Original Article

Mental Stress and Strain Assessment in Digital Work

The Measurement Instrument MESTAT for Employees and Leaders

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Abstract: When digitalizing work, organizations face the challenge of analyzing, evaluating, and mitigating a potential increase in mental workload for employees and managers. This paper presents an instrument to assess mental stress and strain in digital work contexts and the related development process and validation. Based on a literature and instrument review and an interview study, we developed an assessment instrument and validated it in two coordinated studies ($N = 245$, $N = 279$), ultimately resulting in an instrument with 139 items: 27 items addressing demographic aspects and 112 items dispersed over five categories (work task and activity, workflow and organizing, work environment, organizational climate, and personal attitude). To demonstrate the instrument's validity, we calculated a structural equation model based on the framework of the job demands-resources model. The resulting instrument is comprehensive and can also be applied by HR nonprofessionals.

Keywords: mental stress and strain, risk assessment, digitalization

Psychische Belastung und Beanspruchung im Kontext digitaler Arbeit. Das Instrument MESTAT für Mitarbeitende und Führungskräfte

Zusammenfassung: Bei der Digitalisierung von Arbeitsplätzen stehen Unternehmen vor der Herausforderung, eine potenzielle Zunahme der mentalen Arbeitsbelastung für Mitarbeitende und Führungskräfte zu analysieren, zu bewerten und zu mindern. Ziel dieses Beitrags ist es, ein Instrument zur Bewertung von psychischer Belastung und Beanspruchung in digitalen Arbeitskontexten sowie den damit verbundenen Entwicklungsprozess und die Validierung vorzustellen. Basierend auf einer Literatur- und Instrumentenanalyse und einer Interviewstudie wurde ein Bewertungsinstrument entwickelt und in zwei Studien validiert ($N = 245$; $N = 279$), was letztendlich zu einem Instrument mit 139 Items führte: 27 Items zu demografischen Aspekten und 112 Items, die auf fünf Kategorien verteilt sind (Arbeitsaufgabe und -tätigkeit, Arbeitsablauf und Organisation, Arbeitsumgebung, Organisationsklima und persönliche Einstellung). Um die Validität des Instruments zu demonstrieren, wurde ein Strukturgleichungsmodell basierend auf dem Job Demands-Resources-Modell berechnet. Das daraus resultierende Instrument ist universell einsetzbar und kann nicht nur von HR-Personal angewendet werden.

Schlüsselwörter: psychische Belastung und Beanspruchung, Gefährdungsbeurteilung, Digitalisierung

Digitalized jobs have practical advantages for the individual worker, such as relieving them of nonhuman requirements through automation, but they can also lead to an increased mental workload because of changing job demands (Diebig et al., 2020; Hartwig et al., 2020; Rau & Hoppe, 2020). Changes in mental workload naturally have the potential to increase mental stress and strain and, thus, to have a direct impact on work performance. The international standard ISO 10 075–1 defines mental stress as the "total of all assessable influences impinging

upon a human being from external sources and affecting the person mentally" (International Organization for Standardization, 2017, 3.1.1). These external factors influencing the human worker are not limited to lighting or equipment in the work environment, but also the use of digital technologies and the resulting implications for everyday work. Mental strain means the "immediate effect of mental stress (...) within the individual depending on their current condition" (International Organization for Standardization, 2017, 3.1.2). Typical consequences

are – among others – emotional exhaustion, job dissatisfaction, burnout symptoms, fatigue, errors, or aggressive behavior (Fischer et al., 2021; Hartwig et al., 2020; Kaufmann et al., 1982).

The use of digital information and communication technologies has become increasingly common: More than 90 % of employees today at least occasionally communicate via e-mails at work, more than 50 % use social media, and almost 50 % use smartphones or tablets as well as groupware or video conference tools. Besides communication, digital technologies are changing value creation processes (Kraus et al., 2021). In production systems, about 15 % to 20 % of employees are already working with real-time data terminals or remote-control devices (Härtwig & Sapronova, 2021).

Because digitalization is a potential source of both assistance and increased mental stress (Fischer et al., 2021), organizations need to assess the advantages and risks associated with the introduction of digital technologies for the mental health of their employees. Risk assessment identifies potential work-related risks, such as mental stress, to develop and implement mitigation measures and to evaluate their effectiveness to promote the advantages of digitalization for employees. To date, there is no open-access, easy-to-use, and all-purpose instrument to assess the mental stress and strain of employees and managers, also including facets of digital work.

This paper fills this gap and presents an instrument to assess mental stress and strain in digital work as well as the related development process and validation. The development process is based on a literature and instrument review and an interview study. We developed and validated the assessment instrument in two coordinated studies. We also calculated a structural equation model to demonstrate the validity of the instrument.

Digitalization and the Consequences of Mental Stress and Strain

Digital technologies can serve as a resource and help to simplify physical and cognitive activities through better planning and self-determined, flexible work design (Kraus et al., 2021; Schwarzmüller et al., 2018), but they may also lead to more work during the same amount of time, the need to react flexibly on changes in work processes, and hence new stressors, potentially causing strain (Atanasoff et al., 2017; Hartwig et al., 2020; Ragu-Nathan et al., 2008; Turel & Gaudioso, 2018). Work might become more monotonous and entail more periods of nonuse (Cascio & Montealegre, 2016), e.g., when engaging in monitoring tasks with a constant awareness of the current system status and a cognitive readiness for interventions

and decisions on short notice on the part of the employee, which in turn results in mental stress and strain. Furthermore, it can result if new skills are required for well-known tasks, common processes are changed, or work pressure is perceived to increase, e.g., if routes and services are made transparent for supervisors or customers (Ranz et al., 2018). Consequently, the implementation and use of new technologies in digital work settings result in new and changing demands and the need for different employee's competencies (Cascio & Montealegre, 2016; Rieth & Hagemann, 2021).

The relationship between work requirements and competencies at work is crucial for successful digital work and productivity as well as for maintaining the employee's health and employability (Härtwig & Sapronova, 2021). Resources and balanced job demands support the employees' development, but an excessive workload has negative effects on their performance and health (Hartwig et al., 2020; Mayerl et al., 2016).

For Germany, in 2018 there were 708.3 million work incapacity days that caused economic losses of €85 billion because of production downtime and €145 billion because of gross value added (Brenscheidt et al., 2020). Mental illnesses contributed 11.3 % of the total absenteeism rate. Since 2008, the number of sick days because of mental illness has increased by 64.2 %. In 2018, the average yearly duration of mental illness was 26.3 days per case, more than twice as long as the average of 11.8 days in other illness cases (Meyer et al., 2019). The recording of mental stress at work is thus becoming more and more important to assess and positively promote the ability to work. It is also mandatory for German companies (§§ 5, 6 ArbSchG - Bundesministerium der Justiz und für Verbraucherschutz, 2020). However, the prevalence of risk assessments that include psychosocial factors was only 21 % in Germany (Beck & Lenhardt, 2019). The aim of the assessment of mental stress and strain should be to identify work-related mental stress and strain and to develop and implement mitigation measures as well as to evaluate their effectiveness. In this regard, our instrument generates more insight than comparable instruments by also assessing resources and strain, thus making it possible for companies to implement adequate measures to reduce strain and to promote the potentials of using technologies at work.

The Job Demands–Resources Model and the Assessment of Mental Stress and Strain

The relationship of demands and available resources at the workplace is hypothesized in the job demands–resources (JD–R) model, which offers a theoretical frame-

work incorporating findings from stress and motivational research (Demerouti & Bakker, 2011). The main principle of the JD–R model is that every profession possesses specific risk factors associated with work-related stress (Bakker & Demerouti, 2007). Job demands comprise physical (e.g., wearing augmented reality glasses), psychological (e.g., insecurity with technical devices), social (e.g., recipient contact), and organizational aspects (e.g., organizational climate), along with physiological and/or psychological costs. Job demands turn into stressors when filling the demands permanently requires a level of motivation and energy from the employee which is more than they can provide (Bakker & Demerouti, 2007). Job resources are situated at the organizational (e.g., career opportunities), the interpersonal (e.g., supervisor support), or the task level (autonomy). The JD–R model highlights two important underlying psychological processes (Demerouti & Bakker, 2011): On the one hand, it presumes that job demands, such as problems with technologies or working with more and varying technical devices, increase stress, adversely affect employees' health, and deplete their energy; on the other hand, the model supposes that job resources, such as reduction of time for specific tasks or technical support, offer motivational potential and therefore lead to greater work engagement and higher performance. The JD–R model also proposes an interaction effect between job demands and resources which allows resources such as technical support or participation to buffer the negative consequences of demands such as work overload (Demerouti & Bakker, 2011). Therefore, it is important for a holistic view of mental stress and strain to also assess the sources of stress as well as the resources at the workplace and to take these into account for possible mitigation measures.

The state of research on the JD–R model was summarized by Demerouti and Nachreiner (2019), who stress that scientific studies increasingly investigate the core assumptions of the model, for example, concerning burnout (Demerouti et al., 2001). Employees perform better when working in an environment with a balanced workload, as this increases their motivation as well as their performance (Demerouti & Cropanzano, 2010). The JD–R model provides a well-matched framework for relating job demands and job resources to estimating the effects on the employees' mental stress and strain, assessed with a developed instrument to identify resources and risk factors, also in digital work contexts, and to evaluate mental strain. The instrument presented incorporates existing frameworks such as the technostress framework by Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) into a universal risk assessment screening instrument that focuses on the breadth of topics for risk assessment rather than the depth of constructs.

This paper contributes in the following ways: (1) It conceptualizes job demands and resources relevant to mental stress and strain in digital jobs; (2) it condenses a literature and risk assessment instrument review; (3) it reviews the development of a comprehensive as well as an easy-to-use risk assessment instrument for measuring mental stress and strain; (4) it presents the results as framed by the JD–R model.

Instrument Development

The mental stress and strain assessment tool for employees and managers (MESTAT) was developed as a part of a funded research project (DIAMANT, digitalized idea and work management in production, logistics, and trade) in three consecutive steps, starting with a literature and instrument review (Step 1) to analyze the status quo of psychological risk assessments in the context of digital work and current instruments suited to these demands, followed by an interview study to deepen the knowledge about specific demands of digital work (Step 2), and, finally, the construction and validation of the MESTAT in two studies (Step 3). All measures and data exclusions are reported in this paper.

Step 1: Literature and Instrument Review

In a first step, we conducted literature and instrument reviews through the end of 2018 concerning the assessment of mental stress and strain to analyze the implications of digital work for mental stress and strain and whether existing instruments were suited to assess these. We analyzed scientific databases (Web of Science, PSYNDEX, PsychINFO, MEDLINE, Google Scholar, and Springer Link) by applying the following keywords: psychological risk assessment, strain, stress, burnout, digitalization, managers, employees, survey methods, and test methods. Publications from 2010 and thereafter were included in the review if they met the criteria of focusing on the psychological aspects of work, particularly psychological risk assessment and testing methodology. In total, we selected 34 scientific publications for a deeper analysis to identify recent trends with a focus on digital work aspects.

Results

The results of the literature review highlighted multiple important aspects: the prevalence of psychological risk

assessments, their methodological challenges, the importance and challenges of digital work and its consequences, as well as a lack of instruments suited to risk assessments in digital work environments. According to Cernavin et al. (2018), only 50 % of organizations regularly assess mental stress and strain, only 23 % subsequently initiate measures, and only 15.7 % of those evaluate the interventions. The necessity for psychological risk assessments in organizations becomes clear as multiple studies indicate that the dynamics of a changing work environment could lead to new sources for not just resources but also demands (Amlinger-Chatterjee, 2016; Ayyagari et al., 2011; DGB, 2016; Diebig et al., 2018; Genner et al., 2017; Rost et al., 2017; Rothe, 2016).

Examples of aspects that influence mental stress and strain in digital jobs are the kind of and organization of work tasks, the duration of work, structure and distribution of work hours, deadline pressure and pressure to perform, technical aspects, the use of social media as a work tool, and a company's leadership and organization (Amlinger-Chatterjee, 2016; Atanasoff & Venable, 2017; Carstensen, 2015; Diebig et al., 2018; Genner et al., 2017; Hammermann & Stettes, 2015; Hentrich et al., 2017; Peters et al., 2014; Schmidt & Stach, 2015). In general, the relationship between demands and resources is essential when assessing the changes of digitalization, and it is important for how much the changing working conditions affect physical and mental health (Brandl & Bsirske, 2015; Diebig et al., 2018; Hammermann & Stettes, 2015; Joiko et al., 2010; Rothe, 2016).

Besides the theoretical aspects of risk assessment, we also considered the methodological aspect, where the biggest challenge in psychological risk assessments lies in properly identifying the specific characteristics of work environments that can negatively affect a person's health (Metz & Rothe, 2017). Within existing instruments, aspects such as mobile work as well as constant availability are not covered, or the instruments are often not suited to properly assessing the psychological aspects of stress and strain (Absenger et al., 2016; Brandl & Bsirske, 2015; Diebig et al., 2018). In addition, the results indicated that there is presently no instrument for digital work. However, it is important to pay attention to aspects like mobile work, constant availability, and new technology in work processes, as their role is becoming increasingly important for mental stress and strain. The automation and digitalization of work processes (73 %) and mobile-flexible forms of working (72 %) were named most often as topics that companies address regarding digitalization (Genner et al., 2017). A total of 83 % of those surveyed stated that they can work mobile-flexibly; 67 % said it was rather important for them to separate work time from leisure time. However, 46 % reported that they were available digitally outside their work hours, and almost half of the sample reported negative effects on their health and sleep quality. According to reports about digitalization in work environments by Absenger et al. (2016), 87 % of employees work with computers, 67 % with smartphones, and 79 % are using mobile devices in general. Of these 79 %, another 75 % are using their devices outside of their workplace. Additionally, 33 % are regularly working from home, and 78 % report that they are available for their superiors, customers, or colleagues outside of their work hours. 80 % feel that the work intensity has increased, 63 % say that they have to achieve more during the same time, and 44 % feel burned out. In general, studies show that mobile work and flexible work hours are mostly perceived as positive, although it often depends on whether employees and managers can influence the design of these aspects (Brandl & Bsirske, 2015; Hentrich et al., 2017; Peters et al., 2014; Rothe, 2016).

In addition to the literature review, we reviewed existing and new assessment tools developed over the past 5 years, assessing mental stress and strain from the year 2013 until 2018. We included 16 instruments in the analysis (see ESM 1 for an overview), six of which are commercial, nine are only online applicable, nine can be used only by HR specialists, and another nine are all-purpose, meaning they can be used for employees and managers, regardless of occupation, which is important to allow for a widespread assessment of mental stress and strain under the mandatory requirements. In summary, none of the instruments is open-access and applicable online as well as offline and can be used by HR non-professionals and is simultaneously all-purpose. Yet, these very aspects are important for many organizations to apply risk assessment tools regularly and properly.

Step 2: Interview Study

The literature and instrument reviews showed that existing instruments are missing important aspects of digitalized work and thus cannot be used to assess mental stress and strain caused by digitalization. Thus, in a second step, and to build upon the research gathered in the literature and instrument reviews, we interviewed employees ($n = 16$) and managers ($n = 18$) in digital work contexts to learn more about their perspectives. The interview guideline consisted of four topics (ESM 2): First, we asked about the current occupation; second, we addressed the understanding of digitalization, the use of technologies, and their implementation; third, we inquired about the impact of digitalization on the interviewees' daily work routines; and fourth,

we queried about risks and chances through new technology at work and then put these into perspective.

In total, we conducted 34 interviews in early 2019 (ESM 3). Each one-on-one interview took 45 minutes on average. Three interviewers participated in total, but only one was present at any given interview. They were audio-recorded, transcribed, and anonymized and then analyzed by two people using qualitative content analysis (Mayring, 2000). Because of its nine-phase, case-specific model, starting with the determining and genesis of data and ending with the summary of subcategories and main categories (ESM 4 and ESM 5), this approach allows a transparent, systematic, and rule-guided analysis.

Results

Digital technologies have a strong impact on the participants' daily routine in aspects that go beyond the mere execution of tasks, leading to consequences for their mental stress and strain. On the general positive depiction of technology within their companies, the interviewees stressed that the disadvantages of digitalization are often minimized, for example, perceived strain from constant availability would be solved with workers having to find their own way to deal with these effects. Their statements led to the following extension and testing of already existing scales and inclusion of new items, as explained below and shown in detail in ESM 6. The items were later grouped based on the four main dimensions in the guidelines from the Joint German Occupational Safety and Health Strategy (GDA, 2018) into work task and activity, workflow and organizing, work environment, and organizational climate. The category personal attitude was added based on the findings from the interviews and based on indications of the GDA guidelines.

Concerning the category *work task and activity* (1), which includes changes in tasks because of using technology, interviewees highlighted their tasks set reaching a new completeness through technology. They emphasized the support perceived through technology in information procurement as a vital new aspect. The interviewees stressed the importance of emotional aspects of their work, especially when their tasks involve the wishes and needs of customers.

When dealing with new technologies, their development, and implementation, the interviewees especially ascribe importance to the *organizational climate (2)*. More specifically, they discussed the importance of how feedback is provided, how they are involved in the process, how workers collaborate, how managers and colleagues handle mistakes, and whether different departments of the company, but especially blue- and white-collar workers, are treated equally.

The interviewees reported drastic changes in how they work together because of already implemented technology, for example, changes in how they support each other or how they communicate. Therefore, we identified the importance of collaboration and technology, concentrating more on changes within the communication process, also including the impact of home-office options. Already existing risk assessments address the *work environment (3)* in general, but what our study showed is that the demands that big machines can create are underestimated. Especially the possible health risk for other employees and the increased concentration needed to maneuver machines such as forklift trucks or trucks were added.

Concerning the category *workflow and organizing (4)*, results showed that new technology increases time pressure on multiple levels. They emphasized that their new digital workflow requires too much time to do their work in a focused and alert state. We found that general time pressure scales lack such items. New technologies are mostly perceived by employees and managers by the degree to which they make their work easier. In our interviews, the importance of the support and ease which the interviewees perceived to gain from technologies became especially important when concerned with demands and resources. Support for the organization of tasks, the general quality of work, the reduction of errors, and achievements of work goals are relevant. Furthermore, the interviewees underlined their high dependence on the technology they use. The stress caused by technical errors becomes apparent. The interviewees highlighted not only feeling stressed by errors and their workflow being impacted, but that they sometimes are unable to solve problems by themselves. But also their workload in general increases when new technologies are implemented and technical errors occur. Concerning the perception of teamwork through technology, the interviewees emphasized the newfound possibilities to reach agreements. They noted a development toward an easier form of communication, and that this communication is not as personal as it was before.

Aspects belonging to the *personal attitude (5)* concerned challenges with technology or personal development, leading to the inclusion of topics such as motivation or self-efficacy. Regarding motivation and the fun employees experience when using new technology, we identified aspects based on how the interviewees perceived the source of motivation and fun. All aspects identified in the interviews related to demands and resources for employees and managers in digital work were transferred into questions for the MESTAT.

Step 3: Item Generation and Instrument Application in Two Studies

Based on the results from Steps 1 and 2, we selected items for the MESTAT from existing instruments and scales as well as those generated based on the interviews, and then organized them into categories (see ESM 6). All but two items are answered on a 5-point Likert scale. Exceptions are the items on work satisfaction, which use a 7-point Likert scale, and a free-text question about the experiences of teamwork and technology. Items covering mental stress and strain in conjunction with digitalization were the focal point of interest for the generation of new items. In total, we developed 219 items and grouped them based on the four main dimensions in the guidelines from the Joint German Occupational Safety and Health Strategy (GDA, 2018; see above) into work task and activity, workflow and organizing, work environment, and organizational climate. The category personal attitude was added based on the findings from the interviews. In addition, the items were also grouped based on the JD–R model (Bakker & Demerouti, 2007) into demands, resources, stress, and motivation, to compare the final MESTAT with the JD-R framework and demonstrate validity. The developed instrument was then applied in two studies to shorten and validate the risk assessment tool.

Study 1

The aim of Study 1 was to test the developed MESTAT and to reduce the number of items. The items were checked for content-related fit, factor-analytical and statistical characteristics, and, if necessary, sorted out. The questionnaire was also examined regarding its usability. The revised instrument was then used in Study 2.

Participants

Overall, $N = 245$ people participated in the survey, with 128 (52.24%) people completing the full questionnaire and 117 quitting before the end. 117 (47.76%) participants were female, 84 (34.28%) male, 1 identified as diverse (0.41%), and 43 (17.55%) did not provide any information on their sex. The average age was 31.78 years ($SD = 12.5$), with a range of 18 to 69 years. The average length of company affiliation was 6.6 years ($SD = 8.02$). 56 (22.85%) of the participants were in a leadership position, 127 (51.83%) were not, and 62 (25.30%) did not provide any information on whether they were in a leadership position. 132 (53,88%) participants worked full-time, 50 part-time (20,41%), and 63 (25,71%) did not prove

information. 130 (53%) people had a permanent contract, 41 (16.7%) had a temporary contract, and 11 people (4.5%) worked on a freelance basis. 63 (25.7%) did not provide further information. 229 people took part in the online survey, while 16 people filled out the paper-pencil version.

Procedure

The online questionnaire was available from April to August 2019. In addition, we developed a paper-pencil version. The survey was created with the software Unipark (Enterprise Feedback Suite, EFS, Questback). Participants were initially recruited from the researchers' personal and work-related social networks. Companies from the different regions of the authors were also asked to participate in the study. Accordingly, the sample can be considered as a nonprobabilistic convenience sample.

Participants were informed at the beginning about the background of the study, the voluntary nature of participation, and the possibility of terminating the survey at any time. Under the European General Data Protection Regulation (GDPR), the test persons were informed about the processing of their data for exclusively scientific purposes. As an incentive, the respondents could win one of ten vouchers worth EUR 15. The time to complete the survey took 34 minutes on average. The study was accompanied by the Federal Ministry of Labor and Social Affairs and approved by the works councils of the participating companies.

Results

The collected data was converted into IBM SPSS Statistics 26. Extreme values were winsorized. Subsequently, the items were checked for content-related fit, factor-analytical and statistical characteristics, and, if necessary, sorted out.

On a statistical level, each item and scale were assessed given the common psychometric properties: An internal consistency (Cronbach's alpha) higher than .60 was seen as questionable, >.70 was seen as acceptable, >.80 as good, and >.90 as excellent (Nunnally, 1978). Thus, scales below the .60 threshold which could not be improved were dismissed, and scales below .70 were reconsidered. Items with a correlation and discriminatory power lower than .30 were either sorted out completely or converted into stand-alone items if they were deemed necessary. For stand-alone items, the item difficulty (Dahl, 1971) was calculated to determine redundant items that were either too easy (item difficulty <.20 or 20%) or too hard (item difficulty >.80 or 80%).

If a scale generally had an internal consistency below the acceptable threshold value (>.70) and did not include enough items to improve its internal consistency, the

items were usually converted into stand-alone items if deemed appropriate and necessary.

Additionally, all scales were analyzed in a confirmatory factor analysis using IBM SPSS Amos, and an item was sorted out if it improved the fit and the item was deemed unnecessary to the requirements. A model fit with a CFI and a TLI higher than .90 was seen as good (Vandenberg & Lance, 2000), and higher than .95 indicated an excellent fit (Hu & Bentler, 1999). An RMSEA below .08 was deemed an acceptable and below .06 a good fit. An SRMR less than .10 (Vandenberg & Lance, 2000) or .08 (Hu & Bentler, 1999), furthermore, indicated a good model fit. Regarding chi-square, we made sure that a value between 2 and 3 resulted by dividing the value by the degrees of freedom (Hu & Bentler, 1999; Tabachnick & Fidell, 2007). As Hu and Bentler (p. 27) recommend, we viewed the values for CFI/TLI and SRMR in combination. Missing values were not incorporated in the analysis; instead, we created a clean dataset without missing values. The questionnaire was also examined regarding its usability.

All in all, after Study 1 the instrument was shortened by 74 items. Furthermore, one item in the category work task and activity was added (Social interaction (strain)), to assess the potential strain of social interaction. Likewise, another item was added to the scale Scope of action (strain) for a more comprehensive assessment. Thus, the instrument used for Study 2 consisted of 145 items. Thereof, 27 were about demographic aspects and 118 were divided into the categories work task and activity (23 items), workflow and organizing (47 items), work environment (6 items), organizational climate (26 items), and personal attitude (16 items). ESM 6 gives an overview of all scales and single items as well as statistical indicators for the scales after Study 1.

Study 2

The aim of Study 2 was to generate further data on the revised MESTAT to improve its application, check its validity, and further shorten the instrument. For this purpose, a total of five companies from the logistics, (food) trade, and production sectors participated in the survey using online and paper-pencil versions of the questionnaire. Again, we checked all items for content-related fit, factor-analytical, and statistical characteristics and, if necessary, sorted them out. Furthermore, we calculated a structural equation model to demonstrate criterion validity and to show the mechanisms of action in the JD–R model using the scales of the MESTAT. In addition to the MESTAT, we included further established scales in Study 2 for this purpose: the Copenhagen Burnout Inventory (Kristensen et al., 2005), an adaptation of the CBI by the authors which focuses on technological aspects; and the Utrecht Work Engagement Scale Absorption (Schaufeli & Bakker, 2004).

Participants

Overall, *N* = 279 people participated in the survey, with 186 (66.7%) people completing the full questionnaire and 93 quitting before the end. 71 (25.4%) participants were female, 156 were (55.9%) male, and 3 people (1.1%) identified as diverse. 49 people (17.6%) did not provide any information on their sex. The average age was 41.65 years (*SD* = 11.89), with a range of 18 to 65 years. The average length of company affiliation was 10.75 years (*SD* = 10.01). 49 (17.6%) of the participants were in a leadership position, 173 (62%) were not, and 57 (20.4%) did not provide any information on whether they were in a leadership position. 203 (72.8%) participants worked full-time and 12 part-time, 1 person (0.4%) worked on a different schedule, and 63 did not give any information (22.6%). 196 (70.3%) of the 279 people had a permanent contract, while 18 (6.5%) had a temporary contract, and 1 person (0.4%) worked on a freelance basis. 64 people (23%) did not give any information. 246 people took part in the online survey, while 33 people filled out the paper-pencil version.

Procedure

The data for Study 2 were collected within five German companies between November 2019 and April 2020. The contact persons in the companies received an invitation to participate by email before the start of the data collection period. The letter contained background information on the study, an employee information letter for company-wide distribution, the link to the online survey, and the possibility to request a paper-pencil version of the questionnaire. The same opt-in process was used for this study as for Study 1. The same data protection regulations and participation conditions were also applied. No financial or other incentives were used in this study; instead, the volunteer participants were employees and managers from organizations within the production, logistics, and trade industries, participating in a funded research project. In addition, two other companies from the same industries were persuaded to participate in the study. The study was again approved by the works councils of the participating companies. The average time to complete the survey took 49 minutes. One organization used the paper-pencil version of the questionnaire.

Results

We processed and analyzed the data collected in Study 2 in the same manner as described in Study 1. However, we

retained two scales in the instrument despite their having an internal consistency lower than .70: *Technostress* (.69), which consists of four items, and *Scope of action – constraints through technology* (.64), which consists of two items. *Technostress* was kept because of solid CFA-indices (χ^2 (2df) = 2.35, p = .309; χ^2/df = 1.175; RMSEA = .025; CFI = .996; TLI = .982; see Table 1). *Scope of action – constraints through technology* was kept because the questionable reliability might well be influenced by the low number of items (Abdelmoula et al., 2015) – and the items were deemed meaningful enough to be kept in the instrument.

All scales with more than three items were further validated in a confirmatory factor analysis (CFA) using IBM SPSS Amos; items were sorted out whether they improved the fit and the item was deemed unnecessary to requirements. To assess the model fit, we applied the same indicators as in Study 1. To incorporate missing values into the CFA, the model was estimated using the full information maximum likelihood method (FIML). The results of the CFAs are presented in Table 1.

Finally, we reduced the instrument by a further six items across four categories: Two items belonged to the category organizational climate, one item belonged to the category workflow and organizing, one to the category work task and activity, and two items belonged to the category personal attitude. Thus, the final instrument consists of 139 items, 27 of which concern demographic aspects and 112 items (see ESM 6) divided into the five categories work task and activity (22 items), organizational climate (24 items), work environment (6 items), workflow and organizing (46 items), and personal attitude (14 items). In summary, the 112 items are divided into 28 scales and 27 stand-alone items. The final structure and the psychometric properties of the MESTAT are summarized in ESM 6, and all items can be found in ESM 7. Furthermore, the latter shows whether items of a scale were developed by the authors, taken from other authors, or adapted from other authors.

Structural Equation Modeling

In a final step and to demonstrate criterion validity, we used the data collected in Study 2 to calculate a structural equation model (SEM), to show the mechanisms of action in the JD–R model. Included into the SEM were those MESTAT scales that best represented aspects of digital work (see Figure 1) and had a logical fit regarding the different aspects of the JD–R model. Thus, we included 12 scales and 5 stand-alone items. To conduct a thorough analysis and completely represent each aspect of the JD–R model, we also included additional, established scales: the Copenhagen Burnout Inventory (CBI; Kristensen et al., 2005), the Burnout Caused by Technology Scale adapted from the CBI,

which is focused on the perceived influence that technological aspects have on burnout-symptoms, and the subscale Work Engagement Absorption from the Utrecht Work Engagement Scales (Schaufeli & Bakker, 2004).

In the end, the SEM included 20 variables: four in the category *Job demands*, five in the category *Job resources*, four in the category *Motivation*, four in the category *Strain*, and three in the category *Outcomes* (see Figure 1). The SEM was calculated by using IBM SPSS AMOS 26. We added the most relevant constraints to the path model to thoroughly examine the relationships between the different JD–R-categories and their corresponding variables.

Because model fit indices in general can be influenced by either model complexity or sample size, we considered a variety of indices in the current SEM (Kline, 2016; Schweizer, 2010; van de Schoot et al., 2012). The criteria at hand include chi-square, CFI, TLI, and RMSEA. To incorporate missing values, we used FIML in the analysis of the SEM.

The χ^2-statistic shows a significant value (χ^2 = 228.19, df = 154, p = .001), thus indicating that the observed model differs significantly from the estimated model. However, the χ^2-model-fit value is sensitive to sample size and tends to become significant as sample size increases, especially with an N of over 200 (Byrne, 2010). In contrast to the χ^2-statistic, the χ^2-df ratio (χ^2/df = 1.482), the CFI (.932), the TLI (.907), and the RMSEA (.042, CI90 = .030–.053, p-close = .890) all indicate a good model fit (Bollen, 1989; Hu & Bentler, 1999).

The results of the SEM (see Figure 1 and Table 2) show multiple significant effects. All variables load significantly on their respective factor. Regarding outcomes, *Work satisfaction* is the only variable that loads negatively on its factor, as high values of *Work satisfaction* correlate negatively with the other outcome variables *Burnout* and *Thoughts about a job change*.

Following the assumptions of the JD–R model, we found a significant negative covariance between *Job demands* and *Job resources* (x1 = −.162, p < .05). Regarding the direct effects (see Table 2), both *Job demands* and *Job resources* affect *Strain* significantly: *Job demands* shows a highly significant positive effect (x2 = .825, p < .01), and *Job resources* shows a significant negative effect (x3 = −.140, p < .05). Higher values on the *Job demands* variables lead to higher values on the *Strain* variables, while higher values on the *Job resources* variables lead to lower values on the *Strain* variables, whereas *Job resources* has a highly significant positive effect on *Motivation* (x4 = .290, p < .01). Additionally, *Strain* has a significant negative effect on *Motivation* (x5 = −.293, p < .01). While the SEM did not incorporate direct effects between *Job demands* and *Motivation*, as is usual for the JD–R model (Bakker et al., 2010), this does indicate an indirect negative effect of *Job*

Table 1. Confirmatory factor analysis for scales with more than three items, final instrument

	Work task and activity	Organizational climate					Workflow and organizing					Personal attitude
	Change in task-organization through technology	Idea management/innovation (employees)	Idea management/innovation (leaders)	Participation (employees)	Participation (leaders)	Technological support	Time-pressure	Scope of action	Techno-stress	Techno-stress (strain)	Benefits in team work through tech	Motivation & fun
N items	4	4	4	4	4	4	4	4	4	4	4	4
N	279	279	279	279	279	279	279	279	279	279	279	279
Cronbach's α	.84	.88	.79	.87	.83	.91	.85	.74	.69	.86	.89	.74
χ^2	2.992	3.832	.84	.774	.90	4.22	2.29	.615	2.35	.105	.083	1.394
df	1	1	1	1	2	2	2	2	2	1	2	1
p level	.084	.05	.36	.379	.637	.12	.318	.735	.309	.746	.959	.238
χ^2/df	2.992	3.832	.84	.774	.45	2.11	1.145	.308	1.175	.105	.042	1.394
RMSEA	.085	.101	.00	.00	.00	.063	.023	.00	.025	.00	.00	.38
CI90	.00–.202	.00–.216	.00–.37	.00–.151	.00–.094	.00–.49	.00–.124	.00–.084	.00–.124	.00–.110	.00–.00	.00–.169
CFI	.993	.992	1	1	1	.995	.999	1	.996	1	1	.998
TLI	.927	.918	1.02	1.01	1.11	.977	.995	1.05	.982	1.033	1.03	.976

Note. N items = number of items per scale; N = number of participants; α = Cronbach's α; χ^2 = Chi square; df = degrees of freedom; p level = probability level =; χ^2/df =; RMSEA = root mean square error of approximation; CI90 = the 90% confidence interval; CFI = comparative fit index; TLI = Tucker–Lewis index.
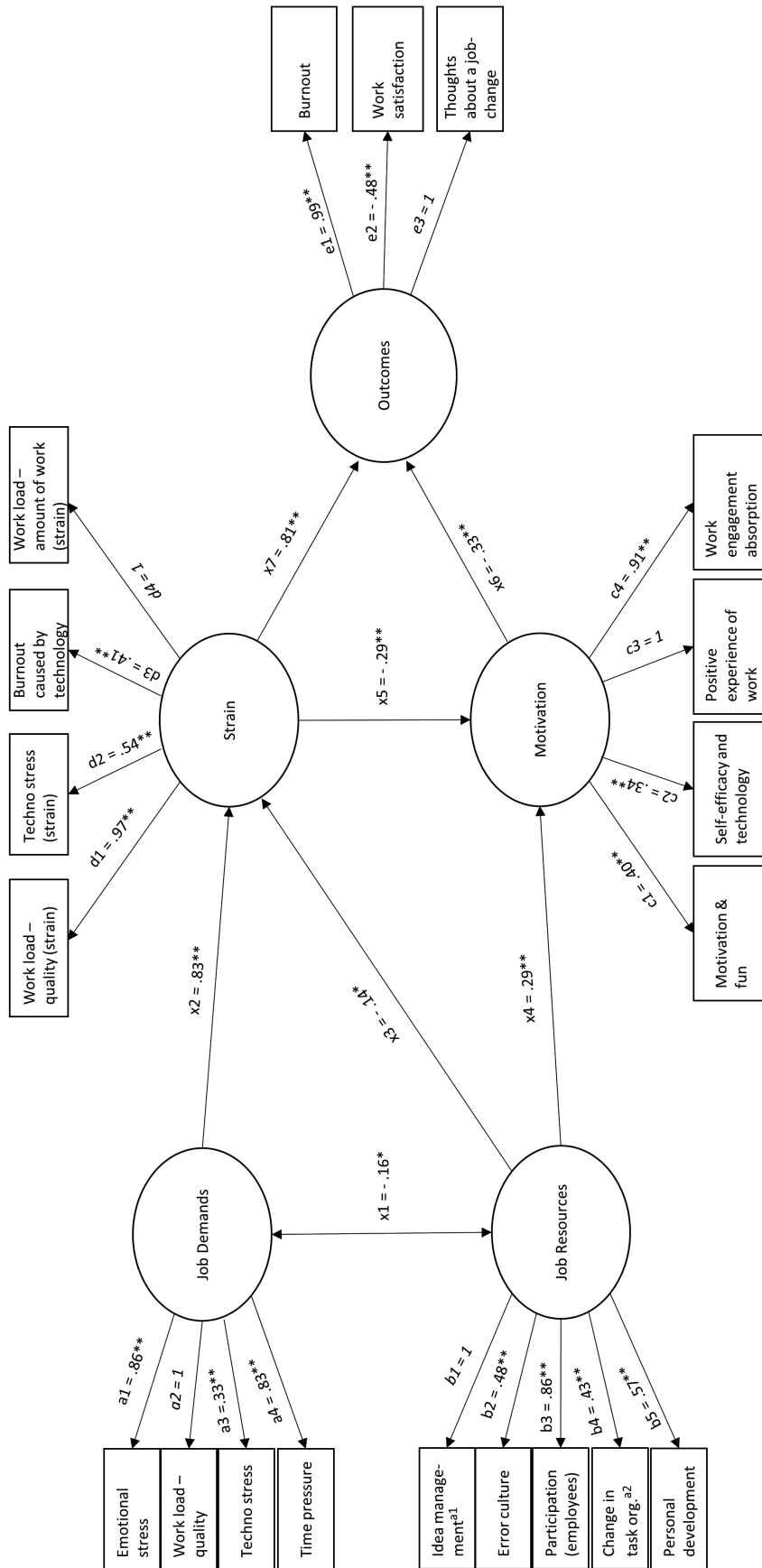
Note. Fixed parameters (1) are cursive; * = *p* < 0.05, ** = *p* < 0.01; a1= variable name shortened for better clarity, full name= idea management/innovation (employees); a2 = variable name shortened for better clarity, full name = change in task organization through technology.

Figure 1. The resulting job-demands resources model for assessing mental stress and strain in the workplace.

demands on *Motivation* through the influence of *Strain*. Finally, both *Motivation* and *Strain* show significant effects on *Outcomes*: On the one hand, *Motivation* has a highly significant negative effect on *Outcomes* (x6 = −.332, $p < .01$), which indicates that high and positive levels on the *Motivation* variables lead to lower values on the *Outcome* variables *Burnout* and *Thoughts about a job-change* but higher values on *Work satisfaction*. On the other hand, *Strain* has a highly significant positive effect (x7 = .811, $p < .01$), thus indicating that high and positive levels on the *Strain* variables lead to higher values on the *Outcome* variables *Burnout* and *Thoughts about a job change* and lower values on *Work satisfaction*.

To summarize, the results of the SEM affirm the theoretical findings of the JD–R model based on the empirical implementation of the newly developed MESTAT. The results show the effect of *Job demands* on *Strain* and, in turn, *Motivation* and *Outcomes* as well as the effect of *Job resources* on *Motivation* and, in turn, *Outcomes* plus the interaction effect between *Job resources* and *Job demands*.

Discussion

In this paper, we focused on the recent development of using digital technologies at work and their consequences for mental stress and strain. We presented a review of the literature and risk assessment instruments for the German-speaking countries and developed a mental stress and strain assessment tool for employees and managers (MESTAT). We furthermore investigated the effects the digitalization of work has for employees and, in contrast to existing approaches, specifically focused on the increased mental workload and the changing job demands and resources. In this sense, digital work can help to simplify activities through better planning as well as more self-determined and flexible work design as job resources (Kraus et al., 2021; Schwarzmüller et al., 2018), but it can also lead to greater work intensification and increased time pressure (Baethge et al., 2018). Since the balance of job demands and resources affects the health and work engagement of both employees and managers (Mayerl et al., 2016), organizations must consider this issue in daily practice and regarding leadership practices (Turel & Gaudioso, 2018).

The developed MESTAT was validated in two coordinated survey studies. In this context, we added the evaluation of an SEM, referring to the JD–R model. Variables from the MESTAT as well as further established scales from other instruments regarding the categories job demands, job resources, motivation, strain, and outcomes were included. Results show that high job demands, such as time pressure or technostress, lead to

Table 2. Factor loadings and main path coefficients of the SEM regarding the job demands-resources model (N = 279)

Path coefficient	Effect parameter	Standard error	p level
x1	−.162	.067	< .05
x2	.825	.111	< .01
x3	−.140	.057	< .05
x4	.290	.074	< .01
x5	−.293	.085	< .01
x6	−.332	.072	< .01
x7	.811	.114	< .01
a1	.857	.122	< .01
a2	1	/	
a3	.326	.069	< .01
a4	.829	.091	< .01
b1	1	/	
b2	.479	.073	< .01
b3	.862	.116	< .01
b4	.427	.084	< .01
c1	.398	.069	< .01
c2	.342	.090	< .01
c3	1	/	
c4	.905	.091	< .01
d1	.974	.138	< .01
d2	.535	.103	< .01
d3	.406	.082	< .01
d4	1	/	
e1	.986	.096	< .01
e2	−.484	.088	< .01
e3	1	/	

Note. x1 = relationship JD & JR; x2 = effect JD on strain; x3 = effect JR on strain; x4 = effect JR on motivation; x5 = effect strain on motivation; x6 = effect motivation on outcomes; x7 = effect strain on outcomes; a = job demands; a1 = emotional stress; a2 = workload – quality; a3 = technostress; a4 = time pressure; b = job resources; b1 = innovation (employees); b2 = error culture; b3 = participation (employees); b4 = change in task organization through technology; b5 = personal development; c = motivation; c1 = motivation & fun; c2 = self-efficacy and technology; c3 = positive experience of work; c4 = work-engagement absorption; d = strain; d1 = workload – quality (strain); d2 = technostress (strain); d3 = burnout caused by technology; d4 = workload – amount of work (strain); e = outcomes; e1 = burnout; e2 = work-satisfaction; e3 = thoughts about a job change; cursive = fixed parameter.

strain and can cause feelings of burnout. Likewise, an increase in strain variables lowers motivation variables like a positive experience of work in general or work engagement. However, job resources, like a positive error culture, letting employees participate in decision-making processes, or creating opportunities for personal development, lower strain values. Moreover, job resources are positively correlated with motivation, which means they increase aspects like a positive experience of work and work absorption. Finally, both variables from the strain

and the motivation categories affect certain outcomes like burnout, work satisfaction, and thoughts about a job change. An increase in strain variables leads to an increase in the variables burnout and contemplation of a job change, but a decrease in work satisfaction, while an increase in the motivation variables leads to a decrease in burnout and contemplation of a job change, but an increase in work satisfaction. In general, the results are in line with the assumptions of the underlying theoretical model (Demerouti & Bakker, 2011) and demonstrate the validity of the MESTAT. However, it also emphasizes the relevance of considering balanced job demands and resources in digital work. In this sense, it is necessary for organizations to design the use and implementation of digital technologies at work and to identify the (new) competencies required for employees and managers to set them up well (Cascio & Montealegre, 2016; Rieth & Hagemann, 2021). Thus, the use of digital technologies not only has the potential to increase mental workload but also to decrease mental stress and support workers. Furthermore, identifying the resulting new job demands and developing measurements to enable the workforce to cope with the changes in their daily routine is paramount. While many aspects of digitalization, such as the use of mobile devices, seem to be common knowledge today, taking them for granted only increases the chances for undetected causes of mental stress and strain.

It remains the task of human-resource management or other relevant staff responsible, to analyze the potential consequences of digitalization projects for the workforce, to develop solutions to avoid negative influences on the health of employees and managers alike, and to make digitalization a success for individuals and organizations. We argue that the MESTAT is a handy tool for enabling the structured and strategic collection of information regarding the impact digitalization has on employees and managers, and that it enables human resource managers to identify where corrections are necessary.

Limitations

First of all, the samples could have been larger. We trace this back to the voluntary participation and the comparatively long test duration, which could have led to people dropping out, although it was necessary for valid instrument development in two steps. Moreover, it could also relate to a possible correlation of mental stress and strain. Second, because of the sample sizes and the subgroups, some scales could not be included in the SEMs for validation purposes. This is especially the case regarding the questions for managers. Thus, the future application of the instrument would support the further concept

clarification. Third, the MESTAT is not completely aligned to the JD–R model and certainly not identical. This fact may have influenced the model fit indices in the overall model. Fourth, the MESTAT was developed within a funded research project. Thus, in Study 2, we recruited employees and managers of the partner organizations from the research project to be participants, meaning that this study was limited exclusively to people from the manufacturing, logistics, and retail sectors. For this reason, it would be desirable in the future to extend the use of the MESTAT to industries such as the service sector, high-risk organizations, and the public sector. Fifth, because of the research focus on sectors instead of occupations, we did not test for occupational effects; this could be addressed in future research.

Implications for Future Research and Practice

The following aspects are outlined for future research and business practice implications regarding the assessment of mental stress and strain in digital work contexts. The increasing application efficiency of risk-assessment tools regarding mental stress and strain is important for practical applications – the transaction costs for such evaluations are usually quite high, especially for SMEs. Therefore, research would have to dive deeper into the objective or apply adequate methods to improve application efficiency in terms of time and resources required.

Further experiences with the MESTAT in different industries are required to enhance the tool itself as well as the data-collection process. Refinements could include the development of specialized subsets directing questions more toward specific application areas, branches, a differentiation of worker types (i. e., blue-/white-collar workers), or subaspects in the case of pure digital jobs, effectively reducing the total number of questions and allowing for faster data acquisition. Likewise, future research could analyze occupational effects.

Furthermore, questions regarding the adaptability of the tool must be evaluated, for example, if adaptions regarding the company and team size or type of work (manufacturing or service industries) are sensible and necessary. The connection between analysis results and mitigation measures must be explored and strengthened empirically. This includes especially the question of whether the MESTAT can also measure an improvement (reduction) of mental stress and strain situations achieved with different measures.

Most importantly, however, the implication of the MESTAT is the fact that organizations now have a way to actively measure and influence mental stress and strain in

digital work contexts. It is no longer a passive field of corporate HR and health management but rather an area in which active analysis and management are feasible. Especially considering the developments in the field of HR analytics, the data are of great benefit to employees and organizations. This might change many things, from individual workplace situations up to the corporate culture, of how to deal with digital changeover situations, in the best-case scenario making workers and organizations more willing to innovate and implement digital technologies as well as to reduce barriers currently inhibiting the effective use of digital means.

However, although scientific literature shows the positive effects of psychological resources, the law has a clear definition of risks, and the category of "personal attitude" is not a mandatory element of risk assessments, so that the promotion of psychological resources is not the same as reducing risks. While the category of personal attitudes can also record personal aspects that influence the perceptions of the risk factors, it should be seen as an additional category that can be employed for evaluation and to show whether positive changes are occurring. The category can also be left out of the risk assessment, in which case it is shorter and can be carried out more quickly.

Conclusion

Digital developments at workplaces are essential and comprehensive events that change work conditions and requirements significantly. This is especially true for the question of the mental workload of employees as work tasks shift from execution to supervision and control. The studies presented served to develop a comprehensive assessment tool for mental stress and strain in digital work. This can improve the analytical situation for organizations facing digital changeovers and take employee-centered design aspects into account from the outset. The discussed consequences of mental illness for employees emphasize the need for proper analysis when implementing new technologies into organizations and the workplace.

Electronic Supplementary Material

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