.08	.12
$\tau^2_{(Level\ 3)}$			.05	.04	–.03	.12	1.22	.22	.28

Note. *k* = number of independent samples; n_{es} = number of effect sizes; CI = confidence interval; LL = lower level; UL = upper level; Z = Wald approximation; R^2 = estimated heterogeneity at Level 2 and Level 3 that is explained by the outcomes; $\tau^2_{(Level\ 2)}$ = heterogeneity of effect sizes within studies; $\tau^2_{(Level\ 3)}$ = heterogeneity of effect sizes between studies.

Table 3. Results of Moderated Meta-Analysis that Compares Job Rotation with Task Rotation for Different Outcome Categories

Subsample: attitudes									
					CI 95%				
Intervention	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Job rotation	4	7	–.00	.07	–.15	.14	–0.04	.97	
Task rotation	9	24	.10	.05	.01	.20	2.19	.03	
$\tau^2_{(Level\ 2)}$			.01	.00	.00	.02	2.26	.02	.02
$\tau^2_{(Level\ 3)}$			.01	.01	–.00	.03	1.66	.10	.12
Subsample: learning and development									
					CI 95%				
Intervention	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Job rotation	4	11	.21	.13	–.04	.45	1.65	.10	
Task rotation	4	4	.09	.13	–.16	.34	0.71	.48	
$\tau^2_{(Level\ 2)}$			.01	.01	–.00	.02	1.27	.20	.00
$\tau^2_{(Level\ 3)}$			.05	.03	–.02	.12	1.51	.13	.10
Subsample: psychological health									
					CI 95%				
Intervention	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Job rotation	4	9	.20	.07	.06	.33	2.82	.005	
Task rotation	7	12	.14	.06	.03	.25	2.57	.01	
$\tau^2_{(Level\ 2)}$			.00	–	–	–	–	–	.00
$\tau^2_{(Level\ 3)}$			.02	.01	–.00	.03	1.89	.06	.07
Subsample: organizational performance									
					CI 95%				
Intervention	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Job rotation	15	19	.12	.04	.04	.19	3.08	.002	
Task rotation	8	35	.03	.03	–.02	.09	1.13	.26	
$\tau^2_{(Level\ 2)}$			.02	.01	.01	.04	4.29	< .001	.06
$\tau^2_{(Level\ 3)}$			.00	–	–	–	–	–	.00

Note. *k* = number of independent samples; n_{es} = number of effect sizes; CI = confidence interval; LL = lower level; UL = upper level; Z = Wald approximation; R^2 = estimated heterogeneity at Level 2 and Level 3 that is explained by the intervention; $\tau^2_{(Level\ 2)}$ = heterogeneity of effect sizes within studies; $\tau^2_{(Level\ 3)}$ = heterogeneity of effect sizes between studies.

Table 4. Results of Moderated Meta-Analysis That Compares Subjective With Objective Outcome Measures for Different Outcome Categories

Subsample: physical health									
					CI 95%				
Measure	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Subjective	13	41	.21	.06	.09	.32	3.53	< .001	
Objective	11	50	.07	.06	–.05	.19	1.19	.23	
$\tau^2_{(Level\ 2)}$			.02	.00	.01	.03	4.84	< .001	.17
$\tau^2_{(Level\ 3)}$			.04	.02	.01	.07	2.39	.02	.00
Subsample: organizational performance									
					CI 95%				
Measure	*k*	n_{es}	Estimate	*SE*	LL	UL	*Z*	*p*	R^2
Subjective	20	34	.18	.03	.12	.25	5.50	< .001	
Objective	11	31	.01	.03	–.07	.06	–0.15	.88	
$\tau^2_{(Level\ 2)}$			.02	.01	.01	.03	3.75	< .001	.29
$\tau^2_{(Level\ 3)}$			.00	.00	–.01	.01	0.55	.58	.16

Note. *k* = number of independent samples; n_{es} = number of effect sizes; CI = confidence interval; LL = lower level; UL = upper level; Z = Wald approximation; R^2 = estimated heterogeneity at Level 2 and Level 3 that is explained by the measurement type; $\tau^2_{(Level\ 2)}$ = heterogeneity of effect sizes within studies; $\tau^2_{(Level\ 3)}$ = heterogeneity of effect sizes between studies.

New work situations call for familiar work design methods: Effects and mediating mechanisms of task rotation in a technology-supported workplace

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Abstract

As some assistive technologies threaten to make jobs increasingly monotonous, task rotation—believed to counteract monotonous jobs—may be an appropriate technology feature. It is uncertain whether task rotation has unique positive effects, why it works, and whether there are any boundary conditions. Drawing on the job characteristics model and self-determination theory, we examined perceived task variety, skill variety, and task identity, and expected satisfaction of the need for competence as mediators of the effect of task rotation on anticipated employee attitudes (job satisfaction, intrinsic work motivation), behavior (subjective performance), and well-being (positive and negative affect). To investigate the boundary conditions of task rotation effects, we drew on person-job fit theory and investigated openness to experience as a moderator of the effects of task and skill variety on the outcomes. Research on the joint optimization of technology and work design, which sociomateriality and the sociotechnical systems approach demand, is confronted with the challenge that workplaces with digital assistance currently mainly exist in laboratories. Thus, we conducted two experimental vignette studies (N_1 = 135, N_2 = 159) about a job where a digital assistance system either indicated the task rotation or only supported work steps. Regression analyses showed direct effects of task rotation on expected job satisfaction and positive affect; in one study each we found direct effects of task rotation on expected intrinsic motivation and subjective performance. There were indirect effects of task rotation on all outcomes except expected negative affect; the indirect effect of task rotation on expected motivation could only be found in one study. Openness to experience did not moderate the effects of task and skill variety on the outcomes. The results support the relevance

of task rotation as a technology feature and indicate that rotations should offer skill variety and task identity.

Introduction

The currently increasing adoption of advanced technologies in the workplace affects the way work is designed and how employees experience their work [1–3]. Depending on the concrete technology and its features, there are various possibilities. A basic distinction can be made between technologies that substitute for workers and others that complement workers in performing specific tasks [4]. An example for the substitution of work are industrial welding robots, which perform monotonous and dangerous tasks previously done by employees (e.g., [5]). The adoption of these technologies can provide relief for the employees, allows them to perform more meaningful tasks, and reduces human errors. Technologies that complement employees are, for example, digital assistance systems. These provide situational support in accordance with work progress, so employees need less knowledge on processes [6]. The adoption of these technologies reduces the need for initial training but can make the job more monotonous because the employee only needs to perform the indicated tasks. In this latter case, which is the focus of the present study, researchers and practitioners are faced with the challenge of designing workplaces where technologies promote, rather than threaten, motivating and fulfilling work [1]. Hackman and Oldham [7], and later also Morgeson and colleagues [8,9], illustrate in their work design models that key outcomes of fulfilling work are positive employee attitudes (e.g., job satisfaction, internal work motivation), improved behavior (e.g., performance), developed cognitions (e.g., learning), and enhanced well-being (e.g., affect). Thus, the question arises how good work design can be considered in technology design to avoid monotonous, unfulfilling jobs.

The combined consideration of technology and its social context is the central tenet of both sociomateriality and sociotechnical systems theory [10–12]. While sociomateriality

stems from the field of management information systems, and sociotechnical systems theory originates from the field of work design, both theories are closely related in that they argue that studying technology without its context—or vice versa—results in an incomplete view [13,14]. In a recent review of technology integration in organizational psychology and organizational behavior (OP/OB), Landers and Marin [15] discuss strategies how OP/OB researchers currently consider technology in their studies and evaluate the usefulness of each approach. They conclude that the most future-proof approach is to consider technologies in terms of their specific features and design characteristics (e.g., pedestrian detection in autonomous cars), as opposed to investigating a certain technology as a whole and comparing it with control groups without the technology (e.g., autonomous driving vs. human-controlled driving). The authors argue that the latter approach would produce outdated knowledge as soon as the technology receives an update because the effects found in a previous study might have been caused by a feature that no longer exists after the update.

When considering digital assistance systems, and their risk of creating simpler and more monotonous work, there is a classic work design method that could be adopted to reduce these risks: task rotation. Task rotation is a work design technique in which employees shift periodically and in a planned manner between a range of tasks in their workplace [16]. It makes jobs richer in variety, and previous studies found that it was positively associated with a range of positive outcomes, such as job satisfaction, work motivation, performance, and psychological health [16–19]. Such effects have, however, not yet been studied in the context of digital assistance systems. Additionally, there are further open questions about task rotation that existing studies have not answered: To better design and investigate task rotation interventions, practitioners and researchers need to know whether existing findings can actually be attributed to unique effects of task rotation, why task rotation works, and whether there are circumstances that might enhance or decrease its effect. As technologies that plan a

rotation are, to our knowledge, not yet widely used in organizations, our aim in the present study was to investigate the technology feature task rotation and the corresponding expectations and perceptions individuals have regarding task rotation in a prospective job.

The first question is whether task rotation has a unique effect on the expected work design outcomes of job satisfaction, intrinsic work motivation, subjective performance, and affect. To answer this, studies would need to have an experimental or quasi-experimental design. However, the majority of (quasi-)experimental studies have investigated the effects of task rotation on ergonomic factors and physical health (for a literature review see, e.g., [20]). To our knowledge, there are only three studies that have analyzed psychological outcomes of task rotation in a (quasi-)experiment [16,21,22], and two of those focused on the more general outcome psychological quality of life. It is important to investigate the unique effects of task rotation because results from correlative studies might only be the result of other unknown or uncontrolled variables. For example, companies that adopt task rotation could also be more likely to allow flexible working hours. Thus, task rotation and flexible working hours might be confounded.

The second question is why task rotation is effective. So far, studies that investigated task rotation have rarely based their assumptions on psychological theories. Some have pointed to the job characteristics model (JCM) [23,24] or the job demands-control model [25] as theoretical explanations for the workings of task rotation, but most deduced their hypotheses only from prior evidence or management approaches, such as the concept of high-performance work systems (e.g., [26,27]). The JCM is “the most influential model of work design” [28] (p. 407), but regarding task rotation, no study has tested whether the perception of certain work characteristics mediates the effects of task rotation on employee-related outcomes. This is problematic because there could also be other explanations for the

beneficial effects of task rotation, such as that it improves physical health, which in turn benefits employee motivation and performance.

The third question is whether task rotation is universally effective or whether there are individual differences that might decrease its effects on the employees. Based on person-job fit theory [29], one could expect that differences in personality characteristics could alter the effects of work design. The theory proposes that compatibility between an employee's needs, desires, or preferences and their job results in more positive job attitudes and behavior, such as job satisfaction and performance [30]. Studies found, for example, that self-competence affected the relationship between job enlargement and job crafting [31], and proactive personality altered the associations between high-performance work systems, such as flexible job design, and, for instance, task performance [32]. Regarding task rotation, we expected that employees with higher openness to experience might perceive rotation as more beneficial. Jobs with task rotation are characterized by changing work environments, diverse tasks, and a certain level of uncertainty, and thus match the preference for variety, a need for change, and an aversion to routines that people with high openness have [33]. We therefore investigated whether openness to experience had an influence on the effects of work characteristics that are related to task rotation on expected employee attitudes, behavior, and well-being.

In this manuscript, we contribute to the understanding of task rotation as a technological feature by investigating answers to these pressing questions through two consecutive studies. We employed experimental vignettes as a means to investigate participants' perceptions of work characteristics and expectations of their reactions in terms of attitudes, behavior, and affect. The vignette methodology was suitable because we wanted to gain insights on how people evaluate prospective work design. In our first study, we investigated four mediators of the effects of task rotation on psychological outcomes. By

analyzing all possible mediators simultaneously, we sought to identify the strongest mediator. Additionally, as we conducted an experiment, we were able to analyze the unique effects of task rotation. The aim of our second study was two-fold. First, we added the moderator openness to experience and analyzed whether it might influence the effects of perceived work characteristics. Second, we wanted to test the reproducibility of the findings of the first study to ensure that they were not only due to chance. As Kepes and McDaniel [34] pointed out, exact replications are one way to be more confident about the effects found in a study. Both studies had sample sizes that were large enough to detect significant medium-sized main effects.

Task rotation as a technology feature

In modern workplaces, work design is increasingly intertwined with the adoption of advanced technologies. Current technological advancements allow organizations to integrate intelligent systems that can collect and process information about their environment via sensors and thus react in real-time to problems and requests [35]. Digital assistance systems are one class of such technologies and include, for example, augmented reality glasses or workspace-integrated displays that instruct employees how to perform each step of a task [36,37]. The key feature of digital assistance systems is that they provide the worker with relevant information in a given situation. This information may include, for example, step-by-step instructions or remarks on special cases [6]. This makes digital assistance systems especially useful for workplaces where employees need to be able to perform the necessary work steps quickly.

Engineers who design technological systems primarily aim to ensure productivity, workplace safety, or the reduction of human errors [38,39], and rarely consider the psychological criteria of work design. In the long term, workplaces with digital assistance systems might therefore be perceived as simple and undemanding because employees no

longer need the knowledge and/or skills that were necessary to perform the job without assistance. Such unchallenging jobs can result in a decrease in job satisfaction and performance, among other things [40]. Task rotation could be an adequate means to increase the variety in such repetitive jobs and thus counteract possible negative effects. The technological possibilities even allow task rotation to be integrated as a feature in digital assistance systems so that the system plans and indicates the rotation cycles. There is much research on creating algorithms for task rotation scheduling that aim at reducing monotony and boredom during task rotation (e.g., [41,42]).

Several studies have investigated job and task rotation (job rotation describes the rotation between whole jobs instead of tasks) and their effects on employees as well as organizations. In jobs with task rotation, employees were more satisfied with their job and had greater work motivation (e.g., [17,19]). Rotation was also associated with greater job involvement, organizational commitment, [18,24] and well-being [18,24,43]. There are also organizational benefits. When employees switched between different workstations, they were more flexible [44], which means that they could be assigned spontaneously to jobs with a temporary high workload to prevent downtime. This could also be the reason why task rotation was also associated with greater labor productivity [45]. It thus appears that both the employees and the organization benefit from task rotation. What these studies have in common, however, is that the rotation was planned by a supervisor or the employees themselves. Task rotation has not yet been investigated in a workplace where a technology is used to plan the rotations, although it is a likely work situation in the near future [46]. There might be differences because technology could increase the feeling of being monitored, or because technology might plan the rotations based on criteria different from that a supervisor would use, among other things. On the other hand, it is possible that the person or algorithm planning the rotation does not play a central role, and that rotation is always perceived better

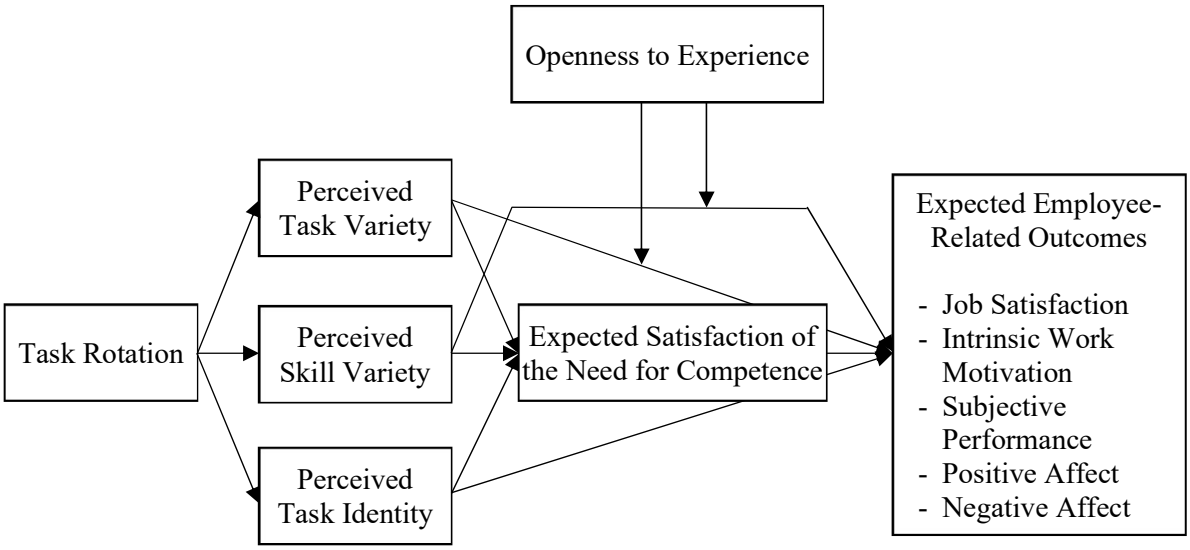
than no rotation. Thus, before examining any of the underlying mechanisms of task rotation, we examined whether the effects from previous, mainly correlative, studies could also be expected in a technology-supported workplace and in an experimental setting.

Hypothesis 1: Task rotation has a positive effect on expected (a) job satisfaction, (b) intrinsic work motivation, (c) subjective performance, and (d) positive affect, as well as a negative effect on expected (e) negative affect.

Mediating mechanisms of task rotation effects

Although the outcomes of task rotation have been investigated in various studies, there is still great uncertainty on the question of why task rotation might have beneficial effects. One explanation could be that rotation between different tasks improves the employees' physical health because the tasks stress different body regions and thus leave time for recovery [47]. Studies found that musculoskeletal complaints were associated with a range of employee responses, such as job satisfaction [48] and work motivation [49]. Another reason why task rotation might affect employee attitudes, behavior, or affect is that it could be perceived as a reward or a privilege, comparable to flexible working hours. When given free choice, the vast majority of employees in a study by Jeon, Jeong, and Jeong [17] preferred some type of task rotation to no rotation. Another explanation, which we focus on in this manuscript, is that task rotation has an impact on employee responses because it enhances certain work characteristics that satisfy basic human needs. In the following, we derive the assumption that the effects of task rotation on anticipated employee-related outcomes are mediated by the parallel mediators perceived task variety, skill variety, and task identity, and the serial mediator expected satisfaction of the need for competence. The conceptual model is displayed in Fig 1.

Fig 1. Conceptual model of the investigated effects.



Openness to experience was only investigated in Study 2.

Task variety, skill variety, and task identity as mediators

We first drew on the JCM by Hackman and Oldham [7] to explain why task rotation would have positive anticipated effects on employees. The model posits that there are five work characteristics that contribute to employee motivation: skill variety, task identity, task significance, autonomy, and feedback. Morgeson and Humphrey [8] identified further factors and extended the JCM into a work design framework with task, knowledge, social, and contextual characteristics. In their meta-analysis, Humphrey, Nahrgang, and Morgeson [40] found evidence supporting the extended framework and also reported effects on other employee-related outcomes besides motivation, such as performance, stress, and job satisfaction.

More recently, Parker, van den Broeck, and Holman [50] have reviewed possible antecedents of work design and stated that one of them were human resource practices, such as task rotation. A job where the employee alternates between different tasks does not necessarily provide all work characteristics. Compared to a job without task rotation,

however, it offers a greater variety of tasks (i.e., task variety), possibly requires more diverse skills (i.e., skill variety), and is more likely to consist of tasks that make up a complete work process (i.e., task identity).

Task variety refers to the extent to which a job requires the employee to perform a diverse set of tasks. It is one of the characteristics that were not part of the original JCM but were added by Morgeson and Humphrey [8]. They argued that it is conceptually different from skill variety because it indicates the performance of multiple tasks as opposed to the use of multiple skills. Task rotation should increase the perceived task variety because the main aim of task rotation interventions is to increase the number of different tasks for the employee (e.g., [51,52]). Task rotation can thus be distinguished from interventions where employees perform a single task that is merely interrupted by rest breaks [53]. Greater task variety is in turn associated with positive employee-related outcomes. Meta-analytic correlates of task variety included, for example, job satisfaction and subjective job performance [40]. When the cited meta-analysis was conducted, there was only limited empirical research analyzing the impact of task variety on other work design outcomes. More recent studies found, for example, significant positive relationships between task variety and vigor (i.e., willingness to invest effort and persist when facing challenges) and dedication (i.e., a strong identification with one's job) [54], and a significant negative relationship between task variety and emotional exhaustion [55].

Skill variety reflects the degree to which an individual needs to use a multitude of skills to perform a job successfully [7]. It can be assumed that task rotation affects the perceived skill variety in a job because a job with multiple tasks is likely to require more different skills than a job with only one task. For instance, in the study by Kuijer, van der Beek, van Dieen, Visser, and Frings-Dresen [52], the employees at a refuse collecting department rotated between truck driving and refuse collecting. One task required the

269 employees to know how to drive a heavy vehicle, the other required knowledge about
270 recyclable materials and the skill of using the lifting mechanism of the refuse truck. It is
271 theorized that jobs that require a variety of skills are perceived as more challenging, which
272 increases the experienced meaningfulness of the job and engages employees [7]. Meta-
273 analytic results showed positive associations between skill variety and job involvement,
274 internal work motivation, and job satisfaction [40].

275 Lastly, *task identity* describes the extent to which an employee is required to perform
276 a whole work process from start to finish with a visible outcome [7]. In most cases, jobs with
277 task rotation should be perceived as more complete compared to jobs with a single task. For
278 instance, in the study by Balogh, Ohlsson, Nordander, Bjork, and Hansson [56], task rotation
279 meant that employees alternated between several tasks in a supermarket (retrieving goods
280 from the storeroom, stocking shelves, attending to customers at the counter, doing cashier
281 work). They were thus able to experience all services necessary for a supermarket to serve its
282 customers. According to the JCM, the possibility to complete a work process from start to
283 finish elicits pride in employees, which then serves as a motivator [7]. Meta-analytic
284 evidence found positive correlations between task identity and, for example, job satisfaction,
285 internal work motivation, subjective performance, and reduced stress [40].

286 Satisfaction of the need for competence as a mediator

287 The JCM states that the relationships between skill variety and task identity and
288 employee-related outcomes are mediated by experienced meaningfulness, (i.e., the degree to
289 which the employee feels that the job is important and has value; [7]). Humphrey et al. [40]
290 found partial support for this assumption in their meta-analysis: Experienced meaningfulness
291 mediated the relationships between the two work characteristics and job satisfaction and
292 internal work motivation, but only partially mediated the relationship with subjective
293 performance, and other outcomes could not be addressed at all due to a lack of primary

studies. It was thus reasonable to examine an alternative mechanism as a serial mediator that might explain the effects of task rotation, via perceived work characteristics, on anticipated employee-related outcomes.

Gagné and Panaccio [57] suggested integrating self-determination theory within the JCM using the satisfaction of basic human needs as mediators between work characteristics and motivation. Self-determination theory is a macro theory of human motivation. One tenet of the theory is that there are three basic psychological needs innate in every human being: the needs for autonomy, relatedness, and competence. The satisfaction of these needs is supposed to be the prerequisite for autonomous motivation, which means that an activity is done out of interest and enjoyment or because it is important to one's values [58].

Although self-determination theory states that all three needs should be satisfied, our focus was on the satisfaction of the need for competence. As de Gieter et al. [59] pointed out, depending on the research aim, it is legitimate to concentrate on only one or two of the basic needs. The need for competence is defined as the need to feel effective in one's actions and to experience opportunities where one's capacities can be exercised and expressed [60]. Thus, employees will likely feel more competent in an environment that provides opportunities to engage in challenging activities and that facilitates learning and skill development. Gagné and Panaccio [57] illustrated that the work characteristics task identity and variety, which we already identified as characteristics of task rotation, could contribute to feelings of competence. Task identity may result in an increased feeling of mastery of one's environment, while task and skill variety likely lead to the development of a broader skill set. As a conclusion, we assumed the following hypothesis.

Hypothesis 2: The effect of task rotation on expected (a) job satisfaction, (b) intrinsic work motivation, (c) subjective performance, (d) positive affect, and (e) negative

affect is mediated by the parallel mediators perceived task variety, skill variety, and task identity, and the serial mediator expected satisfaction of the need for competence.

Individual differences in work design effects

When implementing a work design intervention, such as task rotation, the goal is often that all employees benefit equally from the intervention to keep costs and effort to a minimum. However, past research has shown that the effects of work design differed depending on the employees' personalities and other individual differences (e.g., [31,61]). Thus, it is likely that there are also individual differences in the anticipated effects of task rotation.

An explanation for why an employee's personality could influence the effect of task rotation on expected employee responses is provided by person-job fit theory [29,62]. Person-job fit is defined as the match between an individual's characteristics and those of the job or tasks that are performed in a job [63]. A more specific form of person-job fit is needs-supplies fit, which occurs when an individual's needs or preferences (e.g., a need to feel related to others) are satisfied by the characteristics of a job (e.g., a great degree of teamwork; [64]). In their meta-analysis, Kristof-Brown, Zimmerman, and Johnson [62] found that a high needs-supplies fit is associated with, for example, greater job satisfaction and performance, and lower strain.

As explained above, we have assumed that a job with task rotation provides the supplies of task variety, skill variety, and task identity. The Big Five personality factor openness to experience [65] matches especially the supplies task variety and skill variety because individuals high on this factor are characterized by a preference for variety and novelty, an aversion to routines, a need for change, and an open mind. McCrae and Costa [66] state that personality factors are relatively stable, endogenous basic tendencies that shape an individual's thoughts, feelings, and behaviors. They claim that open individuals have an

active motivation to explore and discover the unfamiliar and have more flexible attitudes when confronted with ambiguity or dissonance [67,68]. A job with task rotation might provide an environment where open individuals can realize their personality—and consequently experience a great fit between personal needs and job supplies—because it offers a wide range of work activities that are not necessarily familiar in advance. De Jong, van der Velde, and Jansen [33] found, for example, that the relationship between skill variety and job satisfaction was stronger for individuals with higher openness to experience. Additionally, in a study by LePine, Colquitt, and Erez [69], openness to experience was a relevant trait in changing task contexts. They found that individuals with higher openness performed significantly better at a decision-making task after there was an unforeseen change in the rules compared to individuals low in openness.

In conclusion, we expected the perceived task variety and skill variety to have stronger effects on the anticipated employee-related outcomes for individuals high in openness to experience.

Hypothesis 3: The effect of perceived task variety on (a) job satisfaction, (b) intrinsic work motivation, (c) subjective performance, (d) positive affect, and (e) negative affect and the effect of perceived skill variety on (f) job satisfaction, (g) intrinsic work motivation, (h) subjective performance, (i) positive affect, and (j) negative affect is moderated by openness to experience. For individuals with higher openness to experience, the effect will be stronger.

Materials and methods

We tested our hypotheses in two consecutive studies. We used Study 1 to investigate the main effects and mediators. In Study 2, we added openness to experience as a potential moderator of the effects of task rotation on perceived work characteristics. The procedure for both studies was identical unless otherwise stated. The data that support the findings of this

study are openly available in Open Science Framework (OSF; https://doi.org/10.17605/OSF.IO/XVKUA).

Participants

We recruited participants via personal contacts, social media, and in Study 1 via SurveyCircle (a survey sharing platform) as well. Participants in Study 1 could take part in a raffle for two gift certificates of 20 euros each. The incentive for participants in Study 2 was that one euro per participant was donated to animal rescue organizations. Before being able to participate in the studies, the participants were informed about the content and duration of the study, that their participation was completely voluntary and that they could terminate their participation at any time, and that their answers would be anonymous. Participants could only continue with the actual studies after they had read this information and had given their consent. We did not obtain written consent because data were analyzed anonymously. Ethical approval for both studies was obtained from the university's ethics committee (IDs 2017-231 and 2019-189). There was a time lag of one year and four months between the data collections. An a priori power analysis revealed that we needed a minimum of 128 participants to find significant medium-sized (d = 0.5) main effects with a power of .80 and a significance level alpha of .05.

Although we described a concrete workplace in our vignettes (described in more detail in the Procedure section), our focus was on the investigation of expected effects of task rotation on employee-related outcomes. Thus, the concrete work setting was irrelevant for our research. We therefore decided to recruit a heterogenous sample so that we were able to draw more generalized conclusions about potential effects of task rotation. The description of a concrete workplace served the purpose of eliciting more similar imaginations within an experimental condition than, for instance, when describing a generic task rotation situation.

Discussions with six people from varying professional backgrounds before conducting the study ensured that participants could understand and imagine the described work situations.

A total of 177 participants in Study 1 and 199 participants in Study 2 completed the study. We excluded 42 participants in Study 1 and 40 participants in Study 2 because they either failed the manipulation check ("In the course of a working day, you conduct the same task the whole time. True or false?") or checked the wrong box for a control question ("Please check the box that says 'strongly agree'"). Therefore, our final sample consisted of 135 participants (n = 60 in the experimental condition, n = 75 in the control condition) in Study 1 and 159 participants (n = 77 in the experimental condition, n = 82 in the control condition) in Study 2. All participants were working a minimum of 17.5 hours per week. In Study 1, they had a mean age of 32.36 years (SD = 11.46; Min = 19; Max = 62), 84 were female and 51 were male. In Study 2, the mean age was 41.38 years (SD = 12.35; Min = 19; Max = 67), 70 were female, 86 male, and three participants did not indicate their gender. Participants were asked to indicate their job title and, where possible, we assigned the corresponding code from the international standard classification of occupations (ISCO; [70]; see Table 1).

Table 1. Occupations of participants.

Occupation	Participants in Study 1	Participants in Study 2
Managers	6.7%	10.1%
Professionals	52.6%	56.6%
Technicians and associate professionals	7.4%	14.5%
Clerical support workers	9.6%	3.1%
Services and sales workers	5.2%	0.6%
Craft and related trades workers	2.2%	2.5%
Elementary occupations	0.7%	–
Plant and machine operators and assemblers	–	0.6%
Missing, or ISCO code could not be assigned	15.6%	11.9%

Procedure

The study was administered online, and the manipulation consisted in a vignette that described an assembly workplace where the employee either rotated (experimental condition) or did not rotate (control condition) between work tasks. A vignette is a description of a fictional scenario, where certain characteristics can be manipulated and therefore experimentally investigated [71]. Compared to laboratory experiments and surveys in the field, experimental vignette studies have the major advantage that they enhance both the internal and external validity [71,72]: Internal validity is increased due to the experimental setting of the vignette, in which only the independent variables are manipulated and other environmental influences are controlled, while external validity is greater than in laboratory experiments because the vignettes describe scenarios that can happen in real life [71].

Experimental vignette studies are widely used in a range of research areas in applied psychology, including organizational justice (e.g., [73,74]), interpersonal relationships at work (e.g., [75,76]), or leadership (e.g., [77,78]). One might argue that vignettes are better suited for the investigation of hypothetical leaders, teams, or organizations, but there are also vignette studies in the field of work design research. Van den Tooren and de Jonge [79] examined, for example, hypothetical cognitively, emotionally, and physically demanding job situations and analyzed how relevant the matching job resources were perceived to be for regulating the demands. Zacher, Dirkers, Korek, and Hughes [80] created vignettes where certain work characteristics had varying degrees of intensity and examined how attractive these jobs were to the participants. Furthermore, there are several studies that examined the mediators and outcomes of the present study with the help of vignettes, more specifically work characteristics [80], satisfaction of basic needs at work [81], job satisfaction [82], intrinsic work motivation [83], positive and negative affect [84], and intended job performance [85].

The study had a two-factorial between-subjects design. Thus, at the beginning of the study, the participants were randomly assigned to one of two conditions. In Study 2, before the participants saw the vignette, they were asked to fill out the openness to experience questionnaire. In both studies, participants were then instructed to read the vignette thoroughly and imagine being the employee at the described workplace as best as they could. The vignettes in both experimental conditions described a workplace for a production mechanic responsible for the assembly of motors. The described work was supported by a digital assistance system that gave illustrated instructions for the necessary work steps. In the experimental condition, the vignette stated that the assistance system was also responsible for indicating a rotation between four tasks (cut material, assemble parts, check voltage, and analyze and fix errors), which occurred every two hours. In the control condition, the vignette text described that the assistance system was responsible for indicating an appropriate time for a break. Participants in the control condition were also told that they performed the same task throughout the whole day and that their colleagues were responsible for the other three tasks. The task in the control condition was one of the four tasks described above, and participants in the control condition were randomly assigned to the respective vignettes.

The described workplace is based on a workplace that has been developed as part of a technological research project (cf. [86]). The four described tasks are supposed to reflect an assembly cycle: Cutting material happens during the preparation, assembling parts is the actual production, checking voltage is the control phase, and analyzing and fixing errors happens during postprocessing. Except for cutting materials, all tasks exist in the actual assistance system. However, they are only short simulations of about two minutes per task. Additionally, the system did not have task rotation implemented yet, which was the focus of this study. We therefore decided against conducting a laboratory experiment using the actual

assistance system. Thus, we created the vignettes and discussed them with six people from varying professional backgrounds to ensure that they understood the scenario.

To increase immersion, we enriched the vignette text with a photo of an employee at the assistance system, as recommended by Aguinis and Bradley [71]. The vignette texts and photo can be found in the online supplementary material (S1 Vignette). To ensure that participants had read the vignettes thoroughly, they were then asked to answer multiple choice questions about the text. These were presented on the same page so that participants could reread the text. After reading the vignette, participants were asked to rate perceived work design characteristics, expected satisfaction of the need for competence, and several expected outcomes from the employee's perspective.

Measures

Except for openness to experience, all measures were prefaced by the instruction that all following questions referred to the situation that the participants were asked to imagine. They should answer all questions from this perspective, as if they were currently working in this workplace. Openness to experience was not prefaced by this instruction because participants should respond to the questions from their own perspective. It was also presented before showing the vignettes.

Openness to experience

We used the respective scale of the Big Five Inventory [87] (German version: [88]) to measure openness to experience. The scale consisted of 10 items assessed on a five-point Likert scale ranging from 1 (*does not apply at all*) to 5 (*applies very much*). A sample item is "I am someone who is original, comes up with new ideas" (Cronbach's $\alpha = .79$).

Work design characteristics

We assessed perceived task variety, skill variety, and task identity with the respective scales of the German version of the Work Design Questionnaire [8,89]. All scales consisted

of four items and were measured with a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A sample item for task variety is "The job involves a variety of tasks," (α = .95 in Study 1, .92 in Study 2); a sample item for skill variety is "The job requires the use of a number of skills," (α = .94 / .89); and an example for task identity is "The job provides me the chance to completely finish the pieces of work I begin" (α = .85 / .84).

Satisfaction of the need for competence

We used the German translation of the Work-Related Basic Need Satisfaction Scale [90,91] to assess how much the participants expected their need for competence to be satisfied in the described workplace. The subscale consisted of six items and was measured with a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). A sample item is "I feel competent at my job" (α = .78 / .71).

Job satisfaction

We measured the overall job satisfaction with a single-item measure from Neuberger and Allerbeck [92] that we adapted for this study. The adapted item is "When you think of everything that is important for your work (e.g., the work itself, working conditions), how satisfied would you be with your work as production mechanic overall?" Participants' ratings were based on a seven-point Kunin scale [93]. According to a meta-analysis by Wanous, Reichers, and Hudy [94], single-item measures of job satisfaction are highly correlated with scale measures of job satisfaction (r = .63).

Intrinsic work motivation

We used the subscale *intrinsic motivation* from the German version of the Multidimensional Work Motivation Scale to assess expected intrinsic work motivation [95]. It consists of three items and the ratings are based on a seven-point Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*). We adapted the stem of the scale as follows "Why

would you put effort into the job as production mechanic?" A sample item is "Because I have fun doing my job" (α = .95 in both studies).

Subjective performance

We measured the expected subjective performance in the described workplace with the self-constructed item "On a scale from 1 to 10, how high do you estimate your performance would be in the described job as a production mechanic based on your maximum performance capacity?" A 1 indicated low performance, a 10 referred to high performance. We indicated the maximum performance capacity as a reference value to ensure that ratings were comparable because it is less prone to intraindividual variations than typical performance [96].

Affect

We measured the expected emotions and sentiments in the described workplace with the German adaptation of the Positive and Negative Affect Schedule [97,98]. The instrument consists of two scales with 10 adjectives each, and participants rated on a Likert scale from 1 (*not at all*) to 5 (*completely*) the extent to which each adjective would apply to them in their job as production mechanic. A sample item is "active" for the positive affect scale (α = .93 / .90) and "upset" for the negative affect scale (α = .89 / .86).

Results

The zero-order correlations of study variables are depicted in Table 2. There were mostly significant correlations in the expected direction between mediators and outcome variables. The experimental manipulation (task rotation vs. no task rotation) was significantly related to perceived work characteristics, expected job satisfaction, expected intrinsic work motivation (only in Study 1), expected subjective performance (only in Study 2), and expected positive affect. There were no significant associations with the anticipated

533 satisfaction of the need for competence and negative affect. The descriptive statistics and
534 standardized mean differences of the experimental conditions are shown in Table 3.
535 Participants in the task rotation condition gave higher ratings for all variables except expected
536 negative affect, which was predicted. The effect sizes ranged from $d = 0.26$ to 1.53 in Study
537 1, which indicate medium to large effects [99]. In Study 2, effect sizes were mostly lower,
538 especially regarding the expected satisfaction of the need for competence ($d = -0.07$ vs. 0.27)
539 and negative affect ($d = -0.02$ vs. -0.26).

Table 2. Zero-order correlations of study variables.

Measure	1	2	3	4	5	6	7	8	9	10	11
1. Task rotation (0 = no rotation; 1 = rotation)	–	.04	.49***	.27**	.59***	–.04	.18*	.13	.17*	.17*	–.01
2. Openness to experience	–	–	.03	.09	.15	.17*	.03	.02	.06	.03	.08
3. Perceived task variety	.61**	–	–	.70***	.31***	.13	.35***	.28***	.33***	.39***	–.06
4. Perceived skill variety	.44**	–	.70**	–	.27**	.26**	.42***	.34***	.35***	.53***	–.24**
5. Perceived task identity	.50**	–	.48**	.49**	–	–.10	.26**	.09	.29***	.26**	–.14
6. Expected satisfaction of need for competence	.13	–	.20*	.35**	.33**	–	.28***	.14	.21**	.26**	–.25**
7. Expected job satisfaction	.19*	–	.47**	.61**	.37**	.36**	–	.37***	.53***	.69***	–.40***
8. Expected intrinsic work motivation	.21*	–	.41**	.51**	.36**	.35**	.53**	–	.25**	.46***	–.14
9. Expected subjective performance	.16	–	.34**	.50**	.30**	.34**	.58**	.48**	–	.50***	–.29***
10. Expected positive affect	.18*	–	.46**	.61**	.42**	.41**	.75**	.58**	.50**	–	–.41***
11. Expected negative affect	–.13	–	–.10	–.19*	–.16	–.44**	–.25**	–.32**	–.26**	–.22**	–

Correlations of Study 1 (N = 135) are presented below the diagonal, correlations of Study 2 (N = 159) are presented above the diagonal.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3. Means and standard deviations of study variables, and standardized mean differences between experimental conditions.

	Study 1					Study 2				
	Task rotation		No task rotation			Task rotation		No task rotation		
Measure	*M*	*SD*	*M*	*SD*	*d*	*M*	*SD*	*M*	*SD*	*d*
Openness to experience	–	–	–	–	–	3.74	0.62	3.70	0.54	0.07
Perceived task variety	2.89	1.12	1.48	0.72	1.53	2.30	0.92	1.36	0.76	1.12
Perceived skill variety	3.78	1.22	2.47	1.06	1.16	2.47	0.98	1.94	0.94	0.55
Perceived task identity	3.16	1.04	2.12	1.08	0.98	3.82	1.14	2.23	1.07	1.44
Expected satisfaction of need for competence	3.69	0.76	3.49	0.71	0.27	3.40	0.66	3.45	0.75	–0.07
Expected job satisfaction	3.65	1.45	3.04	1.61	0.40	3.23	1.52	2.74	1.17	0.36
Expected intrinsic work motivation	4.04	1.82	3.25	1.80	0.44	3.89	1.93	3.37	1.93	0.27
Expected subjective performance	5.75	2.08	5.00	2.62	0.31	5.31	2.23	4.59	2.00	0.34
Expected positive affect	2.41	0.82	2.11	0.80	0.37	2.24	0.79	1.99	0.63	0.35
Expected negative affect	1.50	0.66	1.67	0.65	–0.26	1.62	0.66	1.64	0.64	–0.02

Study 1: $n = 60$ in the task rotation condition, $n = 75$ in the no task rotation condition; Study 2: $n = 77$ in the task rotation condition, $n = 82$ in the no task rotation condition. d = standardized mean difference Cohen's d.

548 # Hypothesis testing

549 To test our hypotheses, we conducted regression analyses using the PROCESS macro
550 (version 3.0) for SPSS (version 23) by Hayes [100]. An overview of all hypotheses and
551 whether they were supported or rejected in our studies can be found in Table 4. In Hypothesis
552 1, we predicted that task rotation had a positive effect on various expected employee-related
553 outcomes. In Hypothesis 2, we stated that this main effect would be mediated by the parallel
554 mediators perceived task variety, skill variety, and task identity, and the serial mediator
555 expected satisfaction of the need for competence. To answer both hypotheses, we conducted
556 separate mediation analyses for each outcome. For each analysis, PROCESS generated 95%
557 percentile bootstrap confidence intervals (thus, the significance level alpha was set to .05)
558 using 5,000 bootstrap samples. The regression coefficients, standard errors, and model
559 summaries can be found in Table 5 (Study 1) and Table 6 (Study 2). To examine Hypothesis
560 1, we investigated the total effects in Table 7 (Study 1) and Table 8 (Study 2). In Study 1, we
561 found that task rotation had a significant positive effect on expected job satisfaction (b =
562 0.61, p = .02), intrinsic work motivation (b = 0.79, p = .01), and positive affect (b = 0.30, p =
563 .03). The effect of task rotation on expected subjective performance (b = 0.75, p = .07) and
564 negative affect (b = −0.17, p = .13) was not significant. In Study 2, we could replicate these
565 findings regarding expected job satisfaction (b = 0.49, p = .02), positive affect (b = 0.25, p =
566 .03), and negative affect (b = −0.01, p = .89), but the effect of task rotation on expected
567 intrinsic work motivation was no longer significant (b = 0.52, p = .09), and the previously
568 insignificant effect on expected subjective performance became significant (b = 0.73, p =
569 .03). In conclusion, we found support for Hypothesis 1a and 1d, and partial support for
570 Hypothesis 1b and 1c. In both studies, we could not find supporting evidence for Hypothesis
571 1e.
572

573 **Table 4. Overview of supported and rejected hypotheses.**

Hypothesis	Study 1	Study 2
H1a: Task rotation → expected job satisfaction	✓	✓
H1b: Task rotation → expected intrinsic work motivation	✓	ns
H1c: Task rotation → expected subjective performance	ns	✓
H1d: Task rotation → expected positive affect	✓	✓
H1e: Task rotation → expected negative affect	ns	ns
H2a: Perceived task variety, skill variety, and task identity, and the expected satisfaction of the need for competence mediate task rotation → expected job satisfaction	✓	✓
H2b: Perceived task variety, skill variety, and task identity, and the expected satisfaction of the need for competence mediate task rotation → expected intrinsic work motivation	✓	ns
H2c: Perceived task variety, skill variety, and task identity, and the expected satisfaction of the need for competence mediate task rotation → expected subjective performance	✓	✓
H2d: Perceived task variety, skill variety, and task identity, and the expected satisfaction of the need for competence mediate task rotation → expected positive affect	✓	✓
H2e: Perceived task variety, skill variety, and task identity, and the expected satisfaction of the need for competence mediate task rotation → expected negative affect	ns	ns
H3a: Perceived task variety → expected job satisfaction is moderated by openness to experience	—	ns
H3b: Perceived task variety → expected intrinsic work motivation is moderated by openness to experience	—	ns
H3c: Perceived task variety → expected subjective performance is moderated by openness to experience	—	ns
H3d: Perceived task variety → expected positive affect is moderated by openness to experience	—	ns
H3e: Perceived task variety → expected negative affect is moderated by openness to experience	—	ns
H3f: Perceived skill variety → expected job satisfaction is moderated by openness to experience	—	ns
H3g: Perceived skill variety → expected intrinsic work motivation is moderated by openness to experience	—	ns
H3h: Perceived skill variety → expected subjective performance is moderated by openness to experience	—	ns
H3i: Perceived skill variety → expected positive affect is moderated by openness to experience	—	ns
H3j: Perceived skill variety → expected negative affect is moderated by openness to experience	—	ns

574 ✓ indicate supported hypotheses, ns indicate rejected hypotheses.

Table 5. Regression coefficients, standard errors, and model summary for all outcomes in Study 1.

	(1) DV: Expected job satisfaction		(2) DV: Expected intrinsic work motivation		(3) DV: Expected subjective performance		(4) DV: Expected positive affect		(5) DV: Expected negative affect	
Predictor	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI
Constant	–0.07 (0.53)	[–1.13, 0.99]	–0.17 (0.69)	[–1.53, 1.19]	0.73 (0.91)	[–1.08, 2.54]	0.25 (0.27)	[–0.29, 0.79]	2.99 (0.26)	[2.47, 3.51]
Task rotation	–0.61 (0.28)	[–1.16, –0.06]	–0.39 (0.36)	[–1.10, 0.32]	–0.58 (0.48)	[–1.52, 0.36]	–0.36 (0.14)	[–0.65, –0.08]	–0.15 (0.14)	[–0.42, 0.12]
Perceived task variety	0.26 (0.14)	[–0.02, 0.54]	0.23 (0.19)	[–0.13, 0.60]	0.11 (0.25)	[–0.38, 0.60]	0.12 (0.07)	[–0.03, 0.26]	0.04 (0.07)	[–0.10, 0.18]
Perceived skill variety	0.60 (0.13)	[0.34, 0.86]	0.51 (0.17)	[0.17, 0.85]	0.85 (0.23)	[0.40, 1.30]	0.30 (0.07)	[0.17, 0.43]	–0.03 (0.07)	[–0.16, 0.10]
Perceived task identity	0.13 (0.10)	[–0.08, 0.33]	0.18 (0.13)	[–0.08, 0.44]	0.14 (0.17)	[–0.21, 0.48]	0.11 (0.05)	[0.01, 0.22]	0.02 (0.05)	[–0.08, 0.12]
Expected satisfaction of need for competence	0.32 (0.16)	[0.02, 0.63]	0.44 (0.20)	[0.05, 0.84]	0.56 (0.27)	[0.03, 1.09]	0.22 (0.08)	[0.06, 0.38]	–0.39 (0.08)	[–0.54, –0.23]
	R^2 = .42		R^2 = .31		R^2 = .29		R^2 = .45		R^2 = .20	
	$F(5,129) = 18.79$, $p < .001$		$F(5,129) = 11.52$, $p < .001$		$F(5,129) = 10.33$, $p < .001$		$F(5,129) = 21.29$, $p < .001$		$F(5,129) = 6.62$, $p < .001$	

N = 135. Unstandardized regression coefficients are reported. DV = dependent variable; CI = confidence interval.

Table 6. Regression coefficients, standard errors, and model summary for all outcomes in Study 2.

	(1) DV: Expected job satisfaction		(2) DV: Expected intrinsic work motivation		(3) DV: Expected subjective performance		(4) DV: Expected positive affect		(5) DV: Expected negative affect	
Predictor	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI
Constant	–0.10 (0.55)	[–1.18, 0.99]	1.71 (0.84)	[0.04, 3.37]	0.64 (0.89)	[–1.12, 2.39]	0.56 (0.28)	[0.01, 1.10]	2.70 (0.28)	[2.15, 3.25]
Task rotation	–0.17 (0.26)	[–0.69, 0.35]	0.17 (0.40)	[–0.63, 0.97]	–0.48 (0.43)	[–1.33, 0.36]	–0.09 (0.13)	[–0.36, 0.17]	0.10 (0.13)	[–0.16, 0.36]
Perceived task variety	0.17 (0.16)	[–0.14, 0.48]	0.16 (0.24)	[–0.32, 0.63]	0.43 (0.25)	[–0.07, 0.93]	0.04 (0.08)	[–0.12, 0.20]	0.12 (0.08)	[–0.03, 0.28]
Perceived skill variety	0.32 (0.14)	[0.04, 0.61]	0.52 (0.22)	[0.08, 0.95]	0.26 (0.23)	[–0.20, 0.72]	0.30 (0.07)	[0.16, 0.44]	–0.19 (0.07)	[–0.33, –0.04]
Perceived task identity	0.22 (0.09)	[0.05, 0.40]	–0.04 (0.14)	[–0.31, 0.23]	0.44 (0.15)	[0.15, 0.72]	0.10 (0.05)	[0.01, 0.19]	–0.09 (0.05)	[–0.18, –0.00]
Expected satisfaction of need for competence	0.43 (0.14)	[0.15, 0.71]	0.16 (0.22)	[–0.28, 0.59]	0.55 (0.23)	[0.09, 1.00]	0.17 (0.07)	[0.02, 0.31]	–0.19 (0.07)	[–0.34, –0.05]
	R^2 = .25		R^2 = .12		R^2 = .20		R^2 = .32		R^2 = .14	
	$F(5,153) = 10.09$, $p < .001$		$F(5,153) = 4.28$, $p = .001$		$F(5,129) = 7.76$, $p < .001$		$F(5,129) = 14.14$, $p < .001$		$F(5,129) = 4.82$, $p < .001$	

N = 159. Unstandardized regression coefficients are reported. DV = dependent variable; CI = confidence interval.

583 **Table 7. Total and indirect effects in Study 1.**

	(1) DV: Expected job satisfaction		(2) DV: Expected intrinsic work motivation		(3) DV: Expected subjective performance		(4) DV: Expected positive affect		(5) DV: Expected negative affect	
Effect	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI
Total effect	0.61 (0.27)	[0.08, 1.14]	0.79 (0.31)	[0.17, 1.41]	0.75 (0.41)	[–0.07, 1.57]	0.30 (0.14)	[0.02, 0.58]	–0.17 (0.11)	[–0.40, 0.05]
Total indirect effect	1.22 (0.24)	[0.76, 1.69]	1.18 (0.33)	[0.61, 1.88]	1.33 (0.37)	[0.60, 2.07]	0.67 (0.15)	[0.40, 0.99]	–0.03 (0.13)	[–0.30, 0.20]
TR → perceived task variety→ DV	0.37 (0.19)	[0.00, 0.77]	0.33 (0.32)	[–0.26, 1.00]	0.16 (0.32)	[–0.48, 0.80]	0.16 (0.11)	[–0.04, 0.41]	0.06 (0.10)	[–0.16, 0.24]
TR → perceived skill variety → DV	0.63 (0.18)	[0.29, 1.02]	0.53 (0.21)	[0.16, 0.96]	0.88 (0.28)	[0.37, 1.48]	0.31 (0.10)	[0.13, 0.53]	–0.03 (0.07)	[–0.16, 0.10]
TR → perceived task identity → DV	0.16 (0.13)	[–0.10, 0.42]	0.24 (0.21)	[–0.16, 0.67]	0.18 (0.21)	[–0.25, 0.60]	0.15 (0.07)	[0.02, 0.29]	0.02 (0.06)	[–0.11, 0.14]
TR → expected need satisfaction → DV	–0.03 (0.06)	[–0.17, 0.08]	–0.05 (0.08)	[–0.23, 0.11]	–0.06 (0.11)	[–0.30, 0.14]	–0.02 (0.04)	[–0.10, 0.05]	0.04 (0.07)	[–0.07, 0.20]
TR → perceived task variety → expected need satisfaction → DV	–0.04 (0.05)	[–0.15, 0.04]	–0.05 (0.06)	[–0.18, 0.07]	–0.06 (0.08)	[–0.24, 0.08]	–0.02 (0.03)	[–0.09, 0.03]	0.04 (0.05)	[–0.05, 0.13]
TR → perceived skill variety → expected need satisfaction → DV	0.07 (0.05)	[–0.01, 0.19]	0.10 (0.06)	[–0.01, 0.24]	0.12 (0.08)	[0.01, 0.30]	0.05 (0.03)	[0.01, 0.11]	–0.09 (0.04)	[–0.17, –0.02]
TR → perceived task identity → expected need satisfaction → DV	0.06 (0.04)	[–0.01, 0.16]	0.08 (0.06)	[–0.01, 0.21]	0.10 (0.07)	[0.00, 0.26]	0.04 (0.02)	[0.01, 0.09]	–0.07 (0.04)	[–0.17, –0.01]

584 *N* = 135. Unstandardized regression coefficients are reported. DV = dependent variable; CI = confidence intervals; TR = task rotation.

585 **Table 8. Total and indirect effects in Study 2.**

	(1) DV: Expected job satisfaction		(2) DV: Expected intrinsic work motivation		(3) DV: Expected subjective performance		(4) DV: Expected positive affect		(5) DV: Expected negative affect	
Effect	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI	*b* (*SE*)	95% CI
Total effect	0.49 (0.21)	[0.07, 0.91]	0.52 (0.31)	[−0.09, 1.12]	0.73 (0.34)	[0.06, 1.39]	0.25 (0.11)	[0.02, 0.47]	−0.01 (0.10)	[−0.22, 0.19]
Total indirect effect	0.66 (0.23)	[0.24, 1.14]	0.35 (0.30)	[−0.30, 0.66]	1.21 (0.32)	[0.60, 1.89]	0.34 (0.14)	[0.10, 0.63]	−0.11 (0.11)	[−0.33, 0.09]
TR → perceived task variety→ DV	0.16 (0.20)	[−0.16, 0.64]	0.15 (0.24)	[−0.30, 0.66]	0.40 (0.27)	[−0.09, 0.99]	0.04 (0.10)	[−0.13, 0.28]	0.12 (0.08)	[−0.06, 0.27]
TR → perceived skill variety → DV	0.17 (0.10)	[0.00, 0.39]	0.27 (0.15)	[0.04, 0.63]	0.14 (0.14)	[−0.13, 0.43]	0.16 (0.06)	[0.06, 0.29]	−0.10 (0.04)	[−0.20, −0.03]
TR → perceived task identity → DV	0.36 (0.14)	[0.09, 0.64]	−0.07 (0.23)	[−0.53, 0.36]	0.70 (0.24)	[0.23, 1.20]	0.16 (0.08)	[0.01, 0.31]	−0.14 (0.07)	[−0.29, −0.02]
TR → expected need satisfaction → DV	0.01 (0.07)	[−0.14, 0.14]	0.00 (0.04)	[−0.09, 0.09]	0.01 (0.09)	[−0.17, 0.20]	0.00 (0.03)	[−0.05, 0.06]	−0.00 (0.03)	[−0.07, 0.06]
TR → perceived task variety → expected need satisfaction → DV	−0.02 (0.04)	[−0.11, 0.06]	−0.01 (0.03)	[−0.06, 0.05]	−0.03 (0.06)	[−0.17, 0.07]	−0.01 (0.02)	[−0.05, 0.02]	0.01 (0.02)	[−0.03, 0.06]
TR → perceived skill variety → expected need satisfaction → DV	0.06 (0.04)	[0.01, 0.15]	0.02 (0.03)	[−0.04, 0.10]	0.07 (0.05)	[0.00, 0.20]	0.02 (0.02)	[0.00, 0.06]	−0.03 (0.02)	[−0.07, −0.00]
TR → perceived task identity → expected need satisfaction → DV	−0.06 (0.04)	[−0.17, 0.00]	−0.02 (0.04)	[−0.11, 0.05]	−0.08 (0.06)	[−0.22, 0.01]	−0.03 (0.02)	[−0.07, 0.00]	0.03 (0.02)	[−0.00, 0.08]

586 *N* = 159. Unstandardized regression coefficients are reported. DV = dependent variable; CI = confidence intervals; TR = task rotation.

To investigate Hypothesis 2, we looked at the total indirect effects in Tables 7 and 8. A significant indirect effect indicates mediation [101]. The confidence interval of the indirect effect did not include zero, which means that the effect was significant, for expected job satisfaction, intrinsic work motivation (only in Study 1), subjective performance, and positive affect. Thus, we found support for Hypothesis 2a, 2c, and 2d, and partial support for Hypothesis 2b. In both studies, we could not find evidence for an indirect effect on expected negative affect. Therefore, we had to reject Hypothesis 2e. Upon closer inspection of the single indirect effects, one can see that the significant indirect effects mainly involved perceived skill variety or task identity, partly combined with the expected satisfaction of the need for competence.

Lastly, in Hypothesis 3, we assumed that openness to experience would moderate the effects of perceived task variety and skill variety on the outcomes. To investigate this hypothesis, we added the interactions between task variety and openness and between skill variety and openness to the existing model. The results showed that the addition of the interaction terms did not significantly increase the percentage of variance explained for anticipated job satisfaction (task variety: $\Delta R^2 = .00$, $F(1,150) = 0.08$, $p = .77$; skill variety: $\Delta R^2 = .00$, $F(1,150) = 0.40$, $p = .53$), intrinsic work motivation (task variety: $\Delta R^2 = .01$, $F(1,150) = 1.23$, $p = .27$; skill variety: $\Delta R^2 = .00$, $F(1,150) = 0.24$, $p = .62$), subjective performance (task variety: $\Delta R^2 = .01$, $F(1,150) = 1.72$, $p = .19$; skill variety: $\Delta R^2 = .00$, $F(1,150) = 0.40$, $p = .53$), positive affect (task variety: $\Delta R^2 = .00$, $F(1,150) = 0.42$, $p = .52$; skill variety: $\Delta R^2 = .00$, $F(1,150) = 0.00$, $p = .97$), or negative affect (task variety: $\Delta R^2 = .01$, $F(1,150) = 1.25$, $p = .27$; skill variety: $\Delta R^2 = .00$, $F(1,150) = 0.01$, $p = .91$). Additionally, the indices of moderated mediation were nonsignificant for all indirect effects. The index of moderated mediation was developed by Hayes [102] and indicates whether an indirect effect is dependent on a moderator. One can assume a moderated mediation when the confidence

interval of this index does not include zero. Thus, we rejected Hypothesis 3 (for more detailed results see S2 Table and S3 Table in the online supplementary material).

As the samples in Study 1 and Study 2 differed significantly in terms of age and gender, we repeated all analyses with these variables as covariates. The analyses yielded comparable results. Thus, differences in the results of the two studies are not due to different sample compositions.

Discussion

Our aim in the present research was to investigate the work design method task rotation as a technology feature of digital assistance systems in more detail. More specifically, we examined whether associations between task rotation and positive work attitudes, behavior, and well-being from previous studies were due to unique effects of task rotation and could also be expected when task rotation was implemented as a feature of technology, by which constructs these effects could be explained, and whether there were individual differences in the effects. To this end, we conducted two consecutive experimental vignette studies in which participants imagined working at a workplace with a digital assistance system that either prescribed a task rotation every two hours (experimental condition) or not (control condition).

We found that participants consistently anticipated positive effects of task rotation on job satisfaction and positive affect. In one study each, task rotation positively affected the expected intrinsic work motivation and subjective performance. In both studies, there was no effect of task rotation on anticipated negative affect. We further found that there were consistent indirect effects of task rotation, transmitted by perceived task variety, skill variety, and task identity in parallel, and expected satisfaction of the need for competence as a serial mediator, on expected job satisfaction, subjective performance, and positive affect. An indirect effect on expected intrinsic work motivation that we found in the first study could not

637 be replicated in the second study. There were no indirect effects on expected negative affect
638 in either of the studies. Lastly, we could not find evidence for individual differences in effects
639 of perceived task and skill variety on anticipated positive employee responses due to the
640 participants' openness to experience.

641 As outlined above, we were not able to support all our assumptions consistently. An
642 explanation is that there was much variation across participants in both conditions. For
643 example, the total effect of task rotation on expected subjective performance was greater in
644 Study 1 ($b = 0.75$) than in Study 2 ($b = 0.73$) but became significant only in Study 2 due to
645 less variation in participants' responses. We had deliberately chosen to use a sample with
646 diverse professional backgrounds so that the results applied to a broader population.
647 However, a more homogenous sample might have produced more consistent results.
648 Furthermore, it is possible that the results for expected job satisfaction and affect were
649 consistent across studies because these have an affective component and are therefore more
650 immediate responses. By contrast, intrinsic work motivation as an attitudinal response and
651 subjective performance as a behavioral response might be more distal because they are
652 determined by affective evaluations [103]. Consequently, it should be considered that the
653 experimental vignette setting could have made it harder for participants to imagine their
654 attitudinal and behavioral responses, as opposed to the more proximal affective responses.

655 Still, we were unable to support our assumption that task rotation leads to
656 significantly less anticipated negative affect than no rotation. An explanation for this result
657 could be that although positive work design or technology features can increase positive
658 affect, the absence of these features does not necessarily increase negative affect because
659 individuals do not know that the job could have more positive features [104,105]. This issue
660 becomes especially apparent in a between-subjects design, which was adopted in this study.
661 While the work with task rotation could be perceived as pleasant, it is possible that the work

depicted in the control condition was not perceived as unpleasant, but rather as neutral. This is supported by the fact that a non-rotating workplace is common for many people. In the CRANET survey of 2014/15 [106], almost half of the European organizations reported that they had not adopted job rotation, which might be a proxy for the adoption of task rotation.

Another result that deserves special attention is that openness to experience did not moderate the effects of perceived task and skill variety on anticipated employee-related outcomes. As there was, however, much variation in participants' responses, it is possible that there are other moderating variables that we did not investigate. Another explanation could be that, according to McCrae and Costa [68], the majority of people are intermediate in openness. This knowledge, combined with the medium-sized means and small standard deviations of our sample (see Table 3), could explain that there might have been too little variance in openness to experience to detect an effect.

Theoretical implications

Although task rotation has been practiced and researched for a long time, it has not yet been investigated as a technology feature and its inner workings were still a 'black box'. The results of our studies give a first indication as to why one can expect beneficial effects of task rotation as a technology feature on employees. First, and most fundamental, we found evidence for unique effects of task rotation on anticipated employee-related outcomes. This adds to the existing knowledge on task rotation because previous studies were mainly correlational and therefore could not exclude alternative explanations, such as confounding effects. The fact that task rotation is often regarded as one high-performance work practice of many (e.g., [107]) is an indication that companies adopting task rotation might also adopt related practices, like self-managed teams (i.e., teams that decide without a supervisor how to perform tasks or which tasks to perform). Therefore, there was no way of knowing whether correlational effects between task rotation and, for example, job satisfaction, might have been

only due to one of the other practices.

Second, we identified perceived task variety, skill variety, task identity, and the expected satisfaction of the need for competence as relevant mediators of task rotation effects. These mediators, together with the predictor task rotation, were able to explain between 12% (expected intrinsic work motivation in Study 2) and 45% (expected positive affect in Study 1) of variance. Thus, we could give an answer to the question why task rotation had positive anticipated effects on some employee-related outcomes. While the work design framework by Morgeson and Humphrey [8,108] is mainly concerned with outcomes of work design, and Parker, van den Broeck, and Holman [50] have suggested a comprehensive framework focusing on influences of work design, we successfully combined both approaches: the human resource practice task rotation as antecedent, perception of work design characteristics as underlying mechanisms, and anticipated affective, attitudinal, and behavioral responses as outcomes. Additionally, we found evidence for the serial mediator satisfaction of the need for competence. This is a first indication that self-determination theory actually does offer alternatives to the mediators of the JCM, as suggested in theoretical considerations by Gagné and Panaccio [57]. As the need for competence was the most fitting with regard to task rotation effects, research on other work design methods would be necessary to investigate whether satisfaction of the needs for relatedness and autonomy are also relevant mediators in the scope of work design interventions.

Practical implications

The increasing adoption of technologies at work poses new challenges to occupational and organizational psychologists [15,35]. Our studies may show that technology does not determine work processes and outcomes per se, but that these also depend on the concrete technology features, which can be derived from work design. Thus, companies planning to implement a new technology should consider the motivational effects of the resulting

712 workplace already in the early stages of the technology design process. In the sense of the
713 sociotechnical systems approach [13,109] and sociomateriality [14,15], technology designers
714 should work together with occupational psychologists to ensure that the technical system
715 (i.e., the digital system and adjacent technologies) and the social system (consisting of the
716 employees and the organization) are optimized in harmony with each other. Our results
717 suggest that task rotation can be one way to improve jobs that run the risk of becoming more
718 monotonous when technology is implemented. The fact that a digital assistance system gives
719 so much guidance that training efforts can be reduced makes task rotation a quite affordable
720 work design technique. A further interesting aspect is that a study by Della Torre and Solari
721 [110] found that the combined investment in high-performance work practices, such as task
722 rotation, and advanced technologies resulted in the greatest labor productivity and economic
723 performance, as opposed to the sole investment in either technologies or work practices.
724 Regarding the concrete design of task rotation interventions, our studies also give
725 indications. Based on the comparison of the investigated mediators, our results would suggest
726 that the tasks in a task rotation cycle should not only be multifarious, but should also require
727 a diverse set of skills and ideally make up a complete work process. An approach to ensuring
728 skill variety could be examining how the occupational information network database defines
729 each skill (https://www.onetonline.org/). For example, the requirement *operation monitoring*
730 is defined as “watching gauges, dials, or other indicators to make sure a machine is working
731 properly” [111]. Thus, it would not be effective to let employees rotate between several tasks
732 that each requires them to observe some sort of performance indicator. Instead, they could
733 rotate regularly between, for example, monitoring and troubleshooting (“determining causes
734 of operating errors and deciding what to do about it”; [111]). That way, the employees would
735 be responsible for a greater part of the work process (because they do not have to rely on a
736 specialist who helps with the troubleshooting), and the job would require different skills.

Limitations and directions for future research

A common criticism of experimental research is a lack of external validity that compromises the generalizability of results [112]. It should therefore be noted that the results of the studies can only be interpreted in terms of prospective work design. As we investigated a hypothetical scenario in an experimental setting, effects of task rotation in complex real work settings might differ. Yet, we had two important reasons to prefer an experimental vignette study to a field study. First, vignette studies offer the unique possibility to investigate scenarios that do not yet exist in the field. This aspect is highly relevant in current workplaces that are affected by fast-changing technologies. For technology designers, it is important to know about the expected consequences of certain technology features while the technologies are still being developed and not when they have already been implemented. Nevertheless, we encourage future researchers to replicate our studies in the field once digital assistance systems with task rotation have become more widely established in real work settings. Second, one aim of our research was to investigate whether there were unique effects of task rotation on the expected outcomes. In field studies, there are usually confounding environmental factors. As an example, it is possible that the departments adopting task rotation are newly founded so that the employees have new colleagues, which can also affect how they feel about their job. To further increase immersion, future research could build on our results and investigate mechanisms of task rotation in microworld simulations. Microworlds are virtual environments that participants interact with and that simulate situations that could happen in real work settings [113,114]. As their development and programming can be resource-intensive, this method was not appropriate for a first assessment of task rotation as a technology feature.

A further limitation of our research is a potential common method bias, because we assessed most variables via self-report [115]. However, there can be no common method bias

762 in the investigated main effects because we experimentally manipulated the independent
763 variable. Regarding the expected mediator and moderator effects, our methodological
764 approach of conducting a vignette study restricted us from using different sources of
765 information. This is usually a recommended remedy against common method bias [116], but
766 is not feasible when all questions concern the participants' perceptions in a fictional scenario.
767 Conway and Lance [117] even stated that self-report measures were appropriate when the
768 targeted information involved perceptions, rather than objective data.

769 As a further direction for future research, we suggest that other individual differences
770 should be examined as possible moderators. We focused on openness to experience because it
771 is one of the basic personality factors [66], but it is possible that the anticipated effects of task
772 rotation on employee-related outcomes rather are affected by more work-related moderators,
773 such as proactive personality. Following the reasoning of Zhang, Bal, Akhtar, Long, Zhang,
774 and Ma [32], one could expect that the effects are stronger when proactive personality is low,
775 because less proactive employees are more dependent on the resources given by their job than
776 more proactive employees, who can provide for their resources through their proactive
777 behavior.

778 Conclusion

779 The increasing adoption of advanced technologies that affect great parts of the work
780 process could make some jobs more specialized and monotonous. In two studies, we
781 attempted to show that task rotation could be a suitable technology feature to counteract
782 potential negative effects. By increasing the perceived task variety, skill variety, and task
783 identity, task rotation is expected to satisfy the need for competence, which particularly
784 affects employees' expected job satisfaction and positive affect.

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Supporting information

S1 Vignette. Vignette texts and photo.

S2 Table. Regression coefficients, standard errors, and model summary for model including interaction effects.

S3 Table. Indices of moderated mediation.